XXX INTERNATIONAL SCIENTIFIC SYMPOSIUM

METROLOGY AND METROLOGY ASSURANCE 2020

PROCEEDINGS

September 7-11, 2020, Sozopol, Bulgaria

http://metrology-bg.org/

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30th INTERNATIONAL SCIENTIFIC SYMPOSIUM

METROLOGY AND METROLOGY ASSURANCE 2020

PROCEEDINGS

7-11 September 2020

Sozopol, Bulgaria

METROLOGY AND METROLOGY ASSURANCE 2020

30th International Scientific Symposium
September 7 -11, 2020, Sozopol, Bulgaria

ORGANISED BY

Technical University of Sofia

- ***Department of Electrical Measurements***
- ***Department of Precision Engineering and Measuring Instruments***

WITH THE ATTENDANCE OF

National Science Fund of the Ministry of Education and Science

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Union of Metrologists in Bulgaria

Bulgarian Academical Association of Metrology

Kozloduy Nuclear Power Plant

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All papers published in the Proceedings of the 30th International Scientific Symposium “Metrology and Metrology Assurance 2020” are reviewed by the International Programme Committee.

CONTENT

PLENARY SESSION

30 Years International Scientific Symposium "Metrology And Metrology Assurance"

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The Scientific Symposium "Metrology and Metrology Assurance" is the only annual scientific forum in the field of metrology and metrology assurance in our country and in the Balkans. It has a main goal – exchange of experience and ideas between colleagues – metrologists working in all fields of science, education, technology, technology, industry.

The symposium started 30 years ago, in September 1990 at the Education, Sports and Recreation Base (USOB) of the Technical University at Sozopol as an annual National Scientific Symposium with international participation. Its founders and organizers are Prof. DSc Vasil Filev and associates from industrial research laboratory (PNIL) "Metrology" and Department of "Electrical Measurement Systems" at the Faculty of Automatics, Technical University – Sofia. The thematic topics of the symposium are in the field of measurements of electrical quantities.

Since 1993, Prof. DSc Hristo Radev, associates from PNIL "Coordinate measurements in mechanical engineering" at the Faculty of Mechanical Engineering, and later the Department of Precision Engineering and Instrumentation at TU-Sofia, are involved. The thematic topics expand to include the field of geometric and mechanical quantities.

The name of the Symposium has changed several times during the years. From its foundation to 2016, it was a National Scientific Symposium with international participation: "Metrology", "Metrology and Reliability" and "Metrology and Metrology Assurance". With the increase of foreign participants since 2017 – the name is International Scientific Symposium "Metrology and Metrological Assurance". These names determine the scientific and applied–scientific nature of the symposium with subject on metrology and metrology assurance of all types of measurements of physical quantities.

Chairmen of the Organizing Committee were Prof. Dr. Ivan Petrov, Prof. Dr. Dimitar Rusev, Prof. Hristo Radev DSc.

The time and place of conduct of the Symposium is traditional, without changes – at the beginning of September, in the town of Sozopol, in the USOB of the Technical University - Sofia.

The organizer of the International Scientific Symposium is the Technical University – Sofia through its two departments – the Department of Electrical Measurement Systems at the Faculty of Automatics and the Department of Precision Engineering and Instrumentation at the Faculty of Mechanical Engineering. Active participation and cooperation in conducting the symposium have the Bulgarian Institute of Metrology, the Union of Metrologists in Bulgaria, the Bulgarian Academic Metrological Society and Kozloduy NPP.

Over the years, the Symposium has been supported by organizations and companies related to metrology and metrology assurance – NIS at TU–Sofia, NIK–47 EAD, SPECTRI EOOD, Unitech, Softtrade etc. At recent years, as a result of active work on research projects, the symposium has the support of the Ministry of Education and Science of the Republic of Bulgaria.

Over the years, the Symposium has affirmed itself as an authoritative scientific forum with wide international participation. The topics of the papers are of strong scientific and applied-scientific nature and are implemented with the problems of metrology and metrology assurance in science, industry and practice. Quality requirements to scientific and applied contributions of reported developments are rising. Since 2000 all reports have been reviewed by members of the International Programming Committee and well established experts in the metrology field.

The symposium has contacts and cooperation with the IEEE (through the IEEE Bulgaria Section). From 2019 the best reports on IEEE topics are published in the IEEE Digital Xplore Library with indexing in Scopus. All other peer-reviewed papers are published in the Proceedings of ISS "MMA" in English in printed and electronic form on the Symposium website.

Number of participants in the Symposium is constantly growing. When it was founded, the participants were 15-20 people. In recent years it has reached about 150. The number of reports presented at the beginning were 10-15, in recent years it reaches 90-100. The number of reports of young scientists, postgraduate students and students is 20% - 25%. International participation is significant. In recent years, the number of foreign papers has reached 50-60% of the total number of developments.

The participants and the audience of the Symposium are specialist metrologists from different fields of science and practice at home and abroad – Technical Universities, Scientific Institutes and Organizations, Metrology Services of public and private organizations and companies etc. Foreign participants are from Germany, England, Denmark, the Netherlands, the Czech Republic, Russia, Ukraine, Belarus, Italy, Israel, Chile, Greece, Romania, North Macedonia, Turkey etc.

This year the XXX International Scientific Symposium "MMA 2020" is held under conditions accompanied by two extraordinary circumstances:

On June 9, 2020, Prof. DSc Hristo Kirilov Radev – long-time Chairman of the International Scientific Symposium "Metrology and Metrology Assurance" and a member of the management of number of Bulgarian and foreign metrology organizations and academies passed away unexpectedly. His merits are the contacts and cooperation of the symposium with IEEE, as well as the significant expansion of thematic areas and the geography of the participants in the symposium. The professionalism, energy and dedication of Prof. Hristo Radev DSc will leave a lasting mark on everyone – organizers and participants in the International Scientific Symposium "Metrology and Metrology Assurance".

The epidemiological situation in our country and all over the world, caused by the coronavirus COVID–19 since the spring of 2020 forced the Organizing Committee of the Symposium to decide to hold the XXX International Scientific Symposium "MMA 2020" on site in the town of Sozopol and to provide the possibility for remote participation – through the On line Webex platform of Cisco. As a result, all foreign and some of the Bulgarian participants applied for remote participation. This will made difficult to communicate directly on the spot. The total number of papers has decreased compared to the XXIX International Scientific Symposium "MMA 2019", but their quality is guaranteed by the reviews and provides the opportunity to publish them in the IEEE Digital Xplore Library with indexing in Scopus.

The organizing and program committees of the XXX International Scientific Symposium "MMA 2020", despite the extraordinary circumstances and difficulties of the current 2020 are confident and will make the necessary efforts now and in the future for successful and fruitful holding of the International Scientific Symposium "Metrology and Metrology Assurance".

Happy anniversary and fruitful work colleagues!

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Measurements for Global Trade

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***Abstract* - This report presents the metrological community's commitment to ensuring confidence in traceable and reliable measurements, the development and implementation of uniform standards, the responsibility of governments for adequate regulation and infrastructure to support global trade.**

Keywords - measurement, metrology, global trade, harmonized legislation

I. Introduction - A Brief Historical Overview

Since ancient times, trade has been a prerequisite for the establishment of units. Mankind has exchanged goods, for the determination of the value of which it has used various "units" - artifacts (skins, seeds, stones, etc.) or parts of the human body - a span, a palm, a step, etc.

In ancient Egypt, for example, gourds, ceramic or metal vessels were used for the volume of a commodity. The main measure for the grain was hecate, equal to 4.54 l (or 4.785 l). For length - the royal elbow (fur), presented as 0.523 m long. a hand equal to seven palms (sedep) and 28 fingers (dzheba). The reference weight was deben, equal to ten kite of 9 grams each; for smaller weights used their parts. They were made of stones, gold, silver, bronze and other materials.

Units for barter trade were also used in medieval Bulgaria.

With the Rila Charter of Tsar Ivan Shishman the Rila Monastery is exempt from taxes:

Fig.1. Charter of Ivan Asen II to Dubrovnik merchants

«In addition to this: if any of the monastic people begin to go with goods for their trade throughout the country and region of my kingdom, let him buy and sell freely and without being hindered by anyone in showing this gold-printed word of my kingdom. and he shall not be deprived of his kumerk, nor of the diavato, nor of any other thing.»

The charter of Tsar Mikhail Asen in 1253, the charter for free travel of the Venetians in Bulgaria, issued by Tsar Ivan Alexander, the contract of the Dobrudzha ruler Ivanko with the Genoese, 1387 and others speak of the trade relations of the Bulgarians.

According to the different materials, the capacity measures were also different. The main measure for milk for shepherds, for example, is a vedro. In addition to a wooden container in which the milk is milked, a vedro also means the amount of milk that fits in it. It is usually equal to 10 or 12 oki. Oka is a Turkish measure, also used for weight, it is equal to 1200 grams and in turn is divided into hundred drams, as one hundred drams are equal to 1/4 of oka. In the Middle Rhodopes, the vedro is divided into kutels (one bowl is equal to 1/5 vedro), quarters (1/4 kutel) and spoons (1/8 chetvartnik). In addition to milk, the wine is also measured with vedro, and most often the vedro in this case is called a polovyak (polvyak, polovek).

The unit of measurement for cereals is called shinik or krina. This measure did not have a definite value and in different regions varies from 10 to 16 - 17 kilograms. The measure kilo was widely known and used, the value of which also varies - 5 krins; 2 shiniks; 2 polvyak (40 oki, Gotse Delchev region); 2 shiniks (20 oki, Sofia region).

Until the 1920s, the most known and used measure of weight was the Turkish oka (1200 grams). For its measurement, metal scales were used, consisting of levers with movable weight on one arm or similar wooden weights, which are divided into divisions from, for example, 1/4 oka to 10 and more okas.

In new Bulgaria, at the 9th session of the Fifth Ordinary National Assembly in 1888, the Minister of Finance, Mr. Nachovich, submitted to the National Assembly a draft Law on Weights and Measures, developed by three Bulgarian scientists with the following motives:

"The measures and weights that are currently used in the Principality are very incomprehensible and are not the same everywhere. The dyulyum at some places is counted for 1200 straddles, at others – 1600 straddles or arshins, the Constantinople kilo is taken somewhere for 20 oki, elsewhere the Danube kilo - 100 oki, the Braille kilo - 400 oki, which leads to large losses for our farmers in sales. In the neighboring countries, with which our population constantly has a takeover, they do so with other measures and weights, which leads to mistakes and fraud, damages to trade, from which the entire population suffers. The impracticality of the measures and weights used in our country is recognized by all other educated countries in Europe and other parts of the world that have introduced the decimal system.

In order to eliminate the reasons for obstructing the proper flow of trade in our country on the one hand, and for the government to have a criterion of measures and weights so that it can always control them and protect the population from all kinds of exploitation, the Ministry entrusted to me is obliged to ask the introduction into use of new measures and weights in the Principality through the law on weights and measures ".

On November 15, 1888, the Fifth Ordinary National Assembly in Veliko Tarnovo passed the Law on Weights and Measures and laid the foundations of metrology in the country. The law was signed by Prince Ferdinand I and published by Decree 278 in the State Gazette no. 7 of 19.01.1889

Even today the task of legal metrology in the Republic of Bulgaria and worldwide is to ensure fair trade, consumer protection, trust in traceable and reliable measurements, development and application of adequate standards for measuring instruments, government responsibility for adequate regulations and infrastructure.

II. Measurements for Global Trade

This year, the metrological community celebrated World Metrology Day under the motto "Measurements for Global Trade".

The Organization for Economic Co-operation and Development estimates that about 80% of world trade is affected by standards or regulations.

In order not to turn the application of these standards and regulations into a technical barrier to trade, international and regional legal metrology organizations are building policies of trust to manufacturers in support of the world market.

According to the World Trade Organization (WTO), global trade in products was a record $ 19.67 trillion in 2018.

The WTO is an intergovernmental organization. It was commenced in 1995 in order to coordinate the liberalization of international trade. It is a successor of the General Agreement on Tariffs and Trade (GATT). The WTO deals with regulation of trade in goods, services and intellectual property between participating countries by providing a framework for negotiating trade agreements and a dispute resolution process. It is the largest international economic organization in the world. The WTO has 162 members, which realize more than 97 % of global trade, and 20 observer governments.

The Technical Barriers to Trade Agreement (WTO TBT) aims to ensure that technical regulations, standards, and conformity assessment procedures are non-discriminatory and do not create unnecessary obstacles to trade. At the same time, it recognises WTO members' right to implement measures to achieve legitimate policy objectives, such as the protection of human health and safety, or protection of the environment. The TBT Agreement strongly encourages members to base their measures on international standards as a means to facilitate trade. Through its transparency provisions, it also aims to create a predictable trading environment.

The price of a significant part of world trade of products is determined with the help of legal units of measurement, controlled measuring instruments, uniform legislation in the field of metrology. To this end, international metrology organizations are actively cooperating to achieve the objectives of the WTO TBT. For example, the International Bureau of Weights and Measures (BIPM) cooperates with the WTO by disseminating information on the importance of quality infrastructure and in particular metrology as a key component of it, among trade regulators and international / intergovernmental organizations, with the status of ad hoc observer in the WTO TBT Committee. One of the instruments used by BIPM for this purpose is the Mutual Recognition Agreement of the Equivalence of National Standards and Calibration Certificates issued by National Metrology Institutes (CIPM-MRA). The CIPM MRA responds to the need for an open, transparent and comprehensive scheme to give users reliable quantitative information on the comparability of national metrology services and to provide the technical basis for wider agreements negotiated for international trade, commerce and regulatory affairs. To date, the CIPM-MRA has been signed by 62 member states and 40 associate members of the CGPM, as well as by 4 international organizations, and includes 154 institutes authorized by the signatories to the agreement.

The International Organization of Legal Metrology (OIML) is an "international standard-setting body" in the sense of the World Trade Organization's Technical Barriers to Trade Agreement. OIML publications should therefore be applied, when appropriate, by all signatories of the TBT Agreement when developing technical regulations. As a tool for mutual recognition of the results of the type evaluation of measuring instruments subject to metrological control, in 2018 OIML introduced its Certification System (OIML-CS). The aim of the OIML-CS is to facilitate, accelerate and harmonize the work of national and regional bodies that are responsible for type evaluation and approval of measuring instruments subject to legal metrological control. In the same way, instrument manufacturers, who are required to obtain type approval in some countries in which they wish to sell their products, should benefit from the OIML-CS as it will provide evidence that their instrument type complies with the requirements of the relevant OIML Recommendation(s). In the short time since its introduction, the OIML-CS now includes 12 national legal metrology authorities – issuing authorities, and 32 utilizers and assossiates that accept and use the examinations and test reports for type approval of a given type of measuring instrument.

Regional metrology organizations are the engines of the implementation of agreements for mutual recognition of measurement results, ie they are the basis for ensuring the free movement of goods and their international trade.

One of the objectives of the European Association of National Metrology Institutes (EURAMET) is to support quality infrastructure in Europe and worldwide by improving the efficiency and effectiveness of the CIPM-MRA, impact on the Joint Committee of Regional Metrology Organizations (CMO) in close cooperation with other RMOs for process optimization and management of CIPM MRA, etc.

The European Co-operation in Legal Metrology (WELMEC) aims to create a harmonized and unified approach to legal metrology in Europe, so as to ensure a single market, without additional legal requirements from individual countries, for the free movement of products.

National metrological institutes and national legal metrology authorities are the conduits on the territory of a country of mutual recognition agreements concluded at international, regional or intergovernmental level. Fulfilling the requirements of the relevant agreements, these institutes assist economic operators in the free trade of a product on the market and in use.

In the European Union, the free movement of goods is ensured by the abolition of customs duties and quantitative restrictions, as well as by the prohibition of measures having equivalent effect. The principles of mutual recognition, the removal of physical and technical barriers and the promotion of standardization have been added to continue the completion of the internal market. The adoption of the new legislative framework in 2008 strengthened the free movement of goods, the EU market surveillance system and the CE marking. Recent studies show that the benefits of the principle of free movement of goods and related legislation amount to € 386 billion a year.

In this regard, various national rules have been replaced by uniform European Union legislation.

Two metrological directives for non-automatic weighing instruments and for measuring instruments set out essential requirements for measuring instruments used for commercial payments - water meters, gas meters, active electricity energy meters, heat meters, measuring systems for liquids other than water (petrol stations, tankers), non-automatic and automatic weighing instruments, taximeters.

Modern development of measuring instruments used in trade is marked by the use of high technology, digitization and measurement software.

Globally, the metrological community seeks to make digital technologies, together with digital platform concepts, useful to all stakeholders in legal metrology.

At the national level, according to the National Statistical Institute, for the first five months of 2020 alone in the ENERGY sector have been traded about 1.4 billion m^3 of natural gas, over 2,300,000 tons of oil and oil products, over 6,000 GW/h of electrical energy and 10 151 thousand tones of solid fuels, i.e. in this sector alone, goods worth several billion levs were measured and traded for the period.

The metrological infrastructure in the country, whose core is the Bulgarian Institute of Metrology, as part of international and regional systems, has not stopped working to achieve fair and transparent trade relations - from the establishment and maintenance of measurement standards of units that are used in commercial transactions (kilogram, kilowatt-hour, liter, meter, etc.) to legal metrological control of measuring instruments used in global trade.

The Bulgarian Institute of Metrology has over 220 internationally recognized capabilities for measurement and calibration (CMC), which provides the opportunity for Bulgarian economic operators to measure their products internationally recognized. The published CMCs are shown in Table I.

To achieve these results, the institute has taken part in more than 80 key comparisons with national metrology institutes to prove the equivalence of the standards maintained in it, and has reported its management system to the EURAMET Quality Forum. Performing its functions, BIM provides metrological traceability in the country, calibrating annually over 4000 measuring instruments and certifying reference materials.

Table I. CMCs ACC. TO FIELDS OF MEASUREMENT

Fields of measurements	**Number of CMCs published in KCDB**
Acoustics, ultrasound and vibration	30
Electricity and magnetism	58
Length	18
Mass and related quantities	24
Photometry and radiometry	7
Temperature	44
Time and frequency	16
Metrology in chemistry	6
Ionizing radiation	23
Total:	**226**

Table II. SCOPE OF NOTIFICATION OF NB 1957

Measuring instrument	**Directive**	**Combination of modules**
Non-automatic weighing instruments	2014/31/EC	B, F, F1, D, D1, G
Water meters	2014/32/EC	F, D
Gas meters Volume conversion devices	2014/32/EC	F, D D
Active electrical energy meters	2014/32/EC	F, D
Measuring system for the continuous and dynamic measurement for quantities of liquids other then water	2014/32/EC	F, D

- *Module B: EU- TYPE EXAMINATION*
- *Module F: CONFORMITY TO TYPE BASED ON PRODUCT VERIFICATION*
- *Module F1: CONFORMITY BASED ON PRODUCT VERIFICATION*
- *Module D: CONFORMITY TO TYPE BASED ON QUALITY ASSURANCE OF THE PRODUCTION PROCESS*
- *Module D1: QUALITY ASSURANCE OF THE PRODUCTION PROCESS*
- *Module G: CONFORMITY BASED ON UNIT VERIFICATION*

BIM has also been notified to the European Commission for conformity assessment of measuring instruments, which makes it easier for manufacturers or their authorized representatives to place their products on the common European market, without additional obstacles and certifications. The scope of the notification is indicated in Table II.

Table III. CONFORMITY ASSESSMENT CERTIFICATES ISSUED BY BIM

Conformity assessment procedure	Number of issued certificates
"Module B: EU- TYPE EXAMINATION"	42
"Module F: CONFORMITY TO TYPE BASED ON PRODUCT VERIFICATION "	450
"Module G: CONFORMITY BASED ON UNIT VERIFICATION"	2
"Module D: CONFORMITY TO TYPE BASED ON QUALITY ASSURANCE OF THE PRODUCTION PROCESS"	6

Customers of the BIM notified body are both Bulgarian producers and producers from the Russian Federation, Turkey and Greece. The certificates issued under the different conformity assessment modules are listed in Table III.

In order to ensure fair trade transactions between the operators in the country, BIM and the bodies authorized for verification carry out control of a number of measuring instruments related to the purchase and sale of certain products or services. Control of measuring instruments for commercial purposes in the country is approximately 1,031,000 MI / year (Table IV).

TABLE IV. VERIFICATIONS OF MEASURING INSTRUMENTS USED IN TRADE TRANSACTIONS

Measuring instruments	Number of verifications carried out in 2019
Water meters*	113 619
Energy meters*	783 920
Thermal energy meters	13 999
Gas meters	20 987
Measuring systems for the continuous and dynamic measurement of quantities of liquids other than water	26 047
Taximeters	20 464
Non-automatic weighing instruments	52 228

- *Data include also the number of MI, verified through a statistical method for lengthen the re-verification period.*

III. CONCLUSION

In conclusion, it can be pointed out that the relationship between measurements and international trade is directly proportional. International, regional and national metrology systems guarantee accurate measurements, providing a sound basis for fair and transparent trade relations.

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SECTION II

SENSORS, TRANSDUCERS AND DEVICES FOR MEASUREMENT OF PHYSICAL QUANTITIES

30th INTERNATIONAL SCIENTIFIC SYMPOSIUM
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18PRT03 MetForTC
Traceable Measurement Capabilities for Monitoring Thermocouple Performance

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***Abstract*—The project 18PRT03 MetForTC "Traceable measurement capabilities for monitoring thermocouple performance" funded by the EMPIR programme is presented in this article. The general aim of this project is to develop novel scientific and technical capabilities providing both the dissemination of the International Temperature Scale of 1990 (ITS-90), which is an important in both developed and emerging NMIs, and accurate temperature measurements by thermocouple and low uncertainty.**

This objective will be achieved by developing novel practical methods and devices (such as dual-type thermometers) for checking thermocouple drift performance in-situ and easy-to-use integrated miniature cells to determine the inhomogeneity of thermocouples for primary and secondary calibration laboratories.

***Keywords*—metrology, thermocouple, traceable measurement**

I. Introduction

The Bulgarian Institute of Metrology (BIM) is a state independent body to the Ministry of Economy. Its main activities are: development, maintenance and improvement of the Bulgarian national measurement standards; ensuring traceability of measurements in the country by calibration; performance of metrological control of measuring instruments.

To improve its capabilities in temperature measurements, BIM joined as a partner in the project 18PRT03 MetForTC. The project is funded by the European Metrology Programme for Innovation and Research (EMPIR). The coordinator is national metrology institute of Turkey (TUBITAK). The duration of MetForTC is 36 months started on 1st June 2019.

II. The Aim of the Project

The general aim is to develop novel scientific and technical capabilities through a EURAMET EMPIR Research Potential Projects.

The overall objective of the project is to develop novel methods and techniques that will significantly improve knowledge and facilities that will provide confidence in the verification of thermocouple performance and improving temperature measurement and control capability.

The project offers a platform for incorporating the above objectives and reduces the scientific disparities between European countries participating in European research.

III. Needs for the Project

The industry need in this field lies in assuring and improving the quality of products, maximizing process efficiency and optimizing energy management for processes operating in the range from 230 °C to 1100 °C.

Thermocouple performance is critically dependent upon uniformity of physical and chemical properties along the length of the thermo element. With use, thermocouples lose homogeneity through heat, chemical exposure, or mechanical damage, causing the measured voltage to differ at the same temperature, resulting in errors and severely reducing the temperature measurement accuracy.

For high precision calibration, primary and secondary calibration laboratories are required to determine the inhomogeneity of thermocouples while performing their calibrations. Unfortunately, standardized, easy-to-use methods and devices are not currently available for the task. At the level of primary laboratories, new and extended traceable measurement methods and devices that will provide confidence in the verification of thermocouple performance are needed.

Knowledge of the lifetime and drift of thermocouples in industrial applications are not very well known and usually thermocouples are replaced periodically to ensure continuity in maintaining process control at an optimal level. However, it can often be very difficult for the user to detect inadequate thermocouple performance. There are no standardized traceable measurement capabilities for the verification of performance of thermocouples in-situ.

This project will develop novel methods and techniques, traceable to the ITS-90 that will significantly improve knowledge on drift and homogeneity as well as confidence in the verification of thermocouple performance for primary and secondary calibration laboratories. Eventually it will lead to a decrease in the uncertainty of the measurement of temperature by thermocouple and the efficiency of industrial processes will be increased.

IV. Objectives of the Project

The project addresses the following scientific and technical objectives:

- To develop and test novel methods and devices for the monitoring of thermocouple drift in-situ in the temperature range up to 1100 °C. These methods have to be suitable for implementation in critical industrial processes in order to assist the users in maintenance and replacement decisions of thermocouple.
- To develop and test easy-to-operate methods and instruments for the assessment of inhomogeneities of thermocouples for secondary calibration laboratories in the temperature range from 230 °C to 1100 °C.
- To design and construct novel measurement facilities that can provide confidence in the verification of thermocouple performance and to identify and quantify the range of drift of the thermocouples. The new facilities, targeting primary calibration laboratories, should have the ability to measure the physical changes and behavior of thermocouples under typical conditions of production and distribution processes with a target uncertainty of less than 1.5 °C.
- For each participant, to develop an individual strategy for the long-term operation of temperature measurements improvement and development of the research capability in Temperature Field and a strategy for offering calibration services. The individual strategies will be discussed within the consortium, with other EURAMET NMIs/Dıs and with a broad spectrum of stakeholders, through questionnaires and workshops organized in the local language. The individual strategies will lead to an overall strategy document to be presented to the EURAMET TC-T, to ensure that a coordinated and optimized approach to the development of traceability in this field is developed for Europe as a whole.

V. Work Packages

- WP1 - Novel devices and methods for in-situ testing of thermocouple drift;
- WP2 - Developing of traceable novel devices and methods for characterization of thermocouple’s inhomogeneity;
- WP3 - Development of novel measurement facilities for verification of thermocouple performance;
- WP4 - Creating impact;
- WP5 - Management and coordination.

VI. Partners

Internal Funded

№	Short Name	Organization legal full name	Country
1	TUBITAK	Turkiye Bilimsel ve Teknolojik Arastirma Kurumu	Turkey
2	BFKH	Budapest Főváros Kormányhivatala	Hungary
3	BIM	Bulgarian Institute of Metrology	Bulgaria
4	BRML	Biroul Roman de Metrologie Legala	Romania
5	CMI	Cesky Metrologicky Institut	Czech Republic
6	FSB	Sveuciliste U Zagrebu, Fakultet Strojarstva I Brodogradnje	Croatia
7	IMBiH	Institut za mjeriteljstvo Bosne i Hercegovine	Bosnia and Herzegovina
8	JV	Justervesenet	Norway

External Funded

№	Short Name	Organization legal full name	Country
1	INM	I.P. Institutul Național de Metrologie	Republic of Moldova
2	MER	Ministarstvo Ekonomije	Montenegro

VII. Potential Outputs and Impact from the Project Results

Projected early impact on industrial and other user communities

Based on information from preliminary contact with the stakeholders, the project’s activities are designed to address the needs in industry, such as petrochemical production, glass fabrication, power plants and the automotive sector operating in the range from 500 °C to 1100 °C, secondary calibration laboratories, manufacturers of temperature sensors and accreditation bodies in participating countries.

The thermocouples are instruments that are the most frequently used in industry. The characterization of thermocouples during the work in this project would improve the knowledge on drift and inhomogeneity which, along with thermal effects, represent the largest contributions to calibration uncertainty. The project will establish the methodology and traceability capabilities which are the basis for more accurate characterization and calibration of thermocouples in the range from 230 °C to the 1100 °C. The participating NMIs will improve capabilities and will therefore be able to provide a higher quality calibration service for industrial and other stakeholders. This will improve the reliability and accuracy of temperature measurements at many levels from NMI/DIs to the accredited commercial laboratories and finally to the end users.

Dissemination of traceability amongst NMI/DIs will provide access to improved capabilities for national and accredited laboratories. The recognized traceability of calibration results will also provide an important contribution to consumer protection. Additionally, there will be a benefit to the industrial companies that rely on such calibration services. Information on the calibration services will be disseminated via accredited bodies in participating countries.

Further, organizing the workshops for accredited laboratories and industry stakeholders and the dissemination of knowledge would be extended to the end-user. Ultimately this will facilitate the dissemination of traceable temperature measurements in ranges relevant for high value manufacturing in the participating countries. the NMI/DIs would build closer relations and strengthen the collaboration with the users' associations, manufacturers, and other stakeholders, as well as provide guidance to traceability and good practice in thermometry.

Workshops at the national level will be held to share the project's outputs. Uptake of the new measurement capabilities developed in the project by partners is expected during and shortly after the project. Early uptake will be among the accredited laboratories, enabling them to confidently demonstrate the performance of their products and ensuring they remain internationally competitive.

Projected early impact on the metrological and scientific communities

The Consultative Committee for Thermometry (CCT) felt the need for establishing the Task Group for Guides on Thermometry (CCT-TG, Guides On Thermometry) and recommends research at NMIs on novel secondary techniques, monitoring the stakeholders' needs. The CCT publication previously entitled "Techniques for Approximating the ITS-90" is also being revised with the new title "CCT Guidelines on Secondary Thermometry". Addressing this objective the project will focus on the approximation of the Kelvin in the proposed temperature range and create impact on the emerging NMI/DIs and calibration laboratories and will be presented to the accreditation authorities in Europe as well as to end users and manufacturers of thermocouples.

Another impact would be an increase in cooperation and liaisons anticipated with other CCs, institutions, organizations, committees, the scientific community, users' associations, manufacturers and other stakeholders, in order to provide guidance to traceability and good practice in secondary thermometry.

The project participants will organize workshops and present the achieved results at conferences and in high-impact-factor peer-reviewed journals. As part of the knowledge transfer, workshops in countries will be organized for constructing of thermocouples.

The individual strategies developed by the partners for the long-term development of their research capabilities in temperature metrology will enable a coordinated and optimized approach to the development of measurement and research capacities between the participating countries and beyond.

EURAMET TC-T will be informed during its annual meetings about the progress achieved in the project and will be actively involved in the development of research capabilities in less experienced NMI/DIs. Further, the achievements will be present at IMEKO TC12, COOMET TC1.10 and EURAMET TC-Q meetings and conferences.

Projected early impact on relevant standards

The project will support active participation in key European temperature related committees such as the Consultative Committee for Thermometry (CCT) and CCT TG – Guides on Thermometry, EURAMET TC-T, EURAMET TC-Q and COOMET TC1.10. Preparation of the calibration guide(s) for the thermocouples is most closely associated with the work of CCT TG. All partners will be directly involved in this work.

In addition, the consortium will promote the results of the project will provide input into the standardization process (ISO, CEN, and EA). For ISO, the standards relevant to the project that are in preparation/revision will be identified, and the work on these standards will be suggested to the appropriate working groups or committees.

The project's link with legal metrology is also important. The results from the project will be presented to the relevant legal metrology organizations (WELMEC, TSE , CROLAB)

Projected wider impact of the project

Establishing traceable measurements in temperature field and collaboration in research (construction of thermocouples, cells and new facilities for characterization of artefacts) will enable important inputs for areas of research, innovation and patenting in this field for future EMPIR projects. An important aspect of this project is the collaboration of less experienced NMIs/DIs with experienced NMIs/DIs. The latter will assist the emerging institutes in establishing their metrology capabilities in the field of temperature.

The improved temperature measurement will have an impact on the competitiveness of European industry, particularly those which are energy intensive (e.g. iron and steel, carbon-carbon composite manufacture, ceramics, and glass). Temperature is one of the most widely measured parameters in a power plant, and irrespective of the type of plant, accurate and reliable temperature measurement is essential for operational excellence.

Longer-term economic, social and environmental impacts

The CCT has identified "High value manufacturing" among the grand challenges – in particular, innovation, improvement of process control and optimal use and "zero waste" of resources and energy. Additionally, the technical roadmap for thermometry, which was constructed by EURAMET TC-T, identifies the research, development and use of traceable temperature measurement as required to ensure the continued fitness and relevance of the SI unit, the Kelvin. Moreover, the TC-T recommended that the high value manufacturing and energy production would be improved if there were better links to traceable temperature measurements– in particular if in-situ traceability was widely implemented.

In regional terms, the EU has made great progress in improving energy and resource efficiency, but further improvement is still a major challenge. Energy efficiency has implications for competitiveness, many of which can be overcome by increasing efficiency (in terms of improved processing/reduced wastage). There are demonstrable links between the adoption of energy-efficient techniques and economic growth and the creation of high quality jobs in a number of sectors.

Establishing traceable measurements in the temperature field and collaboration in research (construction of miniature fixed-point cells and new facilities for characterization of artefacts) will enable important inputs for areas of research, innovation and patenting in future European research.

VIII. Conclusion

The main impact of the project for BIM will be the improvement of its calibration measurement capabilities in the field of thermometry.

BIM will improve the quality of the services offers trough developing of novel practical methods and devices for checking thermocouple drift performance in-situ and easy-to-use integrated miniature cells to determine the inhomogeneity of thermocouples for primary and secondary calibration laboratories.

There will be additional benefit for the stakeholders (power plants, accredited laboratories, accreditation service etc.).

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18PRT01 Probe Trace Traceability for Contact Probes and Stylus Instruments Measurements

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***Abstract*— The project 18RPT01 ProbeTrace "Traceability for contact probes and stylus instruments measurements" funded by the EMPIR program part of Horizon 2020 of the EU is presented in this article. The project aims is to develop traceable and cost effective measurement capabilities for the calibration of form and surface roughness standards. This project will improve the scientific knowledge, instruments, methods and research capability in metrology for contact measurement probes and stylus instruments and enable particularly the new NMIs to develop new capabilities for self-provision of the traceability to SI unit, metre.**

Keywords— metrology, contact probes and stylus instruments, form and surface roughness standards

I. Introduction

The Bulgarian Institute of Metrology (BIM) is a state independent body to the Ministry of Economy. Its main activities are: development, maintenance and improvement of the Bulgarian national measurement standards; building and development of the national system of certified reference materials; ensuring traceability of measurements in the country by calibration; performance of metrological control of measuring instruments.

To improve its capabilities in form and surface roughness measurements, BIM became a partner in the project 18RPT01 ProbeTrace "Traceability for contact probes and stylus instruments measurements". The project is funded by the European Metrology Programme for Innovation and Research (EMPIR), part of the Horizon 2020 European Union Funding for Research and Innovation. The consortium of the project includes the national metrology institutes of Turkey (TUBITAK) as a coordinator, Italy (INRIM), Spain (CEM), Poland (GUM), Portugal (IPQ), Serbia (DMDM), Croatia (FSB), Bulgaria (BIM), Egypt (NIS) and Saudi-Arabia. The duration of project is 36 months starting on 1st September 2019.

II. Needs for the Project

Surface texture is of great importance in specifying the function of a surface. A significant proportion of component failure starts at the surface due to either an isolated manufacturing discontinuity or gradual deterioration of the surface quality. This causes stress corrosion and fatigue failure on the surfaces influencing the proper functioning of the products. Therefore, in the manufacturing industry, surface properties are checked to be within certain limits of roughness and form. The surfaces outside of these limits will result in failures in the performance of the products influencing the productivity of European manufacturing industry. For instance, failure of manufactured parts for wind turbines will stop their activations and lead to very high repair costs particularly for those located on sites difficult to reach. Therefore, an accurate measurement of surface roughness and form is vital to quality control the machining of a workpiece.

Form and surface measurement devices with contact probes and stylus are used to characterize the engineering surfaces. Stylus instruments having relatively small tip radius (e.g. 0.002 mm) are used for determination of surface roughness whereas mechanical contact probes with diameters of 2-5 mm are used for measurement of form errors. The performance of the contact probes and stylus during such measurements will have a significant effect on the characterization results. Therefore, ongoing research is being conducted into their performance characteristics including how the probe tips interact with surfaces of various materials.

Form errors of machined parts are measured in a production line mostly by using coordinate measuring machines (CMMs) which are the key devices for automation and factory of the future (industry 4.0). Reindustrialization with the demand of higher accuracies and lower uncertainties has led to a new generation of CMMs working in scanning mode (which can measure dimension and form simultaneously). When the contact measurement probes are used in continuous (scanning) mode with CMMs, the dynamic performance of the probes must be evaluated.

Contact probe measurement is a classic method that is widely used in measurements of surface roughness, roundness, form and coordinates. Calibrations of the static parameters, such as linearity and sensitivity, have been carried out well to date however there is a need for new traceable standards particularly for surface roughness devices due to a recent increase in the required measurement ranges (e.g. up to 1000 μm). In addition, use of probes for form measurements in scanning mode with a fast scanning speed might be problematic due to required high data acquisition rates, therefore the dynamic performances of the probe including the electronics of the instrument should be well calibrated.

Although there are documentation and methods for using depth setting standards for calibration of contact stylus instruments (ISO 12179 [15], and DKD-R 4-2[18]) mostly available in secondary level labs, there is no documentation for alternative routes or detailed investigations for calibration of reference stylus instruments used for calibration of depth setting standards.

This project will investigate portable traceable displacement generators and their use to establish new direct routes to SI unit meter definition, considering the emerging demands of industry in terms of dynamic properties, precision and larger measurement ranges in regard to contact probes used in form and surface roughness measurements.

The European research capacity in metrology for contact measurement probes and stylus instruments needs to be improved and this project will contribute towards its expansion by increasing the cooperation between NMIs, calibration laboratories and research communities in partnering regions. The capability across Europe is not equitable; knowledge transfer from experienced NMIs to those less experienced is therefore necessary to ensure the development of new cost-effective capabilities that will enable emerging NMIs to achieve direct traceability to the SI unit, the meter.

III. Objectives of the Project

The overall goal of this project is to develop traceable and cost-effective measurement capabilities for the calibration of form and surface roughness standards with uncertainties in the range 10 nm–100 nm.

The specific objectives of the project are:

To calibrate reference stylus instruments for surface roughness measurements using novel portable displacement generators with uncertainties in the range 10 nm–100 nm and to evaluate the efficacy of displacement generators vs existing methods (e.g. depth setting standards) for calibration of stylus devices. Further, to develop novel software for the calibration of stylus devices using sphere standards.

To calibrate reference probes for form measurements in static and dynamic mode using novel portable displacement generators with uncertainties in the range 10 nm–100 nm and to evaluate the current state of the art for calibration of flick standards.

To investigate the traceable calibration of transducers to be used as portable displacement generators under static (+/-1000 μm) and dynamic (+/-100 μm) measurement conditions, including investigations into the set-up of the generators to be used as 'portable'. Further, to prepare two best practice guides on their use in the calibration of stylus instruments and form measurement probes.

To develop noise reduction software, including the use of numerical methods for random noise bias reduction, that can be used to pre-process roughness and form profiles data to reduce the overall uncertainties down to a level of 10 nm in roughness and roundness measurements.

For each project partner, to develop an individual strategy for the long-term operation of the capacity developed, including regulatory support, research collaborations, quality schemes and accreditation. In addition, partners to develop a strategy for offering calibration services from the established facilities to their own country and neighboring countries. The individual strategies to be discussed within the consortium and with other EURAMET NMIs/DIs, to ensure that a coordinated and optimized approach to the development of traceability in this field is developed for Europe as a whole.

IV. Potential Outputs and Impact from the Project Results

A. Calibration of reference stylus instruments using novel portable displacement generators vs existing methods

Artefacts having only specific nominal values (e.g. depth setting standards) are used for calibration of surface roughness devices. In other words, traceability is obtained through fixed artefacts (stylus instruments) calibrated by surface roughness devices. Primary traceability is obtained by calibration of these reference devices using complicated interferometric methods. Only few advanced NMIs have facilities for the required precision level e.g.10-100 nm uncertainty up to 1 mm range. Other NMIs calibrate their reference devices using artefacts calibrated by advanced NMIs just like secondary level labs. Thus, for less advanced NMIs there is a need to calibrate their reference instruments traceable to the SI unit, the meter. Up to now, there is no documentation for alternative routes or any detailed investigations for calibration of stylus instruments (particularly reference ones in NMIs) apart from using depth setting standards.

The project will provide new routes and novel methods for achieving direct traceability to the SI unit, the metre instead of the current necessity of using artefacts with fixed nominal values. NMIs will be able to calibrate their reference devices utilising accessible and portable displacement generators to achieve traceability with an uncertainty better than 10 nm. Calibrations carried out using displacement generators will make continuous sampling possible, whereas when depth setting standards are used, only discrete sampling is possible. Continuous sampling will provide better knowledge for error mapping of the reference stylus instruments as well as reaching the larger calibration ranges e.g. +/-1000 μm. In the case where sphere standards are required to be used, this project will develop openly accessible software to enable the calibration of any manufacturer's device without the need for proprietary software

B. Calibration of reference probes for form measurements in static and dynamic mode using novel portable displacement generators vs existing methods

Form measuring probes are calibrated in static mode mostly using gauge blocks and then the performance of the probe is checked using so called flick standards (or multi wavelength standards) for dynamic measurement conditions. Precise primary calibration of flick / multi wavelength standards is required and this is one of the critical issues for most NMIs since only a few NMIs have the capabilities to do so. The results of a EURAMET comparison between NMIs revealed a partly unsatisfactory agreement between the measured values and strongly varying measurement uncertainties. There is currently no documentation (guides, standards etc.) for primary calibration of flick / multi wavelength standards.

The project will enable calibration of contact measuring probes in static and dynamic mode using accessible and portable equipment having direct traceability to the SI unit, the meter with an uncertainty better than 10 nm. The performance of the reference contact measuring probes will be evaluated in detail. The results will be used to prepare best practice guides for NMIs and manufacturers and will contribute to the establishment of new standards for primary calibration of flick standards (or multi wavelength standards

C. Traceable calibration of transducers to be used as portable displacement generators.

Displacement transducers are able to measure/generate very small displacement steps (down to 1 nm) utilizing various reference measurement systems such as laser interferometers, capacitive sensors, linear encoders etc. They are equipped with piezoelectric systems for high precision applications in order to generate precise displacement steps at nm levels. They can be calibrated by applying laser displacement interferometers to provide direct traceability to the SI unit, the meter. However, use of these motorized systems together with laser interferometers to calibrate stylus instruments/contact measuring probes is complex and difficult.

The aim is to use a displacement transducer as a stand-alone device after its calibration by laser interferometers under static (+/-1000 µm) and dynamic (+/-100 µm) measurement conditions. However, this requires proper investigations since drifts and unpredicted behavior of such systems degrade their high precision properties. The project will go beyond the state of the art by detailed investigation on how to use the displacement transducers as portable displacement generators and by preparing best practice guides on this topic as currently there are none

D. Development of noise reduction software

Noise is one of the main challenges of surface roughness and form measurements. In surface roughness and form measurements, measured surfaces can be extremely smooth and fit into required geometrical shapes (precisely machined e.g. round better than 1/1000 of diameter of human hair). During measurement of such precise parts, noise influences the accuracy of the measurement and may offset the results. Currently, form and surface roughness devices are located on heavy mass tables (granite) or static and active vibration isolation tables for noise reduction. Furthermore, producers of these devices develop their own software and apply their own statistical tools. These software applications are only used for the specific devices of the producers.

Within the project, noise reduction software including the use of numerical methods for random noise bias reduction, will be developed to be used to pre-process roughness and form profile data. It is expected that the overall uncertainties will be reduced down to levels of 10 nm in roughness and roundness measurements. The software will be designed to be used in any commercial form and surface measurement device that can provide electronic data output.

E. Impact on industry

The NMIs will establish new services for calibration of form and surface roughness standards using the traceability route established with the novel methods developed in the project. Improvements will enable various industries (such as automotive, aerospace and energy) to obtain traceable and more reliable measurements of form and surface finish parameters. In addition, newly developed guides will facilitate the application of the new methods for CMM, form and stylus instrument users and manufacturers.

F. Impact on the metrology and scientific communities

Newly developed methods, which will provide alternatives to the conventional ones will create an impact on calibration laboratories and will be presented to emerging NMIs, accredited labs, end users and manufacturers. On a broader scope, the project will strengthen the collaboration of European NMIs and will increase their competitiveness and consistency by producing a draft calibration guide for the use of portable displacement generators for calibration of stylus instruments and contact measurement probes.

G. Impact on relevant standards

After its end, the project will contribute to a further revision of ISO 12179 [15], use of depth setting standards for calibration of contact stylus instruments. The consortium will promote the results of the project within the standardisation community and will provide input into the standardisation process e.g. CCL, EURAMET TC-L, COOMET TC Length and Angle, IMEKO TC 14 "Geometrical Quantities". For ISO, the standards relevant to the project that are in preparation/revision will be identified, and contributions to the work on these standards will be submitted to the appropriate working groups or committees. A contact will be made with the EMPIR project 17NRM03 EUCoM (Standards for the evaluation of the uncertainty of coordinate measurements in industry) [21] to share the project outputs.

H. Longer-term economic, social and environmental impacts

Measurement of form and surface finish parameters relate to functionality of manufactured parts. Better achievements for the desired tolerances on automotive parts will provide better engine parts working more efficiently with improved fuel savings, longer life time, reduction in waste and production time, which altogether will have a positive impact on the environment.

Manufacturers in advanced countries of Europe (such as Germany and France) are establishing manufacturing plants in other countries of Europe and also in Asia, Middle East and Africa. In order to sustain similar quality of the manufactured parts, there is a need for development of metrology capabilities in the respective countries. The project will provide this for surface roughness and form measurements, which will in turn result in improvements of manufacturing processes. This will increase economic growth in Europe and its neighbouring region(s) and enhance industry competitiveness and will therefore be instrumental for creating jobs..

V. Conclusion

The main impact of the project for BIM will be the improvement of its calibration measurement capabilities in the field of surface texture.

BIM will improve the quality of the offered services through developing of novel practical methods in the field of contact probes and stylus instruments measurement to achieve direct traceability to the SI unit, the meter.

There will be an additional benefit for the stakeholders (manufactures, accredited laboratories, accreditation services, etc.).

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30th INTERNATIONAL SCIENTIFIC SYMPOSIUM
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Improvement of Micrometer-normalmeter for Control of Gears in Heavy Engineering

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***Abstract*—The report discusses the measurement of the length of the total normal W by a specialized micrometer for measuring in the conditions of heavy engineering. The need for improvement of a specialized micrometric measuring instrument for W control is substantiated and the results of the empirical study are presented.**

Keywords—Improvement of micrometric normal meter, Length of the general normal of a gear wheel, Specialized measuring instrument, Gear control with large module.

I. INTRODUCTION

Each property of a machine or element is determined by several basic quantitative and qualitative indicators and they are leading factors in the process of technical quality control in the technological stages of production. The length of the common normal W is defined as the distance between two tangents to the different profiles of two or more teeth [1]. In the production process of gears described below, the measurement of the length of the total normal is performed to determine its deviation E_{wr} from the nominal value W, characterizing the thickness of the tooth, respectively the lateral clearance in the gear. From a metrological, technological and operational point of view, the measurement of geometric and in particular kinematic indicators of gear accuracy has historically been divided into two large, fundamentally different groups - methods and devices for production (operational, technological) control, including measurement of differentiated accuracy indicators and acceptance (output / input) control by complex accuracy indicators [5].

The object of the present study are the parameters set in the design documentation of the product, measured during interoperational control. The considered case of element-by-element control does not use as a base the axis of the gear wheel, realized during its installation on the two sliding bearing supports. The test gear consists of a cylindrical gear wheel engaged with one or two racks.

The first and main feature is the possibility of mounting the component. A common discrepancy is the inability to mount to the assembly. For the gear in question, this is possible if the top diameter of the gear is larger than prescribed, and if it is still installed, the gear will be at risk of jamming during operation.

The second sign of deviation from the requirements for quality indicators is related to the reduction of the service life of the element, which leads to a reduction of the resource service life and the whole assembly unit. For example, if the tested gear is less than the total normal length, as a consequence, the length of the practical gear line $(\overline{ab})$ in the gear will be reduced, and hence the overlap coefficient in the gear. Another consequence is that during the operation of the engaged gear pair, interference of the teeth in gearing can occur, leading to higher levels of noise during operation and cyclic shock loads of the gear.

The third feature includes increased design and performance of the product. This case is the least common in practice, as it involves additional, often unjustified investments.

The reasons for the occurrence of the above discrepancies are due to a large number of objective and subjective factors.

The purpose of this report is to justify the practical need for improvement (rationalization) of a specialized micrometric device for measuring the length of the general norm in quality control and management of the produced gears with large modules in a Bulgarian machine building company.

II. EXPOSURE

The kinematic accuracy indicators of the gears and gears regulate those errors that give rise to a variable gear ratio (cyclic, non-constant load) per revolution of the gear.

Two indicators of kinematic accuracy are recommended in the specialized literature for gear control and gears for technological operational control. One is related to the tangential component of the kinematic error (errors in the kinematic circuit from the tool traversal), and the other - to the radial component of the kinematic error (errors in establishing the workpiece on the gear machine).

To estimate the radial component of the kinematic error, the radial beating index F_{rr}, is most often used, and to control the tangential component - the fluctuation of the length of the total normal F_{vwr}.

Simple measuring instruments, such as micrometer normalmeters and calibers, are used to measure and control the length of the general normal. The fluctuation of the length of the total normal F_{vwr} is defined as the difference between the largest $W_r\ max$ and the smallest $W_r\ min$ actual lengths of the total normal when sequentially measuring all the normals along the dental crown [9].

$$W_{vwr} = W_{r\,max} - W_{r\,min} \qquad (1)$$

Similar to radial beating, when measuring the length of the total normal, it is possible to reduce the number of measurements Z_i on the dental crown [9].

When measuring a gear with a specialized measuring instrument for controlling the length of the total normal at a certain stage of production, an average measured value E_{wr} = 112,01 mm was obtained at a nominal value W = 112,15 (+ 0 / -0,11) mm , and the details are classified as non-conforming production. When re-measuring the operator with his measuring instrument having the same measuring range, constant and accuracy class, but from another manufacturer and with a different design, a size W = 112.04 mm was obtained and the part was considered suitable.

After metrological inspection of the two normal meters used, it is established that both measuring instruments are metrologically sound. It is concluded that the problem is in the design of one of the two measuring instruments, realizing the control of W (Fig. 1).

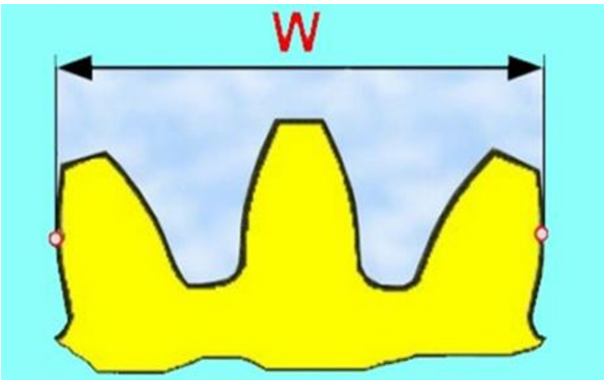

Fig.1.

In Fig. 2. the sub-assembly drawing of the product with the controlled geometrical parameters at technological control with a specialized means for measuring the length of the general normal W is shown.

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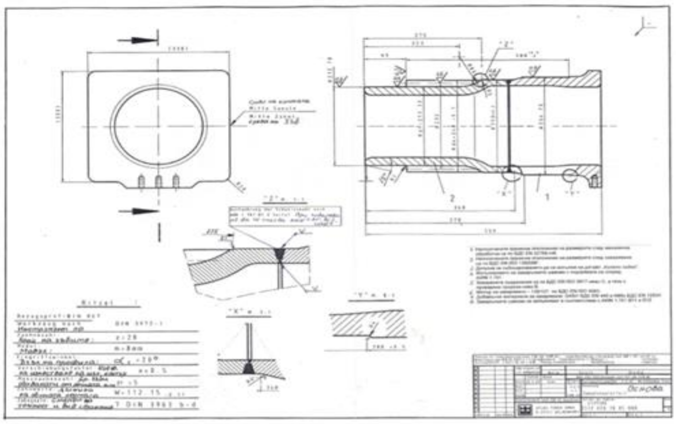

Fig.2.

From the subassembly drawing of Fig. 2 it is seen that the length of the general normal W according to the design documentation must be in the range from Wmin = 112.04 mm to Wmax = 112.15 mm (tolerance T = 0.11 mm).

Table 1 presents information on the specialized micrometer measuring instrument for metrological control provided by the instrument manufacturer.

In Fig. 3 shows the general view of the improved normal meter for measuring the length of the total normal when gearing cylindrical gears with straight teeth by the method of crawling [3].

TABLE I

Production data of the measuring instrument	
Name	Micrometric normal meter
Made in	SUHL / DDR
Trademark	FEINMESSZEUGFABRIK: KS
Accuracy class	First grade
Working range	100 – 125 mm
Upcoming inspection	05.20
Factory number	11080
Constant	i = 0,01

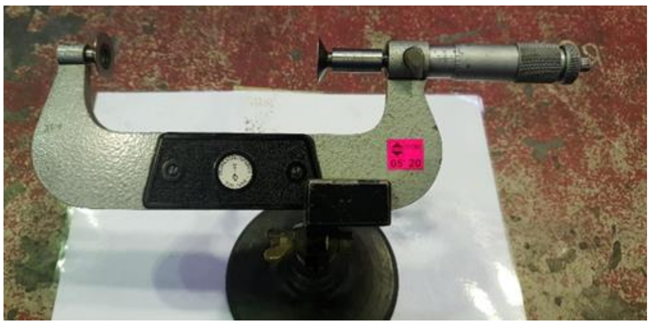

Fig.3.

III. Methods and Research

The main task of the experiment was to determine the factors that most strongly influence the measurement error with the studied measuring instrument [4].

Using an empirical approach to solve the metrological problem, it was found that in the working position for measuring W with the normal meter, the necessary contact points are shifted between the measuring heels of the device and the involute profiles of the teeth of the controlled gear [8]. This position is shown in Figure 4, illustrating the actual operating position of the normal meter *4*

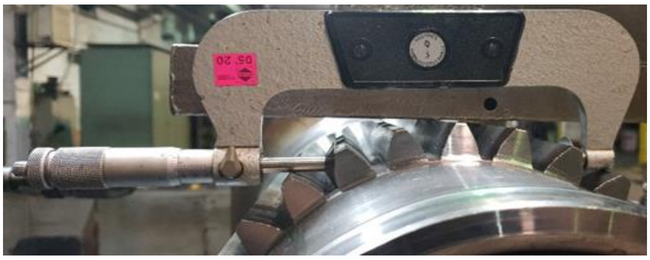

Fig.4.

It was reported that there is a difference of 4.20 m between the diameters of the shafts to which the fixed and movable heels (plates) of the normal meter are attached. In the event that one of the shafts of different diameters comes into contact with the top circle of the controlled gear during the measurement, an detection error occurs, which also results in a measurement error (Figure 5).

For the purposes of the study, a compensation sleeve was designed, through which the diameters of the two shafts were "aligned" and a series of measurements were performed with the improved normal meter with compensation sleeve and without compensation sleeve in real production problem, under real production conditions.

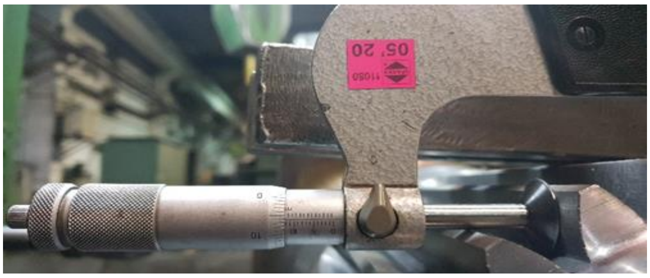

Fig.5.

The results of the three series of measurements with three repetitions for each series without a compensating sleeve of the measuring instrument are presented in Table 2. From the three series of measurements, the same results were reported, and the table shows one result from each series of measurements.

TABLE II

Measurement results with a specialized measuring instrument without a compensating sleeve		
Number of attempts, №	**Value of W according to construction documentation**	**Measured value of W**
№1	112,15 (+0/-0,11)	112,06
№2	112,15 (+0/-0,11)	112,06
№3	112,15 (+0/-0,11)	112,06

After placing a compensating sleeve on the movable shaft of the micrometer, it was again metrologically checked in a specialized factory metrological laboratory for angular and linear dimensions (Figure 6).

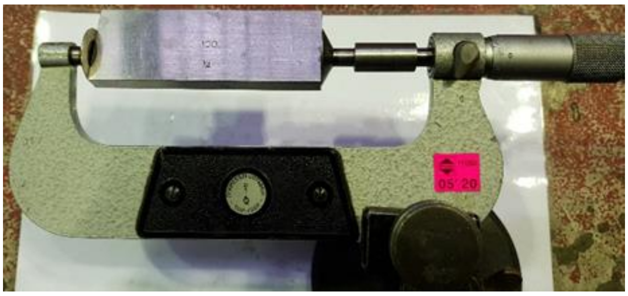

Fig.6.

Using the improved micrometer, three series of measurements were performed, with three repetitions in each series (Figure 7). The obtained measurement results are presented in Table 3.

Fig.7.

TABLE 3

Measurement results with a specialized measuring instrument with a compensating sleeve mounted		
Number of attempts, №	**Value of W according to construction documentation**	**Measured value of W**
№1	112,15 (+0/-0,11)	112,09
№2	112,15 (+0/-0,11)	112,09
№3	112,15 (+0/-0,11)	112,09

As can be seen from Table 3, from the three series of measurements, different results were obtained compared to Table 2, with a reported difference of 0.03 mm.

IV. Conclusion

A metrological discrepancy was identified due to the difference in the diameters of the movable and fixed heel shafts of the micrometer-normalometer when used to further establish the peak diameter of the controlled gear.

The proposed solution / improvement relates to and is suitable for a specific specialized measuring instrument in the conditions of gear control in the field of heavy engineering. This improvement should not be taken as a general rule for streamlining other specialized normal meters for controlling the length of the general norm W when gearing cylindrical gears with an involute or other gear profile.

By means of the improvement made in the positioning of the measuring instrument, an additional setting base is used - the top diameter of the controlled gear wheel and the subjective error in establishing the normal meter when measuring W is avoided.

The rationalization presented in the report is closely in line with the specific needs for control of the manufacturer of gears and the imposed metrological practice in the enterprise when measuring in the conditions of serial production.

An improvement of a specialized micrometric means for measuring the length of the total normal of gears in the conditions of heavy engineering is proposed in order to realize an additional installation base for measurement.

The improved normal meter has been successfully adapted for gear control of involute cylindrical gears with a large module in a machine building company.

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SECTION III

MEASUREMENT AND INFORMATION SYSTEMS AND TECHNOLOGIES

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Analysis of the State Diagram Correctness of Automatic Logic Control Systems on FPGA Paper

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***Abstract*— The work is dedicated to verification of automatic logic control systems by analyzing the correctness of state diagrams of control finite state machines which are represented in the form of the code in the hardware description language. As a method for state diagram analysis the, it is proposed to use the concept of orthogonality, as a system of incompatible events. Analysis of the correctness is carried out by analysis the results of behavioral modeling and logical synthesis using CAD tools.**

***Keywords*— *finite state machine, state diagram, HDL-model, synthesis,* orthogonal Boolean function.**

I. Introduction

One of the metrological tasks is the quality control of the software. If for traditional programming languages these issues are worked out in sufficient detail, then there are no established approaches for hardware description languages.

Hardware Description Languages (HDL) are characterized by dualism. From one side, this is a code in a formal language with all its characteristics and properties, and from another side, this is a description for digital circuit with all restrictions imposed by the corresponding technological base. In addition, a computer-aided design tool (CAD) has a component called synthesizer which is located between the code in the hardware description language (HDL model) and digital circuit. A subset of HDL, which is correctly converted by a synthesizer into digital circuits, which is called, synthesized HDL subset. In addition to the fact that HDL operators, which correctly describe the circuit, must be included in the synthesized subset, the structure of HDL model must fits to certain rules of optimal synthesis. In case of finite state machine (FSM) model, so-called two-processor FSM's pattern, in which the transition and output functions are calculated in one process, and the assignment of new state is performed in another process associated with synchronization.

During verification of logical control system (LCS) it is advisable to apply the functional approach – check not the software HDL-code and the circuit, which was synthesized on its basis, but the functional model of the state machine – the state diagram. It should be noted that from the point of view of synthesis the FSM's pattern uniquely and correctly reflects the functional model of the finite state machine in the form of the state diagram [1].

The rules for checking the state diagram for correctness are developed in sufficient detail and practically standardized. This is check for completeness, consistency, feasibility and the presence of generating circuits [2]. Proceeding from this, an actual task is to develop verification procedures for HDL models of finite state machines taking into account of the correctness under condition of state diagram from one side, and, rules of synthesizers' operation on technology platform of the CAD FPGA from another hand.

II. Correctness Verification of HDL-Model, which is Represented as State Diagram

The syntactical correctness of the state diagram is determined by the fulfillment of the conditions for transition functions: consistency (orthogonality) and completeness. Consistency in the state diagram is provided in the case, if transitions are simultaneously forbidden to any of two or more arcs, which come out from one vertex. The completeness of the state diagram (marks' disjunction of all arcs, which is outgoing from a vertex, is equal to one) is checked after ensuring consistency.

A fragment of the state diagram for vertex a_i with K outgoing arcs is shown in fig. 1.

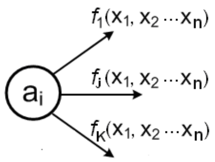

Fig. 1. Mapping of transition function conditions on the graph model

Each arc is associated with logical expression of the transition function conditions $f(x_1,x_2,...x_n)$ in the disjunctive normal form (DNF) also known as sum of products (SOP) form:

$$f(x_1,x_2,...x_n) = f_1(x_1,x_2,...x_n) \vee \ldots$$
$$\vee f_j(x_1,x_2,...x_n) \vee \ldots \vee f_K(x_1,x_2,...x_n).$$

Completeness is checked for each vertex of state diagram by analyzing of transitions' conditions of all arcs, which is outgoing from this vertex, i.e. $\bigvee_{j=1}^{K} f_j(x_1,x_2,\ldots x_n) = 1$. The completeness of conditions is defined as cover of all 2^n products (terms) of Boolean transitions functions set, where n – quantity of transitions' conditions (input variables which initiate transitions from this vertex), i.e. $f(x_1,x_2,\ldots x_n) = 1$.

While ensuring the consistency, for each vertex of the state diagram, the orthogonalization of Boolean expressions of transitions' conditions is checked (the absence of common terms in Boolean expressions of conditions for different arcs) for arcs, which is outgoing from the considered vertex, i.e. $\forall(f_g \cdot f_h = 0),\ g \neq h$ [3].

A normal disjunctive function of the algebra of logic is called orthogonal if all the conjunctive terms are mutually orthogonal. For such function, there is no set of variables' values, which belongs more than to one elementary conjunction, that is, on any set of variables' values, the value of one can be accepted only by one conjunction. If the logical function is presented in the form of a Karnaugh map, the images of conjunctions (products) will not intersect. An example of orthogonal DNF can be its canonical form (CDNF or CSOP), which consists of complete mutually orthogonal conjunctions [4].

Let's consider a method for constructing an orthogonal complete system of transitions functions for the vertex of the state diagram.

Let's use the following definitions: f – complete CDNF from n variables, that is $f(x_1,x_2,\ldots x_n) = 1$ – Boolean function that takes the value 1 on all 2^n sets, f^* – complete CDNF from (n-1) variables, f^{**} – complete CDNF from (n-2) variables, f^{***} – complete CDNF from (n-3) variables and so on. Thus, $f = f^* = f^{**} = f^{***} \equiv 1$.

The orthogonality of Boolean function' terms is ensured by decomposing into the corresponding variables, taking into account the completeness of decomposition into all variables [5].

According to the first theorem, the decomposition will be a follows:

$$f = \overline{x_1} \cdot f^* \vee x_1 \cdot f^* = \overline{x_1} \cdot 1 \vee x_1 \cdot f^* = \overline{x_1} \vee x_1 \cdot f^* = \overline{x_1} \vee$$
$$\vee x_1 (\overline{x_2} \vee x_2 \cdot f^{**}) = \overline{x_1} \vee x_1 (\overline{x_2} \vee x_2 (\overline{x_3} \vee x \cdot f^{***})) =$$
$$= \overline{x_1} \vee x_1 (\overline{x_2} \vee x_2 (\overline{x_3} \vee x_3 \cdot (\ldots \cdot\ (\overline{x_n} \vee x_n)))).$$

Thus, the complete Boolean function of n variables decomposes at least to (n + 1) conjunctions while preserving the essence of all n variables.

As an example, let's consider the complete CDNF $f(x_1,x_2,x_3) = 1$. By definition, a CDNF is orthogonal. We write the complete CDNF and perform the decomposition by x_1 with the replacement of the left side of the decomposition inside brackets with 1.

$$f(x_1,x_2,x_3) = \overline{x_1}\,\overline{x_2}\,\overline{x_3} \vee \overline{x_1}\,\overline{x_2} x_3 \vee \overline{x_1} x_2 \overline{x_3} \vee$$
$$\vee \overline{x_1} x_2 x_3 \vee x_1 \overline{x_2}\,\overline{x_3} \vee x_1 \overline{x_2} x_3 \vee x_1 x_2 \overline{x_3} \vee x_1 x_2 x_3 =$$
$$= \overline{x_1}(\overline{x_2}\,\overline{x_3} \vee \overline{x_2} x_3 \vee x_2 \overline{x_3} \vee x_2 x_3) \vee x_1(\overline{x_2}\,\overline{x_3} \vee$$
$$\vee \overline{x_2} x_3 \vee x_2 \overline{x_3} \vee x_2 x_3) = \overline{x_1} \cdot 1 \vee x_1 \cdot (\overline{x_2}\,\overline{x_3} \vee \overline{x_2} x_3 \vee$$
$$\vee x_2 \overline{x_3} \vee x_2 x_3) = \overline{x_1} \vee x_1 (\overline{x_2}\,\overline{x_3} \vee \overline{x_2} x_3 \vee x_2 \overline{x_3} \vee x_2 x_3).$$

Let's perform similar procedure of decomposition by x_2 for the expression in brackets. Open brackets and get the complete orthogonal function of three variables (1).

Based on this, we can conclude that the complete orthogonal function of n variables has at least (n + 1) conjunctions. So, from each state of the finite state machine with the function of transitions' conditions from n variables $f(x_1,x_2,\ldots x_n)$ there must be at least (n + 1) transitions.

$$f(x_1,x_2,x_3)=\bar{x}_1 \vee x_1(\bar{x}_2(x_3 \vee \bar{x}_3) \vee x_2(\bar{x}_3 \vee x_3)) =$$
$$= \bar{x}_1 \vee x_1(\bar{x}_2 \cdot 1 \vee x_2(\bar{x}_3 \vee x_3)) = \qquad (1)$$
$$= \bar{x}_1 \vee x_1(\bar{x}_2 \vee x_2\bar{x}_3 \vee x_2x_3) =$$
$$= \bar{x}_1 \vee x_1\bar{x}_2 \vee x_1x_2\bar{x}_3 \vee x_1x_2x_3 .$$

One of the ways of visual analysis of the transitions' functions orthogonality is representation of the orthogonal functions using Karnaugh maps. Karnaugh map for the orthogonal function (1) is shown in fig. 2 (a). From this map, it can be seen that for the orthogonal function, groups of ones for the complete CDNF don't intersect, i.e. conjunctions have no common parts.

Karnaugh map for the orthogonal function $f(x_1,x_2,x_3)=\bar{x}_1 \vee x_1\bar{x}_2 \vee x_1x_2\bar{x}_3$ is shown in fig. 2 (b), but this function is not complete, since there is no group which is corresponds to conjunction $x_1x_2x_3$. This is due to the fact that the construction of this function violated the rule of completeness of the function, i.e. $f^* \neq 1$.

Karnaugh map for the orthogonal function $f(x_1,x_2,x_3)=\bar{x}_1 \vee x_1\bar{x}_2 \vee x_1x_2$ is shown in fig. 2 (c), but this function is also not complete, since there is no variable x_3. This is due to the fact that construction of this function violated the rule that in complete function supposed to be no less than $(n + 1)$ conjunctions.

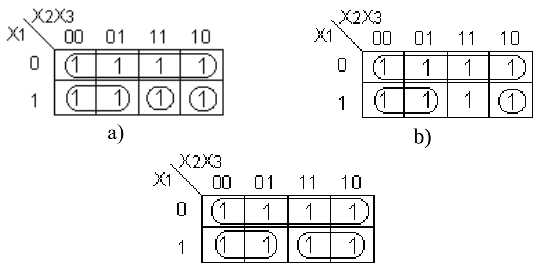

Fig. 2. Karnaugh maps for orthogonal functions

III. Comparison of Synthesis Results of HDL-Codes of Correct and Incorrect State Diagramms

Let's consider an example of the state diagram (fig. 3) with correct conditions for transitions from the a_1 state.

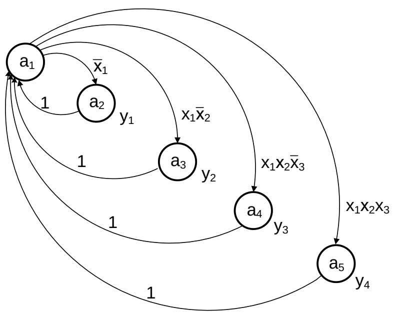

Fig. 3. The state diagram of Moore FSM with the correct conditions of transitions

The transitions' conditions function from the a_1 state is orthogonal, therefore, conditions of transitions are consistent. In addition, the function is complete. VHDL-model of this FSM is shown in fig. 4.

```
library IEEE;
use IEEE.std_logic_1164.all;
entity Fsm_right is
        port (x1, x2, x3, Clk, reset: in STD_LOGIC;
        y1, y2, y3, y4: out STD_LOGIC);
end;
architecture Fsm_right of Fsm_right is
        type State_type is (a1, a2, a3, a4, a5);
        signal State, NextState: State_type;
begin
        Sreg0_CurrentState: process (Clk, reset)
        begin
                if reset='1' then State <= a1;
                elsif Clk'event and Clk = '1'
                then State <= NextState;
                end if;
        end process;
        Sreg0_NextState: process (State, x1, x2, x3)
        begin
        case State is
        when  a1=> if x1='0' then NextState <= a2;
                elsif x2='0' then NextState <= a3;
                elsif x3='0' then NextState <= a4;
                else NextState <= a5;
                end if;
        when  a2=>  NextState <= a1;
        when  a3=>  NextState <= a1;
        when  a4=> NextState <= a1;
        when  a5=> NextState <= a1;
        when others => NextState <= a1;
        end case;
        end process;
        y1 <= '1' when State=a2 else '0';
        y2 <= '1' when State=a3 else '0';
        y3 <= '1' when State=a4 else '0';
        y4 <= '1' when State=a5 else '0';
        end;
```

Fig. 4. VHDL-model of Moore FSM with correct conditions of transitions

Timing diagram of this FSM are shown in fig. 5.

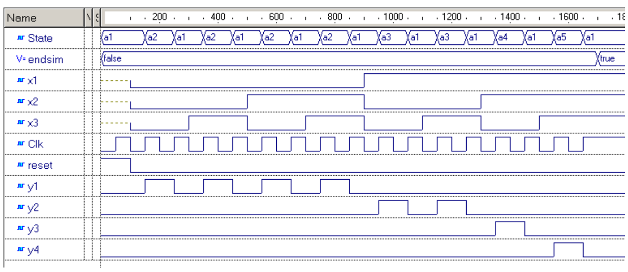

Fig. 5. Timing diagram of Moor FSM with correct conditions of transitions

It reflects the results of simulation in the system ALDEC Active-HDL on all combinations of conditions x_1, x_2, x_3.

The diagram shows that the transitions' conditions function is complete and orthogonal. During the period from 150 ns to 950 ns, the FSM changes to the state a_2 $(y_1 = 1)$ as long as the condition $\bar{x}_1$ is true, i.e. $(x_1 = 0)$, and then returns back to a_1 $(y_1 = 0)$. During the period from 950 ns to 1350 ns, the FSM changes to the state a_3 $(y_2 = 1)$ as long as the condition $x_1\bar{x}_2$ is true, i.e. $(x_1 = 1, x_2 = 0)$, and then returns back to a_1 $(y_2 = 0)$. During the period from 1350 ns to 1550 ns, the FSM changes to the state a_4 $(y_3 = 1)$ as long as the condition $x_1 x_2 \bar{x}_3$ is true, i.e. $(x_1 = 1, x_2 = 1, x_3 = 0)$, and then returns back to a_1 $(y_3 = 0)$. During the period from 1550 ns to 1750 ns, the FSM changes to the state a_5 $(y_4 = 1)$ as long as the condition $x_1 x_2 x_3$ is true, i.e. $(x_1 = 1, x_2 = 1, x_3 = 1)$, and then returns back to a_1 $(y_4 = 0)$.

Let's consider the following example of the state diagram (fig. 6). Conditions of transitions from the state a_1 are incorrect from the point of view of transitions' conditions functions orthogonalization; during transition to a_4 and a_5 there is no variable x_1 in the term, but they don't contradict conditions of transitions $x_1 x_2 \bar{x}_3$ and $x_1 x_2 x_3$. Transitions' conditions functions are complete.

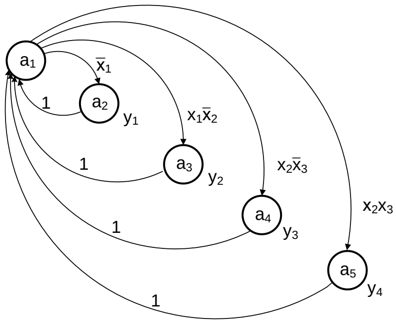

Fig. 6. State diagram of Moore FSM with consistent incomplete conditions of transitions

Transitions from state a_1 can be written in VHDL as follows (fig. 7 (a) or fig. 7 (b)). At the same time, such description is not stylistically correct, but it is not inconsistent and gives the same results during simulation as in fig. 5

```
when  a1=> if x1='0' then NextState <= a2;
           elsif x1='1'and x2='0' then NextState <= a3;
           elsif x2='1'and x3='0' then NextState <= a4;
           else NextState <= a5;
           end if;
```

а)

```
when  a1=> if x1='0' then NextState <= a2;
           elsif x1='1'and x2='0' then NextState <= a3;
           elsif x2='1'and x3='0' then NextState <= a4;
           elsif x2='1'and x3='1' then NextState <= a5;
           end if;
```

б)

Fig. 7. Fragments of the VHDL-model of Moore FSM with consistent incomplete conditions of transitions

In addition, FSM models which are shown in fig. 3 and 6, give exactly the same correct results during synthesis. Synthesis was performed in the system XILINX ISE.

Next, let's consider an example of the state diagram (fig. 8) with a missing transition (by condition $x_1 x_2 x_3$) and incomplete condition for the transition from state a_1 to state a_4: $x_2 \bar{x}_3$ instead of $x_1 x_2 \bar{x}_3$. The transitions' conditions function in this case is non-orthogonal and incomplete.

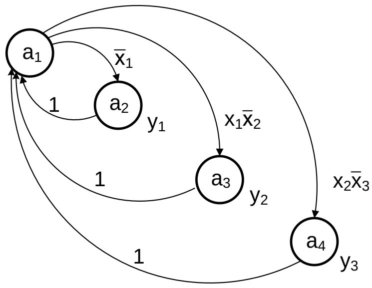

Fig. 8. Moore state diagram with missing transition

A fragment of the VHDL model of this FSM is shown in fig. 9.

```
when  a1=> if x1='0' then NextState <= a2;
           elsif x1='1'and x2='0' then NextState <= a3;
           elsif x2='1'and x3='0' then NextState <= a4;
           end if;
```

Fig. 9. Fragment of the VHDL-model of Moore FSM with missing transition

During simulation of the operation of this FSM (fig. 10), at first glance, everything is fine, but in fact, the variable x_3 is insignificant here, on the set $x_1, x_2, x_3 = 111$ the FSM should not go to any state, but the modeling system put him to the state a_4.

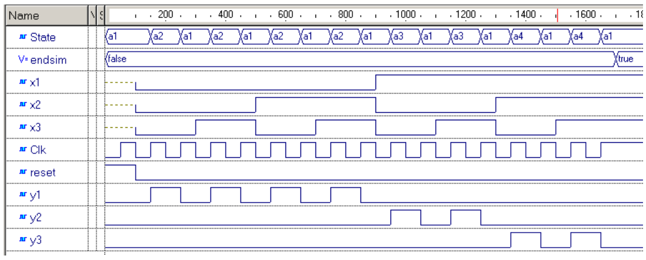

Fig. 10. Timing diagram of Moore FSM with missing transition

Likewise, when conditions $x_1, x_2, x_3 = 010$, the FSM can go into two states a_2 and a_4, which should not be in the case when the FSM works correctly, but the modeling system masks such situation, putting the FSM into the a_2 state. In this example, there is both a lack of completeness and the presence of a contradiction of the transitions' conditions, but this is clearly not manifested at the stages of syntax analysis and simulation.

During synthesis of this FSM can be problems especially in the case of older versions of CAD. For example, when using Xilinx ISE 10.1, a warning appears about four latches in addition to four flip-flops: *Found 4-bit latch for signal <NextState>. Latches may be generated from incomplete case or if statements. We do not recommend the use of latches in FPGA/CPLD designs, as they may lead to timing problems*. That is, instead of two triggers for the four states, 8 triggers of two types are synthesized. This should not be in a correctly synthesized FSM. At the same time, when using the latest version of Xilinx ISE 14.7, this warning will no longer exist.

Thus it is shown that problems associated with incorrect conditions are very difficult to identify during the design process. With equal probability, they can appear both on the timing diagram during behavioral simulation, and in the synthesis process (especially in cases with older versions of

CAD). So, the verification of transitions' conditions for consistency and completeness must be carried out at the stage of forming the state diagram of the FSM.

IV. Conclusion

Construction a logical control system based on FPGA is a modern approach to computer-aided design. One of the most common ways to describe logical control systems is the finite state machine model, which description based on the state diagram. The correctness of the future HDL code depends on the correctness of the state diagram.

The concept of orthogonalization, used to decompose logical functions in the synthesis of digital systems [6], can be also used to check the state diagram for correctness [2]. As a result of the research, it was shown that the transitions' conditions function $f(x_1, x_2, \ldots x_n)$ is non contradictory if it is orthogonal. The orthogonal function of transitions' conditions $f(x_1, x_2, \ldots x_n)$, in its turn, is complete if its terms cover all sets $x_1, x_2, \ldots x_n$.

The verification of HDL model is carrying out at all stages of computer-aided design, namely, at the stage of behavioral simulation (by analyzing timing diagrams), at the stage of synthesizing of the RTL circuit (by analyzing the synthesis report) and at the stage of post-synthesis simulation (by analyzing the timing diagrams, taking into account the technological base). Due to the features of the modeling system, missing transitions or contradictory conditions of transitions at the syntax checking stage are not fixed, moreover at the simulation stage and automated synthesis they may go unnoticed (depending on the version of the synthesizer).

Therefore, verification of the state diagram for correctness is an important and integral step in the automated design of automatic logic control systems, the functioning algorithm of which is presented in the hardware description language

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The Features of Application Method of Continuous Planning of the Process of Diagnosis of the Analogue Systems

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***Abstract*—The authors of the article consider the use of specialized adaptive methods to optimize the diagnostic process for analog and analog-digital systems (ADC). A feature of the systems considered in the article is the lack of a practical possibility of a detailed analysis of the processes which occurs in the diagnosed object under the condition of a constant increase in the complexity of the ADC and as a result of the continuous change in the dynamic properties of the diagnostic object and the diagnostic process itself.**

The work considers the specialized adaptive diagnostic systems in which the effect of "adaptation" to changing conditions is achieved due to the fact that the part of the functions for obtaining, processing and analyzing the missing information about the diagnostic object is carried out not by the designer at the development stage, but by the system itself in the process of its functioning. Such a partial transfer of the functions contributes not only to a more complete use of the working information (a set of data on the status of the ADC obtained directly during the diagnosis) when generating the test influences, but it also significantly reduces the effect of the uncertainty on the quality of the diagnostic process, compensating to some extent for the lack of a priori knowledge of the designer about a controlled process.

Keywords— diagnosis process, adaptive methods, diagnostic systems, Analog Digital Systems, prior uncertainty

I. INTRODUCTION

The increasing complexity of radio-electronic systems (RS) leads to the need to search for methods for diagnosing RS in conditions when there is practically no possibility of analyzing the processes occurring in the analog modules of the diagnosed objects [1]. The more complex the system being diagnosed, the more the uncertainty of the characteristics of analog modules of radio electronic systems grows, i.e. it becomes more and more difficult to determine the nature of the change in the dynamic properties of the diagnostic object and the diagnostic process itself [2,9].

II. THE MAIN PART

The integrated diagnostic methods are based on the use of the information obtained by comparing the measured values of the parameters of the diagnosed equipment with the parameters of its ideal (reference) model. One of the most common methods is the diagnostic method based on the analysis of the response of the system on the basis of the harmonic functions [3]. It is known that the dynamic properties of any radio engineering system can be described by its response h(t), i.e. the weight function. If the function h(t) is expanded in the Fourier series and an analytical dependence is established between the series coefficients for the response h(t) and the parameters of the diagnosed equipment, then on this basis it is possible to carry out the diagnostics.

It is known [3,8,9] that the transfer function of a system is the Laplace transform of its response. Performing similar transformations with the transfer function, we can determine the coefficients a_n and b_n of the Fourier series.

The weight function h(t) in the general case depends on all parameters of the diagnosed object

$$h(t) = f(x_1, x_2, \ldots, x_к)$$

Let h(t) = 0 for $t \geq t_0$. We continue it in an even way. Then the even periodic function h(t) can be expanded in the Fourier series in cosines:

$$h(t) = \sum_{n=0}^{\infty} a_n \cos \frac{n\pi}{t_0} t, \quad (1)$$

where

$$a_n = \frac{2}{t_0}\int_0^{t_0} h(t)\cos\frac{n\pi}{t_0}t\,dt\,.$$

There is a following relationship between the response of the diagnosed object and the real part of the transfer function Re(ω):

$$\mathrm{Re}(\omega) = \int_0^{\infty} h(t)\cos\omega t\,dt$$

Given 1, we can write

$$\mathrm{Re}(\omega,\{x\}) = \int_0^{\infty} h(t)\cos\omega t\,dt\,. \qquad (2)$$

Comparing expressions 1 and 2, we see that for the fixed frequencies they differ only by factor $2/t_0$.

From here we obtain formulas expressing the Fourier coefficients in the terms of the fixed values of the real frequency transfer function of the diagnosed system:

$$a_n = \frac{2}{t_0}\mathrm{Re}[\omega_n,\{x\}], \qquad (3)$$

where $\omega_1 = \pi/t_0$; $\omega_2 = 2\pi/t_0$.

Then we will have

$$h(t) = \frac{2}{t_0}\sum \mathrm{Re}\left(\frac{n\pi}{t_0},\{x\}\right)\cos\frac{n\pi}{t_0}t\,. \qquad (4)$$

It is known that for any bounded and piecewise continuous function, which are the temporal characteristics of the diagnosed equipment, the Fourier series converges on the average to the function

$$\int [h(t) - S_n(t)]^2 dt = 0 \ \text{ at } n \to \infty,$$

where $S_n(t)$ is the sum of the members of the series.

From the convergence it follows that the response of the system can be determined using the discrete values of the real part of the frequency transfer function H(ω). With an increase in the number of terms in the series, the accuracy of the approximation h(t) near 4 increases, but the amount of the computation also increases, since the number of harmonics to be taken into account increases.

To obtain a transient response, it suffices to integrate row 4 from 0 to t_0. Then

$$H(t) = \frac{2}{t_0}\sum_{n=0}^{\infty}\mathrm{Re}\left(\frac{n\pi}{t_0},\{x\}\right)\sin\left(\frac{n\pi}{t_0}t\right). \qquad (5)$$

Or considering equality 3,

$$H(t) = \sum_{n=0}^{\infty} a_n \sin\left(\frac{n\pi}{t_0}t\right).$$

Based on expression 5, they form a system of equations that is used to find the departures of the corresponding parameters of the diagnosed object:

$$H(t_1) = \frac{2}{t_0}\sum \mathrm{Re}\left(\frac{n\pi}{t_0},\{x\}\right)\sin\left(\frac{n\pi}{t_0}t_1\right);$$

$$H(t_2) = \frac{2}{t_0}\sum \mathrm{Re}\left(\frac{n\pi}{t_0},\{x\}\right)\sin\left(\frac{n\pi}{t_0}t_2\right);$$

…………………………………………

$$H(t_\kappa) = \frac{2}{t_0}\sum \mathrm{Re}\left(\frac{n\pi}{t_0},\{x\}\right)\sin\left(\frac{n\pi}{t_0}t_\kappa\right),$$

where $H(t_1)$, …, $H(t_\kappa)$ are the values of the transition characteristic for a system with the nominal parameters measured at intervals $\Delta t = \pi/\omega_0$; $\omega_0 = 2\pi/t_0$.

Since the Fourier coefficients are functions of all parameters of the diagnosed equipment, it is possible to determine the current values of the controlled parameters {x} by solving a system of algebraic equations:

$$a_0 = \frac{2}{t_0}\mathrm{Re}(0,\{x\});\ a_0 = \frac{2}{t_0}\mathrm{Re}\left(\frac{\pi}{t_0},\{x\}\right);$$

……

$$a_n = \frac{2}{t_0}\mathrm{Re}\left(\frac{n\pi}{t_0},\{x\}\right),$$

where a_0, a_1, …, a_n are the current values of the Fourier coefficients taken from the analyzer, the input of which is supplied with a voltage corresponding to the response of the diagnosed object; $\mathrm{Re}(n\pi/t_0, \{x\})$ is the real part of the frequency transfer function.

The second on applicability, you can specify a diagnostic method based on "white noise". This integral method allows you to determine the response of the diagnosed system during its normal operation, i.e. without tripping. It is known that for “white noise” the autocorrelation function is equal to zero for all values of τ, except for the point τ=0, where the random function is multiplied by itself:

$$R_{11}(\tau) = \lim_{\tau\to\infty}\int_{-\infty}^{\infty} U_{ш1}(t)\,U_{ш1}(t\pm\tau)\,dt\,,$$

where $U_{ш1}(t)$ is the voltage of "white noise" at the input of the diagnosed system.

In this case, the relationship between the input and output voltages of the diagnosed system through the response h(t) is determined by the equation

$$U_2(t) = \int_{-\infty}^{\infty} U_1(t-\tau)h(\tau)d\tau\,. \qquad (6)$$

If, in addition to the “white noise", a voltage $U_{c1}(t)$is applied to the input of the diagnosed equipment, then we will obtain the total signal at its output

$$U_2(t) = U_{ш2}(t) + U_{c2}(t),$$

where $U_{c2}(t)$ is the voltage that appears at the output of the controlled equipment after the signal $U_{c1}(t)$ passes through it; $U_{ш2}(t)$ - the voltage at the equipment output.

The cross-correlation function of the voltages $U_{c1}(t)$ and $U_{c2}(t)$ is equal to zero, since the voltage $U_{c1}(t)$ is not supplied to the correlator input.

To automatically obtain the cross-correlation function $R_{12}(t)$, and hence the response h(t), one should use a circuit that allows one to determine the response of the diagnosed equipment for any form of the external signal $U_{c1}(t)$ at its input. Using the obtained function of weight h(t) of the diagnosed equipment, one can determine the current parameters of the diagnosed object.

The method based on the analysis of the transition process in the element-by-element diagnosis of the analog elements of AMES is quite effective [3]. But with this approach, it is imperative to take into the account the non-linearity of the characteristics of the analog devices (it does not matter on the basis of what elements they are built). The nature of phenomena in nonlinear chains is much more complex and diverse than in linear ones. This also applies to the transients, which in the non-linear circuits differ significantly from the transients in the linear circuits.

The nonlinearity of the characteristics of any of the elements of the circuit can lead to both purely quantitative changes in the indicators of the transition process, and to a qualitatively new phenomena. Sometimes the nonlinearity of the characteristic can lead to an increase in the speed of the process in one time interval and to a decrease in another, while the maximum values of the transient currents can increase, but the qualitative side of the phenomena will be preserved. In some cases, as a result of the nonlinearity of the characteristic, new phenomena arise that are fundamentally unattainable in a linear circuit. It is known that in a linear circuit the nature of the transition process is influenced by the circuit diagram and the parameters of its elements, which affect the values of the roots of the characteristic equation. The latter are not the functions of the time and are constant throughout the transition process. In a circuit with nonlinear elements, their parameters depend on the voltages and currents and change the over time, which is often accompanied by new phenomena. For example, a) if the transients in the linear circuits always die out, then this may not be in the non-linear ones, b) after the end of the transient in the linear circuit, the voltages and currents have a source frequency, while in a non-linear circuit oscillations with a frequency different from a source frequency (self-oscillation). The superposition method is not applicable to the nonlinear circuits; therefore, it is impossible to decompose voltages and currents into the forced and free components.

The transient in the non-linear circuits is described using the non-linear differential equations. Due to the fact that a general method for solving such equations was not found, there is no general analytical method that allows us to calculate the transient in a nonlinear circuit of the arbitrary configuration. Depending on the nature of the circuit and the EMF acting in it, various, most often approximate, methods are used to calculate the transient process. Obviously, for a circuit with a constant EMF, the calculation of the transition process is much simpler than for a circuit with a variable EMF. The only condition for modeling the behavior of the diagnosed device is the presence of a test pulse of a certain shape. Moreover, the pulse duration and its shape should be different for different types of analog cascades.

Therefore, to implement this method of AMES functional diagnostics, two additional diagnostic modules are used - a software-controlled functional generator and a high-speed signal processing and a storage module. The connection diagram of these modules to the element under study is performed in accordance with Fig. 1.

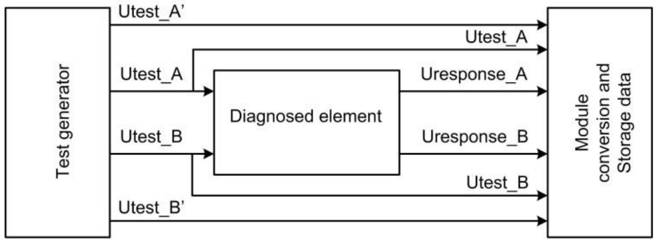

Fig.1. The connection of the functional generator and processing module to the diagnosed element

The block diagram of a program-controlled functional generator is shown in Fig. 2. The control microcontroller of the generator is connected via a USB port to a personal computer.

Through the developed software, a sequence consisting of 100 preset signal level values for each channel is loaded into the microcontroller. In addition, the reference voltage Uref is set as a separate parameter. Thus, it is possible to change the output amplitude of the signal programmatically. At the output of each channel, a reconstruction low-pass filter based on the OPA134 op amp is added, which smooths the steps of the discrete signal levels (removes harmonics above the cutoff frequency) to form an analog signal corresponding to a digital time domain.

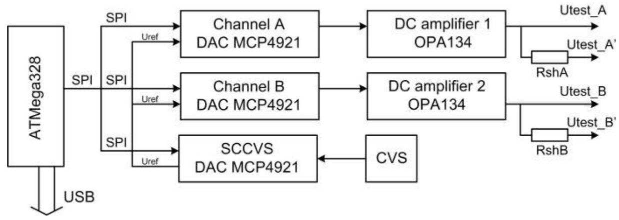

Fig.2. The structural diagram of a program-controlled functional generator

The frequency range of the analog devices that make up the AMES, as a rule, is limited to a frequency of 100 kHz. This is due, first of all, to the low speed of changes in the physical quantities in a technological equipment. As a rule, the maximum frequency of a signal in AMES is possessed by the alternating-voltage reference generators in positioning systems (for example, selsyn, resolvers, etc.). An exception is servo power converters built on the analog components.

When sampling a low-frequency signal, it is assumed that the spectrum of the sampled signal is completely in the first Nyquist zone. However, it is not. The real signal is not limited in the spectrum and in the general case the spectrum of any real signal extends to infinity [4].

If the signal spectrum is not limited by the filter at the input of an ideal sampler, then any frequency component (interference or noise) that is higher than the Kotelnikov upper frequency will be displayed in the frequency band of the useful signal, which is in the frequency range from 0 to $f_{д/2}$. Therefore, when sampling a low-frequency signal at the input of an analog-to-digital converter or a filter on switched capacitors, an analog low-pass filter is always placed to the suppress interfering signals, which allows to reduce the harmful effects of the effect of the superimposing the spectrum of signals.

In Kotelnikov’s theorem, it was implicitly assumed that there was a filter with a rectangular characteristic at the input of the sampler that passes frequencies from 0 to $f_{Д/2}$ and does not pass all frequencies above $f_{Д/2}$. Such a filter is not practical. Therefore, it is very important to determine correctly the requirements for the characteristics of an analog low-pass filter that limits the spectrum of the signal at the input of the sampler (filter to eliminate the effect of the superposition of the spectra).

First, we determine the main parameters of the useful sampled signal. One of the most important parameters of a useful signal is its upper frequency $f_в$. The analog input filter must pass signals lying in the frequency band of the useful signal from 0 to $f_в$, and suppress signals from the second Nyquist zone. In order to make this possible, we select a sampling frequency $f_в$ greater than $2 \times f_в$. Then the frequency $f_Д - f_в$ will be displayed on the frequency $f_в$. Starting from this frequency, the anti-aliasing filter (anti-aliasing filter) should suppress all the components of the input spectrum of the signal.

In addition to the complexity of developing and manufacturing such filters, high-order filters have a number of drawbacks, such as a nonlinear phase response and the associated increase in the group delay of the useful signal at the edge of the filter passband.

An increase in group delay at the edge of the filter passband can lead to the fact that even when working with an audio signal, these distortions will be perceived by the human ear. Phase distortion is even more affected when receiving digital signals or when processing image signals.

All of the above factors lead to the fact that when converting a signal from an analog form to a digital one, it is undesirable to use high-order analog filters to form the spectrum, since they cause the significant distortion of the shape of the original analog signal. Then the only way to increase the dynamic range of the digital device is to increase the frequency spacing of the useful and interfering signals. This can be done by increasing the sampling frequency of the input signal [5].

Typically, the sampling frequency is increased by an integer number of times in order to further limit the bandwidth of the signal using a digital filter and then reduce the sampling frequency of the signal at its output by an appropriate number of times, in other words, to carry out the decimation operation of the digital signal.

Therefore, to form test effects, we use the MCP4921 DAC, with a maximum conversion frequency of 450 kHz. Due to the modular layout the maximum flexibility of the device is provided. If necessary, it is possible to quickly replace or reconfigure individual blocks [6].

The signal processing and storage module consists of a filtering and amplification module, a sampling-storage module, the ADC itself, a static memory module, and a control controller (Fig. 3).

The filtering and amplification module contains a Butterworth bandpass filter with discrete center frequency tuning, an extended horizontal section and a high slope of the frequency response. This frequency response was chosen because the exact shape of the spectrum of test effects is not known in advance and depends on many factors specified during the diagnosis process.

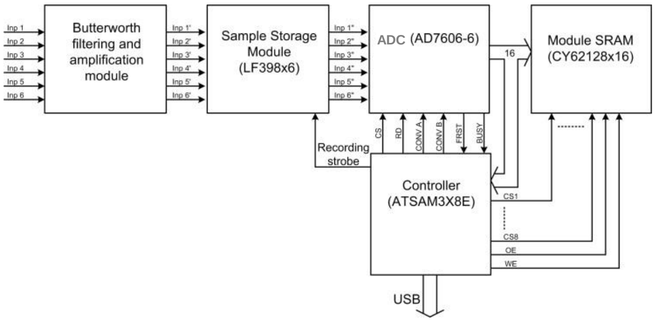

Fig.3. The block diagram of the signal processing and storage module

The 16-bit ADC is assembled on the AD7606-6 chip. It contains six bipolar analog channels with an input range of ± 10 V and output digital signal levels of 0 ... 5 V or 0 ... 3.3 V. This provides the ability to connect the controller without additional pairing [7].

Each channel has an input impedance of 1 MΩ and a conversion speed of 200 kSPS. The possible use of a parallel interface can significantly accelerate the operation of the entire device. The control controller is assembled on an Atmel ATSAM3X8E microcontroller, which is due to the presence of 32-bit registers (which allow reading information from the ADC in two clock cycles) and a high clock frequency (84 MHz). For accurate “binding” to the operation of the ADC, the control controller after the signal “CONV A” and “CONV B” (start of conversion) awaits the removal of the signal “BUSY” (busy).

The SRAM module contains 16 CY62128 static memory chips, a decoder, a block of counters, a level pairing unit. Due to the use of this module, it becomes possible to write high-speed data in read-only mode. If the ADC conversion time is 5 μs, then the total recording cycle will be 10.48 s per channel. After each conversion cycle, the control controller generates two “WE” signals for recording the data from each channel into memory. After the write cycle, the controller overloads the data dump from the static memory to the flash memory card. In this case, an “OE” signal is generated.

The software for the signal processing and storage module contains 4 subprograms integrated into a common software block. In particular: the ADC control routine, the SRAM control routine in write mode, the SRAM control routine in read mode, the routine for writing the data to a flash card. To increase the performance of the controller, the formation of the control signals when reading the data is performed by working with internal registers. This reduces the formation time of control pulses by two orders of the magnitude.

III. CONCLUSIONS

This article discusses the main methods of modeling test effects and proposes a diagnostic method based on the formation of test pulses with deterministic parameters and analysis of the transient process that occurs in the analog devices that make up the AMRS. Also considered is the option of software and hardware for the implementation of this diagnostic method.

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Verification of Automatic Logic Control Systems on FPGA by Analyzing the Correctness of State Diagrams of Control Finite State Machines

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***Abstract* – The work is dedicated to verification of automatic logic control systems by analyzing the correctness of state diagrams of control finite state machines which are represented in the form of the code in the hardware description language. As a method for state diagram analysis the, it is proposed to use the concept of orthogonality, as a system of incompatible events. Analysis of the correctness is carried out by analysis the results of behavioral modeling and logical synthesis using CAD tools.**

Keywords – finite state machine, state diagram, HDL-model, synthesis, orthogonal Boolean function.

I. Introduction

One of the metrological tasks is the quality control of the software. If for traditional programming languages these issues are worked out in sufficient detail, then there are no established approaches for hardware description languages.

Hardware Description Languages (HDL) are characterized by dualism. From one side, this is a code in a formal language with all its characteristics and properties, and from another side, this is a description for digital circuit with all restrictions imposed by the corresponding technological base. In addition, a computer-aided design tool (CAD) has a component called synthesizer which is located between the code in the hardware description language (HDL model) and digital circuit. A subset of HDL, which is correctly converted by a synthesizer into digital circuits, which is called, synthesized HDL subset. In addition to the fact that HDL operators, which correctly describe the circuit, must be included in the synthesized subset, the structure of HDL model must fits to certain rules of optimal synthesis. In case of finite state machine (FSM) model, so-called two-processor FSM's pattern, in which the transition and output functions are calculated in one process, and the assignment of new state is performed in another process associated with synchronization.

During verification of logical control system (LCS) it is advisable to apply the functional approach – check not the software HDL-code and the circuit, which was synthesized on its basis, but the functional model of the state machine – the state diagram. It should be noted that from the point of view of synthesis the FSM's pattern uniquely and correctly reflects the functional model of the finite state machine in the form of the state diagram [1].

The rules for checking the state diagram for correctness are developed in sufficient detail and practically standardized. This is check for completeness, consistency, feasibility and the presence of generating circuits [2]. Proceeding from this, an actual task is to develop verification procedures for HDL models of finite state machines taking into account of the correctness under condition of state diagram from one side, and, rules of synthesizers' operation on technology platform of the CAD FPGA from another hand.

II. Correctness Verification of HDL-Model, which is Represented as State Diagram

The syntactical correctness of the state diagram is determined by the fulfillment of the conditions for transition functions: consistency (orthogonality) and completeness. Consistency in the state diagram is provided in the case, if transitions are simultaneously forbidden to any of two or more arcs, which come out from one vertex. The completeness of the state diagram (marks' disjunction of all arcs, which is outgoing from a vertex, is equal to one) is checked after ensuring consistency.

A fragment of the state diagram for vertex a_i with K outgoing arcs is shown in fig. 1.

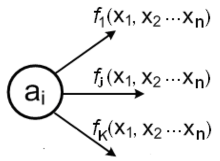

Fig. 1. Mapping of transition function conditions on the graph model

Each arc is associated with logical expression of the transition function conditions $f(x_1,x_2,...x_n)$ in the disjunctive normal form (DNF) also known as sum of products (SOP) form:

$$f(x_1,x_2,...x_n) = f_1(x_1,x_2,...x_n) \vee \ldots \\ \vee f_j(x_1,x_2,...x_n) \vee \ldots \vee f_K(x_1,x_2,...x_n).$$

Completeness is checked for each vertex of state diagram by analyzing of transitions' conditions of all arcs, which is outgoing from this vertex, i.e. $\bigvee_{j=1}^{K} f_j(x_1,x_2,\ldots x_n) = 1$. The completeness of conditions is defined as cover of all 2^n products (terms) of Boolean transitions functions set, where n – quantity of transitions' conditions (input variables which initiate transitions from this vertex), i.e. $f(x_1,x_2,\ldots x_n) = 1$.

While ensuring the consistency, for each vertex of the state diagram, the orthogonalization of Boolean expressions of transitions' conditions is checked (the absence of common terms in Boolean expressions of conditions for different arcs) for arcs, which is outgoing from the considered vertex, i.e. $\forall(f_g \cdot f_h = 0)$, $g \neq h$ [3].

A normal disjunctive function of the algebra of logic is called orthogonal if all the conjunctive terms are mutually orthogonal. For such function, there is no set of variables' values, which belongs more than to one elementary conjunction, that is, on any set of variables' values, the value of one can be accepted only by one conjunction. If the logical function is presented in the form of a Karnaugh map, the images of conjunctions (products) will not intersect. An example of orthogonal DNF can be its canonical form (CDNF or CSOP), which consists of complete mutually orthogonal conjunctions [4].

Let's consider a method for constructing an orthogonal complete system of transitions functions for the vertex of the state diagram.

Let's use the following definitions: f – complete CDNF from n variables, that is $f(x_1,x_2,\ldots x_n) = 1$ – Boolean function that takes the value 1 on all 2^n sets, f^* – complete CDNF from (*n-1*) variables, f^{**} – complete CDNF from (*n-2*) variables, f^{***} – complete CDNF from (*n-3*) variables and so on. Thus, $f = f^* = f^{**} = f^{***} \equiv 1$.

The orthogonality of Boolean function' terms is ensured by decomposing into the corresponding variables, taking into account the completeness of decomposition into all variables [5].

According to the first theorem, the decomposition will be a follows:

$$f = \overline{x_1} \cdot f^* \vee x_1 \cdot f^* = \overline{x_1} \cdot 1 \vee x_1 \cdot f^* = \overline{x_1} \vee x_1 \cdot f^* = \overline{x_1} \vee \\ \vee x_1 (\overline{x_2} \vee x_2 \cdot f^{**}) = \overline{x_1} \vee x_1 (\overline{x_2} \vee x_2 (\overline{x_3} \vee x \cdot f^{***})) = \\ = \overline{x_1} \vee x_1 (\overline{x_2} \vee x_2 (\overline{x_3} \vee x_3 \cdot (\ldots \cdot \ (\overline{x_n} \vee x_n)))).$$

Thus, the complete Boolean function of n variables decomposes at least to (*n + 1*) conjunctions while preserving the essence of all n variables.

As an example, let's consider the complete CDNF $f(x_1,x_2,x_3) = 1$. By definition, a CDNF is orthogonal. We write the complete CDNF and perform the decomposition by x_1 with the replacement of the left side of the decomposition inside brackets with 1.

$$f(x_1,x_2,x_3) = \overline{x_1}\,\overline{x_2}\,\overline{x_3} \vee \overline{x_1}\,\overline{x_2} x_3 \vee \overline{x_1} x_2 \overline{x_3} \vee \\ \vee \overline{x_1} x_2 x_3 \vee x_1 \overline{x_2}\,\overline{x_3} \vee x_1 \overline{x_2} x_3 \vee x_1 x_2 \overline{x_3} \vee x_1 x_2 x_3 = \\ = \overline{x_1}(\overline{x_2}\,\overline{x_3} \vee \overline{x_2} x_3 \vee x_2 \overline{x_3} \vee x_2 x_3) \vee x_1(\overline{x_2}\,\overline{x_3} \vee \\ \vee \overline{x_2} x_3 \vee x_2 \overline{x_3} \vee x_2 x_3) = \overline{x_1} \cdot 1 \vee x_1 \cdot (\overline{x_2}\,\overline{x_3} \vee \overline{x_2} x_3 \vee \\ \vee x_2 \overline{x_3} \vee x_2 x_3) = \overline{x_1} \vee x_1 (\overline{x_2}\,\overline{x_3} \vee \overline{x_2} x_3 \vee x_2 \overline{x_3} \vee x_2 x_3).$$

Let's perform similar procedure of decomposition by x_2 for the expression in brackets. Open brackets and get the complete orthogonal function of three variables (1).

Based on this, we can conclude that the complete orthogonal function of n variables has at least (*n + 1*) conjunctions. So, from each state of the finite state machine with the function of transitions' conditions from n variables $f(x_1,x_2,\ldots x_n)$ there must be at least (*n + 1*) transitions.

$$f(x_1,x_2,x_3) = \overline{x_1} \vee x_1 (\overline{x_2}(x_3 \vee \overline{x_3}) \vee x_2(\overline{x_3} \vee x_3)) = \\ = \overline{x_1} \vee x_1 (\overline{x_2} \cdot 1 \vee x_2 (\overline{x_3} \vee x_3)) = \\ = \overline{x_1} \vee x_1 (\overline{x_2} \vee x_2 \overline{x_3} \vee x_2 x_3) = \\ = \overline{x_1} \vee x_1 \overline{x_2} \vee x_1 x_2 \overline{x_3} \vee x_1 x_2 x_3 . \tag{1}$$

One of the ways of visual analysis of the transitions' functions orthogonality is representation of the orthogonal functions using Karnaugh maps. Karnaugh map for the orthogonal function (1) is shown in fig. 2 (a). From this map, it can be seen that for the orthogonal function, groups of ones for the complete CDNF don't intersect, i.e. conjunctions have no common parts.

Karnaugh map for the orthogonal function $f(x_1,x_2,x_3) = \overline{x_1} \vee x_1 \overline{x_2} \vee x_1 x_2 \overline{x_3}$ is shown in fig. 2 (b), but this function is not complete, since there is no group which is corresponds to conjunction $x_1 x_2 x_3$. This is due to the fact that the construction of this function violated the rule of completeness of the function, i.e. $f^* \neq 1$.

Karnaugh map for the orthogonal function $f(x_1,x_2,x_3) = \overline{x_1} \vee x_1 \overline{x_2} \vee x_1 x_2$ is shown in fig. 2 (c), but this function is also not complete, since there is no variable x_3. This is due to the fact that construction of this function violated the rule that in complete function supposed to be no less than (*n + 1*) conjunctions.

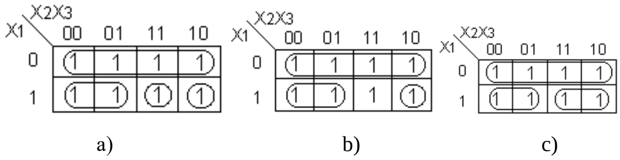

Fig. 2. Karnaugh maps for orthogonal functions

COMPARISON OF SYNTHESIS RESULTS OF HDL-CODES OF CORRECT AND INCORRECT STATE DIAGRAMMS

Let's consider an example of the state diagram (fig. 3) with correct conditions for transitions from the a_1 state.

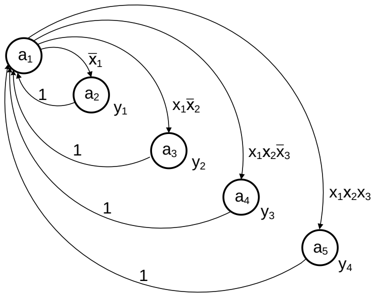

Fig. 3. The state diagram of Moore FSM with the correct conditions of transitions

The transitions' conditions function from the a_1 state is orthogonal, therefore, conditions of transitions are consistent. In addition, the function is complete. VHDL-model of this FSM is shown in fig. 4.

```
library IEEE;
use IEEE.std_logic_1164.all;
entity Fsm_right is
        port (x1, x2, x3, Clk, reset: in STD_LOGIC;
        y1, y2, y3, y4: out STD_LOGIC);
end;
architecture Fsm_right of Fsm_right is
        type State_type is (a1, a2, a3, a4, a5);
        signal State, NextState: State_type;
begin
        Sreg0_CurrentState: process (Clk, reset)
        begin
                if reset='1' then State <= a1;
                elsif Clk'event and Clk = '1'
                then State <= NextState;
                end if;
        end process;
        Sreg0_NextState: process (State, x1, x2, x3)
        begin
        case State is
        when  a1=> if x1='0' then NextState <= a2;
                elsif x2='0' then NextState <= a3;
                elsif x3='0' then NextState <= a4;
                else NextState <= a5;
                end if;
        when  a2=>  NextState <= a1;
        when  a3=>  NextState <= a1;
        when  a4=> NextState <= a1;
        when  a5=> NextState <= a1;
        when others => NextState <= a1;
        end case;
        end process;
        y1 <= '1' when State=a2 else '0';
        y2 <= '1' when State=a3 else '0';
        y3 <= '1' when State=a4 else '0';
        y4 <= '1' when State=a5 else '0';
        end;
```

Fig. 4. VHDL-model of Moore FSM with correct conditions of transitions

Timing diagram of this FSM are shown in fig. 5.

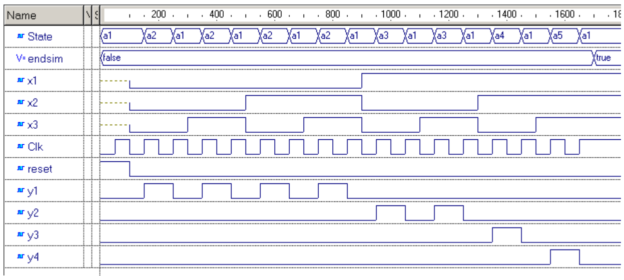

Fig. 5. Timing diagram of Moor FSM with correct conditions of transitions

It reflects the results of simulation in the system ALDEC Active-HDL on all combinations of conditions x_1, x_2, x_3.

The diagram shows that the transitions' conditions function is complete and orthogonal. During the period from 150 ns to 950 ns, the FSM changes to the state a_2 $(y_1 = 1)$ as long as the condition $\bar{x}_1$ is true, i.e. $(x_1 = 0)$, and then returns back to a_1 $(y_1 = 0)$. During the period from 950 ns to 1350 ns, the FSM changes to the state a_3 $(y_2 = 1)$ as long as the condition $x_1\bar{x}_2$ is true, i.e. $(x_1 = 1, x_2 = 0)$, and then returns back to a_1 $(y_2 = 0)$. During the period from 1350 ns to 1550 ns, the FSM changes to the state a_4 $(y_3 = 1)$ as long as the condition $x_1x_2\bar{x}_3$ is true, i.e. $(x_1 = 1, x_2 = 1, x_3 = 0)$, and then returns back to a_1 $(y_3 = 0)$. During the period from 1550 ns to 1750 ns, the FSM changes to the state a_5 $(y_4 = 1)$ as long as the condition $x_1x_2x_3$ is true, i.e. $(x_1 = 1, x_2 = 1, x_3 = 1)$, and then returns back to a_1 $(y_4 = 0)$.

Let's consider the following example of the state diagram (fig. 6). Conditions of transitions from the state a_1 are incorrect from the point of view of transitions' conditions functions orthogonalization; during transition to a_4 and a_5 there is no variable x_1 in the term, but they don't contradict conditions of transitions $x_1x_2\bar{x}_3$ and $x_1x_2x_3$. Transitions' conditions functions are complete.

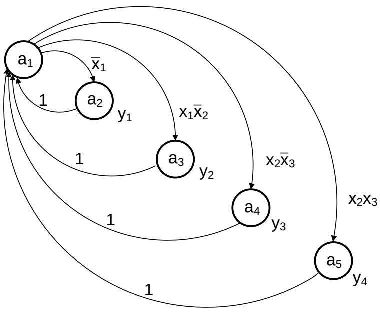

Fig. 6. State diagram of Moore FSM with consistent incomplete conditions of transitions

Transitions from state a_1 can be written in VHDL as follows (fig. 7 (a) or fig. 7 (b)). At the same time, such description is not stylistically correct, but it is not inconsistent and gives the same results during simulation as in fig. 5

```
when  a1=> if x1='0' then NextState <= a2;
```

```
          elsif x1='1'and x2='0' then NextState <= a3;
          elsif x2='1'and x3='0' then NextState <= a4;
          else NextState <= a5;
          end if;
```

а)

```
when  a1=> if x1='0' then NextState <= a2;
          elsif x1='1'and x2='0' then NextState <= a3;
          elsif x2='1'and x3='0' then NextState <= a4;
          elsif x2='1'and x3='1' then NextState <= a5;
          end if;
```

б)

Fig. 7. Fragments of the VHDL-model of Moore FSM with consistent incomplete conditions of transitions

In addition, FSM models which are shown in fig. 3 and 6, give exactly the same correct results during synthesis. Synthesis was performed in the system XILINX ISE.

Next, let's consider an example of the state diagram (fig. 8) with a missing transition (by condition $x_1x_2x_3$) and incomplete condition for the transition from state a_1 to state a_4: $x_2\bar{x}_3$ instead of $x_1x_2\bar{x}_3$. The transitions' conditions function in this case is non-orthogonal and incomplete.

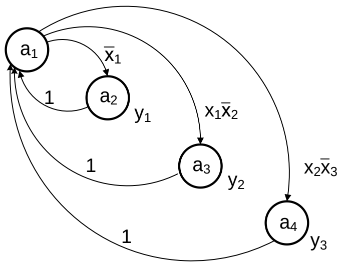

Fig. 8. Moore state diagram with missing transition

A fragment of the VHDL model of this FSM is shown in fig. 9.

```
when  a1=> if x1='0' then NextState <= a2;
          elsif x1='1'and x2='0' then NextState <= a3;
          elsif x2='1'and x3='0' then NextState <= a4;
          end if;
```

Fig. 9. Fragment of the VHDL-model of Moore FSM with missing transition

During simulation of the operation of this FSM (fig. 10), at first glance, everything is fine, but in fact, the variable x_3 is insignificant here, on the set $x_1,\ x_2,\ x_3 = 111$ the FSM should not go to any state, but the modeling system put him to the state a_4.

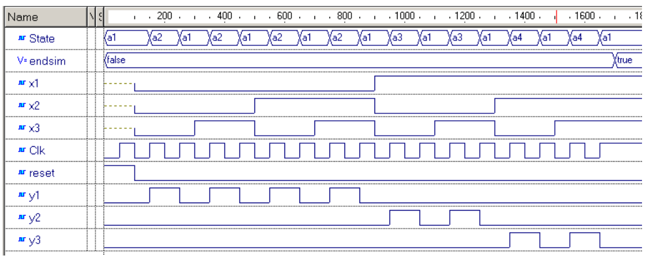

Fig. 10. Timing diagram of Moore FSM with missing transition

Likewise, when conditions $x_1,\ x_2,\ x_3 = 010$, the FSM can go into two states a_2 and a_4, which should not be in the case when the FSM works correctly, but the modeling system masks such situation, putting the FSM into the a_2 state. In this example, there is both a lack of completeness and the presence of a contradiction of the transitions' conditions, but this is clearly not manifested at the stages of syntax analysis and simulation.

During synthesis of this FSM can be problems especially in the case of older versions of CAD. For example, when using Xilinx ISE 10.1, a warning appears about four latches in addition to four flip-flops: *Found 4-bit latch for signal <NextState>. Latches may be generated from incomplete case or if statements. We do not recommend the use of latches in FPGA/CPLD designs, as they may lead to timing problems*. That is, instead of two triggers for the four states, 8 triggers of two types are synthesized. This should not be in a correctly synthesized FSM. At the same time, when using the latest version of Xilinx ISE 14.7, this warning will no longer exist.

Thus it is shown that problems associated with incorrect conditions are very difficult to identify during the design process. With equal probability, they can appear both on the timing diagram during behavioral simulation, and in the synthesis process (especially in cases with older versions of CAD). So, the verification of transitions' conditions for consistency and completeness must be carried out at the stage of forming the state diagram of the FSM.

III. Conclusion

Construction a logical control system based on FPGA is a modern approach to computer-aided design. One of the most common ways to describe logical control systems is the finite state machine model, which description based on the state diagram. The correctness of the future HDL code depends on the correctness of the state diagram.

The concept of orthogonalization, used to decompose logical functions in the synthesis of digital systems [6], can be also used to check the state diagram for correctness [2]. As a result of the research, it was shown that the transitions' conditions function $f(x_1, x_2, \dots x_n)$ is non contradictory if it is orthogonal. The orthogonal function of transitions' conditions $f(x_1, x_2, \dots x_n)$, in its turn, is complete if its terms cover all sets $x_1, x_2, \dots x_n$.

The verification of HDL model is carrying out at all stages of computer-aided design, namely, at the stage of behavioral simulation (by analyzing timing diagrams), at the stage of synthesizing of the RTL circuit (by analyzing the synthesis report) and at the stage of post-synthesis simulation (by analyzing the timing diagrams, taking into account the technological base). Due to the features of the modeling system, missing transitions or contradictory conditions of transitions at the syntax checking stage are not fixed, moreover at the simulation stage and automated synthesis they may go unnoticed (depending on the version of the synthesizer).

Therefore, verification of the state diagram for correctness is an important and integral step in the automated design of automatic logic control systems, the functioning algorithm of which is presented in the hardware description language.

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Optimization of the Activities in the Metrological Laboratory is the Implementation of the Metrological Software MET / TEAM

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Abstract: **The metrological software MET/TEAM is used to ensure the operation of transmitting the units of electrical quantities and the calibration of the working standards in the NPP. This software records the results of measurements in its own database with validated algorithms for measurement uncertainty measurement and generation of calibration certificates corresponding to the requirements of BDS ISO 17025, it is also used for analysis and monitoring of the state of the electrical and radiotechnical quantities.**

Key words: **MET/TEAM, Fluke, calibration, standards, analysis and monitoring.**

IV. INTRODUCTION

Calibration of over 300 digital multimeters, 40 calibrators of direct current signals and 70 multi-value measures for electrical resistance takes place in the NPP. To perform this activity, it is necessary to measure, record, enter and subsequently process an average of 500 measurement results (50 calibration points for 10 measurements) for each device.

To optimize the calibrations and the activities in the Department of Metrological Assurance, metrological software MET/ TEAM Test Equipment Asset Management Software has been implemented which provides the following advantages:

- Possibility for settings in accordance with the needs of the department - a variety of additional fields and bookmarks, quick links, support for templates for manual entry of calibration results, etc.;
- Workflow management - monitoring the movement of the measuring instruments (MI), preparation of maintenance schedules;
- Web-based software - no need of local installation at the workstations, it allows you to open many work screens simultaneously and edit them;
- Support of the quality assurance process for successful accreditation - all changes are recorded and stored into an audit log;
- Automatic e-mail notification for upcoming MI calibration;
- Quick and convenient generation of any references, reports, protocols and calibration certificates using the Crystal Reports XI application, which allows both the use of ready-made templates and the creation of specific ones.

V. METROLOGICAL SOFTWARE CAPABILITIES

Fig.1 User screen - ET/TEAM

- Manage all aspects of calibration with a paperless solution.
- Improve productivity and reduce operating costs.
- Maintaining compliance with regulatory standards.
- Configuration and customization of the business rules.

- Metrological activity planning.
- Creating, tracking and closing of work orders.
- Creating and printing calibration reporting documents
- Delivery information management.
- Tracking information for customers and suppliers.
- Business status.
- Creating data templates and storage procedures.

VI. WORK MANAGEMENT

The calibration management software supports Workflow management, allowing you to easily manage frequently performed tasks.

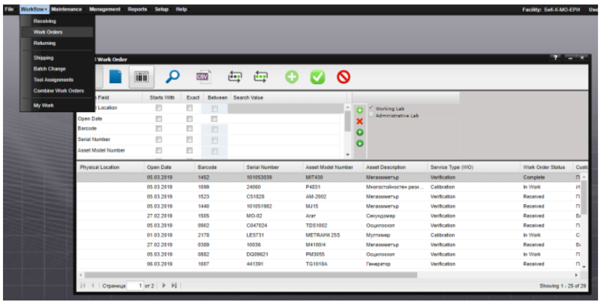

Fig.2 User screen - Workflow management

Retrieving MI or a group of them: select the MI retrieved by the "Search" command or by scanning the barcodes and issuing a handover protocol for clients; configure service types, status, priorities, requiring dates, and other extended data.

Creating a work order: assignment of technicians, schedule implementation date and the following dates for maintenance, selection of a calibration procedure, setting of calibration intervals.

Performing calibration: B MET/CAL, which is integrated into MET/TEAM.

Completing the work order: recording of environmental conditions, recording of working hours, possibility to add a record of the used spare parts and information about a subcontractor, etc.

VII. REFERENCES, REPORT AND DOCUMENTS FROM THE METROLOGICAL ACTIVITIES

To optimize the activity of the Department of Metrological Assurance by means of the metrological software many automatic inquiries are made, and through the Crystal Reports 2013 software report templates have been developed with the possibility to notify the responsible persons by e-mail and send reporting documents from the metrological control.

- MI subject to subsequent periodic metrological control.
- Decommissioned MI.
- The status (Business status) of the work order of MI (acceptance/work/handing over.)

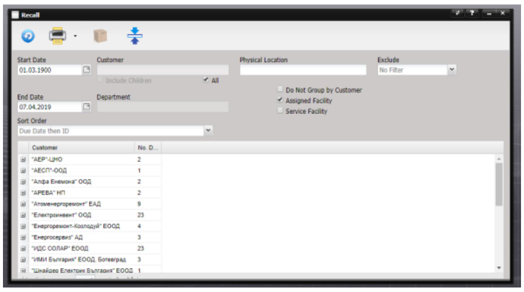

Fig.3 User screen - Recall

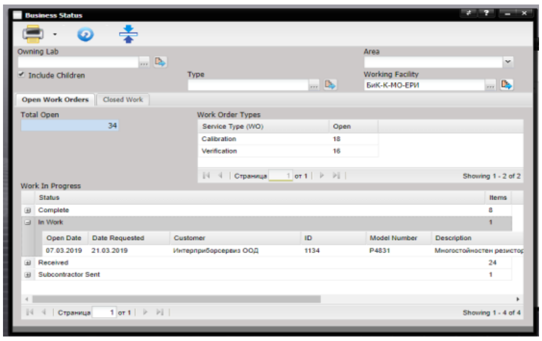

Fig.4 User screen - Business Status

Report on the performed activities for metrological control of the measuring instruments at the NPP.

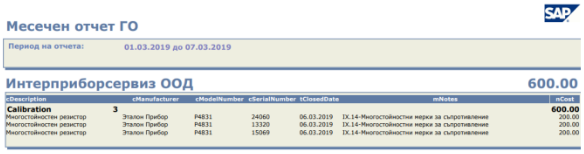

Fig.4 User screen - Reports

Reporting documents from metrological control:
- Calibration certificate;
- Certificate of inspection;
- Inspection report.

VIII. MET / TEAM CUSTOMER PORTAL USER PLATFORM

Web-based platform integrated with MET/TEAM, providing the capability to monitor metrological activities in the specific laboratory by owners of MI and persons responsible for metrological assurance.

Performing user inquiries and reviewing reporting documents and archived copies.

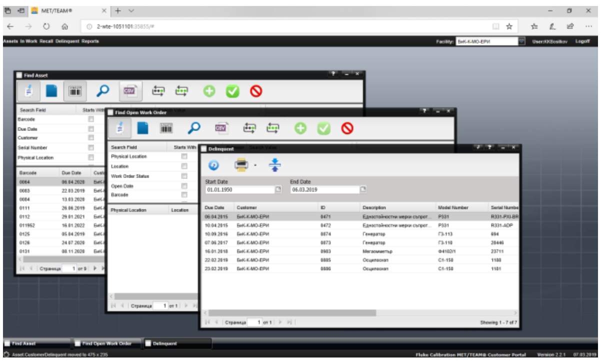

Fig.4 MET/TEAM Customer Portal - Conclusion

The implementation of the metrological software MET/TEAM Test Equipment Asset Management Software for automated metrological control (checks and calibrations) of measuring instruments provides limitation of the subjective factor for errors in the assessment and processing of measurement results, reduction of the time of metrological control and timely preparation of the reporting documents from the activity. Conditions have been created for the accumulation of data from metrological activities.

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[2] MET/TEAM user training

SECTION V

MEASUREMENTS IN THE ELECTRICAL POWER ENGINEERING

30th INTERNATIONAL SCIENTIFIC SYMPOSIUM
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Electrical Power Stations Design Features and Verification Problems for Busbar Current Transformers

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***Summary* — There are considered some problems for metrological support of busbar current transformers operating on the electric power plants busways at Russian Federation. An overwiew of the possibilities for improving of transfer methods for the units of quantities from the state primary standard for electric current measurement conversion factors to solve problems found is given.**

Keywords — busbar current transformers, electrical power plant, primary standard, verification

I. INTRODUCTION

The accounting for electrical energy as a merchandise is entirely based on measuring its quantity. Measurement of electrical energy in industry and power engineering is carried out using transformer-connected meters connected to the network through current transformers (CT) and voltage transformers. Modern meters have a built-in clock and technical means for automatic meter reading (AMR), which makes it possible to link the measurement results to calendar time and record the load graph.

As a rule, all these measuring instruments are combined into an automated information-measuring system for commercial metering of electricity – «АИИС КУЭ» (commercial AMR system).

In accordance with the legislation in force in the Russian Federation [1], measuring instruments used to account for the amount of energy resources for the purpose of mutual settlements are subject to mandatory verification. CTs are included in this category of measuring instruments.

For the metrological support of CT in the Russian Federation (RF), the State Primary Standard of the Units of Conversion Factors for Electric Current GET 152, which was put into operation since 1986 at UNIIM, Yekaterinburg, is responsible.

II. A PROBLEM ARISE

In connection with the reform of the electric power industry in the RF and the creation of an electric energy market, a need arose for measuring the amount of electric power for conducting mutual settlements between market entities. Accordingly, the need to calibrate measuring transformers has become more acute, including the organization of work on their verification at the site of operation.

The technical tasks of verification the working CTs were solved by using modern materials in the design of standard CTs. Standard CTs, load devices and comparison devices, developed and produced since the beginning of the 2000s, make it possible to fully metrologically provide working current transformers, both newly produced and in operation.

All verification laboratories of the Russian Federation, accredited for the right to calibrate CT, are provided with standards of the first (0.01%) or second (0.05%) category (according to verification shedule).

For example: included in the primary standard GET 152, the comparison standard of 1986 (primary rated current from 0.5 to 3000 A) with a magnetic circuit made of permalloy, accuracy class 0.01 weighs 34 kg and has dimensions of 500 × 450 × 450 mm, while the modern comparison standard (2010) with a magnetic core made of an amorphous alloy of accuracy class 0.003 weighs 11 kg and has dimensions of no more than 120 × 200 × 300 mm. The appearance of the described comparison standards is shown in Figure 1.

The weight and size indicators of modern reference equipment ensure its mobility and make it possible to transport this equipment and verify the CT at the site of operation, i.e. it was possible to realize the idea demanded by the market not to bring the device to be verified to the calibration laboratory, but to deliver the transported standard to the place of operation of the verified object. But for all the attractiveness (and sometimes the severe necessity) of such an organizational and technical solution, the same practice revealed a number of new problems.

Fig.1. Appearance of comparison standards made in 1986 and 2010

The largest number of questions, to which there is no unambiguous answer, arose when solving the problem of periodic verification of bus CTs installed on the current leads (busways) of power plant generators

III. Description Of The Problem

At the moment, power facilities and, above all, power plants are being designed, built and modernized, without taking into account the need for periodic verification of the used measuring instruments at the site of operation.

Bus CTs installed on the current leads of generators of power plants are primarily concerned with this problem. On-site verification using a standardized method in accordance with GOST 8.217 [2] is practically inaccessible for them for the following reasons:

lack of free access to the current transformer itself;

the complexity or, in most cases, the impossibility of installing the primary measuring circuit, in which it is necessary to generate a current of up to 120% of the primary rated current;

- the difficulty of connecting the reference current transformer to the primary measuring circuit;
- lack of commercially available AC sources with a power of up to 30 kA of sufficient power (100-150 kW, subject to compensation of the reactive component) to pass the current in the primary circuit.

The regulatory framework in the Russian Federation (standards and other documents containing technical requirements) as of today does not contain many documents that would reflect the system requirements for all of the above positions.

IV. Possible Ways To Solve The Problem

The most ideal option is the manufacture of busbar CTs, in which the interval between checks was equal to the service life. However, this seems to be very unlikely for the reason that CTs failures occur not so much due to hidden defects of any structural elements, but because of uncontrolled influences - mechanical and electrical - during operation.

In this regard, a workable version of such a CT should include in its design built-in diagnostic tools that allow constant monitoring of its condition.

In this situation, for bus CTs in operation, the following actions are possible to verify them:

a) dismantle bus CT and check it in a specialized laboratory;

b) use verification techniques based on indirect measurements [3]. In this case, in order to obtain results comparable with the standardized methodology, the indirect methodology must be validated on at least one copy of the CT of the same nominal and standard version, with the same arrangement of turns of the additional primary winding (equivalent m.m.f. method) as in the CT located at the place of operation and subject to verification;

c) to use the generator of the power plant in the short circuit experiment carried out during planned works as a current source when checking busbar CTs using the standard method; here a split reference current transformer is needed (certain organizational and technical solutions and regulatory framework will also be required);

d) install a detachable reference CT on the current lead and conduct continuous monitoring of the characteristics of the bus CT under test during the operation of the station for a long time interval allowing to cover the required range of the measured current;

e) to provide design solutions for the complex "busway-busbar CT - means of verification", providing for the verification of busbar CT at the site of operation.

All these actions (with the exception of clause "a") require changes to the regulatory documents.

There is no unequivocal answer to the question “what to do” in this situation and it is necessary to take into account many factors that influence the choice of a method for solving this problem. Additional restrictions on the use of indirect measurement methods during verification are imposed by the fact that manufacturers during type approval tests refer only to GOST 8.217 in the type description. Verification using the equivalent m.m.f. method (ampere-turns) is not always possible, as some busbar CTs are very sensitive to the location of the return conductor and / or to the symmetry of the auxiliary primary.

In 2015, UNIIM conducted research on a bus current transformer provided by one of the manufacturers, which has a split secondary winding, with the possibility of on-site verification. This design solution removes the problem described above.

V. Conclusions

When solving the problem of metrological support of bus CT, it must be divided into two parts:

• metrological support of bus CTs in operation;

• metrological support of manufactured bus CTs.

It is necessary to gain practical experience when performing work on checking bus CTs using standard CTs with a split core or optical measuring transducers (based on the Faraday effect) and make changes to the regulatory framework.

The characteristics and design of newly produced tire CTs should strive for the ideal configuration described above. At the same time, when designing current leads from generators of power plants, it is necessary to take into account the need and ensure the possibility of periodic verification of bus CTs, which is not regulated by any regulatory documents in the Russian Federation.

The current law of the Russian Federation "On standardization" [4], in the creation of which in the modern edition the business community was directly involved, provides for an active role of specialized technical committees (TC) for standardization.

Only through joint efforts in the work of specialized TCs on standardization of representatives of CT manufacturers, their consumers and operating organizations can we find optimal solutions to many problems, including those raised in this report.

References:

[1] Federal Law of the Russian Federation "On ensuring the uniformity of measurements" dated 26.06.2008 N 102-FZ

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[3] MI 3123-2008 "GSI. Current transformers. Experimental and computational method for checking measuring current transformers at the places of their operation"

[4] Federal Law of the Russian Federation "On Standardization in the Russian Federation" dated June 29, 2015 N 162-FZ

SECTION VI

MEASUREMENT IN THE HUMANITIES AND SOCIAL SCIENCE

30th INTERNATIONAL SCIENTIFIC SYMPOSIUM
METROLOGY AND METROLOGY ASSURANCE 2020
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Factor Analysis for Humandependent Factors Received in Actions in a Virtual Reality

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***Abstract* -- The aim of the paper is to apply a statistical method called Factor Analysis for the assessment of humandependent factors that are influenced by simulation sickness. The simulation sickness – is a phenomenon that occurs when one person used Virtual Reality. In the paper Virtual Reality is a driving simulation reality and have been investigated connection of some independent variables like - motion sickness, age, person playing video games daily and other factors over simulator sickness using Factor analysis. The input number of variables is 24 received from two questionnaires. Participants were students and members of staff at a University of Applied Sciences in southern Germany. It is proven that for the input of 24 variables from two different questionnaries, when are reduced to eight new factors is explained the 70 % of common variances, which is one good statistical result for the so specific and different data collected from human experience in the virtual reality.**

Keywords — Factor Analysis, Virtual Reality, Humandependent Factors, Simulation Sickness.

I. INTRODUCTION

Virtual reality is a computer-generated environment that simulates a realistic experience [1]. The immersive environment can be similar to the real world in order to create a lifelike experience grounded in reality. Virtual reality has been used in many areas in our modern society such as entertainment, medicine, automotive. Here we are going to discuss the virtual reality in a context of driving, and in specific, driving simulation. Driving simulation is a simulation of a real-life driving experience in a completely controlled and safe environment. This type of environment is operationalized for user evaluations on human-computer interactions in current and future automotive setups. The virtual environment can be easily recorded, controlled, and modified. All these advantages could be very well used in any user evaluation. However, despite the positive aspects, virtual reality has one major disadvantage, it could induce discomfort in the users. The phenomenon is called simulation sickness and it could appear suddenly during and after any virtual reality session. The addition layer of virtual reality to a driving simulation could evoke even more discomfort [2].As the simulation sickness appearance is not a constant, the prediction of the discomfort is a difficult task. Therefore, a different approach to its assessment can give new view on the measurement of this well-known and still not completely understand phenomenon.

In this paper, we conducted a Factor analysis on factors related to simulation sickness to present a reduced number of factors. Factor analysis is a statistical method that originally had been used in psychology [3,4]. By analysing the inter-correlations between sets, measured by using specific standardized test scales, they attempt to identify the quantities and evaluate the contributions due to each quantity. The relationship between the input quantities may be either functional or random. Nevertheless, sometimes there is no strictly functional dependence – like measurements in medicine, biology, and economics. In such psychology type of areas, the development of different processes and phenomena, as a rule, depends on many factors that can hardly be taken into account in their fullness [5]. Nowadays, Factor analysis applies in other areas such as economy, sociology, and even in the exact sciences like engineering [6,7]. When we have lots of data, we want to find some correlation between them. For that reason, we should check if the data are correlated or not. The big volume of data that have been measured is combined in factors, and the purpose of the statistical analysis is to reduce the number of factors, replacing them with new global factors [8]. Thus, the understanding of the problem or hypothesis is more clearly defined, and the necessary efforts will be pointed to the right direction to solve the problem.

In the researches, there are known different types of factor analysis. In our investigation it is used the one, namely PCA-*Principal Component Analysis*. Factor analysis allows for each of the factors to be calculated some factor results, which means that ultimately we can use the factors like as ordinary observable variables. Factor scores are obtained in z-values, with mean zero and unit standard deviation.

In the literature, a well established questionnaire is used for assessing simulation sickness, namely simulation sickness questionnaire (SSQ) [9]. The questionnaire was developed through a Factor analysis and as result 16 factors were chosen to evaluate the phenomenon. Years later, another questionnaire is developed through Factor analysis for assessing discomfort [10]. This questionnaire was based on SSQ and targeted more narrowed field such as simulation sickness induced by any virtually simulated environment. These findings showed that is a common application of the Factor analysis in the process of developing of a new questionnaire. However, normally the questionnaires target only the factors to be evaluated and there is another questionnaire to established factors related to previous experience as well as socio-demographics. To our knowledge, there no reported fusion between these two type of questionnaires using a Factor analysis. The paper aims to test whether the method of Factor analysis is suitable for this task or not. Moreover, the expected outcome of the analysis is set of the reduced factors which has close assessment power as the original questionnaires.

This paper investigates the connection of 24 independent variables which are divided into two groups. The first contains 9 (q1.1 – gender was removed because this is nominal variable) questions such as experience with driving simulation, age, frequent driver and more, the second contains 16 questions such as general discomfort, headache, difficulty focusing and more and their influence over simulation sickness using Factor analysis.

II. Virtual Reality Driving Simulation.

Questionnaires.

Two questionnaires were chosen for the Factor analysis. The first one, questionnaire **Q1 with 9** questions (q1.1 – gender was removed because this is nominal variable), contained questions to determine the socio-demographic information, previous driving, and virtual reality experience and medical history [2]. The questions were divided into three parts: personal information, experience with driving simulators, and comments. Each part contributed to the retrieval of suitable information from the participants. The first three questions were standard socio-demographic questions. The next nine questions measured the previous driving, gaming, and virtual reality experience by using the five-point Likert scale (i.e., from strongly agree to strongly disagree). The last four questions checked the medical history and current state of health of the participant. They indicated if the participant should be allowed to use the virtual reality driving simulation or not. Users who indicated high susceptibility to simulation sickness were pre-warned about the symptoms.

The second questionnaire **Q2 with 16** questions, was a well-known questionnaire for assessing simulation sickness, namely the SSQ [9]. Each question has four possible answers (e.g., none, slight, average, and severe). The self-reported answers reflected the current condition of the participant and at what level each symptom is experienced.

Participants.

Seventy-two participants were recruited for the experiment, most of whom were students of the University of Heilbronn. Participants with medical conditions or history that indicated an increased level of risk in the simulated environment, were pre-warned about the symptoms. 54 male (Mage = 24.91, SD age = 4.27) and 18 female (Mage = 26.39, SD age = 7.26) participants took part in the tests. The minimum age of the users was 18 and the maximum was 47 (Mage = 25.28, SD age = 5.16). Female was 25%.

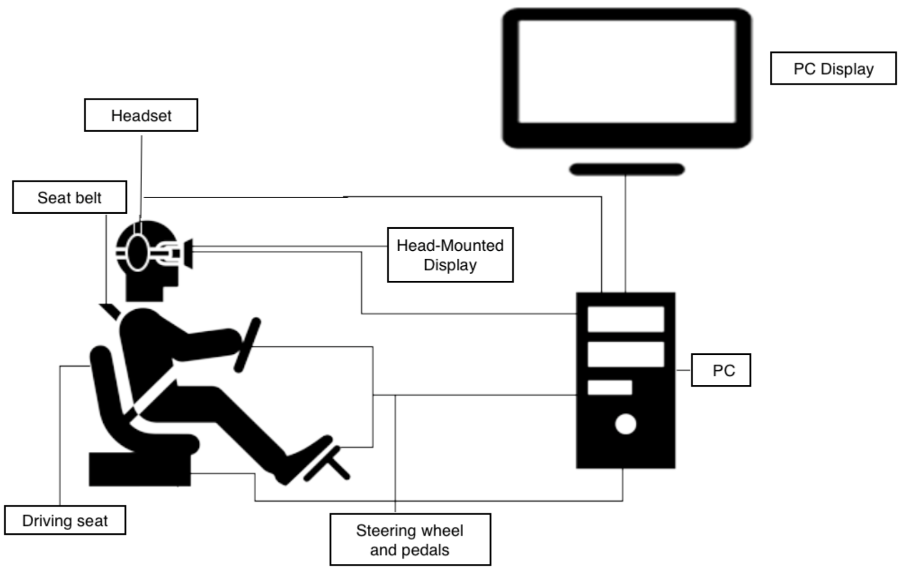

Fig.1. A virtual reality driving simulation setup including the all hardware components.

Experimental setup.

The experimental setup included the following hardware components: Head Mounted Display (Oculus Rift DK2), a high-end virtual reality-ready PC, steering wheel and pedals (Logitech G25), an audio headset (Roccat Kave), a sport driving seat including a seatbelt. The PC used an Intel Core i7-5960X 3GHz processor, Nvidia GeForce GTX Titan X graphic card on Windows 10 with memory of 32 GB. The HMD had OLED display with a screen resolution of 1920 x 1080, field of view of 100 degrees, and refresh rate of up to 75 Hz. A schematic representation of the virtual reality driving simulation setup is illustrated on the Fig.1.

Procedure.

This study used a between-subject, post-test only design. The duration of the test was scheduled for 30 minutes per participant. The whole procedure was described to the participant prior to the test. A few questions regarding the current health status of the participants were asked (e.g., history of epilepsy or vestibular organ dysfunction). Then a consent form was given and shortly explained the possible adverse effect of the participation. After that, the participants were asked to complete a virtual reality driving simulation questionnaire (Q1) prior to their participation. It was explicitly said that the participation could be discontinued at any given moment without any negative consequences. Moreover, an instruction leaflet was provided for them regarding information about driving basic controls. The drive continued 15 min in an urban area. After the virtual reality session was over, the participants were given a questionnaire (Q2) regarding their well-being. The data used in the current work is based on previous work [2], and it was collected through the described procedure.

III. Factor Analysis for Humandependent Factors Received in actions in a Virtual Reality

The SPSS packet for factor analysis was used. The data concerned only 70 participiciants. From the Q1 **was removed q1.1 – gender, because this is nominal variable,** and that **the 8 questions** were: q1.2 – age, q1.3 – study program, q1.4 – frequent driver, q1.5 – experience with driving simulation, q1.6 – stopped driving simulation, because simulation sickness q1.7 – playing video games, q1.8 – worn HMD before, q1.9 – motion sickness. And **16 questions** from Q2 were: q2.1 – general discomfort, q2.2 – fatigue, q2.3 – headache, q2.4 – eye strain, q2.5 – difficulty focusing, q2.6 – salivation increasing, q2.7 – sweating, q2.8 – nausea, q2.9 – difficulty concentrating, q2.10 – fullness of the head, q2.11 – blurred vision, q2.12 – dizziness with eyes open, q2.13– dizziness with eyes closed, q2.14 – vertigo, q2.15 – stomach awareness, q2.16 – burping. The determinant of the correlation matrix is $1.89.10^{-5}$, i.e. small enough to indicate the presence of multicollinearity of variables, a necessary condition for factor analysis. The Barlett's test value, which was used as a measure of sampling adequacy, is near to 0. Consequently, the observed correlation matrix was not an identity matrix and then the factor analysis might be useful with our data. The Kaiser - Meyer – Olkin (KMO) test value, which is used as a measure of the suitability of data for factor analysis, should be over to 0,5, for our analysis it was 0,655.The number of factors was determined by the number of eigenvalues that have values bigger then 1, see the correlation matrix given in Table I (is shown part of it, it is long 24 rows). The eigenvalues show the contribution of the corresponding factor in explaining the overall variation in observed variables. The first two variables are with eigenvalues near 5,5 and 2,5 what means their contribution in the cumulative variance is significant.

We retrieving eight factors, according to the selected method *Principal Component Analysis*. After rotating the eight factors by the *varimax* and *Kaizer* normalization method, we received the solution given in Table I, Table II (is shown part of it, it is long 24 rows), Table III. *Varimax* is the most popular method for factor rotation, it aims to increase the given factor weights, therefore, each of the observed variables to find a better explanation. This method converts the factors into mutually perpendicular bases of factor space, for the first three factors is given Factor Loading Plot in Fig. 2.

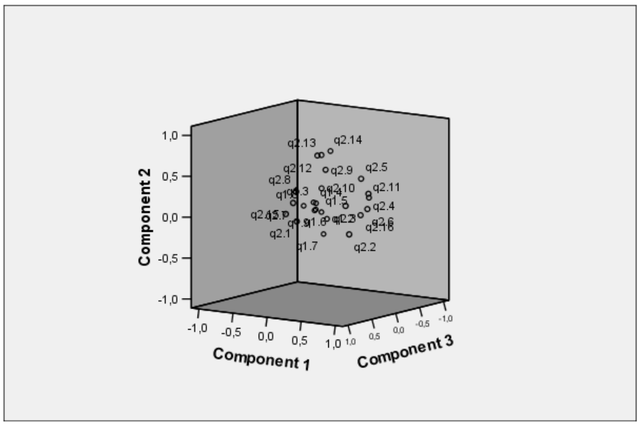

Fig.2. Three-dimensional factor loading plot of the first three factors

The influence of the factors in the distribution of the total variation after rotation is given in Table I. The first factor explained 13,486% of the sample, the second 12,519%, the cumulative variance for the 1 and 2 factors is 26,005%. The third factor explained 10,415% of the sample and the cumulative variance for the 1, 2 and 3 factors is 36,420%. The all fourth factor explained 8,483% of the sample and the cumulative variance for the 1, 2, 3 and 4 factors is 52,343%. The all fifth factor explained 70,883% of the sample which is a statistically good result.This mean one good statistical result, because the data themselves are so specific - psychological and inconsistent, simply in one word they are humandependent. If we get all 24 factors, then the explained variance of the data will be 100%.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5,541	23,085	23,085	5,541	23,085	23,085	3,237	13,486	13,486
2	2,493	10,388	33,473	2,493	10,388	33,473	3,005	12,519	26,005
3	1,965	8,186	41,659	1,965	8,186	41,659	2,500	10,415	36,420
4	1,731	7,211	48,871	1,731	7,211	48,871	2,036	8,483	44,903
5	1,543	6,427	55,298	1,543	6,427	55,298	1,786	7,440	52,343
6	1,455	6,063	61,361	1,455	6,063	61,361	1,598	6,656	58,999
7	1,249	5,204	66,565	1,249	5,204	66,565	1,499	6,245	65,244
8	1,036	4,318	70,883	1,036	4,318	70,883	1,353	5,639	70,883
9	,914	3,807	74,690						
10	,736	3,067	77,757						

ROTATED COMPONENT MATRIX(A)

	Component							
	1	2	3	4	5	6	7	8
age					,831			
study program					,757			
frequent driver						,793		
exp. with DS				,889				
stopped DS exp. because SS				,913				
playing video games								
worn HMD before				,503				
MS								,853
general discomfort			,679					

COMPONENT SCORE COEFFICIENT MATRIX

Component Score Coefficient Matrix

	Component							
	1	2	3	4	5	6	7	8
age	,095	-,116	,015	,066	,491	-,015	-,081	-,071
study program	-,070	-,014	-,081	-,066	,443	,126	,179	,051
frequent driver	,021	,019	-,031	-,033	,043	,499	-,040	,079
exp. with DS	,054	-,042	-,030	,445	,035	,024	,041	-,025
stopped DS exp. because SS	,025	-,013	,014	,458	-,043	-,063	,027	-,016

THE CALCULATED STANDARDIZED SCORES FOR THE INPUT VARIABLES.

Zq1.2	Zq1.3	Zq1.4	Zq1.5	Zq1.6	Zq1.7	Zq1.8	Zq1.9	Zq2.1
1,85037	2,33210	1,02656	-,64790	-,41163	-1,36507	-,72036	,55929	-1,47881
-,84008	-,45845	-,58826	-,64790	-,41163	-,66246	-,72036	-1,10668	-,41163
-1,03225	-,45845	,21915	-,64790	-,41163	,74276	1,96898	,55929	-1,47881
-,26355	-,45845	,21915	-,64790	-,41163	1,44537	1,29665	-1,10668	-1,47881
-,84008	-,45845	-,58826	-,64790	-,41163	,74276	-,72036	1,39228	-,41163
-,64790	-,45845	1,02656	-,64790	-,41163	,74276	-,72036	-,27370	,65556

THE OBTAINED FACTOR VALUES.

FAC1_1	FAC2_1	FAC3_1	FAC4_1	FAC5_1	FAC6_1	FAC7_1	FAC8_1
-,42807	-,69282	-1,45482	-,93870	2,90646	,22152	-,52457	,21818
-,53468	1,09383	-,69684	-,79895	-,64727	-1,39726	,28211	-,94847
,05034	-,29142	-1,43675	-,15965	-1,16734	,22512	-1,47473	1,73000
-,60194	-,16936	-,71636	-,19540	-,73722	,90072	-1,28324	-,32909
-,45707	-,75577	-1,23395	-,68370	-,55053	-,09588	,24127	,97481

After rotating the eight factors by the *varimax* and *Kaizer* normalization method, we received the rotated solution given in Table II. Factor F1 is marked as component 1, the Factor F2 is marked as component 2 and so for the rest up to 8. Here are given the calculated from the program factor weights. From this table it can be seen how the input 24 variables from the two questionnaires are grouped in new eight factors. In factors F1, F2, F3 are variables from questionnaire Q2 with factor weights bigger then 0,5. In factors F4 and F5 are variables from questionnaire Q1 with factor weights bigger then 0,5. Only one q2.7 – sweating has almost equal parts in both factors F3 and F6. Two questions make up each individual factor:

q2.10 - fullness of the head with factor weight 0,748 and q1.9 - motion sickness with factor weight 0,853. And new eight factors look like this now:

F1 = { q2.2, q2.3, q2.4, q2.5, q2.6, q2.11, q2.16}

F2 = { q2.9, q2.12, q2.13, q2.14}

F3 = { q2.1, **q2.7**, q2.8, q2.15}

F4 = { q1.5, q1.6, q1.8}

F5 = { q1.2, q1.3, q1.7}

F6 = { q1.4, **q2.7**}

F7 = { q2.10}

F8 = { q1.9}

If we would like to see the equations for calculating every one of the factors, it would be the following equation:

$$Fj = \sum_{i=1}^{24} (\text{COMP. SCORE COEFF. MATRIXi. x.} \, Zqi)$$

Where j = 1÷8 (we have 8 output factors), Zqi– *standardized* scores for input variables (we have 24 input variables).The coefficients from the COMPONENT SCORE COEFFICIENT MATRIX are given in Table III .

The calculated *standardized scores* for the input 24 variables, are calculated using SPSS program are shown in Table IV (the table is 24 columns wide and 70 rows long and only the first few are shown). A standardized z-score [11] represents both the relative position of an individual score in a distribution as compared to the mean and the variation of scores in the distribution. A negative z-score indicates the score is below the distribution mean. A positive z-score indicates the score is above the distribution mean. Z-scores will form a distribution identical to the distribution of raw scores; the mean of z-scores will equal zero and the variance of a z-distribution will always be one, as will the standard deviation. The code names of the variables are as follows: Zq1.2 is *standardized scores* for q1.2 – age, Zq1.3 is *standardized scores* for q1.3 – study program and so on for all other 24 input variables.

Using the COMPONENT SCORE COEFFICIENT MATRIX multiplied with *standardized scores* for each column of Table IV we received the values of the new factors:

$$\boldsymbol{F1 = 0,095.Zq1.2 - 0,070.Zq1.3 + 0,021.Zq1.4 + \ldots \textit{up to 24 th var}}$$

$$\boldsymbol{F2 = -0,116.Zq1.2 - 0,014.Zq1.3 + 0,019.Zq1.4 + \ldots \textit{up to 24 th var}}$$

$$\boldsymbol{F3 = 0,015.Zq1.2 - 0,066.Zq1.3 - 0,031.Zq1.4 + \ldots \textit{up to 24 th var}}$$

$$\boldsymbol{\ldots}$$

$$\boldsymbol{F8 = -0,071.Zq1.2 + 0,051.Zq1.3 + 0,079.Zq1.4 + \ldots \textit{up to 24 th var}}$$

For our eight factors the calculated values only for the first row from the *standardized scores* Table IV are shown below:

$$\boldsymbol{F1 = 0,095.1,85037 - 0,070.2,33210 + +0,021.1,02656 + \cdots = -0{,}42807}$$

$$\boldsymbol{F2 = -0,116.1,85037 - 0,014.2,33210 + +0,019.1,02656 + \cdots = -0{,}69282}$$

$$\boldsymbol{F3 = 0,015.1,85037 - 0,066.2,33210 - -0,031.1,02656 + \cdots = -1,45482}$$

$$\boldsymbol{\ldots}$$

$$\boldsymbol{F8 = -0,071.1,85037 + 0,051.2,33210 - +0,079.1,02656 + \cdots = 0,21818}$$

Calculated in this way new values for the eight new factors are given in Table V (the table is 8 columns wide and 70 rows long and only the first few are shown).

IV. Conclusion

A statistical method of analysis was applied in the field of assessment of humandependent factors that are influenced by simulation sickness. The investigation had been conducted in the statistical environment SPSS and it proved its qualities and applicability.

The input variables were 24 questions divided into two questionnaires. The first questionnaire contained 9 questions to determine the socio-demographic information, previous driving, and virtual reality experience and medical history and the second questionnaire with 16 questions, was a well-known questionnaire for assessing simulation sickness. Those statistical approach showed that the fusion of 24 questions could be well represent with only eight new factors with high cumulative variance of 70,883%. It is shown that one question q1.9 - motion sickness has factor weight 0,853 and form individual factor F8, the same is for q.2.10 - fullness of the head. What means those two questions have very big influence over the common variance.The investigation also could be used for development of new questions for investigating the humandependent factors that are influenced by simulation sickness.

For further investigations is possible to substitute all input 24 observed variables with those eight new factors and continue some other statistic investigation. This shows the main advantage of the statistical approach – we could see that the so psychological and humandependent data of all input variables could be combined in a small number of factors and the input data still keeps the representative and informative nature. Also we have proved that those kind of data can be processed statistically and there is received a significant, meaningful statistical results.

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Cartography of Emotions and a Modern View of Elements

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***Abstract*—Based on metrological empirical methods in humanities, the present paper proposes new systematic ways of mapping, describing and classifying our emotional preferences. The most important result obtained in this ongoing series of experiments is that rather than experiencing the same arbitrary sets of emotions, people are divided from their moment of birth into four distinct groups with their preferable emotional components, which, in their turn, are in accordance with the traditional philosophical views of the four basic elements.**

Keywords—emotions, open-ended questions, elements, time, measurements in the humanities

I. Introduction

The prominent British physicist David Bohm wrote that “implicitly time is taken as the ground of everything in scientific work” [1]. Emotions are not exceptional, and they are tightly linked with time. On the one hand, according to the emotion scientists, “emotions are events that develop over time” [2, p.103]; different emotion-related experiences, such as steadfast moods or momentarily excitements, have different durations [3]. On the other hand, emotions manifest themselves outwards in different ways, both among people of different ages and among people of different historical epochs [4]. Like the seasons, emotions might be cyclical [5], or they might be experienced differently by people with different birth dates (termed *Theta-factor* or *Birth Points*, *BP*) [6].

Additionally, time in Latin is *tempus* (in Italian *tempo*), and the root of this word is used for terming temperature, musical pace or temperament. As soon as temperament is mentioned, there is an association with the emotional responses, with the classical four-temperament theory, and the four basic elements (Greek *stoicheîon*). In antiquity Empedocles and Plato spoke of the four elements – Fire, Earth, Air and Water – as the four basic abstract principles of the Creation. This definition of elements was radically changed by Antoine-Laurent Lavoisier (1743-1794) known as the founder of modern chemistry. Following Lavoisier, nowadays natural sciences use elements in a sense of the major building blocks of the material world (e.g. Mendeleyev's periodical table of elements). As a result, physics and chemistry has focused mainly on the Earth element, ignoring all the others, namely Fire (associated with desires or motivation), Air (Logos or abstract ideas) and Water (feelings or emotions). Though such modern thinkers as C. G. Jung or Gaston Bachelard continued to treat elements in their metaphorical sense of the four primordial creative principles, their theories lacked strong experimental evidence. To fill this void, it was proposed to undertake a two-stages experimental project, titled as *Cartography of Emotions*.

The first stage was mostly qualitative, and its purpose was getting insights from historical inquiries. A sequence of studies of poetic metaphors, which are characteristic to the well-known philosophers, scientists, poets, Nobel Laureates and musicians, had yielded meaningful results [6, 7, 8]. It was found qualitatively that depending on their birth date and dominating element people often confuse “I feel” with “I think,” “I sense,” “I wish,” or “I believe”. In other words, for each creative person there is one prevailing element, be it Air, Fire, Water or Earth, with which he/she most strongly resonates. Somewhat simplifying, for Fire, the most important feelings are their energy, desires, spirit; for Air – intelligence, thinking, mind; for Earth – material world, body, outward stimuli; for Water – emotions, faith, soul. These results were consistent with the observations of the French philosopher Gaston Bachelard who regarded the four elements as the “hormones of the imagination” [9], suggesting that “the four categories of souls in whose dreams fire, water, air or earth predominate, show themselves to be markedly different” [10, p. 89].

This situation reflects Anaïs Nin words: “We don't see things as they are, we see things as we are”. The problem begins when one person sees one's own perception so “normal” and “natural,” that it becomes obvious for him/her to expect seeing it as the only “normal” for the others as well. As a result, our ability to convey our inward experiences to others is so limited that in addition to hurting our feelings it affects even our rational or professional reasoning. Indeed, the differences between different groups are so profound that they can significantly diminish our ability and willingness to listen to the others. For example, in modern physics, David Bohm has described the problems caused by such basic lack of willingness to accept something "not normal" and refusal to listen: "Even Einstein and Bohr were not able at a certain point to listen to each other" [1, p. 76].

The qualitative results of the first stage were so striking that it was decided to undertake the second stage of a quantitative and more detailed analysis of our contemporaries. At this stage an open-questionnaire method was used both for explorative and systemizing purposes. The present paper is a concise synopsis of this pioneer venture.

II. Collecting Data

Emotions and feelings belong to an inner realm of our existence, and although it is hard to overestimate their role in our lives and decision-making processes, it is very difficult to get objective information about them. To focus on our subjective and personal experience, in this study it was decided that the fastest and most reliable way to collect information about emotions was to ask specialists and laypersons (both are equally considered "experts") to name their five most important feelings or emotions. Such an approach of open-ended questions and the method of anonymous questionnaires allowed participants to answer in their mother-tongues, in their preferred styles, words and length.

Furthermore, the main assumption of this survey is that if any participant decides that "X" is an emotion, then this "X" allows to that person to perform an emotional function, and therefore by definition of the study is accepted as an "emotion". To be more specific: this experiment did not try to distinguish emotions and feelings from nonemotions; it did not try to evaluate the intensity of the feelings or judge their "positive" or "negative" nature either. Instead, regarding each participant as an expert, we accepted all the answers as a true mirror of one's emotional realm. (This method is consistent with Feldman-Barrett's approach to the collective emotions [11]).

In the course of this experimental survey that ran from 2017 to 2019, a total of 1419 participants from 14 countries, aged from 14 to 90 years, filled the same questionnaires, formulated in the three principal languages of the survey (Hebrew, Russian, English). All the participants took part in the experiment on a voluntary basis. To avoid cultural, educational and other possible differences, subjects of both genders and of different socio-economic status were involved. To minimize the possible environmental influences, people were approached and asked to fill a form at different types of events, such as at concerts, lectures or symposiums; at work, clinics or during their holidays, etc.

Each form contained just one question: "What are your 5 most important Feelings or Emotions?" These were open questionnaires and the participants could name emotions / feelings in their preferred style and their native languages. They also could fill blanks anonymously without fear for their privacy.

In addition, participants were asked to write down their exact birth date (i.e. day, month and year). This data allowed assigning each participant to the corresponding predominant element.

III. The Results

Three types of Answers

All and all, there were 753 filled blanks in Hebrew, 603 in Russian, and the rest in English, Bulgarian, German, French and Italian. On average, participants named 5.0 important emotions with a minimum of zero and a maximum of 13 answers.

At first, all the filled forms were divided into four groups, according to the dominant element for their birth date. It turns out that the Water-born group has shown greater readiness to participate in this experiment than the Earth-group. This difference (14.6%) is consistent with the traditional view of the Earth element as the less emotional one. This qualitative result is impressive *per se*, and it can outline issues for further research.

The second step was to analyze the results of the experiment on the nominal scale. It was found that the participants described their emotions in many ways and gave them different names. By their styling, all the answers could be divided into three types. The first type of answers reflected the state of confusion among those participants who rarely verbalized their feelings. About 0.6% of all the participants were ready to state explicitly that they had never experienced any emotions at all and had no idea what they were. This result is consistent with the studies of alexithymia. This term was coined in 1973 by the psychiatrist Peter Sifneos; it comes from the Greek roots *a* (lack), *lexus* (word) and *thymos* (emotion) and literally means "without words for emotions". Individuals with alexithymia have trouble in describing emotions as well as differentiating between emotions and bodily sensations.

The second type of answers described personal specific experiences which could not be reduced to a single term and instead were expressed in long sentences. For example: "Revelation and love for wisdom" or "I like to cook for those whom I love". About 13% of all the answers belonged to this type.

The third type described emotions that participants could name in a single word. To describe their emotions the participants used 389 single words in Russian, 315 single words in Hebrew and 110 words in English. According to Lisa Feldman Barrett, those feelings, which have generally recognized names, reflect the current cultural collective attitude to emotions [2], and as such they are of the greatest value for the present research. It is proposed in the present study to list an emotion as a basic one if it is described as a single-word answer and in addition satisfies the following requirements:

- In all the languages of the survey this emotion could be described by a single word, indicating that it was deeply rooted in the collective universal experience of people speaking various native tongues.
- This emotion was listed at least by one participant in each of the three principle languages of this survey (Hebrew, Russian and English).
- It should be listed by a significant number of participants. In the current survey that minimal number was chosen as 5% of all the participants, which made at least 70 people.

All these requirements were met just by seven emotions: Love (63.2%), Joy (44.9%), Happiness (15.3%), Anger (12.7%), Sadness (11.9%), Fear (9.5%) and Calmness (8.8%).

This result *per se* is of its own value because it portrays emotional preferences of our contemporaries which are radically different from the previous generations. Significantly, this finding is in accordance with the historical observances described in the monograph *The History of Emotions* [4].

Constructing Categories

In addition to these basic emotions and feelings, the participants attributed feelings or emotions to a vast range of conscious reasons, moods, sentiments, intensions, attitudes, dispositions, motives, desires, purposes, aims, achievements, understandings, thoughts, beliefs, moral values, meanings, objects, subjects and actions, including numerous nuances in different languages. To overcome the language barriers as well as to ignore multiple nuances of different emotions it was decided to aggregate similar experiences into larger groups or categories. For example, such emotions as *anxiety, horro*r, *terror, angst, panic* or *worry* were categorized as **Fear**. Such process is consistent, for example, with a view that "an emotion is not a thing but a category of instances, and any emotion category has tremendous variety" [2, p. 26]. In the end of the scrupulous sorting, 26 major categories of emotions were formed, namely (in alphabetical order): Aesthetics, Anger, Behavior and Character Traits, Belief, Calmness, Compassion, Coloring, Creativity, Confidence, Courage, Desire, Devotion, Disgust, Fear, Gratitude, Happiness, Intellect, Joy, Love, Morality, Relationships, Sadness, Physical sensations, Sociability, Stimuli, Wonder. Those few answers that did not fit in either of these categories were aggregated into the 27th category, called Miscellaneous.

Quantitative Evaluation

The next step was to arrange all the data in four tables, one for each element. Each table included one row for each participant belonging to that group and 27 columns for emotional categories. Each row displayed the number of answers of a specific participant related to each category. When a participant did not mention an emotion from certain category in his or her answers, then zero was displayed in the corresponding cell. The resulting four tables served as the basis for subsequent statistical analysis.

For further quantitative estimation. a Parameter of Emotional Intensity – PEI (X, Y) was introduced. For each category X in relation to each element Y, it is defined as the total number of answers N belonging to this category, divided by the number of participants born in that specific element Y.

For example, PEI (Joy, Fire) is the number of answers in the category "Joy" given by Fire-born subjects, divided by the number of all the participants born in the element of Fire. In case when

PEI (X1, Y1) = PEI (X1, Y2) = PEI (X1, Y3) = PEI (X1, Y4),

the representatives of different elements are indistinguishable by their attitude to the category X1. In other words, when the ratio PEI (X1, Y1) / PEI (X1, Y2) ≈1, there are no differences between the elements Y1 and Y2 in their preference of the category X1. Such a situation was observed, for example, in the categories of Love and Happiness. It means that all the participants, regardless of their elemental belonging, accept equally Love and Happiness as one of their prevalent feelings.

The higher the ratio PEI (X1, Y1) / PEI (X1, Y2), the greater are the chances that the representatives of the elements Y1 and Y2 can be distinguishable regarding their attitude to X1. Strikingly, unlike Love or Happiness, there were significant differences between the preferences of the four groups regarding several other categories. The largest values received for ratios of PEI were:

PEI (Belief, Water) / PEI (Belief, Earth) ≈ 8

PEI (Stimuli, Earth) / PEI (Stimuli, Water) ≈ 3.1

PEI (Intellect, Air) / PEI (Intellect. Fire) ≈ 3.1

PEI (Desire, Fire) / PEI (Desire, Air) ≈ 2.4

PEI (Fear, Air) / PEI (Fear, Water) ≈ 2.2

PEI (Courage, Earth) / PEI (Courage, Water) ≈1. 9

Such significant differences between the parameters encouraged further statistical analysis.

For this purpose, once again the answers of each participant were aggregated into 27 categories, so that each questionnaire was represented as a vector of 27 different values. As some participants wrote down multiple answers aggregating into the same category, values ranged between 0-6 (0 – meaning the category wasn't mentioned in the questionnaire, 6 – meaning the category was mentioned 6 times in the questionnaire). For each of the 27 categories, two statistical tests were applied to test the null hypothesis that there is no significant difference between the answers of the four groups (Air, Water, Fire, Earth).

The first test used was the one-way ANOVA. This analysis of variance (ANOVA) developed by Sir Ronald Aylmer Fisher, tests the null hypothesis that two or more groups with differing sizes have the same population mean [see, e.g. 12]. The second test used was Pearson's chi-squared test, which is used on groups of categorical data to determine how likely it is that any observed difference between the groups is random [13]. For this test, the answer vectors of each participant were modified to be binary (i.e. 0 – the category wasn't mentioned in the questionnaire, 1 – the category was mentioned in the questionnaire).

Both tests showed the same result – the null hypothesis was rejected ($\alpha<0.05$) for 5 of the 27 categories – **Intellec**t, **Desire, Fear**, **Courage** and **Stimuli**. The probability that a violation of the null hypothesis is revealed in 5 of the 27 categories is approximately 0.008, which is significantly less than the generally accepted P-value, equal to 0.05. In other words, it is possible to speak with a high degree of confidence about the emotional distinguishability of the representatives of the four elements.

Meaningfully, the Water group was the most active one in the categories of Belief and Morality. Nevertheless, the insufficient number of participants left this observation statistically inconclusive. This observation calls for future testing of larger numbers of participants.

Consistency Between Quantitative and Qualitative Evaluations

Statistics are very important, but it is equally important to discuss typical trends and responses of the representatives of each of the elements.

The Fire-born participants tended most than others to identify emotions with intentions, motivations and drive. Among their preferable emotions were: “energy of life” and “desire”.

The Earth-group participants were more associated with their physical senses, behavior and actions. For them it was not rare to call an emotion “a book” or “work”, rather than the feelings experienced by them while reading or working.

The Air-group was more inclined to rationality, tending to diminish the value of the physical or physiological level and to overestimate the role of the mental one. Their emotions dealt with looking for meaning and its adequate verbal expression. A few typical answers: “thinking and thoughtfulness”, “understanding of joy”, sympathy, fear, obscurity”, “Self-knowledge”.

The Water-group chose to sink in the sea of joys and sorrows, to focus on the highest moral values and describe such intangible feelings as “belief”, “the joy of light, appearing almost always”, “co-joyfulness”.

Significantly, the detected differences in preferences of participants were not random, but rather coinciding both with the traditional descriptions of their dominant elements, and with the results of the first stage of the *Cartography of emotions*. Together all these observations implied a possibility that we indeed can speak of the distinct emotional features of people with strong affinities to each of the four elements.

From a quantitative point of view, the very fact of distinctiveness of emotional preferences of the representatives of the four elements can be considered as an important measurable result of the *Cartography of Emotions* and a first attempt to validate, though indirectly, the four-elements theories.

From a practical point of view, it took people many years to get used to the idea that even our closest relatives (such as our parents or children) might have a different blood type and that in such case blood transfusion from us might not heal but rather kill them. Now it is important to explore the possibilities that just as blood comes in distinct types, so can our inborn emotional nature belong to four different groups.

Conclusions

As a first experiment in this area, *Cartography of Emotions* might be considered as a pilot experiment. In the future it might be expanded by testing a larger number of participants and using more sophisticated statistical tests. Nevertheless, for me the most impressive result of this study is in the fact that the detected differences between the groups are consistent with the traditional contrasts between the corresponding elements. Moreover, they are consistent with the qualitative differences detected previously in the lives and creativity of well-known people.

Additionally, and what is not less important, these results have both theoretical and practical value. They can provide a temporal map enabling us to lessen tensions and build more harmonious relationships among people with different types of emotional nature. On a personal note, for more than three years I have been conducting a weekly course on temporological studies in Haifa, into which I have incorporated this emerging view on elements. Many attendants report that once they conceptualize the inborn emotional differences, this approach helps them to develop more harmonious relationships. I believe that one day we shall learn to respect and embrace all the elements of our nature reaching the state of mind where volition (Fire), deeds (Earth), thoughts (Air) and feelings (Water) will blend, becoming harmonious and inseparable.

We are making just first steps in the systematic exploration of a possible four-element nature. Of course, there might be many surprises on a long road to more conscious relationships, but a start has been made. Let this journey be auspicious for all the explorers.

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SECTION VII

MEASUREMENTS IN THE ECOLOGY, BIOTECHNOLOGY, MEDICINE, AND SPORT

30th INTERNATIONAL SCIENTIFIC SYMPOSIUM
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"SafeAir" Software to Analyze Air for Allergen Content

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***Abstract* - The "SafeAir" software system to analyze air for allergen content was investigated. The developed software product allows you to automatically provide data concerning air condition and provides the ability to independently analyze, receive hazard warnings and be able to call for help in a critical situation. The development methods are based on JavaScript technology, MySQL database server and NodeJS Web server.**

Keywords— allergens, air condition, dust, plant pollen, fungal spores, NodeJS, MySQL, JavaScript, SafeAir

I. INTRODUCTION

The term "allergy" was coined by the Viennese pediatrician Pirke in 1906. He noted that some of his patients had symptoms which could have been caused by certain substances (allergens) from the environment: dust, plant pollen, fungal spores or certain types of food. Subsequently, it became clear that numerous mechanisms involving various chemicals caused the appearance of many symptoms previously classified as "allergy". Hay fever, or pollinosis, is an allergic disease caused by pollen from trees, herbs, shrubs, etc. Up to 15% of the population is allergic to pollen in Ukraine, this is the most common allergic disease.

II. PURPOSE AND OBJECTIVES OF THE STUDY

The purpose of the study is to create a system satisfying the needs of allergyprone people.

Until now, there has been no single treatment method that would completely treat allergy. That is why, it is so important to be able to avoid contact with allergens which could lead to various unpleasant or even fatal outcomes. Nowadays there are devices to analyze the content of pollen or spores in the air, but they are not combined into a single system that could provide a number of services rather than just informing. Also, these devices are difficult to purchase, because they are not available in the public domain.

So, there came up an idea to create a system that would satisfy the needs of people with allergy. In the modern market this problem is quite new, because fewer people suffered from allergies previously. But, according to the studies, this situation has changed currently, this is due to the fact that modern people practice proper hygiene, and, therefore, the immune system is not well developed.[1]

III. ANALYSIS OF THE SUBJECT DOMAIN

The software is an interaction of mobile and Internet technologies. Since a significant number of the world's population has the skills to use personal computers or laptops with Internet access and smartphones based on the Android operating system, the given service will perfectly complement the technological system of any potential user.

As an alternative, one can mention the "Yandex.Weather" service, which allows you to view information concerning pollen; but this service cannot satisfy all the needs of potential users, because the area, in which this service is available, is very small, and the information about pollen is limited to only a few types of plants.

Like any software product, the given system has certain business risks. The developed product may face the following risks:

- The desire to use simpler types of systems;
- The cost of software and hardware development;
- The low need for the system in the countries with low risk of allergy in the winter or all year round due to the lack of flowering plants.

This system is intended for users of any age category. The system allows you to view information about the state of the air on the map, thereby helping people with allergy to take appropriate measures in advance or even avoid the danger zone. Also, the users purchasing a sensible device will be able to independently analyze the air and receive warnings about the threat, and in case of an acute allergic reaction they will be able to immediately call an ambulance.

IV. DESCRIPTION OF THE ADOPTED DESIGN DECISIONS

The main use of the product is to provide a user with information about the air condition and to give an opportunity to independently analyze, receive a warning about any danger and be able to call for help in a critical situation.

It is necessary to implement the following site functions:

- To view, edit, delete personal data of the user;
- To view the world map as to air conditions;
- To be able to connect or disconnect a smart device to the user profile;
- To obtain the user statistics (amount, pollen or spore types consumed by the user).

The following functions of the mobile application are implemented on Android:

- To view, edit, delete the user's personal data;
- To view the world map as to air conditions;
- To make an emergency call;
- To be able to connect or disconnect the smart device to the user profile.

The server:

- Performs the user access control to the service;
- Carries out data storage in the database;
- Carries out processing of the data received from a mobile phone and reasonable downtime;
- Encrypts data in the database and when transporting data between the server and the user;
- Generates the world map of air conditions.

The smart device provides the following features:

- Scans the air;
- Sends the scan results to the server;
- Displays data on the display (battery power, scan results, time, etc.);
- Sends a signal of entering the high-risk zone;
- Ensures an emergency call.

The following assumptions are considered within the framework of this system:

- The air analysis device already exists, but it is being improved by a team of engineers;
- The sensor analyzing the content of allergens in the air is reliable;
- A potential user knows how to use a personal computer with Internet access and has the skills to work with a smartphone based on the Android operating system.

The system has the following main limitations:

- Asymmetric RSA encryption is used as the encryption algorithm;
- The size of the database;
- Maximum load of configured servers;
- The use of software development technologies (developed web pages meet the requirements of modern Web technologies: programming languages such as Javascript, ECMA-262, CSS 3, HTML 5)
- Localization in Ukrainian and English (the most common language in the world).

Description of Design Decisions

The relational database MySQL v.5.7 was used in developing the system for storing data. The programming language Java 8 was used to develop the server and the mobile application. HTML 5/CSS 3 will be used in the development of the Web application. The communication system with the API is implemented using the HTTPS/1.1 TCP/IP protocol. A smart device emulator is implemented using the NET Framework 5.1. [2,3,4]

Architecture Description

Client-server architecture is one of the architectural patterns of the software. It is the most common concept in creating distributed network applications and provides for interaction and data exchange between them. It provides for the following main components:

- A set of servers to provide information or other services to the programs that access them;
- A set of clients that use the services provided by the servers;
- A network that enables communication between clients and servers.

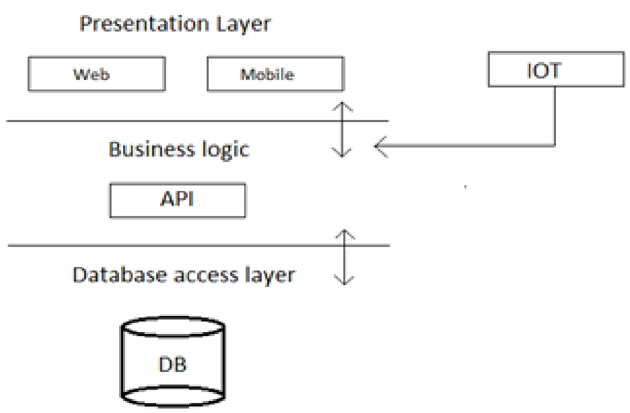

Fig.1. Project architecture

Fig. 1 shows the interaction between various components of the system. So, to get the result from the user's web browser, it sends a request to the front-end server, the front-end server processes the data and, if necessary, sends a request to the back-end server. The back-end server, in turn, validates the data and refers to the database, the components transmit the result to the user in the opposite direction.

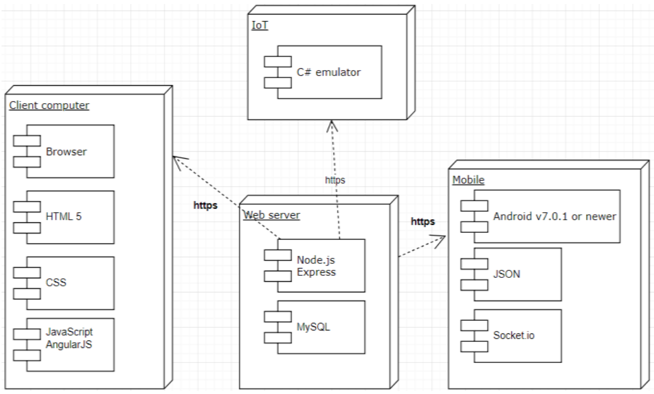

Fig.2. Deployment diagram

During the design process, it was investigated that the system under development would store user data, namely the personal data (name, address, phone number, email and password), device data, accounts, cards.

The database data are organized in accordance with the data organization model. Thus, the modern database, in addition to the data itself, contains their description and may contain means for processing them. Therefore, we obtain a database of five tables (see Fig. 3). The relational DBMS MySQL was chosen as the DBMS.

Relations between user and his allergy kinds, user statistics connected with causes of danger and map data.

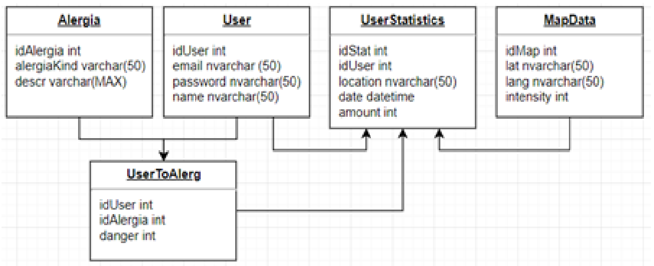

Fig.3. The structure of the database system

The front end is implemented using the following technologies:

- HTML5;
- CSS;
- JavaScript;
- AngularJS;
- Ajax.

Also, front end could be implemented using bootstraps and libraries with raster or vector tile map services like OpenStreetMap.

In the further development, next issues should be fixed:

- notification infrastructure on mobile devices and in the browser;
- sharing information about data, which was fetched from smart devices;
- filter by harmful substances type on global map;
- the ability for users to choose the type of allergy that a particular user has, rather than based on information obtained from tied devices, as if the user has no devices - no information about his allergies.
- because the system stores user health data, system security needs to be improved.

Fig.4. Usecase website diagram (Sign in, viewing air condition on the world map, editing Personal Information, authorization, registration, login into account, viewing personal information)

To create a mobile application, the Java programming language was used in the Android Studio environment. To implement the functionality, the ApacheHttpsClient library was used, which allows you to process HTTP secure service layer requests. Receiving and sending data occurs using the HttpsClient class.

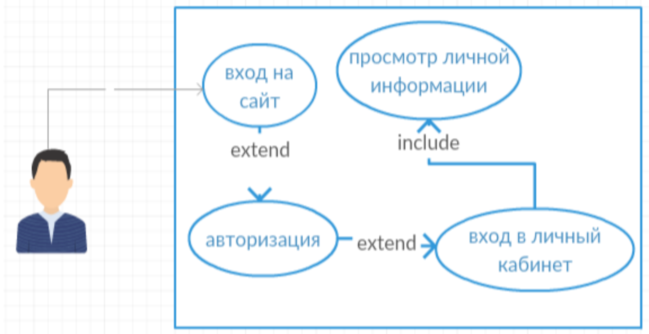

Fig.5. Usecase diagram of the mobile application (Sign in, autorization, login into account, viewing personal information)

The mobile application can be launched on any mobile device with Android 7.0+ system and Internet access.

In connection with the use of bootstraps, it is possible to use the main version of the site as mobile.

Fig.6. The main page of the program

The emulator is implemented using the C # programming language and the NET platform. To create the interface, Windows Forms was used.

To start working with the system, you should enter the website. Upon entering the website, there opens the main page, which has two “Sign in” and “Sign up” buttons and a global air condition map supporting all the functions of Google Maps.

In order to register, you should click the “Sign up” button on the main page of the site.

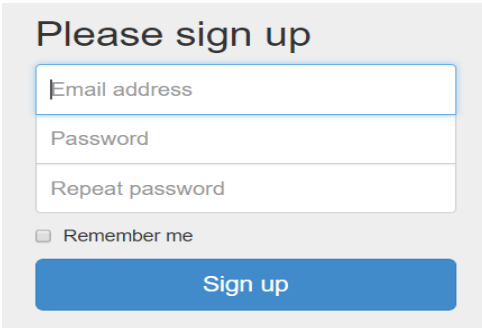

Fig.7. Registration form

After the registration or authorization, you should log in to your personal account. It gives the opportunity to view the statistical information, as well the information on the available devices, add or delete it.

List of the devices also show types of allergens, dust and another harmful substances. Each of devices also show actual information about coordinates, registration, etc.

Fig.8.

No significant deficiencies were identified during testing. That is, none of the test results mattered or failed. In each test case, the expected result coincides with the actual one.

There are ways to improve the software product, which can simplify its use.

In the following versions of the system it would be advisable to add:

- a mobile version of the site, which would greatly facilitate the use of the site from mobile devices;
- support for more languages, which will facilitate the use of the site in different countries;
- support for more users that the system can serve at the same time.

V. Conclusions

The developed system will be useful for people with pollinosis, that is, allergies to pollen or fungi spores contained in the air. This system may also be of interest to the companies involved in air cleaning or designing air purification devices.

With a smart device, like smartphone or tablet you will be able to evaluate the quality of the work performed. This product will help a person to control the level of danger in potential risk zones and provide the opportunity to call for help.

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Digital Agriculture Industry – Development of Sustainable Strategies for Industry Automatization

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***Abstract*—Despite the big and rapid growth of technologies during the 21st century, there is still an industry that is lagging behind with the optimization and launch of its digital transformation. In fact, this is the agricultural sector. Therefore, in recent years, many attempts have been made to develop and implement optimized processes and technologies, in order to increase production and reduce costs while maintaining product quality. But the automatization and digitization itself is very complicated to implement. When not done by proficient experts, this can cause huge losses and downgrade. The purpose of this publication is distinguish the critical factors while developing strategies for plant production automatization.**

Keywords—digital agriculture industry, smart production, automated systems, smart greenhouses, automated plant production, digital transformation, digitalization

I. Introduction

Today, we are witnessing something which was thought to be imaginarily and extraordinary – the world is changing drastically! It firstly started long time ago with our personal data, such as documents, photos, music, etc. It didn't took much time until the next phase began - the business realized the true potential of the globalization and started adopting it, while changing its needs drastically, making the digital transformation irreversible. There is no more doubt whether the digital transformation is happening or not. It has already started and believe it or not - we are part of it.

The promise of digital transformation is to help companies, and even industries, to create new value, by adopting and implementing digital technologies, like artificial intelligence (AI), cloud computing, augmented reality (AR), virtual reality (VR), industrial internet of things (IIoT), Blockchain etc. The leading companies are already showing bright signs of improvements, thanks to the data-driven decisions. The main thing which they are doing is transforming their business models according the new trend, such as connecting their operations, gaining access to relevant data and digitizing processes.

But implementing such large-scale changes in an organization might be risky. Capturing the benefits of the modern trends is a key factor in keeping up with the competitors. There comes the tricky part – a proper risk analysis of the as is – to be and the creation of clear roadmap, pursuant with the weaknesses of the industry. Although the benefits may seem predominant, a poorly managed transformation can downgrade the organization.

Despite the many positive factors and signs, there is still an entire industry (with small exceptions) which was delaying the implementation of this new trend. The agricultural farmers and companies were keen on keeping the traditional way of working, which made them fall behind the business and economic evolution. This slow down led to multiple challenges in the industry. Because of the rapid urbanization and the global population growth rapidly (from 7.6 billion in 2018 to over 9.6 billion in 2050), there will be a remarkable increase in the food demands. At the same time, there is a lack of natural resources as fresh water and arable land. This requires an urgent alteration of the whole agricultural system. Digital technologies are opening up an entire 'new world' regarding crop management. Producers' and agronomists' jobs are changing due to large amounts of data and tools they have at their disposal. However, how to incorporate these properly at a farm level, is still a learning process for most of them [1]. Digital transformation may be part of the solution. It is main part of the next industrial revolution, named the "Fourth Industrial Revolution" (or simply Industry 4.0).

II. Description of the Problem

The efficiency of farming lies in a farmer's ability to predict natural conditions and react to them in the quickest way possible. A few decades ago, the precision of such forecasts wasn't so reliable — now, it's impressively high thanks to instant data gathering and distribution [14]. Despite its conservatism and stiffness, the agricultural industry realized that globalization without digitalization is impossible. Nowadays agriculture doesn't only limit to cultivate crops rather following convenient and efficient way to grow more crops. The demand & usefulness of greenhouse technology is increasing with increase in population and there is no alternative of it to cope with epicurean lifestyles of people. Not only that, it is not convenient to rely on natural climatic condition in agriculture [5].

Before deep-diving into the problem, firstly we will define the terms of digitalization and digital transformation. According to the market forecasts for the next decade, “the digital agricultural revolution will be the newest shift which could help ensure agriculture meets the needs of the global population into the future. Digitalization will change every part of the agri-food chain. Management of resources through-out the system can become highly optimized, individualized, intelligent and anticipatory. It will function in real time in a hyper-connected way, driven by data. Value chains will become traceable and coordinated at the most detailed level whilst different fields, crops and animals can be accurately managed to their own optimal prescriptions. Digital agriculture will create systems that are highly productive, anticipatory and adaptable to changes such as those caused by climate change. This, in turn, could lead to greater food security, profitability and sustainability [3]. The correlation between industrial revolutions and agricultural revolutions is clearly visible. There is only one thing left – the acceptance of the change. As Daniel Newman said “people in the industry—farmers, food producers—must embrace the digital transformation trends in agriculture. By using technology as a sustainable and scalable resource, we will be able to take agriculture to new heights, keeping farm to fork in our future [4].

So, what is this “digitalization” and what does the “digital transformation” mean?

According to Gartner’s IT Glossary, “digitization is the process of changing from analog to digital form”, while the “digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business”. Also, from there we have the definition of digital transformation – it can refer to anything from IT modernization (for example, cloud computing), to digital optimization, to the invention of new digital business models. The term is widely used in public-sector organizations to refer to modest initiatives such as putting services online or legacy modernization. Thus, the term is more like “digitization” than “digital business transformation [2].

There are many circumstances which cannot be neglected when talking about digital transformation. Some constraints are the required technology, including availability, connectivity, affordability etc. Also, there are some basic conditions, which has to be fulfilled, like infrastructure and connectivity (mobile subscriptions, network coverage, internet access, and electricity sup-ply), affordability, educational attainment (literacy, ICT education) and institutional support. Most of the developing countries have seen the gap in this industry and started many initiatives in the context of creating a good environment for development of new processes and methodologies.

Digital agriculture is the use of new and advanced technologies, integrated into one system, to enable farmers and other stakeholders within the agriculture value chain to improve food production. But less than 20 percent of acreage to-day is managed using digital agriculture technologies (e.g., variable-rate spraying) due to the high cost of gathering precise field data. The fourth agricultural revolution is associated with many innovations in sustainable agriculture, some emerging and some more established, which are interacting and co-evolving in a wider “ecology of innovation”; Such an ecology of innovation includes “big” emerging smart technologies (e.g., AI, Internet of Things, Cloud Computing, robotics), as well as “smaller” farmer and/or community-led innovations. When it comes to technology and data available within the agricultural industry, there’s a large amount of choices these days. It’s important that retailers understand and are able to provide guidance for growers about what works and what doesn’t work as well. Understanding the technologies and datasets are important and how to best use them is even more crucial. Precision agriculture is a term widely used in the industry today. Precision agriculture is an approach to farming that employs data sensors, connected devices, remote control tools, and other advanced technologies to give farmers more control over the field and the team [14]. It helps growers better respond to variability within a field or series of fields to improve overall crop health and increase yields. Digital agriculture tools include the variety of technology and software systems that provide data to enhance decision making in precision farming, and if used properly, can help reduce waste, increase profits and protect the environment. Using technology for farm management in-creases data accessibility. With precision agriculture, the team members are no longer bound to the office space. Thanks to cloud-based technologies, all the necessary data is free for access any time from any device.

According to a research done by Altimeter Group “Only one-quarter of the companies we surveyed have a clear understanding of new and underperforming digital touchpoints, yet 88% of the same cohort reports that they are undergoing digital transformation efforts.”[15] Briefly said, a big part of the organizations Altimeter spoke to reported that they are performing their Digital Transformation without even knowing what it actually is.

III. Problem Solution

With the help of smart sensing elements, growers can predict best conditions for plant growth and what nutrients their crops need. At the moment our ability to collect vast amounts of data easily outstrips our ability to convert it in-to usable information. Predictive analytics can play a critical role for decision makers who need to interpolate and forecast from a current situation to an alternative state. There are many technological solutions to implement this. And there we need the answer of the question - how to do this without putting a whole industry into risk? Unfortunately there is no one and only answer of this question.

Many seniors in this area today are aggressively seeking for ways to transform their companies and business models, aiming to improve their performance and yield.

According to a research performed by Altimeter based on a survey of 554 professionals from brands, consulting firms and other organizations with at least 1000 employees across North America, Europe and China, the top drivers of the digital transformation are:

- P1 - Growth opportunities in new markets – 51%

- P2 - Evolving customer behaviours and preferences – 46%
- P3 - Increased competitive pressure – 41%
- P4 - New standards in regulatory and compliance – 38%
- P5 - Evolving employee behaviours and preferences – 26%
- P6 - Proactive investment to fight disruption – 26%
- P7 - Lack of expertise, literacy and understanding of digital trends – 19%
- P8 - Decline in business performance – 12%
- P9 - Other – 1%

These transformation drivers may be assumed also for the industry of agriculture. In order to perform the change management properly, every leader should be aware of his change driver. The first step before starting this kind of transformation is to realize that it doesn't have a set of beginning or endpoint. It can be better explained as a state of mind for an organization for continuous improvement.

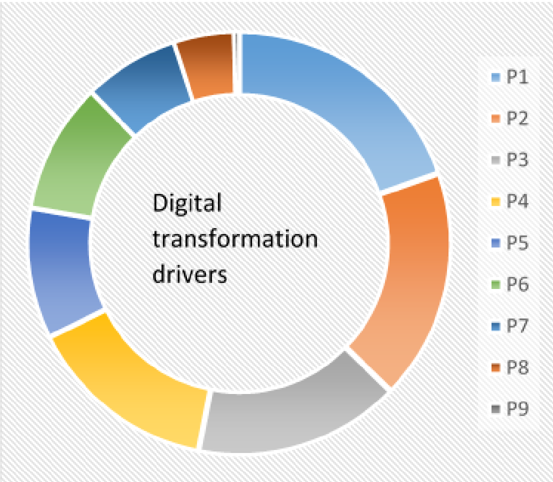

Fig.1.

After finding himself in one of these situations listed above, every change manager has to identify the benefits which the transformation will bring to the stakeholders. Every development strategy has to be accompanied with a proper risk management. There are many tools, which can be used in order to identify the critical points. The easiest to use and understand tool is the Risk Matrix.

		Impact				
		1	2	3	4	5
Likehood	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

Fig.2.

According to the matrix above, 2 critical factors can be identified:

- Likehood / Risk Probability
- Impact

These factors are giving the clear picture of the 4 different types of risks:

- Low – in green – can be accepted
- Moderate – in yellow – can be accepted after minimal changes
- High – in orange – can be accepted after major changes
- Extreme – in red – cannot be accepted

After performing a proper risk management and identifying the risks, they can be further analysed by using a SWOT diagram. SWOT analysis (or SWOT matrix) is a strategic planning technique used to help a person or organization identify strengths, weaknesses, opportunities, and threats related to business competition or project planning [16]. It consists of 4 parts:

- Strengths: characteristics of the business or project that give it an advantage over others.
- Weaknesses: characteristics of the business that place the business or project at a disadvantage relative to others.
- Opportunities: elements in the environment that the business or project could exploit to its advantage.
- Threats: elements in the environment that could cause trouble for the business or project.

	Helpful	Harmful
Internal origin	Strengths	Weaknesses
External Origin	Opportunities	Threats

Fig.3.

Filling these tables might look a bit tricky at the beginning for every change manager. But without having the clear picture of possible outcomes, the project of implementing new technologies will be catastrophic. Although it seems easy, choosing the right technologies to implement is also very important. The choice of technology mostly depends on the process which is going to be optimized. The focus should be on the specific needs and business objectives.

After identifying the possible blockers and critical factors, the next step should be selecting a proper change management tool with the corresponding risk mitigation and prevention tools.. The process of digitization can be considered as a big change management project. There are many tools available, but according to the complexity of the project (the level of digitization) a different one may be used. The proposed ones by the authors are:

- PDCA – Plan/Do/Check/Act – recursible model that provides a framework for the improvement of a process or system. It can be used to monitor a single issues or guide an entire improvement project or initiative.
  - Plan – define a clear problem statement, gather and analyse the data. Develop a plan for implementation.
  - Do – execute the plan developed in the previous step.
  - Check – gather the data from the DO step and compare to the expected outcomes.
  - Act – also called Adjust. Improve the process.
- Kotter's 8 step model of change - The 8-Step Process for Leading Change was cultivated from over four decades of Dr. Kotter's observations of countless leaders and organizations as they were trying to transform or execute their strategies. [17]. This model may be used in bigger agricultural organizations, where bigger number of stakeholders are involved. In these situations, this model provides a better spread of the urgency for innovation and modernization.
  - 1st step – create a sense of urgency
  - 2nd step – build a guiding coalition
  - 3rd step – form a strategic vision & initiatives
  - 4th step – enlist a volunteer army
  - 5th step – enable action by removing barriers
  - 6th step – generate short-term wins
  - 7th step – sustain acceleration
  - 8th step – institute change
- ADKAR model for change management - The Prosci ADKAR® Model is a goal-oriented change management model that guides individual and organizational change [18]. This model is suitable for medium-to large organizations, where the stakeholders are not willing to accept the change, which might be the most common situation in the sector of aggrobusiness. The abbreviation stands for:
  - **A**wareness of the need for change
  - **D**esire to support the change
  - **K**nowledge of how to change
  - **A**bility to demonstrate skills & behaviours
  - **R**einforcement to make the change stick

Conclusion

While traditional ICTs were the weak ties for diffusion of innovation, modern day ICTs are bringing vast amount of information to rural communities [9]. Precision agriculture is the key to farming that employs data sensors, connected devices, remote control tools, and other advanced technologies to give farmers more control over the field and the team. Increasing the productivity is an age-old ultimatum for the agricultural industry. The digital transformation of this industry will definitely help large and small scale farms improve processes, boost their yield, and increase profitability, helping to meet the growing global food demand and lowering the overall environmental impact of farming. Despite the fact that much work is needed in the area of digitalization in agriculture and rural areas, the potential environmental, economic and social benefits are significant. Only introducing technologies is not enough to generate good results. To be able to use the full potential of digitized agriculture, both literacy and education levels has to be increased

The digital transformation should be seen as a way of thinking and state of mind instead of just a trend. As this is going to be a very important part of every business, working with a specialized outsourcing provider may be a smart idea for organizations which are looking to introduce new technologies in their everyday processes. There are many tools which can be used in order to create the best implementation strategy, but choosing the right one might be tricky for some individuals. As digital agriculture develops, it will be critical to make the technology available to as many farmers as possible and to implement it in ways that minimizes negative impacts on those who work in the sector [8]. This will vastly in-crease efficiency as well as create new markets and opportunities. This is a process which step by step takes organizations through different phases of innovation and needs to be carefully managed.

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Development of Panels of Recyclable Materials to Improve Energy Efficiency During the Winter Season

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***Abstract*—in this paper the steps for developing of panels from recyclable materials to improve energy efficiency during the winter season are presented. Two types of panels are developed – one panel being coated with Plexiglas and the other with a Fresnel lens.**

Keywords — aluminum cylinders, Plexiglas, Fresnel lens, heating

I. Introduction

In winter, temperatures reach very low values and in each home and office different heating methods are used (air conditioners, converters, etc.). Using these methods is expensive and not always effective. In most cases, in order to maintain a suitable temperature, the heating sources must work around the clock. If they are used only when there are people in the room, it will take a long time to reach the desired temperature and will consume almost the same amount of energy if the sources work constantly.

To improve energy efficiency, it has recently been developed a model made of hollow aluminum cans (cans of alcoholic and soft drinks) placed in a cardboard box with black walls. The aluminum boxes are connected to each other in groups and arranged in several columns in the cardboard box. The front of the box is closed with Plexiglas. The light passes through the Plexiglas and heats the boxes, whereby the air space inside them heats up. [1]

The paper shows all the steps and the methodology for creating panels to improve energy efficiency during the winter season.

II. Making of the Panels

a. Preparing the aluminum cylinders

Aluminum recyclable cylinders are used for the production of aluminum pipes / clusters /. The Aluminum cylinders (fig.1) have the following dimensions: height 171 mm, a width (at the middle part) 69 mm and a thickness of the aluminum wall 0,5 mm (dimensions are approximate). Each of the clusters is made up of two aluminum cylinders assembled in height, the approximate height of one cluster being 342 mm. Prior to the fabrication of the aluminum tubes, each of the cylinders undergoes the primary processing described below.

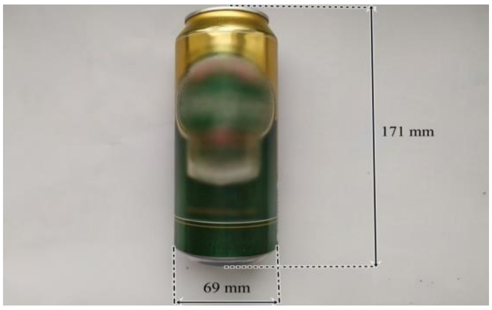

Fig.1. Dimensions of the used cylinders

All aluminum cylinders are tightly sealed on the underside, so for the construction of the clusters it is necessary to drill them. Using a driller with a diameter of 2 mm, three holes (centers) are drilled at equal distances from each other. The holes are widened with a drill of 9 mm. The result is presented in fig. 2.

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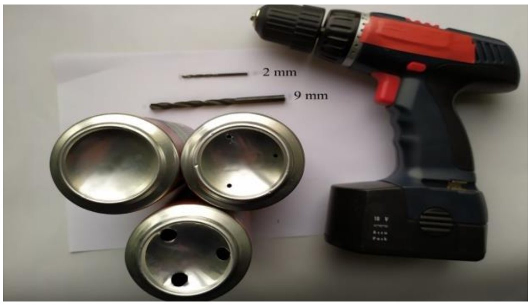

Fig.2. Expansion of the holes

Fig.3. Upper part of the cylinders

At the top, the recyclable aluminum cylinders have a small hole, shown in fig. 1.3, which in this case must be widened.

An emery board is used, which removes a smaller part of the metal edge of the aluminum cylinder. The results presented in fig. 4.

Fig.4. Cut with sandpaper

Fig.5. Assembled aluminum pipes

After the primary processing of the aluminum cylinders, the clusters (aluminum pipes) are assembled. It is carried out as follows: a second is placed towards the upper part of the first aluminum cylinder, the lower part of the second lying on the upper part of the first. In order for the cylinders to remain stable, heat-insulating silicone is used, which serves as an adhesive. This action is repeated during the assembly of each of the clusters, and the final result is presented in Fig. 5.

For the purposes of the study, clusters composed of two aluminum cylinders, painted in black, were used. The cylinders are painted with black spray, thus the paint is evenly distributed on the surface of the cylinders. The painted cylinders are presented in fig. 6.

For future developments of the panels, the use of clusters made of four and more aluminum cylinders is planned.

Fig.6. Painting the pipes

b. Developing the casing of the panels

The next task is to develop the casing where the aluminum pipes will be placed. Fig. 7 shows draft of the casing with dimensions of all sides (front, rear and side views). Brown indicates the wood used for the panel frame, and gray indicates the insulation.

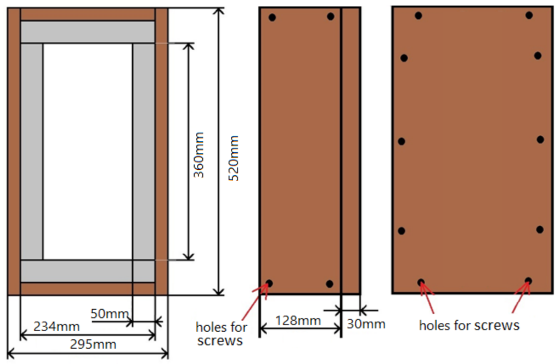

Fig.7. Draft of the panel's casing

Very important step in creating the casing is the correct sizing of the materials. The frame of the casing is made of wood with a thickness of 30 mm.

Several steps are performed in succession:

- Cutting the base - a board measuring 300 mm wide and 500 mm high. The frame will be built on this board and the insulation will be placed together with the aluminum pipes.

- Cutting two new boards with dimensions 128 mm wide and 500 mm high, which will be used for the side walls.
- Cutting two other panels measuring 128 mm wide and 234 mm high, which will be used for the top and bottom of the panel.

After cutting the necessary boards, they are fastened to each other, with screws with a length of 80 mm shown in fig. 8. In fig. 9 the final version of the fastening of the boards can be seen.

After assembling the boards and obtaining the presented casing from fig. 9, the insulation is installed. In this case, Styrofoam insulation with a thickness of 50 mm was used. Styrofoam is used because of its wide distribution, its good insulating properties and its low price.

Fig.8. Screws for fixing the frames

Fig.9. Result after fixing the boards

Following the same steps as when making the wooden casing. Using a model knife, two pieces measuring 234 mm long and 128 mm wide, and then two other pieces measuring 360 mm long and 128 mm wide are cut and placed in the wooden casing as shown in fig. 10.

Fig.10. Result after fixing the boards

After placing the side insulation, another piece with dimensions 135 mm wide and 360 mm long is cut and placed so that it locks the other parts. Photo 11 shows the final result.

Fig.11. Result after fixing the boards

Each of the steps listed so far is applied in the production of the second panel to make the two panels as identical as possible. Already finished and painted aluminum pipes are placed in the formed "socket" and the panel gets the look of fig. 12.

Fig.12. Panel after laying the aluminum pipes

The last step in finishing the panel is to install Plexiglas, which will keep the pipes from falling out and allow the sun's rays to heat them. The Plexiglas is 500 mm long and 290 mm wide and is attached to the wooden frame with several 20 mm screws shown in fig. 13.

Fig.13. Plexiglas fixing screws

After placing the Plexiglas, the panel acquires the appearance of fig. 14.

Fig.14. Final view of the assembled Panel with Plexiglas

As described so far, one panel will be covered with Plexiglas and the second will use a Fresnel lens. When closing the second panel, it was found that the Fresnel lens was not the right size and did not close the panel tightly on all sides. For this reason, a new piece of Plexiglas was cut, with the dimensions of the first, but with a hole in the middle corresponding to the dimensions of the Fresnel lens - 334 mm long and 130 mm wide. This refraction avoids double refraction of the rays. After placing the lens, the panel acquires the appearance of fig. 15.

Fig.15. Final view of the assembled Panel with Fresnel lens

The final step in making the panels is drilling holes through which the measuring transducers will be placed in (thermocouples) to follow the change of the temperature simultaneous in both panels can be placed. For each panel 2 thermocouples are used - one to measure the accumulated temperature in the cylinders and the second outside the cylinders but still in the panel. After placing the thermocouples, the panels have the appearance shown in fig. 16.

Fig.16. Front view of the finished panels (on the left panel with Plexiglas, on the right panel with Fresnel lens)

III. CONCLUSIONS

The developed panels in the shown above way are used to compare the accumulated energy from both types of panels. For full estimation of the practical use of both technologies (with Plexiglas and Fresnel lens) the panels should be examined not only for accumulating heat energy from the sun, but how this energy will be able to heat a given space (what temperature can be reached and for what amount of time).

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