

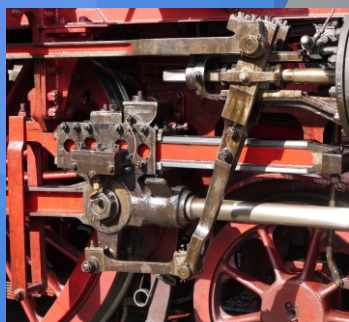
INTERNATIONAL SCIENTIFIC JOURNAL

INDUSTRY 4.0

ISSN (PRINT) 2543-8582

ISSN (PRINT) 2534-997X

YEAR III ISSUE 2/2018



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PUBLISHED BY
SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING
“INDUSTRY 4.0”, BULGARIA

INTERNATIONAL SCIENTIFIC JOURNAL

INDUSTRY 4.0

YEAR III, ISSUE 2 / 2018

ISSN (PRINT) 2543-8582, ISSN (WEB) 2534-997X

PUBLISHER

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING "INDUSTRY 4.0"

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MACHINE OPERATION RESEARCH - PRODUCT AND MACHINE DATA INTEGRATION

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Abstract: Data from machine operation is an important source for product-relevant quality aspects. The integration of machine data into the digital product life cycle processes enables the improvement of products, systems and processes. In product development in particular, future machine generations can be engineered being more adapted to the requirements for operation issues during use phase, enabled by product and machine data inspection and analysis. In this paper, we propose a comprehensive and generic reference data model called Field Data Model (FDM), organising well-structured product and machine data. The FDM is part of Product Lifecycle Management (PLM), enabling data integration from heterogeneous data sources like PDM, machine control systems and machine-related sensors. The FDM is part of a Field Data Management System (FDMS) that is used to automatically set up and organize Field Objects (FO), representing – real or virtual – machines or machine components of special interest to machine manufacturers or machine operators.

Keywords: Product Lifecycle Management, Data Integration, Lifecycle Engineering

1 Introduction

Information on machine status and behavior just as from operation processes during use phase – encoded by machine data – are sources of innovation. In product development, machine data can be used to improve future machine generations that are more reliable and better meet the requirements for operation issues. Even the value of current machine generations can be sustained or increased by machine data [1, 2]. In the use phase, product data can be utilized for machine reconfiguration [3]. Product data can also be used to eliminate or prevent machine errors [4]. In this way, there is a growing demand for an intensive cross-exchange of data between the operating and development phase. Hence, machine manufacturers in particular have great interest in gathering and analyzing machine data to extract valuable information. Only a limited amount of machine data is currently used yet.

Machines are increasingly equipped with sensors, computer systems and modern communication interfaces that provide the required machine data. Satisfying the demand for machine data also needs to face organizational deficits with respect to company-wide data and process management. The fact of different machine models, configurations and generations coming from different machine manufacturers and being used by different machine operators results to a wide spectrum of possible combination. The inherent complexity currently can only be managed with considerable effort.

Product and machine data need to be integrated consistently to get valuable gain of information as described by the so-called Closed-loop PLM concept [2]. Approaches for product and machine data integration only implement one-sided storage using the machine manufacturer's Product Data Management (PDM) [5, 6]. Concerning this, data is beyond the control of the machine operators whose interest, however, is to protect their data and not to pass it unregulated to the outside world. Machine manufacturers are also aware of their data. The protection of expertise prohibits the unwarranted transfer of product data to the machine operators. Binding regulations and contracts are necessary to overcome the implied organizational deficits. Furthermore, the development of fundamental concepts and models for product and machine data integration needs to be taken forward.

2 Related Work

2.1 Product Lifecycle Management

PLM is a strategic and integral management approach for process and data integration relating to the product life cycle that is a core process of industrial companies. It starts with product development, production and ends up with product use and recycling phase. Product development comprises the planning of products, associated equipment, resources as well as manufacturing

processes [7]. PLM specific processes, methods and tools enable the availability and provision of product information at the right time, in the right quality and order as well at the right place. PLM ensures a consistent and persistent information storage using PDM as data backbone.

PLM is well established in product development and production. Otherwise, the integration of use phase specific resources and systems with PLM is insufficiently solved [8, 9]. Data provided by machines is often incomplete and not available in the required quality for product development objectives. Management systems increasingly face the challenge of managing and leveraging information from the use phase efficiently, using specific data and process models. Therefore, PLM will be used increasingly in the operational phase in the future [10].

2.2 Product Data

Modern Product Development is characterized by a holistic and systemic product view that has led to changes in the way products are developed. Digital tools for product design, simulation and production planning are omnipresent. The intensive use of these development tools causes an increased volume of product specific and life cycle relevant data [7]. This data is part of the product model, the result of product development [11, 12]. Finally, any machine is an instance of a specific product model configuration.

Domain-specific engineering models describe each functional, physical, organizational and geometric aspect of a prospective machine. All these product aspects are encrypted by data that is heterogeneous in type and rely on various data models respecting domain- and modelling tool-specific particularities. Such structured data is usually stored in files. Files contain metadata, considering information for description and administration.

Product data is managed by PDM in a consistent and structured way. PDM ensures the unambiguous reproducibility of any product configuration. Figure 1 shows the PDM Basic Data Model. As a core concept of PDM, file-based engineering models are organized using documents. Thus, in the Entity Relationship Diagram the entity type *Document* is related to *File* – a *File* again is stored in a *Vault*. *Part* entity type represents all components that are necessary to produce a configuration-right machine.

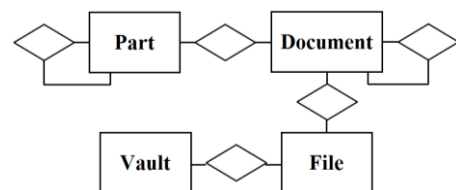


Fig. 1 The PDM Basic Data Model

In the PDM context, all entity types have well-defined semantics. It can be assumed, most PDM applications are built on the PDM Basic Data Model. Thus, each entity type can theoretically be used for data integration purposes but from a strategic perspective, *Part* entity type is most appropriate. The top part of the hierarchical organized part structure corresponds to the machine or a machine component configuration to be manufactured.

2.3 Machine Data

Machines are increasingly equipped with sensors that collect various operating data regarding machine state and operation processes. Such data is primarily used for automation purposes, ensuring trouble-free machine operation. Because of the advancing digitization and networking of machines, the total volume of operating data, generated by sensors and information-processing devices, has increased worldwide – from 2010 to 2015 by a factor of 10.000 – up to 10 Zettabyte [13]. By 2020 and beyond an exponential growth of this data volume is predicted. In 2025, 160 Zettabyte of new data is expected to be generated [14].

Machine data is part of the technology related operating data (Table 1). It is assigned to specific machines or machine components. Machine data can also be interpreted as field data that results out of the interaction between user and machine during operation phase.

Table 1: Types of Operating Data [15]

Operating Data			
Organisation related Data		Technology related Data	
Job Data	Personal Data	Machine Data	Process Data
job status, number of manufactured pieces etc.	attendance and working hours, labour costs etc.	error messages, consumption of resources, sensor readings etc.	quality, adjustment, process parameters etc.

Field data provide quality-relevant information about machine usage [16]. It can also be assigned right to specific machines or machine components. Thus, machine data is an integral part of PLM. It can be interpreted as an intersection of operating and field data (Figure 2).



Fig. 2 Machine data as an intersection of operating and field data

Depending on data sources and communication requirements, machine data can be structured or semi-structured. Structured data is commonly found in database management systems. Semi-structured data is typical for spreadsheets or flat files [17]. In this context, communication technologies like OPC UA have become de facto industry standard protocols for data exchange and integration purposes e.g. in the promising field of Industrial Internet of Things. Such protocols are based on very own data models that are adapted for storing device information, error protocols or communication data.

Different data models deriving from various data sources like standardized communication protocols can be traced back to a general structure and more generic view on machine data as shown in Figure 3. The entity type *Information Object* represents any kind of physical, information relevant thing like a production plant, a machine or machine component. The entity type *Object Item* is kind of a wildcard and stands for any structured Information related to an Information Object. The Generic Machine Data Model can be used for historical data, stored in distributed and heterogeneous databases, as well as for machine live data. Regarding data analysis objectives, the Generic Machine Data Model can also be used to organize training datasets.

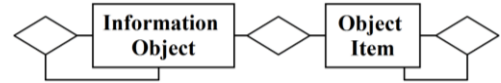


Fig. 3 The Generic Machine Data Model

3 Data Integration

3.1 Methodology

A profound understanding of the structures and semantics of product and machine data is essential for successful data integration. According to the IEC TC 65/290/DC, several harmonization levels are differentiated in order to establish compatibility of information systems. Each harmonization level refers to a specific object for integration. Data integration initially requires the integration of data models (IEC, 2002). In our case, the data models from product development and machine operation can either be integrated by bilateral conversion rules (loose coupling) or by an integration data model as reusable artefact (close coupling) [18]. In this paper, an integration data model called *Field Data Model* (FDM) is proposed that meets the following core requirements:

1. The integration data model realizes the consistent linking of product and machine data in a structured form.
2. The integration data model is usable for various purposes of data usage like data query, analysis and visualization across multiple domains.

A stringent methodology is required to meet the core requirements. In Design Science approved research methodologies exist, which can be used to support any artifact development (like data models) [19]. The basic prerequisite for a successful development outcome is a deep understanding about the contextual information background. Reference catalogues and suchlike can be used to fall back on verified basics [20].

3.2 Field Data Model

The FDM is a comprehensive and generic reference data model. It can be adapted to create individual data models for application cases as for machine tools, electronic devices or automobiles. FDM can be modified to meet the application-specific requirements and realize the consistent linking of product and machine data. Data sets based on the FDM can be used by different resources and users of PLM.

According to [21] the FDM is designed as a three-part model. The *Part Data Model of Product Development* – the lower of the FDM (see Figure 4) – is partially based on the PDM Basic Data Model (see subsection 2.2). Document, File and Vault entity types are used for the *Part Data Model of Machine Operation* – see the upper part of the FDM. This data model follows the generic view on machine data, as described in 2.3.

Both part models are linked by a single entity type called *Field Object* (FO) as key element for model integration. The FO is a virtual representation for exclusive machines as well as machine components that are of special interest to machine manufacturers or machine operators. Such machine components can have a mechanical, electrical, electronic or information processing background. The FO is related to the *Information Object* and *Part* entity types, considering any number cardinalities including zero. In other words, a FO can be related to no or any number of parts or information objects.

The inverse relations of FO result in a sub-data model called *Field Object Structure* (FS) (the broken line bordered area in Figure 4). A FO can be related to no or any number of FO. Such relations representatively describe – logical, mechanical, electrical or topological-related – couplings and interactions between machines or machine components. Thus, the FS represents relationships that do not exist in any engineering model. For instance, the closeness of

purposes. Alternatively, it is more reasonable to define general attributes. For example, any sensor (Information Object) has Measured Value and Measurement Time as attributes related to the Object Item 'Measurement'. This example indicates unequivocally, general data from operation phase like sensor readings is currently not sufficiently considered by the FDM. For that reason, we are planning to extend the reference data model by commonly used entity types. However, the final adaptation of the FDM requires the active involvement of machine manufacturers and machine operators. Individual requirements must be fulfilled to set up analyzable data sets based on the FDM.

A vast and growing amount of machine data is already available nowadays that need to be managed efficiently. In particular, the raw data provided by sensors cannot be integrated in product development processes without being processed. Thus, machine data integration is inefficient without data reduction and preparation. The utilization of the available machine data exceeds in particular the capacities and capabilities of small and medium-sized enterprises. Thus, a process model closely adapted to the FDM is required, which involves data preparation and reduction.

Creating and linking FO manually is time-consuming and at high risk of error. It is almost impossible to create a Field Structure of complex assemblies manually. For this, new digital tools are required. These tools can be part of different product life cycle processes. In product development, structured FO for example can be generated manually or automatically after design release. Another challenging problem to be solved is the consistent linking of FO and Information Objects. Such links must be fully established after production phase. Appropriate digital tools are also required for this purpose.

An information system for FO management is required to solve the problems being discussed. In [21] the architecture of such a management system called *Field Data Management System* (FDMS) is described. The FDM is an integral part of such a FDMS that has interfaces to databases of product development like PDM and machine operation. From a functional perspective, the FDMS fully implements the document-based management approach, which is already part of the FDM (see subsection 3.2). This approach meets the same administrative policies that are essential in PDM. FO-release and change processes are possible.

Further work about semantics is also necessary. Finally, no semantics is required for pure data integration but common and unified semantics is an essential requirement for successful data evaluation and interpretation.

5 Conclusion

In this paper, we proposed a comprehensive and generic reference data model called Field Data Model, organizing well-structured product and machine data and being a prerequisite for cross-domains data queries or analyses. The Field Data Model is part of the Product Lifecycle Management strategy, enabling data model integration from heterogeneous data sources from product development and machine operation. The data required for data integration are from the Product Data Management as well as from machine-related information objects like sensors or machine control systems. The Field Data Model is an integral part of an information system for Field Data Management that is in development. Machine demonstrators of different application cases confirm the validation of such a management system.

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A COMPARISON OF SEQUENTIAL QUALITY CONTROL METHODS

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Abstract: This research considers the problem of sequential quality control and presents different methods for the quick detection, with low false alarm rate, of a change in a stochastic system. The paper focuses on recently proposed control schemes called Nested Plans. These schemes include two unknown parameters that essentially impact their efficiency. The research presents a way to find the optimal values of the parameters, and shows that Nested Plans with the correct choice of the parameters are very efficient, robust and simple for practical applications.

Keywords: QUALITY CONTROL, SEQUENTIAL ANALYSIS, NESTED PLANS, CUSUM.

1. Introduction

There are extensive references in statistics and engineering literature on the subject of early detection, with low false alarm rate, of parameter changes in stochastic systems. Such problems are very important in the context of quality and reliability control. The ingredients of the change-point detection problem are a sequence of observations whose baseline distribution has some density that may change to an alternative density. A common performance measure for any inspection scheme is the average run length (ARL). Let N be a stopping time (the random variable corresponding to the time when an alarm is raised). The in-control ARL (average run length until a false alarm) and the out-of-control ARL (average run length from change to its detection) are defined as expectations of the stopping time N under the pre-change distribution and the post-change distribution, respectively. The first formal sequential method has been proposed by Shewhart (Shewhart [1]). He proposed raising an alarm the first time that an observation exceeds the known baseline mean by more than three standard deviations. The method is known to be very good in detecting a large change quickly. Later, various more efficient methods have been proposed. Lorden [2] proved that the minimum over all stopping times with in-control $ARL \geq A$ is

$$\frac{(1+o(1))\log A}{E_{F_2}(\log(f_2(X)/f_1(X)))}, \quad (1)$$

where $E_{F_2}(X)$ denotes the expectation of the random variable X under the assumption that X is distributed according to the post-change distribution, $f_1(x)$ and $f_2(x)$ are the pre-change and the post-change densities, respectively, $o(1) \rightarrow 0$ as $A \rightarrow \infty$.

Relatively recent results showed that if the pre-change and the post-change distributions are known and $A \rightarrow \infty$, then out-of-control ARL of the CUSUM and Shiryaev-Roberts control charts achieve the asymptotic lower limit (1) (Pollak [3], Tsai et al. [4]). Nonetheless, the most popular control chart is still Shewhart. In spite of its lesser efficiency, its simplicity makes it easy to apply in practice since unlike CUSUM and Shiryaev-Roberts control charts, it does not require sophisticated computer programs. This research focuses on recently proposed control schemes called Nested Plans. These schemes include two unknown parameters that essentially impact their efficiency. The research presents a way to find the optimal values of the parameters, and shows that Nested Plans with the correct choice of the parameters are almost as efficient as the asymptotically optimal Shiryaev-Roberts and CUSUM control charts and almost as simple in practical application as Shewhart method.

2. General sequential methods

In many common situations, we assume that we survey

sequentially independent observations $X_1, X_2, \dots$. Initially, the observations follow an in-control distribution $F_1(x|\theta_1)$ with a density function $f_1(x|\theta_1)$. It is possible that at ν , an unknown point in time, an accident is in effect, causing the distribution of the observations to change to an out-of-control distribution $F_2(x|\theta_2)$ with a density function $f_2(x|\theta_2)$, where θ_1 and θ_2 are parameter vectors. In this section we focus on four mentioned in introduction sequential methods. Each method is defined by its stopping time as presented below.

2.1 The Shewhart sequential procedure

The general Shewhart stopping time is

$$N_S = \min\{n: f_2(X_n|\theta_2)/f_1(X_n|\theta_1) \geq C\}, \quad (2)$$

where $C > 0$ is a threshold value tuned to satisfy a desired ARL to false alarm. Since the random variable N_S is distributed according to the geometric distribution, the in-control ARL and the out-of-control ARL for the Shewhart method can be straightforwardly calculated as

$$E_{F_1(x|\theta_1)}(N_S) = \frac{1}{P_{F_1(x|\theta_1)}(f_2(X|\theta_2)/f_1(X|\theta_1) \geq C)}, \quad (3)$$

and

$$E_{F_2(x|\theta_2)}(N_S) = \frac{1}{P_{F_2(x|\theta_2)}(f_2(X|\theta_2)/f_1(X|\theta_1) \geq C)}, \quad (4)$$

respectively, where we define by $P_F(B)$ and $E_F(N_S)$ the probability of the event B and the expectation of the stopping time N_S under the assumption that the observations come from distribution F .

2.2 Nested Plans as sequential procedures

These schemes consist of two steps: a variable plan and an attributes plan (see Lumelskii et al. [5], Feigin et al. [6]). On the first step, the observations are divided into groups of n observations (including the case $n=1$): $(X_{11}, X_{12}, \dots, X_{1n})$, $(X_{21}, X_{22}, \dots, X_{2n})$, ... and it is assumed that there is no a change inside these groups. After that, for the group i ($i=1, 2, \dots$) the Bernoulli variable Z_i is defined as

$$Z_i = \begin{cases} 1 & \text{if } \prod_{j=1}^n \frac{f_2(X_{ij}|\theta_2)}{f_1(X_{ij}|\theta_2)} \geq C, \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

where $C > 0$ is some threshold and his choice completely specifies the Bernoulli distribution of the random variables $Z_1, Z_2, \dots$. On the second step, the zero-one observations $Z_1, Z_2, \dots$ are considered and the out-of-control alarm is triggered if there are 2 ones among the last d observations $Z_i, i=1, 2, \dots$. Thus, the Nested Plans include two parameters: n and d , whose values should be determined before applying the method. The in-control ARL and the out-of-control ARL for the Nested Plan are defined as

$$E_{F_1(x|\theta_1)}(N_{NP}) = \frac{n(2 - P_1^{d-1})}{Q_1(1 - P_1^{d-1})} \quad (6)$$

and

$$E_{F_2(x|\theta_2)}(N_{NP}) = \frac{n(2 - P_2^{d-1})}{Q_2(1 - P_2^{d-1})}, \quad (7)$$

respectively, where N_{NP} is a stopping time, $P_h = P(Z_i = 0 | X_{ij} \sim F_h(x|\theta_h), j=1, 2, \dots, n)$, $Q_h = 1 - P_h, h=1, 2$.

2.3 The Shiryaev-Roberts and the CUSUM procedures

The Shiryaev-Roberts and the CUSUM stopping times are defined as $N_{SR} = \min\{n: R_n \geq C\}$, $N_{CU} = \min\{n: \Lambda_n \geq C\}$, respectively, where $R_n = \sum_{i=1}^n \Delta_n^k$, $\Lambda_n = \max_{1 \leq k \leq n} \Delta_n^k$,

$$\Delta_n^k = \prod_{i=k}^n \frac{f_2(X_i|\theta_2)}{f_1(X_i|\theta_1)}, \quad C > 0 \text{ is a threshold value tuned to satisfy a}$$

desired ARL to false alarm. There are no exact analytical results for the in-control ARL and the out-of-control ARL for the Shiryaev-Roberts and the CUSUM procedures. However, the CUSUM procedure has a non-asymptotic optimal property (Moustakides [7]). That is if the pre-change and the post-change distribution of the observations are known, then the CUSUM procedure most rapidly detect a change in distribution among all procedures with a common bound specifying an acceptable rate of false alarms, i.e. in-control ARL. For the Shiryaev-Roberts procedure, an asymptotic (as the in-control ARL $A \rightarrow \infty$) optimality has been shown (Pollak [8]). Note that the optimal properties of the Shiryaev-Roberts and the CUSUM procedures hinge on the true pre-change and post-change densities. Since $f_2(X|\theta_2)$ is usually a representative of possible post-change densities while in practice the true post-change density is unknown, even a small misspecification of $f_2(X|\theta_2)$ can result in the true out-of-control ARL being very different from its asymptotically optimal value. Moreover, there are many situations where $f_1(X|\theta_1)$ is unknown, then even a small misspecification of $f_1(X|\theta_1)$ can result in the true in-control ARL being very different from the nominal one (Pollak [3]).

3. A Comparison of the out-of-control ARLs of considered methods

In this section we compare the out-of-control ARL of the Nested Plans with that of the Shewhart method and asymptotically optimal methods, where the in-control ARL is the same for all methods. For simplicity we assume that the pre-change and the post-change distributions are $F_1(x|\theta_1) = N(\mu_1, \sigma^2)$ and $F_2(x|\theta_2) = N(\mu_2, \sigma^2)$, respectively, where $\mu_2 = \mu_1 + r\sigma$, $r > 0$. Then, by equation (2), the Shewhart stopping time is

$N_S = \min\{n: X_n \geq C\}$ and its in-control and out-of-control ARLs are defined according to equations (3), (4), as $E_{N(\mu_1, \sigma^2)}(N_S) = 1/(1 - \Phi((C - \mu_1)/\sigma))$ and

$E_{N(\mu_2, \sigma^2)}(N_S) = 1/(1 - \Phi((C - \mu_2)/\sigma))$ respectively, where $\Phi(x)$ is the standard normal cumulative distribution function. In particular, if $E_{N(\mu_1, \sigma^2)}(N_S) = A$, then $C = \sigma Z_{1-1/A} + \mu_1$, where

$$Z_{1-\alpha} = \Phi^{-1}(1 - \alpha), \quad 0 < \alpha < 1, \text{ and}$$

$$E_{N(\mu_2, \sigma^2)}(N_S) = \frac{1}{1 - \Phi(Z_{1-1/A} - r)}. \quad (8)$$

The stopping time of the Nested Plan is defined as in section 2.2,

where by equation (5), $Z_i = \begin{cases} 1 & \text{if } \bar{X}_i \geq C, \\ 0 & \text{otherwise} \end{cases}$, $\bar{X}_i = \frac{\sum_{j=1}^n X_{ij}}{n}$. Then, the

in-control and the out-of-control ARLs of the Nested Plan are given by equations (6) and (7), respectively, where $P_h = P_{N(\mu_h, \sigma^2)}(\bar{X}_i < C)$, $Q_h = 1 - P_h, h=1, 2$. Thus,

straightforwardly, if P_1 is known, then $C = \mu_1 + Z_{P_1} \frac{\sigma}{\sqrt{n}}$,

$$P_2 = \Phi(Z_{P_1} - r\sqrt{n}). \quad (9)$$

First, we present a way to determine the parameters n and d of the Nested Plan for a chosen value $r=1$ as the representative of a possible change in the expectation of the assumed normal distribution. Then, determining $r=1$, we compare the out-of-control ARL of the Nested Plan (with a specified parameters) with that of the Shewhart method and asymptotically optimal methods for different values of the in-control ARL. Finally, we consider misspecifications of r and misspecifications of distribution after a possible change and examine the robustness of the Nested Plan and the Shewhart methods.

3.1 Determining parameters of the Nested Plans

Let $r = (\mu_2 - \mu_1)/\sigma = 1$ be the representative of possible change in the expectation of the assumed normal distribution. Note that, by equation (6), the in-control ARL of the Nested Plan with the specified parameters n and d is the function of one variable P_1 ,

$$g(P_1) = n(2 - P_1^{d-1}) / ((1 - P_1)(1 - P_1^{d-1})), \text{ where } P_1 = P_{N(\mu_1, \sigma^2)}(\bar{X}_i < C).$$

Since, for any fixed $A > 2n$, $g(0) = 2n < A$, $g(P_1) \xrightarrow{P_1 \rightarrow 1} \infty$ and

$g(P_1)$ is the increasing function of P_1 , the equation $g(P_1) = A$ has a unique solution that can be obtained numerically. Then, using this solution, the values of $P_2 = P_{N(\mu_2, \sigma^2)}(\bar{X}_i < C)$ and the out-of-

control ARL of the Nested Plan can be calculated by equation (9) and (7), respectively. The following Tables 1 and 2 present values of the out-of-control ARL of the Nested Plan with the in-control ARL $A=500$ and 1000, respectively, for different parameters:

$$n \in [1, \dots, 10], \quad d \in [1, \dots, 8].$$

Table 1: Out-of-control ARLs of the Nested Plan, where $A=500$, $r=1$.

n/d	2	3	4	5	6	7	8
1	20.62	18.81	18.28	18.14	18.16	18.26	18.40
2	13.75	12.89	12.84	12.99	13.22	13.47	13.73
3	12.34	11.83	11.96	12.22	12.50	12.78	13.05
4	12.39	12.08	12.29	12.59	12.87	13.13	13.37
5	13.10	12.92	13.17	13.45	13.70	13.92	14.12
6	14.20	14.10	14.59	14.59	14.81	14.99	15.14
7	15.55	15.50	15.94	15.94	16.11	16.25	16.38
8	17.08	17.07	17.43	17.43	17.57	17.68	17.78
9	18.74	18.75	19.04	19.04	19.15	19.24	19.31
10	20.50	20.53	20.75	20.75	20.83	20.90	20.96

Note that for $r=1$, by equation (8), the out-of-control ARL of the Shewhart procedure with the in-control ARL $A=500$ is equal to $E_{N(\mu_2, \sigma^2)}(N_S) = 33.27$. Moreover, for the considered case, the Kullback–Leibler information quantity is $E_{N(\mu_2, \sigma^2)}\left(\log\left(\frac{f_{N(\mu_2, \sigma^2)}(X)}{f_{N(\mu_1, \sigma^2)}(X)}\right)\right) = r^2/2 = 0.5$. Therefore, by equation (1), the asymptotic minimum out-of-control ARL over all possible procedures is approximately equal to $\log 500/0.5 = 12.43$.

Table 2: Out-of-control ARLs of the Nested Plan, where $A=1000$, $r=1$.

n/d	2	3	4	5	6	7	8
1	30.69	27.55	26.48	26.05	26.90	25.89	25.96
2	18.10	16.66	16.41	16.49	16.69	16.94	17.21
3	15.02	14.17	14.21	14.45	14.75	15.07	15.38
4	14.29	13.74	13.92	14.23	14.55	14.87	15.16
5	14.53	14.17	14.41	14.74	15.05	15.33	15.58
6	15.29	15.06	15.33	15.64	15.91	16.15	16.36
7	16.39	16.25	16.52	16.79	17.02	17.22	17.39
8	17.73	17.65	17.90	18.12	18.31	18.47	18.61
9	19.24	19.21	19.42	19.60	19.75	19.88	19.99
10	20.88	20.87	21.05	21.20	21.32	21.42	21.51

For this case, the out-of-control ARL of the Shewhart procedure is equal to $E_{N(\mu_2, \sigma^2)}(N_S) = 54.62$, and the asymptotic minimum out-of-control ARL over all possible procedures is approximately equal to $\log 1000/0.5 = 13.82$. Tables 1 and 2 show that the out-of control ARL of the Nested Plan is strongly depends on the parameters n and d . However, even for the worst choice of the parameters this procedure is more efficient than the Shewhart's method and for the best choice of the parameters the Nested Plan is comparable with the CUSUM and the Shiryaev-Roberts procedures.

3.2 Analysis of the robustness of the Shewhart and the Nested Plan Methods

Table 3 below presents out-of-control ARLs of the Shewhart and the Nested Plan methods with the in-control ARL=500,1000, for values of $r = (\mu_2 - \mu_1)/\sigma$ that are different from its representative value $r=1$. Note that the parameters of the Nested Plan were obtained based on this representative value.

Table 3: Out-of-control ARLs of the Shewhart and the Nested Plan procedures

In-control ARL=500		
r	Nested Plan (n=3, d=3)	SHEWHART
0.7	22.77	68.49
0.8	17.99	53.19
0.9	14.85	41.84
1	11.83	33.27
1.1	11.26	26.67
1.2	10.24	21.50
1.3	9.53	17.51
In-control ARL=1000		
r	Nested Plan (n=4, d=3)	SHEWHART
0.7	26.30	119.05
0.8	20.26	90.91
0.9	16.35	69.93
1	13.74	54.62
1.1	11.96	42.92
1.2	10.73	34.01
1.3	9.87	27.24

Table 3 shows that the Nested Plan is much more effective than the Shewhart procedure for all values of r and the gap between out-of-control ARLs of the Nested Plan and the Shewhart procedure increase when decreasing the change in expectations of the pre-change and the post-change distributions. The next Table 4 presents out-of-control ARLs of the Shewhart and the Nested Plan methods with the in-control ARL=500,1000, for different post-change distributions. Note that these procedures were specified taking into account that before a possible change the observations come from the standard normal distribution and the post-change distribution is the normal distribution with the expectation $\mu=1$ and the variance $\sigma^2=1$. That is, the Shewhart stopping time was defined as $N_S = \min\{n: X_n \geq Z_{1-1/A}\} = \begin{cases} \min\{n: X_n \geq 2.88\} & \text{if } A=500 \\ \min\{n: X_n \geq 3.09\} & \text{if } A=1000 \end{cases}$. For the

Nested Plan, by equation (6), the value of P_1 that corresponds to optimal values of the parameters n and d is $P_1 = \begin{cases} 0.9413 & \text{if } A=500 \quad (n=3, d=3) \\ 0.9527 & \text{if } A=1000 \quad (n=4, d=3) \end{cases}$. The procedure raises an

alarm if there are 2 ones among the last d observations Z_i , $i=1, 2, \dots$, where for $A=500$, $Z_i = \begin{cases} 1 & \bar{X}_i \geq 1.5658/\sqrt{3}, \\ 0 & \text{otherwise} \end{cases}$, $\bar{X}_i = \frac{1}{3} \sum_{j=1}^3 X_{ij}$

and for $A=1000$, $Z_i = \begin{cases} 1 & \bar{X}_i \geq 1.6716/2, \\ 0 & \text{otherwise} \end{cases}$, $\bar{X}_i = \frac{1}{4} \sum_{j=1}^4 X_{ij}$. Thus, for

a real post-change distribution F , the out-of-control ARL of the Shewhart method is defined as $E_F(N_S) = \begin{cases} 1/P_F(X \geq 2.88) & \text{if } A=500 \\ 1/P_F(X \geq 3.09) & \text{if } A=1000 \end{cases}$. The out-of-control ARL of the

Nested Plan is given by equation (7), where for $A=500$, $P_2 = P_F(\bar{X}_3 < 1.5658/\sqrt{3})$, $d=3$ and for $A=1000$, $P_2 = P_F(\bar{X}_4 < 1.6716/2)$, $d=3$. Table 4 considers cases where the post-change distribution F is a distribution of the random variable $X+1$, $X \sim F^*$ and F^* is a Uniform, Normal, Student and Laplace distribution with different parameters but with zero expectation. That is considered post-change distributions have the expectation 1 and different variances.

Table 4: Out-of-control ARLs of the Shewhart and the Nested Plan procedures

In-control ARL=500		
F^*	Nested Plan (n=3, d=3)	SHEWHART
Unif(-2,2)	12.29	33.33
Unif(-2.5,2.5)	12.65	8.06
$t_{(3)}$	12.27	12.65
$t_{(5)}$	12.02	16.95
Norm(0,1)	11.83	33.27
Laplace(0,1)	12.17	13.10
Laplace(0,0.7)	11.53	29.33
Laplace(0,0.5)	10.81	85.90
Laplace(0,0.4)	10.25	219.89
Laplace(0,0.3)	9.48	1053.43
In-control ARL=1000		
F^*	Nested Plan (n=4, d=3)	SHEWHART
Unif(-2.5,2.5)	15.15	12.20
Unif(-3,3)	15.67	6.59
$t_{(3)}$	14.73	15.61
$t_{(5)}$	14.26	22.22
Norm(0,1)	13.74	54.62
Laplace(0,1)	14.54	16.17
Laplace(0,0.7)	13.36	39.60
Laplace(0,0.5)	12.09	130.73
Laplace(0,0.4)	11.26	371.72
Laplace(0,0.3)	10.24	2121.36

Table 4 shows that the Shewhart procedure sometimes is a good tool but may break down completely and almost always inferior to the Nested Plan. Moreover, the Nested plan looks as a stable and robust procedure for all considered situations.

4. Conclusions

This research examined different schemes for sequential quality control. In particular, the efficient CUSUM and Shiryaev-Roberts procedures have some optimal properties for changepoint detection. Nonetheless, the most popular control chart is still Shewhart. In spite of its lesser efficiency, its simplicity makes it easy to apply in practice. The paper focuses on recently proposed sequential schemes called Nested Plans. It turned out that this approach provide efficient and robust results. Due to their simplicity for practical applications these methods can be a good alternative to the Shewhart procedure. Hopefully this paper will stimulate future theoretical and applied research on this topic.

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ANALYTICAL AND NUMERICAL ASPECTS OF THE SOLUTION OF THE PROBLEM OF A VISCOUS WEAKLY COMPRESSIBLE LIQUID MIXTURE MOTION THROUGH THE VERTICAL PIPE OF THE CIRCULAR CROSS-SECTION

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Abstract: The paper considers a way of the numerical solution of a system of partial differential equations describing the nonstationary flow of a viscous liquid along a vertical straight pipe of circular cross-section. The result obtained is not final, because the proposed approximation scheme is the simplest and provides only the first order of accuracy. Computer modeling has shown that such an approximation is suitable only for a small time interval.

Keywords: NON-STATIONARY HYDRODYNAMICS, LIQUID MIXTURES, WEAK COMPRESSIBILITY, VERTICAL PIPE, MATH MODELING, NUMERICAL SOLUTION

1. Introduction

The problem of investigating the motion of a viscous liquid along a vertical pipe arises in the field of extraction of petroleum products. It is necessary to predict the pressure, density and velocity of the mixture that rises from the depth along the pipe. To understand whether, for example, pressure changes are so critical that they will lead to partial destruction of equipment.

It is known that an analytical solution of equations describing real physical processes is possible only for a narrow class of problems (for example, the heat equation or wave equation on a straight line or in simple form regions). In other cases, it is necessary to apply numerical methods to obtain an approximate solution of the problem. Here arise questions of convergence and stability of the numerical algorithm.

2. Mathematical model

Equations, describing the viscous weakly compressible liquid motion along the vertical pipe of the circular cross-section have the following form [1]:

$$\frac{\partial \rho}{\partial t} + v \frac{\partial \rho}{\partial z} + \rho \frac{\partial v}{\partial z} = 0, \quad (1)$$

$$\frac{\partial^2 v}{\partial r \partial z} = \frac{\partial p}{\partial r}, \quad (2)$$

$$\frac{\partial v}{\partial t} + v \frac{\partial v}{\partial z} = -\rho g + \frac{1}{\rho} \left(\mu \left[\frac{\partial^2 v}{\partial r^2} + \frac{1}{r} \frac{\partial v}{\partial r} \right] + \lambda \frac{\partial^2 v}{\partial z^2} - \frac{\partial p}{\partial z} \right). \quad (3)$$

The system of equations (1)-(3) was obtained on the basis of the basic equations of hydrodynamics [2]. Three equations contain three unknown functions: density $\rho(z)$, pressure $p(z)$ and velocity $v_z(r, z, t)$. For the unique solvability of these equations it is necessary to have initial and boundary conditions:

- the pressure at the pipe inlet and near the pipe wall:

$$p(r, 0, t) = p_0, \quad (4)$$

$$\left(\frac{\partial p}{\partial r} + \frac{\partial p}{\partial z} \right) \Big|_{r=R} = 0 \quad (5)$$

- the density at the initial moment of time and at the pipe inlet:

$$\rho(r, z, 0) = \rho_0, \quad (6)$$

$$\rho(r, 0, t) = \rho_0; \quad (7)$$

- initial velocity:

$$v(r, z, 0) = \varphi(r, z); \quad (8)$$

- velocity at the wall of the pipe:

$$v(R, z, t) = 0; \quad (9)$$

- velocity at the pipe outlet:

$$v(r, L, t) = \psi(r, t). \quad (10)$$

Suppose that the density is weakly changing with the z coordinate, consequently, in equation (1) the product $v \frac{\partial \rho}{\partial z}$ may be neglected, since it is very small in comparison with the other terms.

To find the numerical solution of system (1)-(3) we introduce a uniform grid:

$$\bar{\omega}_r = \left\{ r_i = i \cdot h_r, \quad i = \overline{0, M}, \quad h_r = \frac{R}{M}, \quad r_0 = 0, \quad r_M = R \right\} \quad - \text{grid by variable } r,$$

$$\bar{\omega}_z = \left\{ z_j = j \cdot h_z, \quad j = \overline{0, N}, \quad h_z = \frac{L}{N}, \quad z_0 = 0, \quad z_N = L \right\} \quad - \text{grid by variable } z,$$

$$\bar{\omega}_t = \left\{ t_k = k \cdot h_t, \quad k = \overline{0, K}, \quad h_t = \frac{T}{K}, \quad t_0 = 0, \quad t_K = T \right\} \quad - \text{grid by variable } t.$$

To approximate the equations we use finite differences. Consider equation (1) and taking into account the assumption made, we obtain the following difference scheme:

$$\frac{\rho_{i,j}^{k+1} - \rho_{i,j}^k}{h_t} + \rho_{i,j}^k \frac{v_{i,j}^k - v_{i,j-1}^k}{h_z} = 0.$$

It is not difficult to obtain

$$\rho_{i,j}^{k+1} = \rho_{i,j}^k \left(1 - \frac{(v_{i,j}^k - v_{i,j-1}^k) h_t}{h_z} \right). \quad (1')$$

Boundary and initial conditions for the density are approximated exactly:

$$\rho_{i,j}^0 = \rho_0, \quad (6')$$

$$\rho_{i,1}^{k+1} = \rho_0. \quad (7')$$

We do the same with the equation (2):

$$p_{i-1,j}^{k+1} = p_{i,j}^{k+1} - \frac{v_{i+1,j+1}^{k+1} - v_{i-1,j+1}^{k+1} - v_{i+1,j-1}^{k+1} + v_{i-1,j-1}^{k+1}}{4dz}, \quad (2)$$

and its boundary conditions

$$p_{i,0}^k = p_0, \quad (4')$$

$$p_{M,j}^{k+1} = \frac{(p_{M,j-1}^{k+1} - p_{M-1,j-1}^{k+1}) dz}{dr} + p_{M,j-1}^{k+1}. \quad (5')$$

For the equation (3) we apply the simplest explicit difference scheme:

$$\begin{aligned} & \frac{v_{i,j}^{k+1} - v_{i,j}^k}{dt} + v_{i,j}^k \frac{v_{i,j}^k - v_{i,j-1}^k}{dz} = \\ & = -\rho_{i,j}^k g + \frac{1}{\rho_{i,j}^k} \left(\mu \left[\frac{v_{i+1,j}^k - 2v_{i,j}^k + v_{i-1,j}^k}{dr^2} + \frac{1}{r_i} \frac{v_{i,j}^k - v_{i-1,j}^k}{dr} \right] + \lambda \frac{v_{i,j+1}^k - 2v_{i,j}^k + v_{i,j-1}^k}{dz^2} - \frac{p_{i,j+1}^{k+1} - p_{i,j-1}^{k+1}}{dz} \right). \end{aligned}$$

We express $v_{i,j}^{k+1}$:

$$v_{i,j}^{k+1} = -\rho_{i,j}^k g dt + \frac{dt}{\rho_{i,j}^k} \left(\mu \left[\frac{v_{i+1,j}^k - 2v_{i,j}^k + v_{i-1,j}^k}{dr^2} + \frac{1}{r_i} \frac{v_{i,j}^k - v_{i-1,j}^k}{dr} \right] + \lambda \frac{v_{i,j+1}^k - 2v_{i,j}^k + v_{i,j-1}^k}{dz^2} - \frac{p_{i,j}^{k+1} - p_{i,j-1}^{k+1}}{dz} \right) - v_{i,j}^k \frac{v_{i,j}^k - v_{i,j-1}^k}{dz} dt + v_{i,j}^k. \quad (3')$$

3. Numerical experiment

Equation (1') is solved on the basis of known values of velocity and density at the previous time layer. Equations (2') and (3') need to be solved jointly on the same time layer, but sequentially along the coordinate, because of the boundary conditions. The pressure on the new layer in height is calculated from the pipe wall to its axis.

We set ourselves by simple initial conditions: the Poiseuille distribution for the velocity, the density at all points, the given differential pressure (fig. 1, 2, 3).

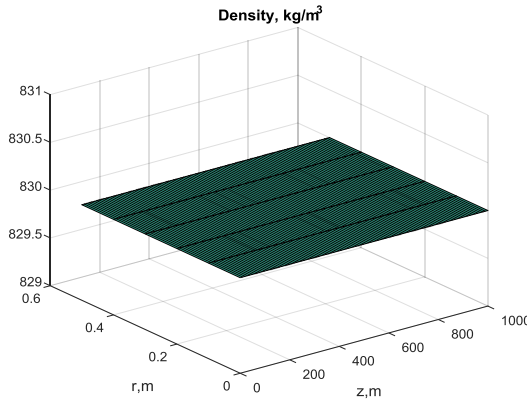


Figure1. The initial density

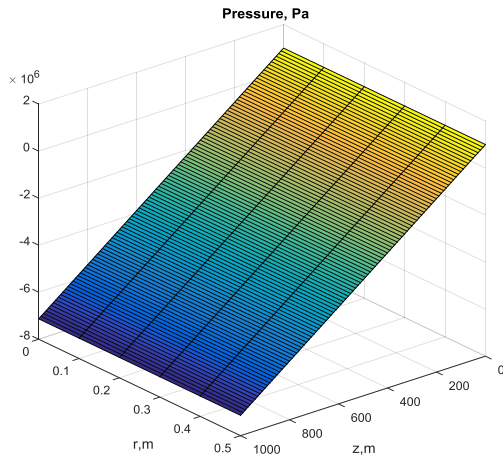


Figure 2. The initial pressure distribution

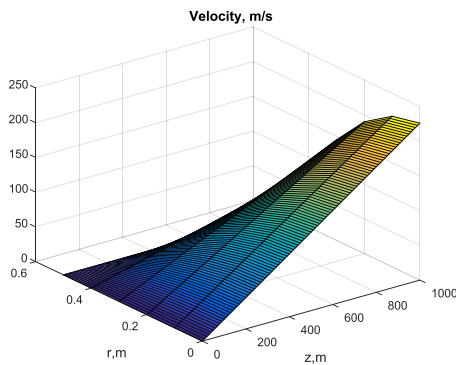


Figure 3. The initial velocity distribution

After the calculations performed, we get the following results (fig.4,5,6)

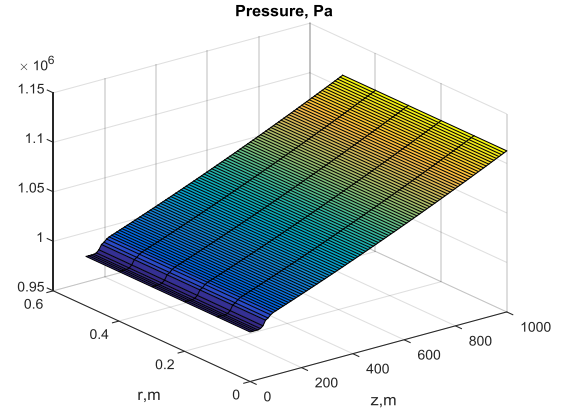


Figure 4. Pressure field

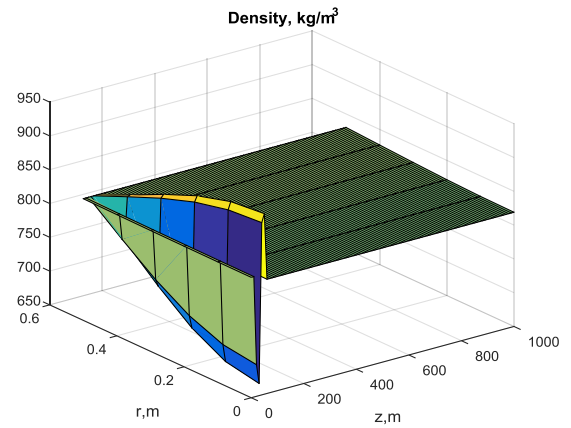


Figure 5. Liquid density

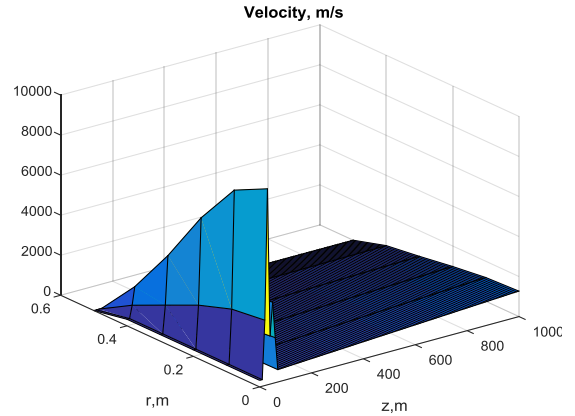


Figure 6. Velocity distribution

The proposed scheme is conditionally stable, and in the problem under consideration, acceptable results are obtained for a small time interval and a small step in time.

In the future, when the equation (2) is approximated, we will most likely have to follow a different path. So this equation can be integrated over r :

$$p(r, z, t) = \frac{\partial v}{\partial z} + f(z, t).$$

It is logical to define the function $f(z, t)$ as hydrostatic pressure, which acts in the liquid besides the dynamic pressure в жидкости

помимо динамического, and which depends only on the level of liquid lifting, i.e. z coordinate (and implicitly on t).

4. Conclusion

The method described in this paper is only the first approximation to the solution of the system of equations (1)–(3). The main difficulty lies in the fact that differential equations of different orders enter into this system, and equation (3) is also nonlinear. In the future, approximation methods that ensure greater accuracy of these equations will be considered, and solution methods suitable for a system of partial differential equations of different orders.

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MATHEMATICAL MODELING AND SIMULATION OF POWER UNIT WORKING ON MOTOR FUELS DERIVED FROM NATURAL GAS IN TOTAL LIFE CYCLE

МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ И РАСЧЕТНЫЕ ИССЛЕДОВАНИЯ ПОКАЗАТЕЛЕЙ СИЛОВОЙ УСТАНОВКИ, РАБОТАЮЩЕЙ НА МОТОРНЫХ ТОПЛИВАХ, ПОЛУЧЕННЫХ ИЗ ПРИРОДНОГО ГАЗА, В ПОЛНОМ ЖИЗНЕННОМ ЦИКЛЕ

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Abstract: The article is devoted to the problem of comprehensive evaluation of the efficiency of the use of various alternative fuels obtained from natural gas (NG) in a total life cycle (TLC). Despite the fact that all types of motor fuel under consideration are produced from NG, the energy and environmental consequences of their use may vary significantly. Goals of this research are: developing TLC mathematical models of a power unit operating on motor fuels obtained from NG (compressed NG, liquefied NG, methanol, dimethyl ether, synthetic diesel fuel and hydrogen) and conducting a simulation in order to determine energy and environmental indicators for the use of the considered fuel types. The results of simulation allow to choose the most promising types of alternative fuels according to the criteria of energy efficiency and a level of environmental pollution by harmful substances and greenhouse gases.

Key words: TOTAL LIFE CYCLE, MATHEMATICAL MODEL, ALTERNATIVE FUELS, NATURAL GAS, POWER UNIT

1. Introduction

Effective use of natural energy resources is important for the development of different industries and lowering of anthropogenic loads on environment and climate by lowering of emission of polluting substances and greenhouse gases. A special role in the solution of this problem is assigned to vehicles with engines powered by alternative types of fuel, first of all – by the natural gas (NG). [1,2,3]

Direct NG use, as well as obtaining other alternative motor fuels from NG, allows to increase the engine durability and the vehicle operation life by 1.3 - 1.5 times, to reduce the transportation prime cost by 15 - 25% due to a lower price of gas motor fuel, as well as to reduce essentially the harmful substance emissions to environment (carbon oxide – by 2.5 times, nitrogen oxides – by 2 times, hydrocarbons – by 3 times, smoke – by 9 times).

In many countries, the large-scale transport development programs are implemented in the direction of energy efficiency and environmental safety. The European Union (EU) is a leader on the matter. Thus, in 2011, the White Paper / Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System (COM/2011/0144) was adopted suggesting that a share of used "standard-fueled vehicles" in public transport should be halved by 2030 and phased out in the cities by 2050.

The EU 2030 Climate and Energy Framework adopted in October 2014 sets the goals of lowering of greenhouse gas emissions by 40% in comparison with the level of 1990, achievement of renewable energy share up to 27%, as well as the resumption of activities aimed at the energy efficiency increase.

In the Russian Federation (RF), the main operating packages of legislation governing and providing to increase the use of motor fuels obtained from NG are as follows: the Russian Federation Government Order of 13.11.2009 No. 1715-r "Energy Strategy of Russia for the Period till 2030 (ES-2030)"; the Russian Federation Presidential Order of 17.12.2009 No. 861-rp "Climate Doctrine of the Russian Federation"; the Russian Federation Government Order of 13.05.2013 No. 767-r "On Expansion of Use of Natural Gas as Motor Fuel" ("On Regulation of the Relations in the Sphere of the Use of Gas Motor Fuel including NG as Motor Fuel"); the List of Instructions of Vladimir Putin, the President of the Russian Federation, following the meeting on prospects for using gas motor fuel of 24.06.2013 No. PR-1923; the Russian Federation Government Decree of 15.04.2014 No. 328 "On Approval of the

State Program of the Russian Federation "The Development of Industry and Increase of its Competitiveness" (Main activity 1.7 "Expansion of Use of Natural Gas as a Motor Fuel"); the Russian Federation Government Decree of 07.12.2015 No. 1339 "On Amendments to the State Program of the Russian Federation "Energy Efficiency and Energy Development" and the Decree of the President of the Russian Federation of 01.12.2016 No. 642 "On the Scientific and Technological Development Strategy of the Russian Federation".

Thus, a main goal of this research is the comprehensive evaluation of the efficiency of the use of various alternative fuels obtained from natural gas (NG) in a total life cycle (TLC) by development of TLC mathematical models of the power unit and carrying out of numerical analyses in order to determine energy and environmental indicators or parameters of the use of the considered fuel types.

At the TLC evaluation, the following fuel types are accepted: compressed natural gas (CNG), liquefied natural gas (LNG), methanol, dimethyl ether (DME), synthetic diesel fuel (DT) and hydrogen. It should be noted that environmental and energy consequences of the use of these types of motor fuels obtained from NG are different. It is explained by the fact that technologies of extraction of the fuels and routes of their distribution are significantly different.

2. The solution of the examined problem

Taking into account the known procedures for evaluation of power unit and fuel indicators or parameters in TLC and according to requirements of ISO 14040, ISO 14041, ISO 14042, ISO 14043 (in the Russian Federation - GOST R ISO 14040 - 14043) international standards, the mathematical models describing material and energy flows of the abovementioned motor fuels obtained from NG for stages of the power unit TLC were developed. At mathematical modeling, the following unit processes were considered: NG extraction, its transportation, NG compression, NG liquefaction, obtaining of synthesis gas, methanol, DME, synthetic DT, hydrogen, as well as obtaining of auxiliary fuels and electric energy necessary for the life cycle and the process of fuel use.

TLC of the power unit operating on the considered fuels includes three stages: fuel production, auxiliary processes and fuel use. For different types of motor fuels, the stages of auxiliary processes and fuel use, as well as a part of unit processes (NG

extraction, NG transportation), will be identical as to the mathematical description.

This article shows the mathematical model of TLC of the power unit fueled by CNG in more detail. Mathematical models for other motor fuels considered in this research are not presented due to the limited volume of the article.

NG extraction process

Input flows

Amount of extracted NG (raw material) necessary for TLC, kg:

$$(1) M_{EXT,NG}^{in} = \left(1 + g_{EXT,NG} \left(\frac{1}{\eta_{EXT}} - 1 \right) \right) M_{TRAN,NG}^{EXT},$$

where $g_{EXT,NG}$ is the NG consumption ratio for NG extraction process; η_{EXT} is the NG extraction process efficiency factor; $M_{TRAN,NG}^{EXT}$ is the NG amount at NG transportation process input, kg (see Formula 8).

Amount of auxiliary fuels at NG extraction process input, kg:

$$(2) M_{EXT,aux,fuel}^{AUX,FUEL} = \sum_i \left[\left(\frac{1}{\eta_{EXT}} - 1 \right) g_{EXT,aux,fuel_i} \frac{Hu_{NG}}{Hu_{aux,fuel_i}} M_{TRAN,NG}^{EXT} \right],$$

where $g_{EXT,aux,fuel_i}$ is the i auxiliary fuel consumption ratio for NG extraction process; Hu_{NG} is the NG low heat value, MJ/kg; $Hu_{aux,fuel_i}$ is the i auxiliary fuel low heat value, MJ/kg.

Heat energy of NG (raw material) for NG extraction process, MJ:

$$(3) E_{EXT,NG}^{in} = Hu_{NG} M_{EXT,NG}^{in}.$$

Heat energy of auxiliary fuels for NG extraction process, MJ:

$$(4) E_{EXT,aux,fuel}^{AUX,FUEL} = \sum_i (M_{EXT,aux,fuel_i}^{AUX,FUEL} Hu_{aux,fuel_i}).$$

Electric energy for NG extraction process, MJ:

$$(5) E_{EXT,el.en.}^{EL} = \left(\frac{1}{\eta_{EXT}} - 1 \right) g_{EXT,el.en.} Hu_{NG} M_{TRAN,NG}^{EXT},$$

where $g_{EXT,el.en.}$ is the electric energy consumption ratio for NG extraction process.

Output flows

Amount of harmful substance environmental emissions at NG extraction process, kg:

$$(6) M_{out,HE}^{EXT} = \sum_k \sum_i \left[E_{EXT,aux,fuel_i}^{AUX,FUEL} e_{i,k} + E_{EXT,NG}^{in} (1 - \eta_{EXT}) g_{EXT,NG} e_{EXT,k} + M_{out,CH_4}^{EXT} \right],$$

where $e_{i,k}$ is the k harmful substance specific emission at i auxiliary fuel burning in technological unit, kg/MJ; $e_{EXT,k}$ is the k harmful substance specific emission at NG burning at NG extraction process, kg/MJ; M_{out,CH_4}^{EXT} is the methane emission at NG extraction process, kg:

$$(7) M_{out,CH_4}^{EXT} = e_{EXT,CH_4} M_{TRAN,NG}^{EXT} Hu_{NG}.$$

Here, e_{EXT,CH_4} is the specific methane emission caused by process features and leaks, kg/MJ.

Amount of NG at NG transportation process input, kg:

$$(8) M_{TRAN,NG}^{EXT} = \left(1 + g_{TRAN,NG} \left(\frac{1}{\eta_{TRAN}} - 1 \right) \right) (M_{COMP,NG}^{TRAN} + M_{AUX,FUEL,NG}^{TRAN} + M_{EL,NG}^{TRAN}),$$

where $g_{TRAN,NG}$ is the NG consumption ratio for NG transportation process; η_{TRAN} is the NG transportation process efficiency factor; $M_{COMP,NG}^{TRAN}$ is the NG amount at compression process input, kg (see Formula 19); $M_{AUX,FUEL,NG}^{TRAN}$ is the NG amount at auxiliary fuel obtaining process input, kg (see Formula 16); $M_{EL,NG}^{TRAN}$ is the NG amount at electric energy obtaining process input, kg.

NG heat energy for transportation process, MJ:

$$(9) E_{TRAN,NG}^{EXT} = Hu_{NG} M_{TRAN,NG}^{EXT}.$$

Heat energy environmental dissipation due to use of electric energy, the energy of combustion of auxiliary fuels and natural gas for NG extraction process, MJ:

$$(10) E_{out,en.to env.}^{EXT} = E_{EXT,el.en.}^{EL} + E_{EXT,aux,fuel}^{AUX,FUEL} + E_{EXT,NG}^{in} (1 - \eta_{EXT}) g_{EXT,NG}.$$

NG transportation process

Amount of natural gas at NG transportation process input, kg, is determined from Formula 8.

Amount of auxiliary fuels at NG transportation process input, kg:

$$(11) M_{TRAN,aux,fuel}^{AUX,FUEL} = \sum_i \left[\left(\frac{1}{\eta_{TRAN}} - 1 \right) g_{TRAN,aux,fuel_i} \frac{Hu_{NG}}{Hu_{aux,fuel_i}} M_{COMP,NG}^{TRAN} \right],$$

where $g_{TRAN,aux,fuel_i}$ is the i auxiliary fuel consumption ratio for NG transportation process.

NG heat energy for transportation process, MJ, is determined from Formula 9.

Electric energy for NG transportation process, MJ:

$$(12) E_{TRAN,el.en.}^{EL} = \left(\frac{1}{\eta_{TRAN}} - 1 \right) g_{TRAN,el.en.} Hu_{NG} M_{COMP,NG}^{TRAN},$$

where $g_{TRAN,el.en.}$ is the electric energy consumption ratio for NG transportation process.

Heat energy of auxiliary fuels for NG transportation process, MJ:

$$(13) E_{TRAN,aux,fuel}^{AUX,FUEL} = \sum_i (M_{TRAN,aux,fuel_i}^{AUX,FUEL} Hu_{aux,fuel_i}).$$

Output flows

Amount of harmful substance environmental emissions at NG transportation process, kg:

$$(14) M_{out,HE}^{TRAN} = \sum_k \sum_i \left[E_{TRAN,aux,fuel_i}^{AUX,FUEL} e_{i,k} + E_{TRAN,NG}^{EXT} (1 - \eta_{TRAN}) g_{TRAN,NG} e_{TRAN,k} + M_{out,CH_4}^{TRAN} \right],$$

where $e_{TRAN,k}$ is the k harmful substance specific emission at NG burning at NG transportation process, kg/MJ; M_{out,CH_4}^{TRAN} is the methane emission at NG transportation process, kg:

$$(15) M_{out,CH_4}^{TRAN} = e_{TRAN,CH_4} M_{COMP,NG}^{TRAN} Hu_{NG}.$$

Here, e_{TRAN,CH_4} a specific methane emission caused by process features and leaks, kg/MJ.

Amount of NG at auxiliary fuel obtaining process input, kg:

$$(16) M_{AUX,FUEL,NG}^{TRAN} = \sum_i \left[\left(1 + g_{AUX,FUEL,NG} \left(\frac{1}{\eta_{AUX,FUEL_i}} - 1 \right) \right) \frac{\sum_j E_{j,aux,fuel_i}^{AUX,FUEL}}{Hu_{NG}} \right],$$

where $g_{AUX,FUEL,NG}$ is the NG consumption ratio for auxiliary fuel obtaining process; $\eta_{AUX,FUEL_i}$ is the i auxiliary fuel obtaining process efficiency factor; $E_{j,aux,fuel_i}^{AUX,FUEL}$ is the i auxiliary fuel heat energy for j process input, MJ:

$$(17) E_{j,aux,fuel}^{AUX,FUEL} = \sum_i (E_{EXT,aux,fuel_i}^{AUX,FUEL} + E_{TRAN,aux,fuel_i}^{AUX,FUEL} + E_{EL,aux,fuel_i}^{AUX,FUEL}),$$

where $E_{EL,aux,fuel_i}^{AUX,FUEL}$ is the i auxiliary fuel heat energy for electric energy obtaining process input, MJ:

$$(18) E_{EL,aux,fuel}^{AUX,FUEL} = \sum_i (M_{EL,aux,fuel_i}^{AUX,FUEL} Hu_{aux,fuel_i}).$$

Amount of auxiliary fuels for electric energy obtaining process input, including NG, kg:

$$(19) M_{EL,aux,fuel}^{AUX,FUEL} = \sum_i \left[\left(1 + g_{EL,aux,fuel_i} (1 - \eta_{EL_i}) \right) \frac{E_{EL,aux,fuel_i}^{EXT}}{Hu_{aux,fuel_i}} \right],$$

where $g_{EL,aux,fuel_i}$ is the i auxiliary fuel consumption ratio for electric energy obtaining process; η_{EL_i} is the efficiency factor of electric energy obtaining process from i auxiliary fuel.

Amount of natural gas at NG compression and refueling process input, kg:

$$(20) M_{COMP,NG}^{TRAN} = \left(1 + g_{COMP,NG} \left(\frac{1}{\eta_{COMP}} - 1 \right) \right) M_{FU,mot,fuel}^{COMP},$$

where is the NG consumption ratio for NG compression and refueling process; η_{COMP} is the efficiency factor of NG compression and refueling process; $M_{FU,mot,fuel}^{COMP}$ is the amount of CNG at fuel use process, kg (see Formula 27).

Heat energy of NG at natural gas compression and refueling process, MJ:

$$(21) E_{COMP,NG}^{TRAN} = Hu_{NG} M_{COMP,NG}^{TRAN}.$$

Heat energy environmental dissipation due to use of electric energy, the energy of combustion of auxiliary fuels and NG for NG transportation process, MJ:

$$(22) E_{out,en,to,env}^{TRAN} = E_{TRAN,el,en}^{EL} + E_{TRAN,aux,fuel}^{AUX,FUEL} + E_{TRAN,NG}^{EXT} (1 - \eta_{TRAN}) g_{TRAN,NG}.$$

NG compression and refueling process

Input flows

Amount of NG and heat energy of NG at NG compression and refueling process input shall be calculated according to Formula 20 and Formula 21 respectively.

Electric energy for NG compression and refueling process, MJ:

$$(23) E_{COMP,el,en}^{EL} = \left(\frac{1}{\eta_{COMP}} - 1 \right) g_{COMP,el,en} Hu_{NG} M_{FU,mot,fuel}^{COMP},$$

where $g_{COMP,el,en}$ is the electric energy consumption ratio for NG compression and refueling process.

Output flows

Amount of harmful substance environmental emissions at NG compression and refueling process, kg:

$$(24) M_{out,HE}^{COMP} = \sum_k \sum_i [E_{COMP,NG}^{TRAN} (1 - \eta_{COMP}) g_{COMP,NG} e_{COMP,k} + M_{out,CH_4}^{COMP}],$$

where $e_{COMP,k}$ is the k harmful substance specific emission at NG burning at NG compression and refueling process, kg/MJ; M_{out,CH_4}^{COMP} is the methane emission at NG compression and refueling process, kg:

$$(25) M_{out,CH_4}^{COMP} = e_{COMP,CH_4} M_{FU,mot,fuel}^{COMP} Hu_{NG}.$$

Here, e_{COMP,CH_4} a specific methane emission caused by process features and leaks, kg/MJ.

Amount of CNG and heat energy of NG at fuel use process input shall be calculated according to Formula 27 and Formula 28 respectively.

Heat energy environmental dissipation due to use of electric energy, the energy of combustion and NG for NG compression and refueling process, MJ:

$$(26) E_{out,en,to,env}^{COMP} = E_{COMP,el,en}^{EL} + E_{COMP,NG}^{TRAN} (1 - \eta_{COMP}) g_{COMP,NG}.$$

Fuel use process

Input flows

Amount of CNG at fuel use process input, kg:

$$(27) M_{FU,mot,fuel}^{COMP} = W m_{FU,CNG},$$

where W is the engine work, kWh; $m_{FU,CNG}$ is the specific CNG consumption per 1 kWh of a power unit operation, kg/kWh.

Heat energy of CNG, MJ:

$$(28) E_{FU,mot,fuel}^{COMP} = Hu_{CNG} M_{FU,mot,fuel}^{COMP}.$$

Output flows

Amount of harmful substance environmental emissions at fuel use process, kg:

$$(29) M_{out,HE}^{FU} = \sum_k W e_{FU,k},$$

where $e_{FU,k}$ is the k harmful substance specific emission at fuel use process per 1 kWh of power unit operation, kg/kWh.

Net energy (work) obtained from CNG use, MJ:

$$(30) E_{out,work}^{FU} = 3,6W.$$

Heat energy environmental dissipation due to use of CNG, MJ:

$$(31) E_{out,en,to,env}^{FU} = E_{FU,mot,fuel}^{COMP} - E_{out,work}^{FU}.$$

A mathematic model of TLC of the power unit working on CNG in total

Input flows

Raw material resources, kg:

$$(32) \quad M_{TLC}^{in} = M_{FPS,NG}^{in} + M_{APS,raw}^{in}.$$

Energy, MJ:

$$(33) \quad E_{TLC}^{in} = E_{FPS,NG}^{in} + E_{APS,raw}^{in}.$$

Output flows

Harmful substances, kg:

$$(34) \quad M_{out}^{TLC} = M_{out,HE}^{FPS} + M_{out,HE}^{APS} + M_{out,HE}^{FUS}.$$

Energy to the environment, MJ:

$$(35) \quad E_{out,en.to env.}^{TLC} = E_{out,en.to env.}^{FPS} + E_{out,en.to env.}^{APS} + E_{out,en.to env.}^{FUS}.$$

Energy (useful work), MJ:

$$(36) \quad E_{out,work}^{TLC} = E_{out,work}^{FUS}.$$

3. Results and discussion

There were numerical studies carried out based on the published inventory data and using the developed TLC mathematic model. [4,5] The calculation results for CNG are given in Figures 1-3. The TLC analyses for other motor fuel types are currently under development.

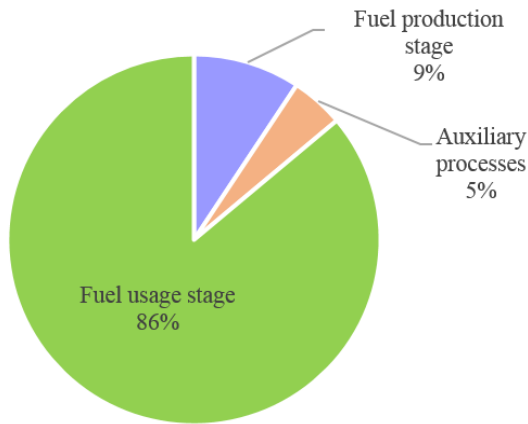


Fig. 1 Structure of energy consumption throughout TLC by stages.

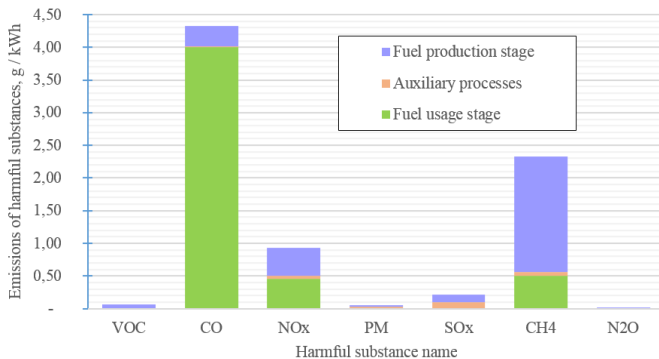


Fig. 2 Structure of harmful substances emissions throughout TLC.

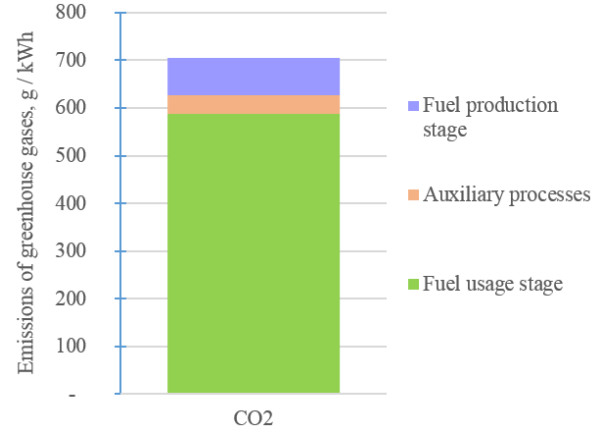


Fig. 3 Structure of CO₂ emissions throughout TLC.

4. Conclusion

Following the comprehensive effectiveness evaluation of the application of different alternative motor fuels obtained from NG, the following may be noted for the TLC:

- the developed mathematic models consider energy and material flows in the power unit TLC, consumption of natural resources and energy, harmful substances emissions to the environment;
- results of numerical analyses carried out using the developed mathematical model allow to compare and select the most promising types of alternative fuels according to the criteria of energy efficiency and a level of environmental pollution by harmful substances and greenhouse gases emission.

This paper is made within the applied research and experimental developments under Agreement No. 14.626.21.0005 dd. 23 October 2017 for the following: "Creation of family of single fuel gas engines and dual fuel gas and diesel engines on the basis of KAMAZ-910 diesel engine having high energy and economy performance indicators" (unique project identifier RFMEFI62617X0005), made with the Ministry of Education and Science of the Russian Federation.

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COMPARATIVE ANALYSIS OF LITHIUM-ION BATTERIES FOR EV/HEV APPLICATIONS

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Abstract: For the serial production of electric cars, the development of Li-Ion cell technology to achieve high energy density of packaging batteries is critical and is subject to great research and development. This paper reviews the latest developments in cell technology and cathode chemistry for the production of traction lithium-ion batteries. Are made non-destructive testing and comparative analysis of the most important characteristics of the batteries with the known Li-Ion cell electrochemistry. The advantages and disadvantages of different types of Li-Ion cells are presented. Conclusions were made on the degree of applicability of the respective types of lithium-ion batteries in EV / HEV applications.

Keywords: LI-ION - LITHIUM-ION BATTERY; EV/HEV- ELECTRIC AND HYBRID VEHICLES; BMS-BATTERY MANAGEMENT SYSTEM.

1. Introduction

Enhanced EV / HEV production depends on the development of lithium-ion batteries to store and manage energy. Although lithium-ion technology is relatively young, it has significant potential for both reducing costs and increasing energy density (specific Wh / kg energy) by rationalizing the manufacturing process. Specific energy is a key indicator in the production of Li-Ion cells for EV. The advantage of energy density lies in the fact that less electrolyte is required, which allows faster transfer of ions from the anode to the cathode which, when assembled, results in a lower cell weight and hence lower total weight of the battery pack for EV. In recent years, great progress has been made in the development of Li-Ion cell technology to achieve high energy density.

2. Purpose of the work

To review the cell characteristics and chemistry of cathode materials for the production of traction lithium-ion batteries. Perform battery tests with the most popular Li-Ion cell electrochemistries, analyzing the advantages and disadvantages of different cell types. To draw conclusions on the degree of applicability of the respective types of lithium-ion batteries in EV / HEV applications.

3. Characteristics of the most used battery cells for EV / HEV

Largest distribution in EV / HEV battery production has received the following types of Li-Ion cells: LFP, NCA and NMC [4,5]. The most common classical LCO cell with LiCoO₂ cathode material has a high specific energy (240Wh / kg) but is not suitable for EV / HEV applications because of its propensity for ignition and harmfulness. The main cell characteristics are as follows:

- Specific energy. This feature has recently proven to be the most important, due to the development of battery management systems, the BMS, which has helped remove major flaws in increased density (heating, ignition, etc.).

- Chemical composition of the cathode material. It depends on the specific energy of the cell, and hence the maximum EV range with one charge [4,5].

- Cell size. Until recently, prismatic design of cells was considered to be the most suitable for EV. However, it is only suitable for LFP cells that are fire-safe but have low energy density. The reason is that in this design there is a greater probability of microscopic "short-circuits" between the electrodes in the folding zones and causing the "fugitive heat" effect (spontaneous temperature rise and cell destruction) [6]. Therefore, most of the NCA and NMC for EV cells are cylindrical, where there are no sharp folds between the electrodes and the heat-fugitive effect is less likely. The most widespread in EV are the cells of size 18650 [11].

- Internal resistance (impedance). This is an important functional feature of the cell. It is necessary to know the impedance of the cell to calculate the generation of Jaw heat or the loss of power in the cell. With cell aging, its internal resistance increases. This reduces the ability to receive and hold charge, but the OCV will still display as normal and even higher, despite the reduced battery capacity. Periodic comparison of actual internal resistance with new battery resistance will show any deterioration in battery functionality [8].

- Charging / dilution characteristic curve. Another main functional characteristic is the charge / dilution curve. It depends mainly on the choice of anode and cathode materials. This is an important feature that determines cell behavior during charging / discharging and is fundamental in the development of algorithms and software for battery management and monitoring systems.

4. Subject of research, equipment and methodology

In order to determine the most promising cells for EV / HEV applications, non-destructive tests of the basic functional characteristics have been performed - internal impedance and charging / discharging characteristics of cells of different design and different cellular electrochemistries of the most popular types of Li-Ion batteries for EV / HEV applications.

4.1. Object of the study

The object of the study is LFP, NCA and NMC type 18650 Li-Ion cylindrical cells, and a large LFP prismatic LFP cell line with LiFeYPO₄ cathode material. Cylinder cells are new, commercially purchased by different distributors [1,2,3]. From a used battery pack for EV, two large prismatic cells with the largest difference in nominal voltage at OCV were tested (Table 1). Cells are tested without protectors and control systems. Tests are subject to at least two cages of the species.

Table1: Commercial characteristics of the species Lithium - ion cells used for EV / HEV

Type	Format, mm	Commercial name	Nominal V
LFP	Φ18x65	LFP18650 Zelle	3,2
NCA	Φ18x65	NCR18650A	3,6
NMC	Φ18x65	INR18650-29E	3,7
LFP	179x62x218	LYP100AHA	3,3

4.2. Apparatus for research

For the experimental tests a modern safety device was developed, working together with the LabVIEW software package and LabJack U12 test card. It can work with different type and format Li-Ion cells [8]. Photographs of the unit in action are shown in Fig. In Fig. 1.a) shows a large prismatic cell test and Fig. 1.b) cylindrical cell test format 18650.

4.3. Experimental Research Methodology

1. Preliminary testing

The objectives of the preliminary test are:

- Determine the charge / dilution curve and assess to what extent the characteristics of the new cells meet the characteristics of the manufacturer;
- Make a comparative analysis of the charging / dilution curves of three types of the most common in the practice of EV applications lithium-ion cells with different electrochemistry to identify differences in their behavioral patterns during charging / dilution.

All cells must be fully charged to the allowable level before testing begins. The cell format 18650 is then diluted with a current of 0.25 C, with C being the battery capacity taken from the manufacturer's data. Dilute for 1 to 4 hours (up to 250 minutes) depending on the capacity of the cell types. The test is carried out with the apparatus shown in Figure 1 (b). The test results are shown in Figure 2.

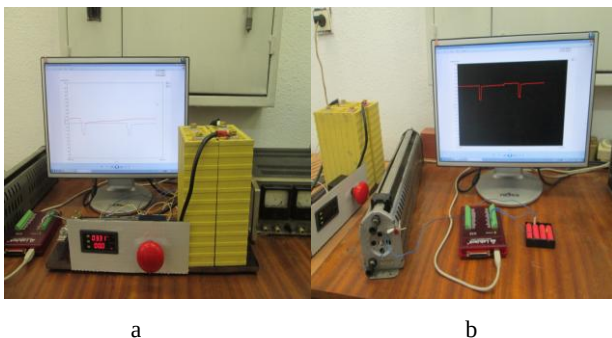


Fig.1 Images of the impedance measurement unit and the charging / dilution characteristics of lithium-ion cells. Fig. 1a) for large prismatic cells; FIG. 2.b) - For cylindrical cells format 18650.

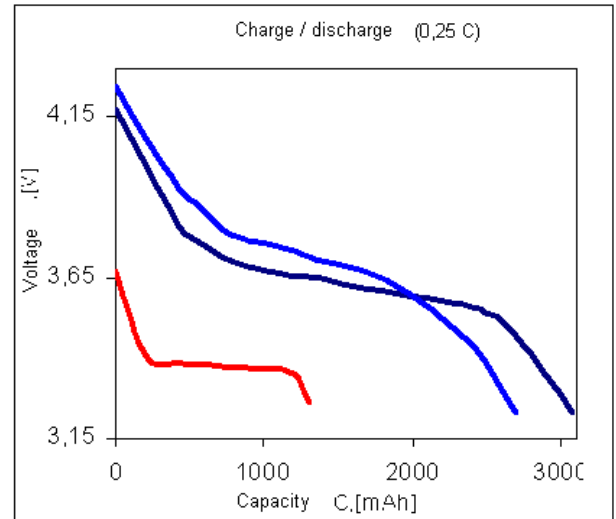


Fig.2. Load / discharge curves of cylindrical cell format 18650 with different cathode materials

2. Full cycle with 0.25C DC charging / discharging current.

Fig. 3. shows cell voltage during a pre-test cycle with a 25 A charge / discharge current of a large LFP cell and a 0.8 A charging / discharging current of a small NCA cell. The cell voltages are displayed as a function of the charge state (SOC). This allows direct comparison of voltage levels between charge and discharge in the same charge state of the two cell types. At the large prismatic cell, the charging and dilution time is halted for a short time for each 10% change in capacity to measure the voltage and analyze the relaxation at OCV [11]. In the NCA type cell, relaxation is not necessary because the charging curve matches the dilution curve, i.e., no special charging / dilution cycle is required as in the large cell.

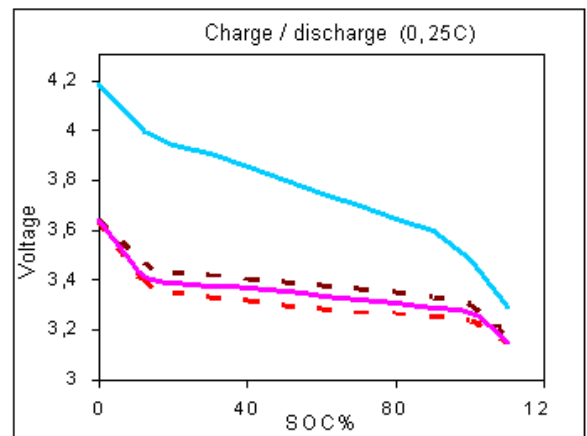


Fig. 3. Cellular voltage development in a 0.25C charge / discharge current with a large LFP cell break and a small NCA cell.

3. Determine the internal resistance

An electrical method [8] is used to determine the impedance. In order to determine the internal resistance, it is first necessary to measure the OCV of the cell. Then a load must be connected through the cell, which will cause a current to flow. This will reduce the cell voltage due to the drop in IR voltage across the cell, which corresponds to the cell's internal resistance. Then the cell voltage must be measured again when the current is running. The

Rin impedance is calculated according to the law of Ohm by the V cell between the two measurements and the ΔV_{cell} difference in voltage current I flowing through the cell according to formula (1).

$$R_{in} = \Delta V_{cell} / I, m\Omega \quad (1)$$

For the test, an impulse current of 1.5 ° C is applied for each individual cell for 2 seconds. Using a 2 second pulse time is sufficient to allow cell voltage to stabilize but has a negligible effect on SOC. The pulse current for the large LFP cells is 150A and the current for the small NSA is 4.5A.

5. Analysis of experimental results and discussions

The average values of the impedance test data and the specific energy of the cell types calculated from the charging / dilution curves are presented in Table 2. The analysis of the experimental results of Fig. indicates that the charging / dilution curves of different types of cylindrical cells differ.

Table2: Test results

Type	Cathode materials	Capac. Ah	Imp. mΩ	Energ Wh/kg
LFP	LiFePO ₄	1,4	40	110
NCA	Li(NiCoAl)O ₂	3,1	79	260
NMC	Li(NiCoMn)O ₂	2,9	75	220
LFP	LiFeYPO ₄	100	39	90

The nominal (working) area of the LFP cells is seen to be rectilinear with a very small slope, i. E. the voltage changes very little over the charge / discharge time. It is also seen that the characteristics of NCA and NMC cells resemble and differ only in capacity [4]. Therefore, the actual charging curve characteristics match the performance characteristics given by the manufacturer and the next tests can be performed.

In FIG. represents the cell voltage charge / discharge curve during testing at a 0.25C DC charge / discharge with large LFP cell breaks and no pause (continuous cycle) on a small NCA cell. The difference from the graph in Fig. 2 is that the voltage on this graph depends on the SOC and not on the time that the maximum capacity is reached. The upper cut-off curve of the LFP cell cycles represents a charge (brown), and the lower cut-off curve (red) represents the break with one-minute break when OCV is counted. Measurements of cell voltage during the test cycle indicate that the cell does not reach balance at the end of the pauses if the response step is paused for 1 minute which is very small. This makes the test more difficult and neglects because it extends the test cycle time to several days. It is necessary to accelerate the cycle time. This is done with a special algorithm where continuous averages (purple line) are interpolation between voltage levels at the end of 1 minute long pauses. This allows the test cycle to run in a very short time, with no great relaxation pauses [4,10]. Also from

the analysis of the charge / dilution curves of the two cells, it is confirmed that the nominal area of the NCA cell curve has a non-linear character and the nominal curve region of the LFP cell has a linear characteristic. This means that the load state (SOC) assessment in NCA cells becomes much easier by measuring voltage only, whereas for LFP cells, due to the small slope of the dilution curve, the SOC measurement with voltage measurement only is imprecise. It is also necessary to measure the amount of electricity (Coulon count), which complicates the algorithm and the software of the respective management system (BMS).

Figure 1 (a) of the monitor graphically shows the impulses impulses of two large LFP (LiFeYPO₄) cells, and in Figure 1 (b) the impulses of two small NCA cells. There is a slower relaxation of OCV in large cells than small cells. See also, the larger internal resistance of one LFP cell having a higher OCV. Therefore, bigger cells with higher voltages have a higher internal resistance or are not well balanced. Small NCA cells have exactly the same impedance and relax immediately, which means their high quality. From the data in tab. 2 shows the smaller impedance of LFP cells compared to other species. This means longer life and more charging / discharging cycles of this cell type.

6. Conclusions

- LFP cells are of great fire safety and security. Their functionality is very good, they have a large number of charge / discharge cycles and up to 1-2 years ago they were considered the most suitable for EV / HEV applications [8,10]. However, they have one major disadvantage - low specific energy, making this battery unpopular for modern EVs. Especially difficult to balance and require complex software to determine SOC, large prismatic LFP cells.
- NCA cells offer high energy density and are widely used in consumer electronics. They form the basis of Panasonic's battery packs in the current EV models of Tesla motors [11,12].
- NMC cells are also suitable for use in EV. NMC Chemistry is used by Renault and BMW for EV. According to Samsung, the current specific power of its NMC is 130Wh / kg (about half of Panasonic's NCA, but by 2019/2020 it would be 250-300 Wh / kg.) The cost of producing NMC cells for the time being is 12-19% higher than NCA [9,11,13].

In the near future, intelligent BMS developed by leading companies, specifically for NCA and NMC cells, will contribute to the formation of EW battery packs with power over 100KWh and specific energy over 350Wh / kg with high quality and high safety.

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WATER MONITORING IOT SYSTEM FOR FISH FARMING PONDS

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Abstract: Fish like many living organisms have specific tolerant range of various environmental parameters, thus fish farming of specific types of fish species requires certain conditions that have to be reached. Moreover, the people that work in the fish farming ponds have to be engaged in all day activities to maintain the living fish habitat. Therefore, monitoring and taking actions to maintain the habitat's sustainable environment for certain fish species inside of fishing ponds over distributed machine to machine communication, which will shorten the time needed for some basic actions, is the main motivation for this paper. In this paper we present an upgrade on a functional Internet of Things (IoT) system for monitoring fish farming ponds. The IoT system consists of various sensors that measure important factors of the water quality like temperature, light intensity or water level, as well as small board computer that processes the data and sends sound and visual notifications to the fish farming manager. The current system lacks the ability to process the data to the end-user via web or mobile platform. Due to remote distance of the fish farming ponds and their location dependence of clean fresh water, one solution of this problem is using expansion module like Wivivity modem to enable the end users in real time to monitor and control certain aspects of the fish farming pond IoT system. Wivivity modem allows user to communicate to the IoT system via WiFi connection, cellular, LoRaWAN or satellite communication; all in one product. Later on, this module can be integrated with IoT platforms including Jasper, Microsoft Azure or Amazon Web Services. For future work, we plan to expand not only the applicable services on different platforms, but also add more control modules and sensors to the existing IoT system for specific fish species.

KEYWORDS: FISH FARMING PONDS, MONITORING, WIVIVITY, TEMPERATURE, PH, AUTONOMOUS

1. INTRODUCTION

In the recent years with advancement in monitoring and automation technology, research in aquaculture resulted in development of production technologies that improved the quality of the fish farming ponds, thus leading to improvement and increasing of fish production. Fish farming pond is an artificial man-made eco-system and on the most basic level we can differentiate two types of ponds, ponds that breed tropical fish that are used as pets commonly known as aquariums in stead of ponds, and ponds that breed fish for food. Our focus in this paper are the ponds that breed fish for food, typically build and maintained in remote eco-clean areas, near to water springs, and any outside environmental stress will negatively impact on the fish production. This is due to the fact that fish are cold-blooded animals that regulate their temperature directly by the surrounding environment. Consequently on this, temperature is one of the many key parameters that is needed to be monitored, combined with other important factors like light intensity, water level in the pond and etc. Therefore, the monitoring of this eco-system is a problem combined of some multiple sub problems that are linked between each other, and they are in constant interactions. Their interaction is a complex process that needs a lot of time, dedications and knowledge by humans to be controlled and maintained.

In the past decade we have witnessed an enormous progress in the exploitation of the power that is offered to us by the computing machines into almost every field of production process. The machines are usually used to automate the processes and lower the human interactions steps to reduce the risk of an error. The idea of such a system that automates the fish farming industry, came from a couple of problems that this technological process faces. One of the problems is the time consuming process of manually checking and measuring every parameter and every part in a fish farming pond. Second problem is the lack of possibility to put them in sort of remote location which you can check once a day, not multiple times in very remote areas, most of the time without any internet connection. Furthermore, we have to include the problem of running the fish farm sometimes without human presens even for a couple of days.

In this direction, the paper aims to present a smart IoT system that is used to automate the monitoring and maintenance of a fish farming pond in remote locations, with a goal to bring it closer to its natural form by the most effective means using remote monitoring via wireless communication technologies like cellular, LoRaWAN, WiFi or Satellite communication. This smart system aims to reduction of the environmental stress that affects the fish population in the fish farming pond. This is a very active research area and researchers have developed similar systems, that try to automate the

monitoring of the fish farm environment. Authors in [1], have provided an automated IoT system for automated fish farming where they monitor the water temperature, pH and water level, using Wi-Fi remote connection, which could be a problem for systems that are placed far from areas where cellular or any type of internet connection is available. In order to address this problem, the authors in [2], proposed a GSM type of notification by sending SMS messages to the end-user. One disadvantage of this proposed system, is the process of notification to the end-user after specific time intervals or after a certain parameter value is reached, and not in real-time. To overcome this in one sense of real-time monitoring, the authors in [3], proposed combination of IoT system in [2] with CCTV cameras, which constantly monitors the fish farming pond. Other authors investigate the possibility of using power out of the standard power grid [4], which is typical for remote places. This raises other important problem for fish farming ponds remotely located in a forest or in mountains terrain, and that is the availability of internet connection. One possible solution is to use LoRaWAN or satellite networks that can be used to cover large areas, and especially satellite communication where we can reach areas that are typically not covered by mobile cellular networks. Wivivity [5] works with all these types of networks worldwide, across different networks - without requiring different designs for every region, supporting various connections (Wi-Fi, 3G, 4G, LTE, SIGFOX, LoRaWAN and satellite connections). Another positive impact of this module is the elimination of expensive truck rolls and skilled techniques, this modem can be easily hot-swapped on the small board computer directly on the site to the required type of connection. With this modem, IoT devices can support new form of connectivity and the proposed water monitoring fish pond farming IoT system can be used in very remote areas, typical for eco-tourist sites where fish farming ponds are usually placed.

The rest of the paper is organized as follows; in Section 1 we will present the current state of the monitoring system for fish farming ponds and detail description of the sensors used for the monitoring system. Section 2 presents the current state of the water monitoring IoT system for fish farming ponds, followed by section 3, which discusses the benefits from the implementation of the Wivivity module for remote communication and potentially new sensors that will increase the the fish quality and their production. The conclusion of the paper is given in Section 4.

2. CURRENT STATE OF MONITORING SYSTEM FOR FISH FARMING PONDS

The current system includes the Arduino Mega2560 [6] board one of the many small board computers, that consumes very low power and it is widely available. Connected to this control unit are various sensors for monitoring some of the parameters which can be

labeled as input units, actuators such as relays that can be labeled as output units, executive units that affect some parameters, such as the heater and some interactive elements such as LEDs, buzzer, LCD display presented on Fig. 1

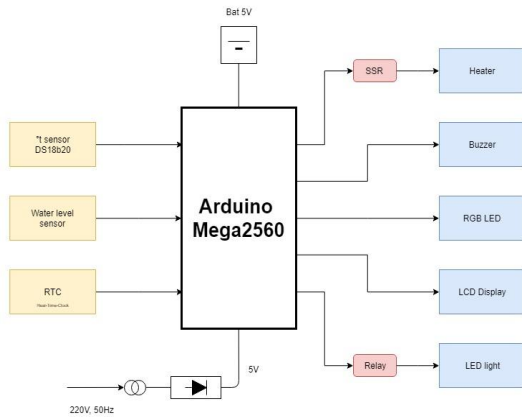


Fig. 1. System schematic of the water monitoring IoT system for fish farming ponds.

The IoT smart monitoring system includes several sensors to sense the environment and based on the readings from these sensors, the fish pond manager can make important decisions for improving the quality and quantity of the fish production. We give detail explanation of the sensors and the actuators used in the current IoT system (see Fig. 2)

The temperature is the driving factor of all processes that happen in the fish pond. It's not only affecting the development and growth of the plants and other animals in the pond, but also regulates the oxygen level in the water. The optimal temperature for tropical fish is 25°C with allowed deviations of 2°C and for fish that live in rivers like the trout that temperature is too hot so the optimal temperature for it is around 14°C. Therefore is a need to monitor and regulate this parameter through additional equipment. The monitoring is done by a waterproof DS18B20 [7] digital temperature sensor with accuracy of $\pm 0.5^\circ\text{C}$ (See Fig. 2 - Box 1). Data is read from the sensor and depending on the values the board sends control values to the heating equipment. The regulation or heating of the water is done by an Omron GL3 205p1c Solid-State-Relay (see Fig. 2 - Box 2), which receives the control signal from the board and then turns off or on the heater. This kind of relay is used because it has a fast reaction time, it is electronic (there are no mechanical contacts as in standard relay) and it's more durable of the harassment done by the PID heating algorithm. Also in this parameter there is a heater element. All of the standard heaters for fish pond or aquariums have a thermostat built in, but in this system with the control of the heater from the board the risk from malfunction of this element is lowered multiple times.

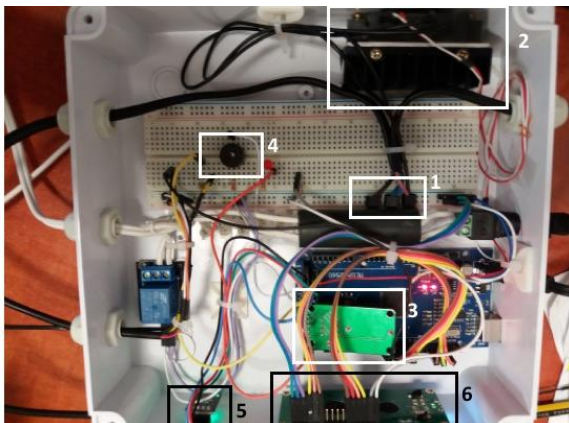


Fig. 2. Implementation of the IoT water monitoring and control system for fish farming ponds.

The role of the light intensity in the fish breeding process is very important because only with fully securing the proper lighting, natural or artificial, you are allowing the fish and the plants to have a normal life cycle. If you are breeding a fish type that is a natural occupant in that area where the pond is, the needs of light are automatically satisfied, but if you are breeding other types of fish you need to control it. It is important to determine what type of light is most suitable, in which intensity and the time interval. Basically you need to determine the day/night cycle. The lightning parameter affects the fish color, feeding habits, mating drive, orientation and territory placement, and also affects photosynthesis of the plants and the oxygen levels in the water. The most suitable "day" period in the ponds is between 10 and 12 hours, it can be longer but it can't be lower in any case. In our system we regulate the day-night cycle using RTC module (DS1302 RTC [8] - (see Fig. 2 - Box 3)) which indicates the time and depend on it we switch on or off the light. We use LED for lightning and with a little more complex solution you can even control the LED intensity depending on the clock, you can have less bright light in the morning and evening and highest brightness during mid-day.

Every change in the water level, either raising or lowering, it affects in a great manner the finishes in the pond and causes suitable reaction from them. The fish occupy some area of movement, feeding and relaxing, either at the bottom or at the top of the pond, and by lowering the water level that area shrinks and causes inadequate living conditions and may cause battle for survival among the fish. This is why we need to keep the amount of water at some constant level. The IoT monitoring and control system measures the water level in the pond using a simple magnetic float sensor, Water level sensors float switch P45 [9], which notifies the end-user when the water drops below our desired limit. Using a float sensor instead of the conventional electric sensor such as droplet depth detection sensor is much more friendlier to the occupants of the pond because there is no water-electricity contact.

The IoT system at this stage communicates to the end-user to a set of sound and light (visual) notification that are placed in the control room of the fish farming pond. The sound notifications are produced using buzzer (see Fig. 2 - Box 4), which sends sound signals whenever some of the measured parameters goes out of the desired range. This is very important in many monitoring systems, not just to notify the fish farm manager when he decides to change some important monitoring factor(s), but also for the alerting when some of the critical factors are mismanaged. Another important aspect of the IoT monitoring system is the light notification, which in our system we achieved by using RGB LED diode (see Fig. 2 - Box 5) [10]. This diode presents the current temperature state using different voltage levels (blue, green and red color) thus representing the temperature degree of the fish farm water (cold, normal and hot). If the measured temperature is out of the predefined range, or out of the defined min and max range, the RGB diode together with the sound buzzer will notify the fish manager with applicable color (blue for cold, red for hot). And finally, we implemented an LCD notification screen (see Fig. 2 - Box 6), that displays the current state of the monitored parameters and controlled using from the IoT sensors for the fish farming ponds. If something goes out of hand it displays text message with the problem that is detected.

3. REMOTE MONITORING AND OTHER SENSORS

Current IoT system lacks the ability to process the data to the fish farming manager via any remote platform: web or mobile platform. However thanks to the great robustness of the Arduino platform, by using various expandable modules, the current system can be expanded using different types of modems. In our case in this paper work, we decided to use Wivivity module [5], which can provide internet connectivity through GSM, Wi-Fi, LoRaWAN or satellite communication. This is very important in our case of fish farming ponds, since the location of the fish farming pond can be very remotely and in many cases no mobile and thus no internet communication is available.

The Wivity module is a interchangeable modem that offers a modular approach to the IoT connectivity part (see Fig. 3). By using the plug-and-play technology in a form of USB pluggable module, it can be easily installed and maintained. This doesn't requires any technical knowledge for the fish farming managers and more important it can interconnect several fish ponds in different areas, so you can easily use the modem that suits the most for that location and without code changes. Another aspect of this device is power flexibility, beside the main power is drawn from the Arduino Mega 256, the device has additionally micro-USB connector that supply more power. The next feature that allows better and faster connection is the possibility of interchange between fixed and movable antennas. The device also supports Java execution on board, and have built in SIM module. From the connection perspective, it has an built in protocol stack, that offers transparent and non-transparent TCP/UDP client and server, as well as SMTP/FTP/HTTP/DNS and Ping client. Another great aspect of this device is the support of the TLS for all previous mentioned protocols, thus providing better security for IoT devices. A typical communication between two IoT devices with this module is initiated with HTTP request which is passed to the Wivity modem using the usb or serial port. This HTTP server resides on the Wivity modem, and this server pushes data to the backend cloud server no matter what communication network is used. For all this is to work, we can use development kits like SIGFOX [11], in order to make more functions available to the end-user. On top of this layer for remote monitoring and control, an application interface for a web or mobile application which will indicate the status of the pond and it will give possibility to set some new values to the parameters of the system like new min/max temperature, working light hours etc, should enable the end-user more pleasant experience. Since the Wivity modem can be expanded not by other hardware, but also with other software modules, we can use to further ease the enchant the notification panel for the fish farming manager. One such option will be sending SMS messages for the most vital events that can jeopardize the fish environment.

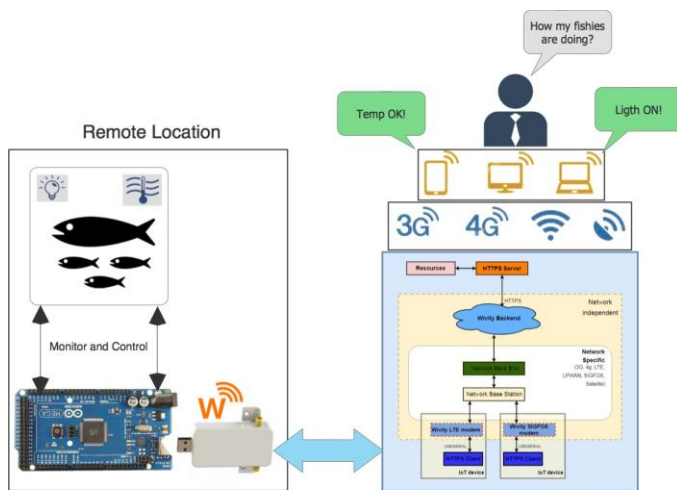


Fig. 3. Water monitoring IoT system for fish farming ponds with Wivity module.

Another important factor is further development of the system in terms of adding new sensors that will improve the fish production and quality. Sensors that measure the pH or Dissolved Oxygen have priority in our plans for improving the IoT system. PH sensor, like the sensor presented in [12], play an important role, because this sensor measure the level of acidity in the water, which should be maintained between 6 and 8. If pH goes below, 5 the water becomes to acid for the fish and they will suffer from several diseases like tissue coagulation necrosis, acid erosion of the gill [14]

tissue etc, and will eventually die. Aeration or measuring dissolved oxygen is another factor that is vital for fish farming ponds. This parameter describes the level of dissolved oxygen in the water. It is affected by the temperature, pressure and salinity. It's utilized in aerobic decomposition of organic matter, respiration of the fish, and chemical oxidation of minerals. Low dissolved oxygen levels will slow or stop the fish growth. If it drops below the level of endurance of the fish it will cause death. There are several sensors for measuring dissolved oxygen, but there is already a pre-built one for arduino from DFRobot[13]. Another idea is to use this sensors to connect to an air pump and automatically control the level of oxygen in the water. Depending on the dissolved oxygen level you can add or lower the power to the pump.

4. CONCLUSION

In this paper we have presented water monitoring IoT smart system for managing and improve the fish productions in fish farming ponds. The current implemented system consists from the most vital sensors that are needed to monitor the water quality and notify the fish pond manager on-site. We upgraded this system by adding a hardware module that will allow the end-user to monitor and in the future to control vital parameters in the most remotely fish pond locations. The Wivity module can be easily installed and configured, without the need of any high level of technical knowledge. Additionally to this, if the end-user requests, the Arduino platform can be remotely configured as remote server or client with ease, as well as other hardware settings. Further on, module for mobile and web interface should be developed for more easy user interaction. In future we plan to expand the IoT water monitoring system by adding a variety of other sensors, like sensors that will measure pH or dissolved oxygen vital for the fish life cycle.

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ELECTRICITY GENERATION BY MEANS OF MICROORGANISMS FROM DIFFERENT PHYSIOLOGICAL GROUPS

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Abstract: Microorganisms from three different physiological groups (sulphate-reducing, iron (III)-reducing and fermenting bacteria) were used to generate electricity by means of two-sections microbial fuel cells. The power generation by this system varied within a large area (from 250 to 3200 mW/m²) and depended on the type, form and quantity of the organic donors of electrons, the enzymatic activities of the microorganisms in the anodic section and the efficiency of aeration in the cathodic section.

Keywords: MICROBIAL FUEL CELL, ELECTRICITY GENERATION, SULPHATE REDUCING BACTERIA, IRON-REDUCING BACTERIA, FERMENTING BACTERIA

1. Introduction

The ability of some microorganisms to generate electricity in constructed fuel cells is connected with the microbial ability to transfer electrons from different organic substrates to the surface of anodic electrodes located in the anoxic sections of the relevant fuel cells. Some of these microorganisms (mainly bacteria and archaea) are able to form biofilms on the anodic surface and to transfer the electrons directly, through microscopic pipes located in the pili on the microbial surface. The most active microorganisms using this mechanism are some bacteria possessing the so called anaerobic iron respiration. These bacteria are typical heterotrophs able to remove electrons from some organic compounds and to transfer them via the microbial respiratory chains to ferric ions acting as final electron acceptors. The most studied from these bacteria are some species related to the genera *Geobacter* and *Shewanella*. They are able to form stable biofilms on the anodic electrodes in the constructed microbial fuel cells. In these cells the electrons are removed from the anode by means of wires (usually consisting of copper) and are transferred to contact with a suitable resistance located outside the anodic section. As a result of such treatment, a position of the chemical energy of electrons is transferred to electricity and the electrons reach the aerobic cathodic section in which they react with the protons to form water molecules (Rabaey and Verstraete, 2005; Du et al., 2007; Lovely, 2008).

Apart from the Fe³⁺-reducing bacteria, microorganisms (also bacteria) related to two other physiological groups are also used in investigations for electricity generation: sulphate-reducing bacteria (mainly of the genera *Desulfovibrio*, *Desulfobacter* and *Desulfomonas*) and fermenting bacteria (mainly of the genera *Bacillus*, *Pseudomonas* and *Clostridium*).

Some data about our investigations on the possibility of strains related to different species from the three physiological groups mentioned above to generate electricity by means of identical fuel cells are shown in this paper.

2. Materials and Methods

The ability of different microorganisms to generate electricity was tested by means of a variant of the microbial fuel cells of the type which was selected on the basis of the results from several previous experiments. The cells used in this study were plexiglas cylindrical columns 80 cm high, with an internal diameter of 12 cm. A perforated slab graphite – Mn⁴⁺ anode and a graphite – Fe³⁺ cathode were located in the bottom and in the top section of the

column, respectively. The two sections were separated by a permeable barrier of 5 cm thickness consisting of a 2.5 cm layers of glass wool and a 2.5 cm layer of glass beads. The feed stream containing the potential energy sources for the microorganisms was supplied to the bottom anodic section of the column and the effluents passed through cathodic section and continuously exited at the top. Air was injected during the treatment to the cathodic section.

The feed streams, i.e. the nutrient solutions used for the cultivation of the microorganisms intended for generation of electricity by the microbial fuel cells were as follows: for the sulphate-reducing bacteria – the nutrient medium of Widdel and Pfening (Widdel, 1988), for the ferric iron-reducing bacteria – the nutrient medium of Kostka and Nealson (1988) and for the fermenting bacteria – in the standard meat-peptone bouillon.

The quality of the waters treated by the microbial fuel cells was monitored at the inlet and the outlet of the relevant fuel cell. The parameters measured included: pH, Eh, dissolved oxygen, chemical composition, temperature, voltage of the open circuit and power. The isolation, identification, and enumeration of microorganisms were carried out by the classical physiological and biochemical tests (Karavaiko et al., 1988) and by the molecular PCR methods (Sanz and Köchling, 2007; Escobar et al., 2008).

3. Results and Discussion

The comparative experiments performed during this study revealed that strains related even to one and the same taxonomic species can differ considerably from each other with respect to their ability to generate electricity under identical experimental conditions (Tables 1 – 3). This is quite normal having in mind that the ability of such microorganisms to degrade one and the same organic substrate, i.e. to extract electrons from it, is often also quite different. Furthermore, in some cases strains related to different physiological groups have a very similar ability to generate electricity even under the presence of different concentrations of the relevant organic substrates. In most cases very essential for increasing the electricity generation was the efficient aeration in the cathodic section. It was possible to conclude that the power generation by such systems depends on the type, form and quantity of the organic donors of electrons, the enzymatic activities of the microorganisms in the anodic section and the efficiency of aeration in the cathodic section.

Table 1. Efficiency of electricity generation by means of sulphate-reducing bacteria

Sulphate-reducing bacteria	COD, mg O ₂ /l.h	Power, mW/m ²
Desulfovibrio spp.	620 – 1630	420 – 1700
Desulfobacter spp.	550 – 1270	370 – 1400
Desulfomonas spp.	480 – 1040	320 -1200
Mixed populations	410 - 1720	410 - 1550

Table 2. Efficiency of electricity generation by means of Fe (III)-reducing bacteria

Fe (III) - reducing bacteria	COD, mg O ₂ /l.h	Power, mW/m ²
Shewanella loihica	590 – 1410	410 – 1400
S.odeinensis	510 – 1270	350 – 1200
S.putrefaciens	440 – 1040	320 – 970
S.alga	370 – 990	350 – 950
Geobacter metallireducens	640 – 1450	420 – 1000
G.ferrireducens	510 – 1090	320 – 990
G.sulfurreducens	440 – 1020	300 – 950
G.hydrogenofilus	390 - 820	320 - 790

Table 3. Efficiency of electricity generation by means of fermenting bacteria

Fermenting bacteria	COD, mg O ₂ /l.h	Power, mW/m ²
Bacillus subtilis	680 – 1700	410 – 1630
Bacillus spp.	710 – 1670	410 – 1540
Pseudomonas sp.	520 – 1400	280 – 1250
Clostridium spp.	410 – 1250	250 – 1400
Mixed populations	350 - 1450	370 - 1520

Similar conclusions were made on the basis of the results from the experiments in which natural microorganisms present in the organic substrates (compost from plant leaves, manure of different origin, sawdust) were used to generate electricity (Table 4).

Table 4. Electricity generation from different organic substrates by means of microorganisms inhabiting these substrates

Organic substrates	Initial COD, mg O ₂ /l.h	Microbial cells, maximum numbers/g	Power, mW/m ²
Compost from plant leaves	210 - 1040	3.10 ⁸	500 - 2100
Manure of different origin:			
- birds	205 – 910	3.10 ⁸	450 – 1900
- sheeps	235 – 1090	6.10 ⁸	600 – 2300
- cattle	320 - 1220	>8.10 ⁸	800 – 3200
Saw-dust from trees	170 - 620	1.10 ⁸	500 - 1400

However, it must be noted that after several repetitions of the experiments using inocula from the relevant preceding test the compositions of these inocula changed, in most cases, to different positive extents. This approach can be accepted as a way for selecting some electricity active microorganisms.

Acknowledgements: The authors expressed their gratitude to the National Science Found of Bulgaria for the financial support connected with this study (project TO2/2/2014).

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MOLD DESIGN AND PRODUCTION BY USING ADDITIVE MANUFACTURING (AM) - PRESENT STATUS AND FUTURE PERSPECTIVES

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Abstract: This paper covers the advanced Additive Manufacturing (AM) techniques applied to injection mold design and production. Its aim is to do a comprehensive analysis on what AM is doing for the recent and future perspectives in the field of mold's production.

Further analyses are done on the possible use of Rapid Tooling (RT) techniques based on AM technologies. These include plastic mold inserts made using high strength polymer resins and metal-based technologies for direct tooling work.

Moreover, the work also reviews conformal cooling channel design based on laser sintering AM technologies and its effect in improving mold cooling efficiency to reduce cycle times, which is an important issue in the injection molding process.

Finally, a brief techno-economical analysis is presented, as well as a comparison between the two different types of molds – the conventional ones, and molds produced by rapid tooling. The conclusions leads toward future usage of RT and AM in the mold design and production.

Keywords: injection molding, additive manufacturing, 3d printing, rapid tooling, stereolithography, laser sintering

1. Introduction

Injection molding as a manufacturing process has always been a challenge because the tooling design is always specific for each part. This means that toolmakers have to use a variety of manufacturing technologies in order to produce a tool with a precise shape, correct feeding and cooling channels and easy ejection.

With the rise of additive manufacturing technologies in the last decade, a lot of the limitations in conventional manufacturing have been circumvented. Additive manufacturing uses layer-by-layer fabrication of three-dimensional physical models directly from a computer-aided design (CAD) model. AM takes the virtual design from a CAD or some other 3D modeling software, transforms it into thin, horizontal cross-section layers and then stacks those layers together in physical space, one after another until the physical model is completed. When this process is used to produce physical prototypes and models for various applications it is referred to as Rapid Prototyping (RP). When AM technologies are used to directly manufacture tools or tooling inserts for injection molding or for any other technology that requires a specific shape to produce a part, then the process is called Rapid Tooling (RT).

Rapid Tooling involves all AM procedures that lead to final parts used as cores, cavities, or inserts for tools, dies and molds. Two sub-levels must be distinguished: direct tooling and prototype tooling (Fig. 1.1).

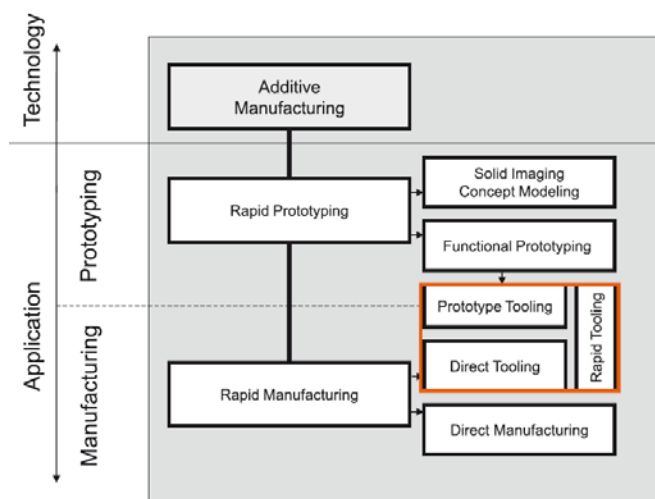


Fig. 1.1 AM: rapid tooling, defined as a subcategory that integrates prototype tooling and direct tooling (Source: [4])

Direct Tooling is technically equivalent to Direct Manufacturing but leads to tool inserts, dies and molds (Fig. 1) in series quality. It is important to understand that “Direct Tooling” does not mean that the entire tool is made by AM, in fact only tool components, such as cavities or sliders, are generated. The entire tool is made using these cavities and standard components or inserts within a traditional tool making process.

Prototype Tooling is used when a mold in series quality often is too time and money consuming for small series manufacturing. If just a few parts are needed or details are changed frequently, a temporary mold made from substitute material is typically sufficient. This kind of mold shows the quality of functional prototypes but meets, at least partially, the direct tooling application level.

The primary advantage of RP and RT is its ability to create almost any shape or geometric features, even those complex shapes that would be virtually impossible to machine. With additive fabrication, the machine reads in data from a CAD model and lays down successive layers of different materials, and builds up the physical model from a series of layers. Those layers are joined together or fused automatically to create the final shape matching the CAD model.

2. Rapid tooling technologies

Currently, there are several AM technologies that can be used for rapid tooling purposes. This paper will focus on two: Selective Laser Melting (SLM) and Stereolithography (SLA).

Selective Laser Melting (SLM)

SLM machines (Fig. 2.1) consist of a build chamber to be filled with powder with a grain size of up to 50 µm and a laser scanner unit on top that generates the x-y contour. The chamber is designed as a movable piston that can be adjusted at any z-level. The top of the powder bed defines the build area in which the actual layer is built. The whole build chamber is preheated to minimize laser power and completely flooded by shielding gas to prevent oxidation. The laser beam contours each layer. The contour data are obtained from the slice data of each layer and directed by the scanner. Where the beam touches the surface, the powder particles are locally molten. The geometry of the melting spot is defined by the laser beam diameter and the traveling speed. While the beam travels further, the molten material solidifies by thermal conductivity into the surrounding powder. Finally, a solid layer is achieved. After solidification of one layer, the piston at the bottom

is lowered by the amount of one layer thickness, thus lowering the whole powder cake including the semi-finished part. The emerging space on the top of the powder is filled with new powder taken from the adjacent powder feed chamber using a roller. The roller rotates counter-clock wise to its linear movement in order to spread the powder uniformly. This procedure is called recoating.

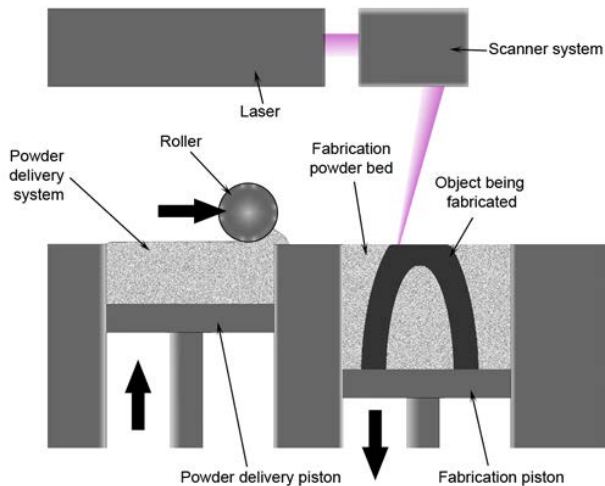


Fig.2.1 Selective Laser Melting (SLM) – Schematic
(Source:cadimensions.com)

After recoating, the build process starts again and processes the next layer. The whole process continues layer by layer until the part is completed. In most cases, the top layer is made using a different scan strategy in order to improve its solidity. After the build is finished and the top layer is processed, the whole part, including the surrounding powder, is covered by some layers of powder. This so-called powder cake has to be cooled down before the part can be taken off by removing the part from the surrounding powder. The cool-down can be done in the machine; however cooling down in a separate chamber allows immediate beginning of a new build job.

The process is generally called selective laser melting, (SLM) but depending of the machine manufacturer, the process can be called differently (ex. EOS-GmbH has patented the DMLS technology). It was developed in particular to process metal parts that need to be very (> 99%) dense, and is used to manufacture injection molding inserts for larger production series, that have a specific geometry difficult to manufacture with conventional means. Since the parts manufactured by SLM have a high density and isotropic mechanical characteristic they can be used as Direct Tooling inserts.



Fig.2.2. Golf Ball blow-mold Left: Conformal cooling Right: Direct Tool cavity (Source: <https://www.eos.info>)

This approach can potentially reduce the number of steps in the process and potentially impact overall part accuracy. The limitation in additive fabrication of tooling tends to be the required post-processing to achieve the required surface finish. Some processes

like DMLS (EOS) and Laser Consolidation (Accufusion) have good raw finishing results, but typically mold inserts require additional polishing [4].

Selective Laser Melting (SLM)

A laser stereolithography machine consists of a build chamber filled with the liquid build material and a laser scanner unit mounted on top of it which generates the x-y contour. The build chamber is equipped with a build platform fixed on an elevator-like device that can be moved in the build (z-)direction. On this platform the part is built. The laser beam simultaneously does the contouring and the solidification of each layer as well as the bonding to the preceding layer. The motion of the beam is controlled by the slice data of each layer and directed by the scanner.

If the curable build material is applied by print heads, the process is called polymer printing or polymer jetting. It can be regarded as a 3D printing process; however, due to the part building by UV curing of liquid monomers it is a polymerization or stereolithography process. The build material is directly applied to the build platform through a multi-nozzle piezo-electric print head. The solidification is done simultaneously by a twin light curtain. It is created by two synchronously traveling high performance UV lamps. The layer thickness is only 0.016 mm, which creates very smooth surfaces. Adjacent layers are processed by moving the platform in the z-direction. The process continues layer by layer until the part is finished. The parts need supports during the build process. The supports are generated automatically and build simultaneously by a second set of nozzles so that each layer consists either of build or of support material. Consequently, the supports are solid and consume a large amount of material. The support material can be washed out without leaving marks in a mostly automated process.

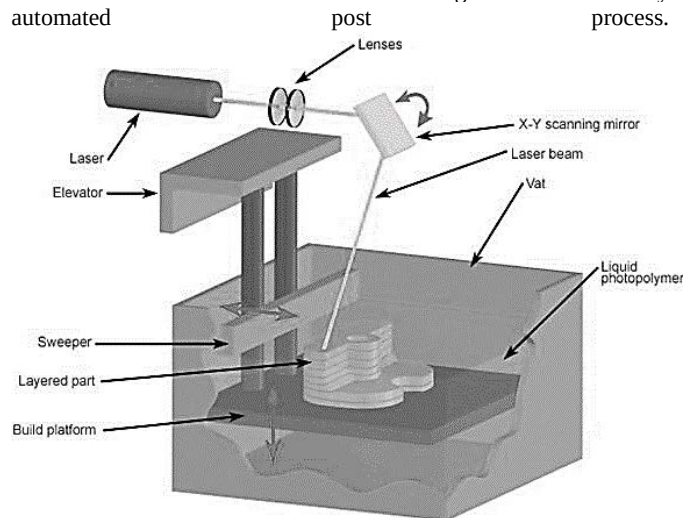


Fig.2.3. Stereolithography (SLA) – Schematic
(Source: <http://www.custompartnet.com>)

By using stereolithography based AM like the Stratasys patented PolyJet 3D printing (Fig. 2.3) we can manufacture prototype tooling to validate the performance of the plastic parts. This is a viable production technique for short runs and smaller series, but since the material properties of the mold resin require different processing parameters (molding temperature, injection pressure, packing time etc.) currently SLA is used mostly to assess the parts functionality. This is possible because the prototype tooling can be finished in 2 to 3 days. Conventional tooling on the other hand, can take up to few months to manufacture.

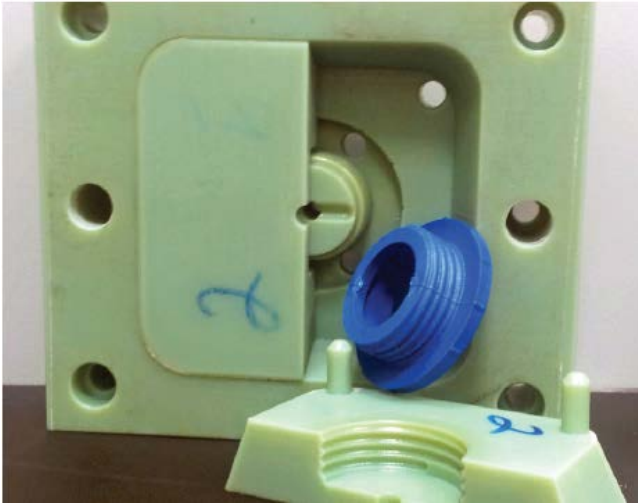


Fig.2.3. Three-piece mold made with PolyJet Digital ABS material (Source: Stratasys.com)

3. Conformal cooling

Since the inception of industrial injection molding, keeping an even temperature on the surface of the mold has been a constant challenge. Optimal cooling reduces cycle times by a significant amount since it often takes more than 50% of the entire cycle time.

The cooling system is extremely important to the economics and operation of the designed mold, and yet remains one of the most under engineered systems in injection molds. Perhaps the reason for the lack of engineering is that the temperature distribution is not that obvious when molding compared to flow related defects.

Improperly designed cooling systems often result in two undesirable outcomes. Firstly, cooling and cycle times are much longer than what could have been achieved. Secondly, significant temperature gradients arise across the mold, causing differential shrinkage and warpage of the moldings. To operate effectively, cooling systems must be carefully designed to manage the heat flow throughout the mold without incurring undue cost or complexity.

When optimizing mold cooling there are 4 basic principles:

1. Wall thickness. Cooling time increases exponentially with the wall thickness of the part. With 1mm walls, many materials cool in five seconds. At 5 mm, cooling times extend from 40 to 75 seconds.

2. Thermal diffusivity. This ratio of thermal conductivity to heat capacity is important because the lower the thermal diffusivity of the material, the longer it will take to extract heat from molten plastic.

3. Mold temperature. Higher mold temperatures help reduce pressure during the filling phase and improve surface finish, but they can double or triple cooling time.

4. Depth and pitch. The size, depth, and spacing of cooling channels should result in temperature differences across the mold surface of no more than 5°C for semi-crystalline materials and 10°C for amorphous materials. More channels spaced closer together near the surface of the mold accelerate cooling while maintaining surface temperature uniformity.

In their quest to maintain even temperatures, manufacturers have used baffles, bubblers and heat pipes; they've laminated blocks together and added complex drilling set ups to their molds. Over the last decade, conformal cooling has been proposed as a solution for controlling injection molding temperatures. Mold inserts can be built with internal cooling channels that follow the contour of the cavity beneath the surface (Fig. 3.1, b). Because the

shaping of the cooling channels follows the contour of the mold, the method is called conformal cooling. Due to the increased heat extraction, the productivity of a plastic injection mold can be increased significantly. In addition, cooling and heating channels can be designed to obtain an integrated heat management system and thus much more effective tools.

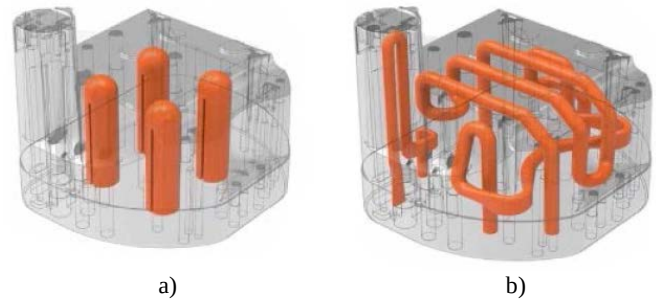


Fig. 3.1 Conventional cooling channel core with bafflers (a) vs. conformal cooling channel design (b) (Source: 3dsystems.com)

In recent years, a lot of case studies have been done proving the effectiveness of cooling channels for parts with complex geometry. One of those studies featured by 3DSystems with is for a core with a tapered helix that is positioned on the inside of a spacing cone used for industrial assemblies (Fig 3.2). Conformal cooling channels were created by rotating a teardrop configuration so that one side was parallel to the outer surface of the core while maintaining a constant distance from it. By running the cross-section along a tapered helix, Bastech was able to design geometry that the ProX DMP 200 could build in a single run.



Fig. 3.2 A Bastech mold core insert with conformal cooling channels prototyped using 3D Systems' Stereolithography (SLA) technology and printed in maraging steel on the ProX® DMP 200. (Source: 3dsystems.com)

As expected, the conformal cooling mold maintained a lower temperature throughout the run and reduced cycle time by 14%. This design can also be applied to molds made by materials other than metals, but as it stands now, metal based AM technologies are still the standard when it comes to designing conformal channels for larger production series molds.

Table 3.1: Baffled vs. Conformal Core – Cycle time [3dsystems.com].

	Conventional	Conformal	Savings
Mold Temp	44 °C	44 °C	
Cooling	10.5 sec.	7.5 sec.	
Cycle Time	35 sec.	30 sec.	5 sec./part

Table 3.2: Baffled vs. Conformal Core (Source: 3dsystems.com).

	Start Up	20 shots	40 shots	60 shots		
	Mold Temp °C	Mold Temp °C	Mold Temp °C	Mold Temp °C	Flow [l/min]	Cycle time [s]
Baffle core	29	37	39,5	38,2	5.3	58
Conv. Cavity	28	28,3	28,7	26,8	5.3	58

	Start Up	20 shots	40 shots	60 shots		
	Mold Temp °C	Mold Temp °C	Mold Temp °C	Mold Temp °C	Flow [l/min]	Cycle time [s]
Baffle core	29	33,67	33	32.5	5.7	45
Conv. Cavity	28	30	29,67	29,67	5.7	45

Cooling channel surface area of baffled core = 1561 cm²
Cooling channel surface area of conformal core = 3368 cm²

The use of conformal cooling channels optimizes the molding process by providing a constant temperature gradient throughout the mold all the while increasing the total surface area of the cooling circuit. This also results in savings in manufacturing the inserts.

Table 3.2: Baffled vs. Conformal Core – Cost savings [3dsystems.com].

	Conventional	Conformal	Savings
Design	30	7	\$1,495.00
Programming	40	17	\$1,495.00
Machining	74	56	\$990.00
Material/ AM Build	\$350.00	\$5,400.00	-\$5,050.00
EDM	72	0	\$3,960.00
Polishing	38	45	-\$385.00
		Total	\$2,505.00 [16%]

However, conformal cooling adds new layers of design and production complexity to the moldmaking process, placing it beyond the means of most shops. The investment in AM machines is not always justified, especially when manufacturing simpler injection molded parts. In those cases, the use of conformal cooling is not needed and conventional channels manufactured with drilling can be used to get similar results.

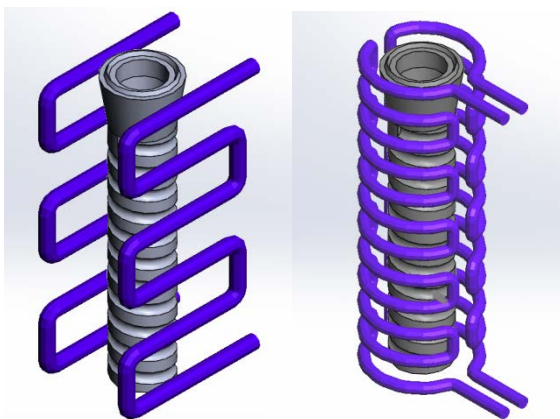


Fig. 3.3 Conventional cooling channel (a) vs. conformal cooling channel design (b) for a plastic part with simple geometry

A simple FEA analysis of the part shown in Fig. 3.3 with constant coolant flow and mold temperatures showed that the

conformal cooling design only improves the cooling time less than 5%

4. Conclusion

3D printing is commonly used to build prototype parts for the detection of issues related to form, fit and function. Yet, 3D printed prototypes cannot provide a complete assessment of an injection molded part's functional performance because 3D material properties are different than those actually used in injection molding. AM technologies based on SLA can replace soft, aluminum tools that, until recently, were the only option for manufacturers to conduct design and functional testing of injection molded products.

Currently, metal based AM processes are the only viable technologies for large series of injection moldings. At this point conformal cooling channels are the main reason why AM inserts are used in injection molding tools, however the use of the tooling inserts made by laser sintering techniques can be further extended to manufacture specific geometries of the mold that are more prone to wear and have to be replaced after a specific number of runs.

Injection mold tooling made with composite SL resins is viable for use in short-run injection molding, allowing for the production of hundreds of parts. With fine control of process parameters, the process repeatability should be acceptable for the majority of small-to-medium-sized parts.

Finally, the anisotropy in dimensional accuracy as well as the thermal management of AM tooling and dimensional accuracy of the cavity and core are some issues that have to be addressed in order to maximise tool life and part quality.

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A RESEARCH ON THE STATIC STABILITY OF THE MAVS USING VIRTUAL TUNNELS

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Abstract: This report discusses the using of a free software to determine the aerodynamic coefficients of a developed MAV. The coefficients obtained, as well as the aerodynamic forces and moments, have been investigated for their applicability in the balancing and static stability of this type of aircraft. The results of the work are used to synthesize a suitable autopilot.

Keywords: MINI UNMANNED AIR VEHICLES (MAVs), AERODYNAMIC COEFFICIENTS, BALANCING, STATIC STABILITY, FREE SOFTWARE, AUTOPILOT

1. Introduction

In the development of MAVs, it is necessary to select an appropriate control system to perform the tasks which are to be carried out by this type of aircrafts.

The synthesis of such kind of control system is directly related to the properties and characteristics of the MAVs. In this case, it is necessary to study in advance the object which is to be controlled in order to introduce characteristics close to the real ones in the algorithms of the MAVs flight-navigation complex.

A big challenge for the designers of the control system is the handling of non-standard airfoils, for which it is not known what the flying characteristics of the MAVs will be.

In order to reduce this uncertainty in the present work, the characteristics of static stability in the vertical and horizontal flying planes of non-standard airfoils for MAVs flying wing type were investigated.

For achieving this goal, it is necessary to observe the conditions of longitudinal and lateral equilibrium, to obtain the balancing diagrams and hence to determine the static stability of the longitudinal and lateral direction.

2. Stability research of a prototype of the developed MAV

For the development MAV, the equilibrium conditions in the longitudinal and lateral channels were first found, and then balancing diagrams were researched. Static stability in the vertical plane at glide angle has been established at $\beta = 0^\circ$ and at balancing deflecting angle δ_δ as well as in the horizontal plane at a balancing angle of attack $\alpha = \alpha_\delta^0$. For the purpose of the study, velocity was selected in the longitudinal direction $V_x = 3$ m/s.

The software product to be used as a virtual aerodynamic tunnel is XFLR5 [1, 2]. This product has its advantages and disadvantages. Its biggest advantage is that it is free and many developers prefer to work with it to study the characteristics of MAVs.

2.1. Stability research of a prototype of the developed MAV in longitudinal direction

The general case of longitudinal equilibrium of the MAVs is given by the expressions:

$$(1) \begin{cases} \sum X = 0 \\ \sum Y = 0 \\ \sum Z = 0 \\ \sum M_x = 0 \\ \sum M_y = 0 \\ \sum M_z = 0 \end{cases}$$

where the force indexes are aligned with the XFLR5 coordinate system designations [4, 5, 6] and α_p is the angle of mounting of the engine.

Equilibrium of the Forces by:

- the tangent to the trajectory is provided by the engine operating modes;
- the normal to the trajectory is ensured by the choice of the angle of attack.

In the longitudinal movement for balancing of the MAVs the pitching moment is determinative. The coefficient of this moment is given by the expression [3]:

$$(2) \quad M_{pitch} = \sum (C_{L_i} \cdot l_i) - \sum (C_{D_i} \cdot l_i)$$

It can be seen from (2) that for equilibration of the longitudinal moment four methods of balancing the MAVs in the vertical channel are used:

1. to use self-stabilizing airfoils for wing construction (first member of (2));
2. to move the masses in the MAVs so that it gets balanced (second member of (2));
3. to change the V-shape of the wing (third member of (2));
4. to change the angle of the elevator from zero to the balancing δ_δ (fourth member of the(2)).

The first method is inapplicable to this study because the airfoils were obtained when making a MAV from readymade templates. The second method produces a result within the range $\pm 4^\circ$ at negative attack angles, which is not acceptable.

The variation of the V-shape of the wing within the frame $\pm 10^\circ$ yields a result similar to the method described above.

For the purposes of the study, the result gives the last one that is the fourth method. In this balancing test is used only the elevator of MAV.

Figure 1 shows the longitudinal motion picture in the vertical plane in the environment of the XFLR5.

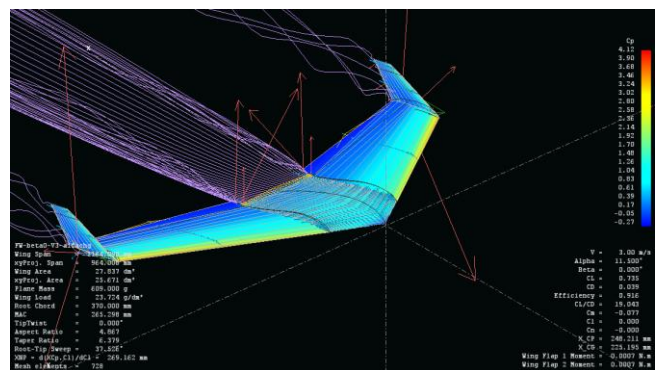


Fig. 1. Stability research of the developed MAV in longitudinal direction.

For the purpose of the survey, the angle of attack changes in the range $\alpha = (-20:6)^\circ$. The results obtained for the pitching moment coefficient $c_m = f(\alpha)$ and the lift force coefficient $c_L = f(c_m)$ are shown in Figure 2.

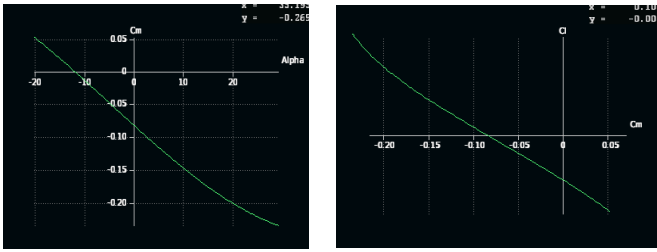


Fig. 2. Coefficients of the pitching moment and lift force.

From this figure (Figure 2) it can be seen that when $c_m = 0$ the angle of attack and the coefficient of lifting force are negative. This means that the model can not fly even though it is statically stable. In other words, it must be balanced in the vertical plane.

Another parameter which monitors the balance of the MAV in the longitudinal movement is the position of the center of pressures on the X axis (Figure 3).

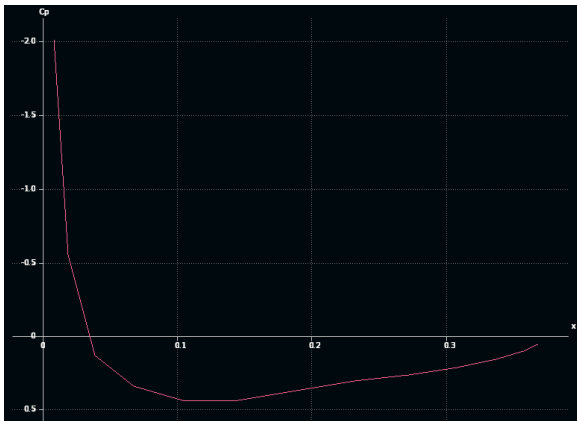


Fig. 3 The position of the center of the pressures on axis X.

Figure 4 shows the dependence of the coefficient of the pitching moment from the angle of attack after balancing deflection of the elevator.

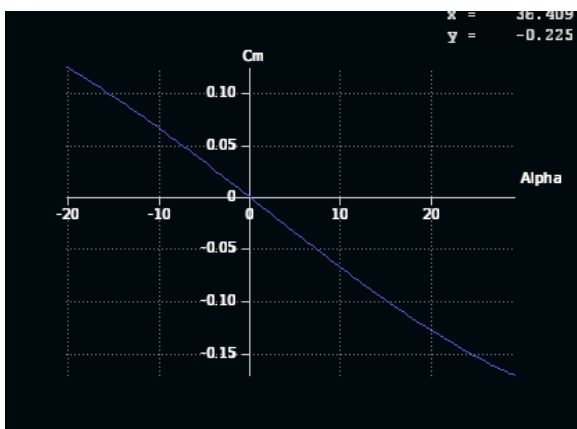


Fig. 4 Coefficient of the pitching moment in a function of the angle of attack

The results shown in Figure 4 are obtained at a balancing angle $\delta_e = -7.3^\circ$, which for the XFLR5 product means an upward deflection of the elevator. For the balancing angle of the attack is

obtained $\alpha = (28510^\circ)$ which is close to the computational error.

After balancing of the MAV on the pitch movement, it is checked for the lifting force coefficient (Figure 5).

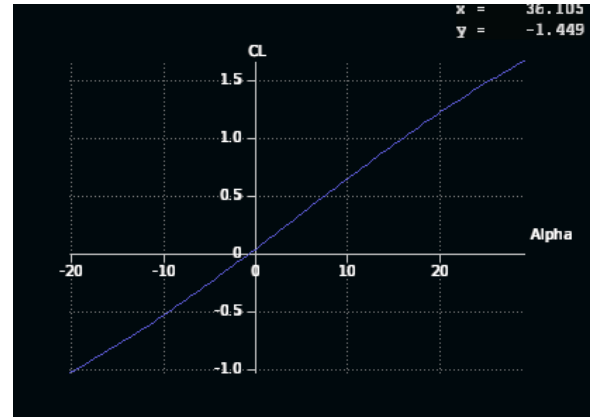


Fig. 5 Coefficient of the lifting force in a function of the angle of attack.

For the balancing angle of the attack, the coefficient of the lifting force is $c_L > 0$, which means that the balanced in the vertical plane MAV can fly.

The picture of the position of the center of pressure on the X axis (Figure 6) is now different from Figure 3.

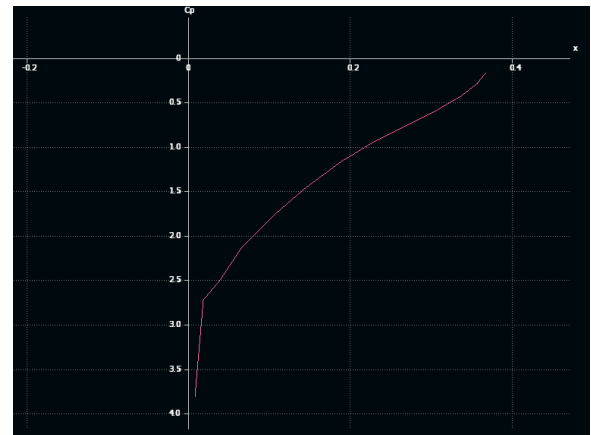


Fig. 6 The position of the center of the pressure on axis X after balancing

In Fig. 7, it is shown the change of the application point of the pressure center in the direction of the axis X in function of the angle of attack.

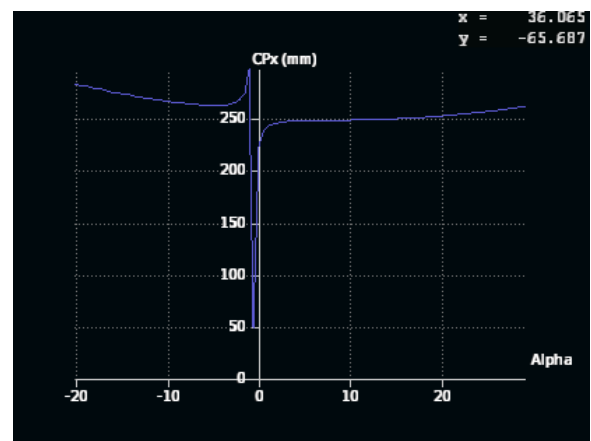


Fig. 7 Changing position of the point of the pressure in X-direction

From this graph (Figure 7) it becomes clear that there is no singularity at the angle of attack because the pressure point remains on the X axis and the pitch reference point coincides with the point of application of the pressures.

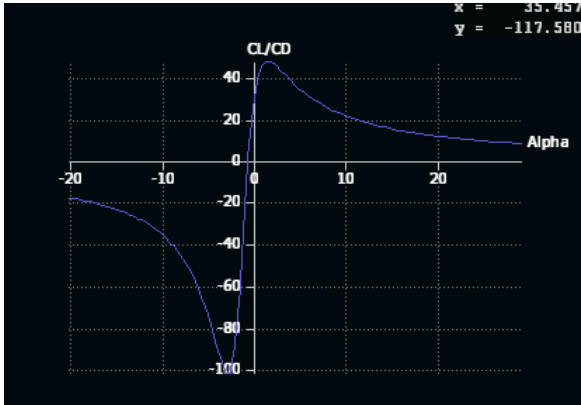


Fig. 8 The quality of the wing in a function of the angle of attack

The quality of the wing for this type of MAVs at angles of attack close to the balancing one approaches its best (Figure 8).

For MAVs operating at low Reynolds numbers with comparatively small variations in flight velocity, the balancing diagrams give a single value for the deflection angle of the elevator. Then, for the static stability of these aircrafts to the angle of attack, it is judged by Figure 4 and Figure 5. Based on these figures it can be concluded that the aerodynamic focus is behind the center of the gravity, which creates an additional pitching moment, striving to reduce the angle of attack - or the plane is statically stable to the angle of attack.

As the speed increases, the lift force of the investigated aircraft also increases. From there, the plane has a tendency to increase the angle of the trajectory slope and hence decrease its speed. At the expense of this trend, there is an extra pitching moment that seeks to counter the rise in the lift power. It follows that the aircraft is statically stable in speed.

2.2. Stability research of a prototype of the developed MAV in latitudinal direction

The conditions for static stability in the lateral channel are given by the equations [3]:

$$(3) \begin{cases} \sum F_x = Y_g \cos(\gamma) \cos(\beta) = 0 \\ \sum M_x = N_1 \beta + N_2 \delta = 0 \\ \sum M_y = N_1 \beta + N_2 \delta = 0 \end{cases}$$

which conform to the designations accepted in product XFLR5 [4, 5].

The exploration in the environment of the XFLR5 of the MAVs in the horizontal plane of the lateral movement is shown in Figure 9.

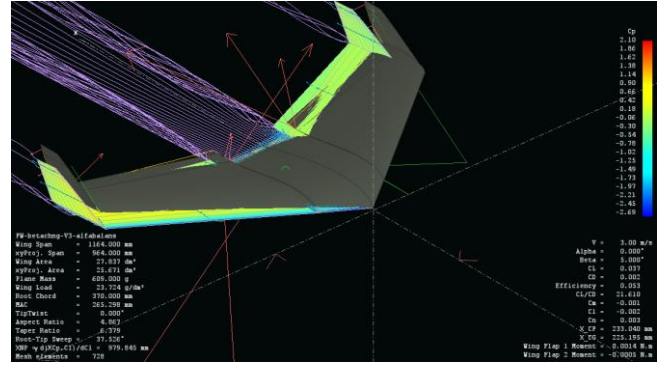


Fig. 9 Stability research of the developed MAV in lateral direction.

Consideration type MAVs are balanced in lateral movement only with ailerons. Then for the coefficients of the heading and lateral moment are gotten the following expression:

$$(4) \begin{bmatrix} r_{\beta} \beta + r_{\delta} \delta = 0 \\ r_{\beta} \beta = 0 \end{bmatrix}$$

When performing a flight with sliding angle, an aerodynamic force are appeared and applied to the lateral aerodynamic focus. In Figure 10 it is shown the dependence of the lateral force on the sliding angle.

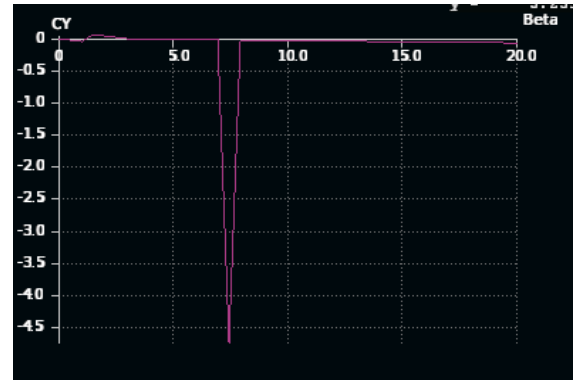


Fig. 10 Coefficient of the lateral force in a function of the angle of sideslip.

From Figure 10 it can be seen that, within the limits of the small sliding angles, the lateral force attempts to damping the fluctuation of the nose of the aircraft, but, as the sliding angle rises, this tendency is lost.

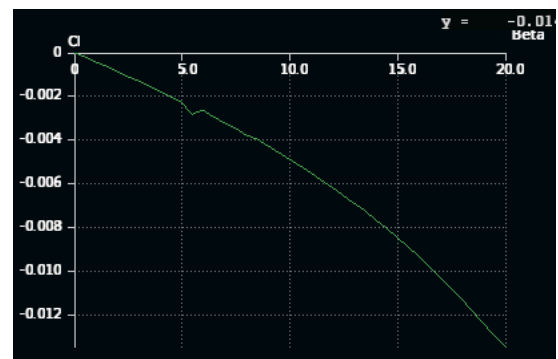


Fig. 11 Coefficient of the moment of rolling as function of the angle of sideslip.

As a result of the lateral force, a thrust moment is appeared. Its coefficient is shown in Figure 11 and a lateral torque has a coefficient shown in Figure 12.

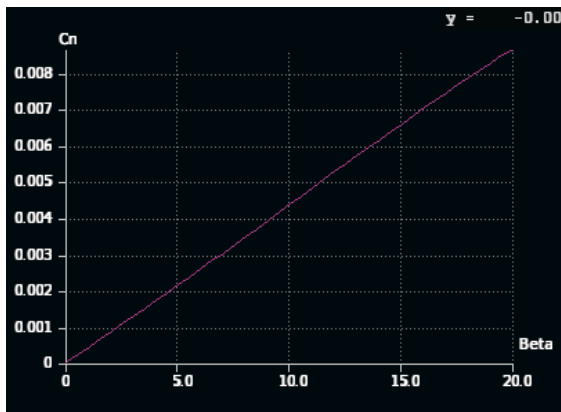


Fig. 12 Coefficient of the moment of heading as function of the angle of sideslip.

The rolling moment seeks to roll the plane and heading moment has tendency to remove the sliding.

The displacement of the lateral center of pressure relative to the sliding angle is shown in Figure 13.



Fig. 13 Changing position of the point of the pressure in Y-direction

For static heading stability it is judged from the results in Figure 11. It becomes clear that the center of gravity of the MAV lies in the front of the side aerodynamic focus, which is why the coefficient of the heading moment is negative. Therefore, this MAV is static stable in the heading.

Lateral static stability is established with results shown in Figure 13. In this figure it can be seen that the investigated MAV is statically unstable laterally.

3. Conclusions and results

1. MAV in longitudinal and lateral motion was investigated.
2. In the longitudinal movement MAV is statically stable in velocity and angle of attack.
3. In the lateral movement, studied MAV is statically stable in heading, but it is statically unstable laterally.

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ONE WAY FOR CREATING VISUAL EFFECTS

ЕДИН НАЧИН ЗА СЪЗДАВАНЕ НА ВИЗУАЛНИ ЕФЕКТИ

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Abstract: In this article is exposed one way for creating digital illustrations for commercial purpose. The method combines traditional drawing and calligraphy, 3Ds Max, VRay and Photoshop. The idea of the article is to demonstrate how to build an entire project from the scratch. The purpose of the article is to show how different software for graphic designing with different purpose can be combined together with a traditional art in order to achieve maximum as a result

Keywords: IMAGE, PHOTOSHOP, 3D STUDIO MAX

1. Introduction

The images and illustrations take big part in the modern world. But in order them to be successful and to attract the attention of the crowd it is needed to be created to different and creative way. All of the commercial worlds need illustrations for their purpose. In the article I chose to talk about how to make an illustration for a book cover. The cover shows different kind of arts – calligraphy, tinted glass, gems and wooden box. The purpose of it is to be a contrast of the created missing art in the world of the book.

2. Main part – Creation of an illustration for books, magazines and other commercial activities.

I decided to start the book cover with a hand drawing and later to continue with two different soft wares – Photoshop and 3Ds Max. And finally I mixed the work together in the final result. The idea of the cover is to do a calligram with a circular calligraphy with several rings. Then placing a wooden box in the middle of the canvas and disperse gems around the letters. The viewport of everything will be from above.

The first part of the project is doing a calligraphy. The needed materials for it are 100x75mm paper sheet, pilot parallel pens – 2.4mm and 6mm (can be found everywhere) and calligraphy ink. The idea is to make a circular calligraphy. To do this we first need to do a calligraphy web. To draw it we need to measure the length of each of the circles by using the formula $p=d\pi$ (where p is the length, d is the diameter). After calculating the lengths of each circle we draw a calligraphy line with the same length as the circle. To build the calligraphy line we draw lines for the capital letters, the small letters, the ascending and the descending letters. After calculating the lengths, the connections between the different circles and the space between them we draw the circles (including circles for the capital letters, small letters, ascending and descending) on the paper sheet (100x75mm) and then draw lines that divide the circles into sectors.

After the calligraphy web is done we need to work on the preferable design and to choose a calligraphy font (for example Fraktur, Textura, Copperplate, etc). Modern varieties of the fond Fraktur are used in the project. The final step in this part is to do a scan of the calligraphy.

For the second part we will use 3Ds Max and VRay. Autodesk 3Ds Max, formerly 3D Studio and 3D Studio Max, is a professional 3D computer graphics program for making 3D animations, models, games and images. It is developed and produced by Autodesk Media and Entertainment [1].¹ It has modeling capabilities and a flexible plugin architecture and can be used on the Microsoft Windows platform. It is frequently used by video game developers,

many TV commercial studios and architectural visualization studios. It is also used for movie effects and movie pre-visualization. For its modeling and animation tools, the latest version of 3ds Max also features shaders (such as ambient occlusion and subsurface scattering), dynamic simulation, particle systems, radiosity, normal map creation and rendering, global illumination, a customizable user interface, new icons, and its own scripting language [2].²

Vray is a render plugin. It's a plugin, which means that it adds functionality to an existing program. Vray's features mainly aim at creating photorealistic images, together with improving rendering speed. Currently, VRay exist for 3D Studio Max, Maya, Rhinoceros 3D, Sketchup, Softimage, Blender and there's even a standalone version available [3].³ It is developed by the Bulgarian company Chaos Group and you can find the plugin in their official site.

In 3Ds Max we will create the wooden box and the gems but we will work on two different projects for them. That's why I will divide this part in two smaller parts.

The chosen design for the wooden box is a hexagon. The lid is built with different colored small pieces of glass. To do it we start with building a cylinder and we set the sides to 6 so we can get a hexagon, cap segments – 1 and chose the radius and the height (in the project $r=50$, $h=45$). Afterwards we convert it in editable poly and start modifying the hexagon. We mark the face and use the inset tool (amount 5) to make 1 polygon inside then we use extrude to make the shape concave. This is our box (Fig. 1).

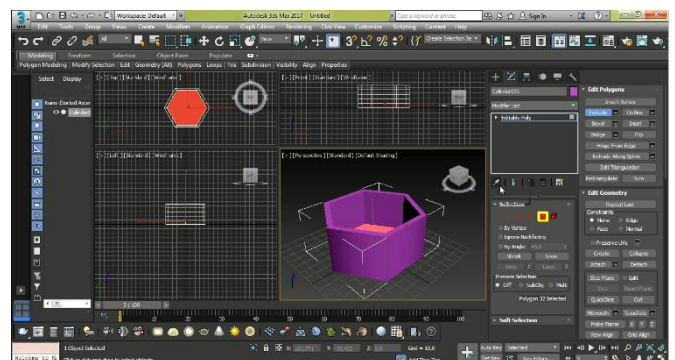


Fig. 1. The wooden box is a hexagon

Then we create another hexagon with the same radius and smaller height (in the project $h=10$). This will be our lid. Again we need to convert it to editable poly. This time we work on the two faces beginning with inset two times in a roll (used amount 1 for the first time and 32 for the second). The idea is with one of them to create the edge and with the other one the center, that's why one of them should be with small amount and the other with proper larger

¹ <http://slideplayer.com/slide/10560987/>

² <https://www.autodesk.com/products/3ds-max/overview>

³ <http://www.aversis.be/tutorials/vray/vray-20-what-is-vray.htm>

amount. Then we use it again on each segment of the hexagon as well as the center segment. We need to use again small amount (amount – 2). Then we mark the inner polygons on the two faces and delete them. We have a concave figure with empty trapezoids and an empty hexagon in the center. Afterwards we delete the edges that are not needed by marking them and using the Remove tool. We select the edges that are not connected and with Bridge tool we connect them (Fig. 2).

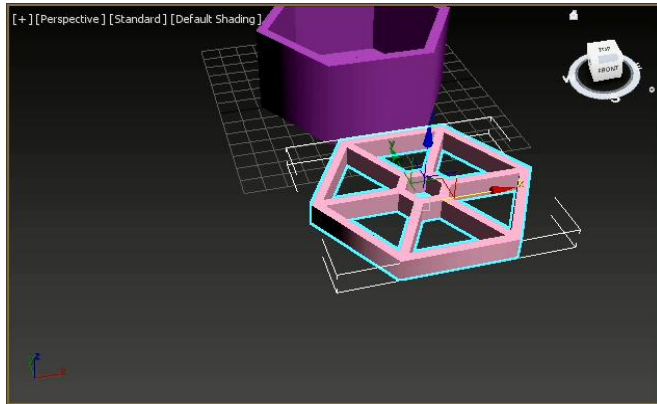


Fig. 2. Bridge tool

To design the glass pieces for the lid we need to create a simple box shape with less height than the lid (used Parameters: Length – 40, width – 40 height – 7; L, W, H Segs – 1). We place the box shape in one of the trapezoids of the figure and convert it to editable poly and by selecting the vertexes we modify it to a trapezoid. Then we make copies and rotate each copy in 60° on the Z axis from the previous and place them in the next trapezoid of the lid. Then we create a small hexagon with the same height as the box shape and place it on the proper place in the lid (Fig. 3).

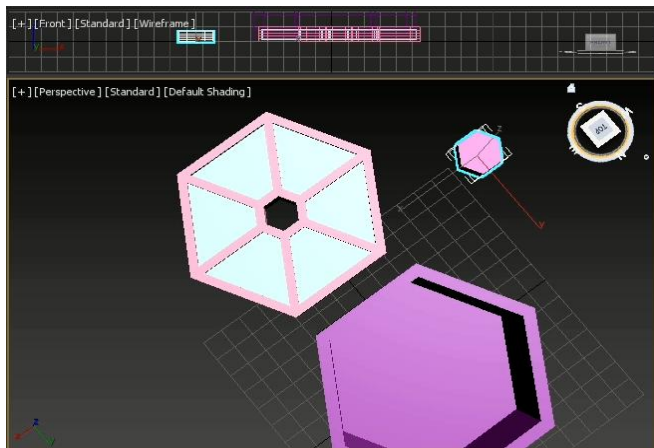


Fig. 3. The designing of glass pieces for the lid

To create the wooden material we need a prepared wooden texture in advance. Then we turn the render and light options to V-Ray mode so we can use V-Ray materials. We open the Material editor and from the Material/Map Browser we choose V-RayMtl to create a V-Ray material. From the options we change the Reflect color to middle grey (R: 35; G: 35; B: 35; H: 0; S: 0; V: 35); HGlossiness – 0,9; RGlossiness – 0,9; turn on Fresnel reflections; IQR Fresnel – 1,6; Max depth – 5; Refract color – black; Glossiness – 1,0; IQR – 1,6; turn on affect shadows. Afterwards we need to go to the button of the menu on Maps section. Then we set the Diffuse to our prepared wooden texture, picking it from the hard drive location. We drag the diffuse map with the mouse and drop it on Bump and we use as a method – copy. The bump amount should be 50 (Fig. 4). To finish this step we need to drag the material from the Material panel and drop it on the hexagon box and on the lid for it.

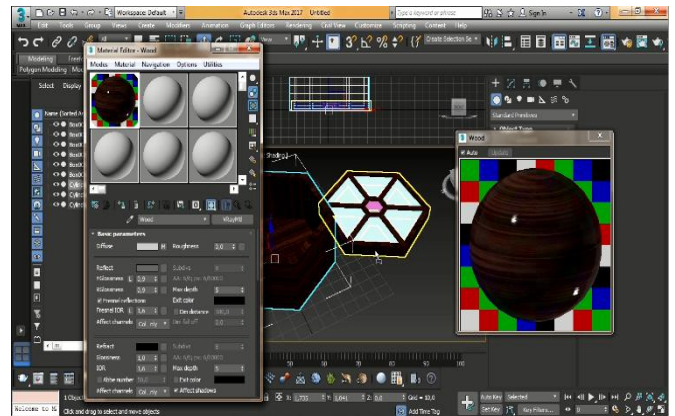


Fig. 4. Advance preparation of wooden texture

To create the tinted glass material we need to use again V-RayMtl. From the options we need to change the Reflect color – white; HGlossiness – 0,9; RGlossiness – 0,9; turn on Fresnel reflections; Refract color – white; turn on Exit color (on the Refract section) and change it to blue (R: 17; G: 5; B: 255; H: 172; S: 250; V: 255); Fog color – blue (R: 17; G: 5; B: 255; H: 172; S: 250; V: 255); Fog multiplier – 0,9 (Fig. 5).

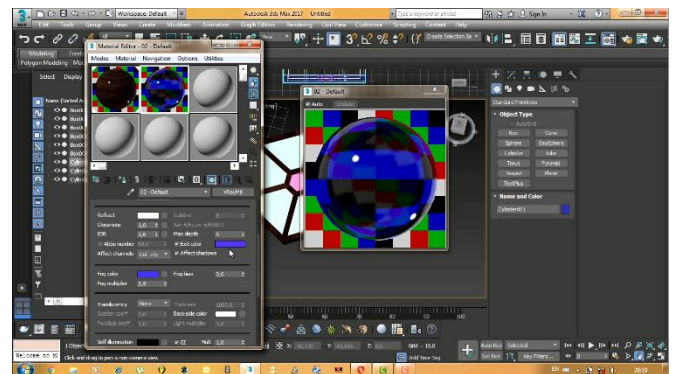


Fig. 5. Creation the tinted glass material

Since we want our glass pieces to be tinted in different colors we copy our material 6 times and change the Exit color and Fog color in each of the copies. (Used colors: Red – R: 255; G: 8; B: 8; H: 255; S: 247; V: 255; Purple: R: 83; G: 5; B: 170; H: 190; S: 248; V: 170; Orange: R: 255; G: 123; B: 5; H: 20; S: 250; V: 255; Green: R: 3; G: 181; B: 32; H: 92; S: 251; V: 181; Turquoise: R: 3; G: 227; B: 247; H: 131; S: 252; V: 247; Yellow: R: 252; G: 255; B: 9; H: 43; S: 246; V: 255;)

We move the lid on top of the box and design hinges by creating 2 little cylinders and placing them properly.

One of the most useful tools in producing computer animation is the ability to link objects together to form a chain. By linking one object to another, you create a parent-child relationship. Transformations applied to the parent are also transmitted to child objects. A chain is also referred to as a hierarchy[4].⁴ Common Uses for Hierarchies - Link a large collection of objects to a single parent so they can be easily animated and transformed by moving, rotating, or scaling the parent; link the target of a camera or light to another object so it tracks the object through the scene; link objects to dummy objects to create complex motions by combining multiple simple motions; link objects to simulate jointed structures to animate characters or mechanical assemblies [5].⁵

⁴ <https://knowledge.autodesk.com/support/3ds-max/learn-explore/caas/CloudHelp/cloudhelp/2017/ENU/3DSMax/files/GUID-0AE92021-9E16-4616-840B-B19773AD9A6E-htm.html>

⁵ <https://knowledge.autodesk.com/support/3ds-max/learn-explore/caas/CloudHelp/cloudhelp/2017/ENU/3DSMax/files>

We want to link the lid with the glasses and the box in a hierarchy so the lid can open freely. To do that we need to click on the Select And Link icon on the toolbar, select the glass pieces as children and then drag the link cursor to the wooden lid as a parent object. We do another link between the lid and the box. We select the lid and the hinges and drop the link cursor on the wooden box. (Fig. 6) Now we can open and close the lid. In the design the box is open so the light rays can go through the glass pieces of the lid.

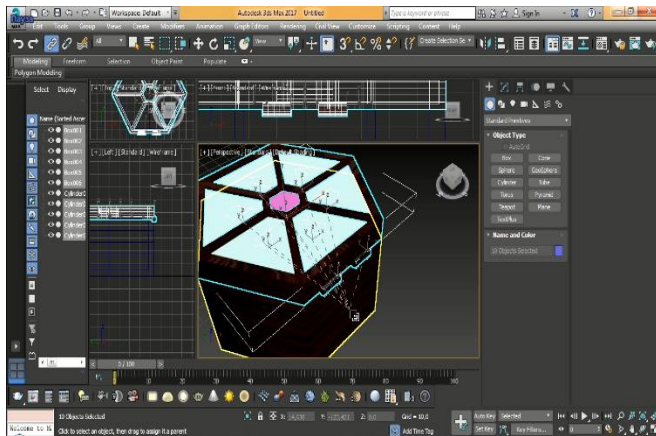


Fig. 6. Select And Link Tool in creation of the hierarchy links

We adjust the light by creating 2 VRayIES light and place them sideways. To design a studio scene we create a plane on the Z axis and change its color to white and leave the viewport on TopView (Fig. 7).

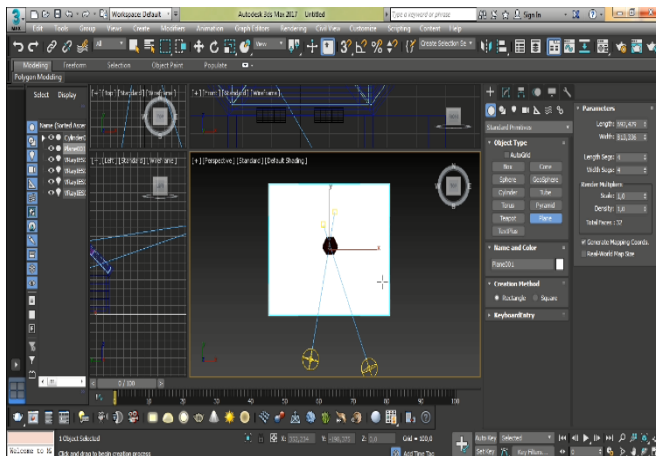


Fig.7. Scene adjustments in preparation for rendering

The final step is to open the Render setup and choose a resolution (used 1400x1050) and render the image and use to render the viewport.

The second 3Ds Max project is designing the gems. In order to do this we start a new project and create 7 box shapes (used Parameters: Length – 30, width – 30 height – 10; Length Segs: 1, Width Segs: 10, Height Segs – 1). We need to work on them one by one by converting them into editable poly and modifying their vertexes so we can get a shape similar to gems. (Fig. 8) We apply the same VRay glass materials. We adjust the light by creating 2 VRayIES light and place them sideways. To design a studio scene we create a plane on the Z axis and change its color to white and leave the viewport on TopView.

Then we open the Render setup and choose a resolution (used 1400x1050) and render the image and use to render the viewport.

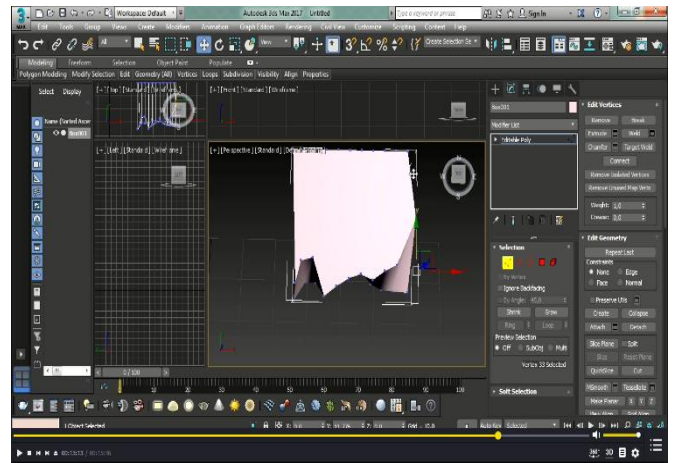


Fig.8. Modifying vertexes from box shape into different form

The final part of the project is in Photoshop where we will connect everything in one and finalize the project. Photoshop is Adobe's photo editing, image creation and graphic design software. The software provides many image editing features for raster (pixel-based) images as well as vector graphics. It uses a layer-based editing system that enables image creation and altering with multiple overlays that support transparency. Layers can also act as masks or filters, altering underlying colors. Shadows and other effects can be added to the layers. Photoshop actions include automation features to reduce the need for repetitive tasks. An option known as Photoshop CC (Creative Cloud) allows users to work on content from any computer. Photoshop is used by photographers, graphic designers, video game artists, advertising and meme designers. The software is available for a monthly fee. Photoshop CC is compatible with Intel-based Mac computers and Windows PCs[6].⁶ It can be found on their official web site.

First we open the image with the calligraphy and we need to erase the white background. In order to do it we click on the eraser tool from the Tool panel with the right button and a window with eraser tools will show. From there we need to select the Magic Eraser Tool. With it we erase the background with a simple click. We repeat the process in every closed space until the background is erased. After that we make color corrections from Layer – New Adjustment Layer – Curves and then Layer – New Adjustment Layer – Hue/Saturation. By that we add 2 adjustment levels for the colors and the contrast.

Then we open the image with the box and make color corrections from Curves. We drag it and drop it on the picture with the calligraphy which is our main picture and rename the layer to Box. We change the Blend Mode to Multiple and if needed erase and blur the background of the layer (Fig. 9).

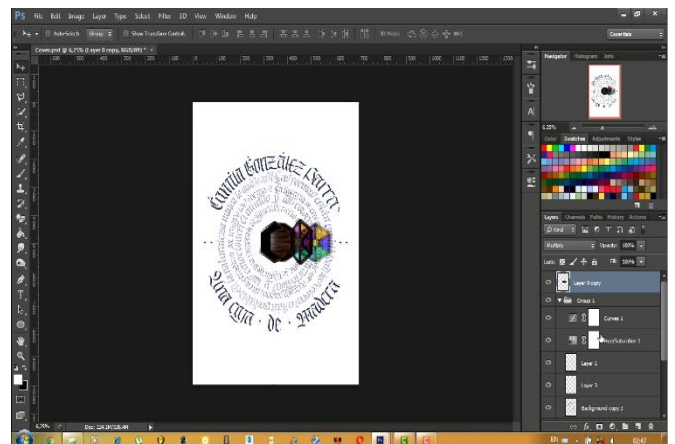


Fig.9. Converted Blend Mode into Multiple on the Box layer

⁶ <https://whatis.techtarget.com/definition/Photoshop>

We open the image with the gems and make color corrections from Curves and again drag and drop it in our main picture, renaming the layer to Gems. We clear the background of the layer and switch to the normal eraser tool to clear any imperfections around the gems. To change the positions of the gems we need to use the Lasso selection tool and mark the gem we want to reposition. By just using the commands ctrl+x (cut) and ctrl+v (paste) we cut the gem and place it in new layer (Note: we can find cut and paste in the Edit menu). We repeat this procedure with all the gems that we want to reposition. Than we merge the gem layers into one by marking them in the layer panel and right click – Merge Layers. Afterwards we need to change the Blend Mode to Darker Color (Fig. 10).

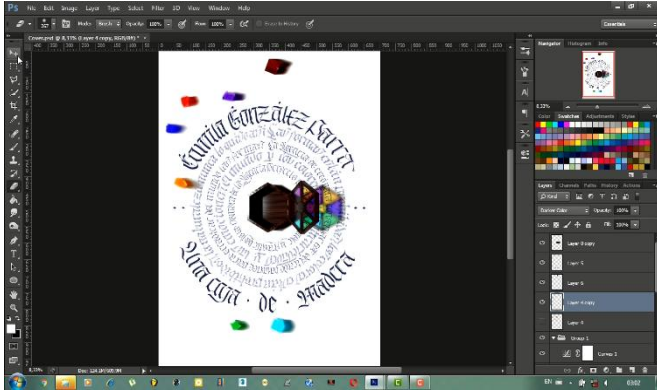


Fig. 10. Converted Blend Mode into Darker Color on the Gems layer

Final step is to add a layer below the calligraphy layer and to create a gradient between light and dark grey (d2d2d2 - 8a8989). We will use this layer as a background (Figure 11).

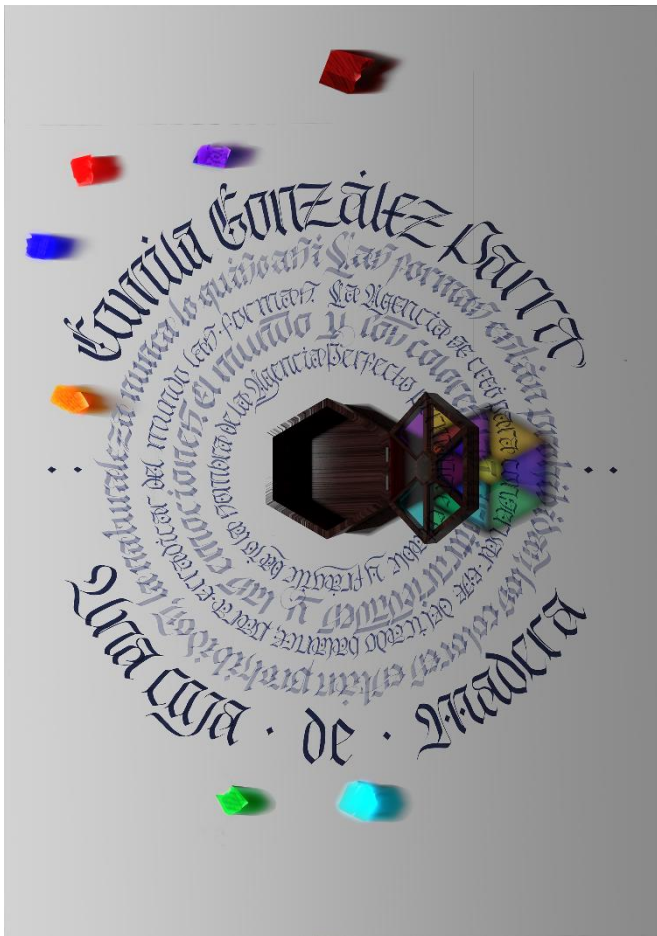


Fig. 11. End result

3. Conclusion

In the modern world there are many ways of creating an illustrations. The approach is in the hands of the creator, the one that builds the entire project. He is the one that organizes the idea and how to build every part of the project to the moment that he realize that idea into reality. In the end he is the first person he is satisfied by his creation and then the auditory that the product is targeted as well as the commercial purpose that is sought.

In a result of the following steps in the article we achieved a final illustration that is approved by the author of the book as well as the creator of the image. We used several different methods combining them to realize the final project.

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5. <https://knowledge.autodesk.com/support/3ds-max/learn-explore/caas/CloudHelp/cloudhelp/2017/ENU/3DSMax/files>
6. <https://whatis.techtarget.com/definition/Photoshop>

OPPORTUNITIES OF IMPLEMENTATION OF "INDUSTRY 4.0" FOR DEVELOPMENT OF TRANSPORT INDUSTRY IN UKRAINE

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Abstract: Due to intentions of Ukrainian economy to join European Union there are many threats and opportunities on the way. Ukraine has a number of industries producing goods, products and services needed in Europe. The growth of economic ties with EU makes Ukrainian manufactures stronger and has become a question of key importance during last decade. Meantime, Ukraine remains within rather tense conditions of technological lag but with some promising abilities in agriculture and food industries supplemented with a great potential in area of information technologies. This distinctive combination of abilities make it feasible for Ukraine both to become a strong partner for EU and to do a great leap of industrial progress within "Industry 4.0" concept. Nevertheless, one of crucial problems for Ukraine is to build an innovative infrastructure to meet requirements of intellectual transport system conforming to EU "Industry 4.0". This research paper is focused on discussion of these new features of transport industry and opportunities for Ukraine to make its transport industry a leading advantage for the whole economy. Those drastic changes in Ukrainian transport would procure an excellence for other industries implementing "Industry 4.0", the same as to become a test ground and an exclusive source of experience for EU on "Industry 4.0" implementation.

Keywords: INDUSTRY 4.0, TRANSPORT INDUSTRY, UKRAINE, SMART FACTORY, AUTONOMOUS RAILWAY

1. Introduction

There are many aspects of "Industry 4.0" remaining a mainstream for development of modern economics during recent years [1]. A great interest to develop the concept of "Industry 4.0" in Europe was led by German governmental efforts since 2010 [2]. Many other countries within European Union payed much attention to develop and adopt those concepts for needs of their own. Actually, the interest to "Industry 4.0" became one of the key features in contemporary globalization [3]. One of the key problems felt to become crucial is the problem of building new infrastructure to support "Industry 4.0" and to update transport logistics. Some countries, like Austria, are doing efforts to find their own place in circumstances of a new world economy [4]. Some researchers are investigating the scope of problems of "Industry 4.0" [5–7] or solving some particular problems like "learning" or "smart" factories [8]. One should understand the complexity of the problems being raised by "Industry 4.0". It requires consolidating efforts of both governments, businesses and society, with the support of some NGO, like EFFRA (European Factories of the Future Research Association) and others. Despite of progress in technologies development to build smart factories and to automate goods production, there are some important aspects of supporting the factories supply chains and ensuring both continuous resources supply and products distribution. This yields different thoughts about changing transport and logistics [9].

Present research discusses the problem of implementation of "Industry 4.0" and its opportunities for Ukraine to find own place within newly built European economy. The particular attention is focused on transport industry of Ukraine as a fundamental basis to connect Ukrainian factories with European Union and to meet challenges of global logistics. According to agricultural potential of Ukraine [10], we are making some accent to agriculture and food industry.

2. Prerequisites and means for solving the problem

Ukraine is a very good situated from the point of view of geographic position (Fig. 1). There is a center of an imaginary "crossroad" connecting Europe with Asia and Africa: the cross lines from Ireland to Japan and from Sweden to Egypt. The crossroad falls directly in the Western Ukraine near the city of Lviv. Moreover, it is not the only convenience: Lviv, as a western gate of Ukraine, is a center of 800 km circle with almost equal distance both to a port of Riga in Latvia and to a port of Varna in Bulgaria (Fig. 2). There are ports of Odesa in Ukraine, Gdansk in Poland

Kaliningrad in Russia and Klaipeda in Lithuania within the distance. Straight line of 800 km in length reaches also Berlin and Dresden in Germany, Sofia in Bulgaria, Salzburg in Austria, Constanța in Romania, Ljubljana in Slovenia, Zagreb in Croatia, Sarajevo in Bosnia and Herzegovina, Prishtinë. There are inside this circle the whole Belarus, Lithuania, Poland, Moldova, Romania, Hungary, Slovakia and almost whole Czech Republic, most territory of Austria, Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Bulgaria and Latvia.

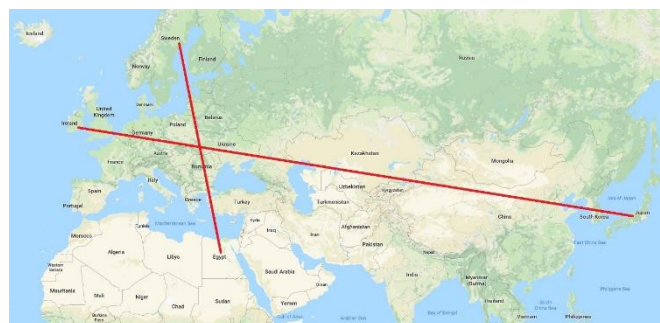


Fig. 1 Geographic location of Ukraine as a "crossroad" (map retrieved from Google Maps)

This can be the motivation to consider Ukraine as a good location for the purposes of logistics: placing transport and storage facilities, organizing transport hubs etc.

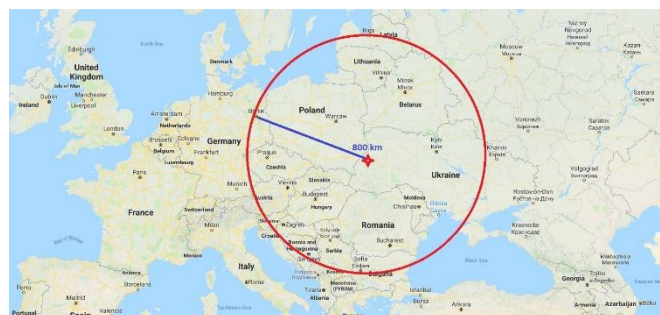


Fig. 2 Geographic location of Lviv in Western Ukraine: 800 km circle (map retrieved from Google Maps)

One may wonder about the distance of 800 km that we choose for the circle radius at Fig. 2. We offer a very easy explanation for that. The simplest way to define a distance is to multiply an average speed to a maximum time limit for transportation:

$$\text{Distance} = \text{Speed} \cdot \text{Time}. \quad (1)$$

According to equation (1), it is very easy to guess a possible distance of transportation with respect to maximum possible speed for each type of transport (see Table 1). We considered for Ukraine three types of transport: air, railway and auto. Due to speed limits for auto transport, we assume its possible speed up to 60–120 km/h. Both air and railway transport we can divide into two groups each – fast and regular. Due to current experience of railway transport in Ukraine, there are two evident speed groups: a regular one with old rails (trains move slow enough here, 50–100 km/h) and a fast one with a newer rails (trains move fast enough, 120–180 km/h, but it is not a high-speed rail yet). The speed groups for air transport represents typical speeds of the planes. For example, many planes (similar to Boeing-737 or Airbus A 320) can fly faster than 800 km/h and up to approximately 1000 km/h (for Boeing-747 or Airbus A 380), and some Ukrainian transport planes (like An-124 “Ruslan”) has a regular speed 800–850 km/h. Meanwhile, there are many planes in Ukraine like An-24 or An-12 having regular speed about 460 km/h or 550 km/h, but definitely less than 800 km/h. That is why consideration of fast and regular speed groups for railway and air transports in Table 1 seems reasonable.

Time	Transport	Speed	Distance
< 1 hour	Air (fast)	800–1000 km/h	800–1000 km
	Air (regular)	400–800 km/h	400–800 km
	Railway (fast)	120–180 km/h	120–180 km
	Railway (regular)	50–100 km/h	50–100 km
	Auto	60–120 km/h	60–120 km
< 2 hours	Air (fast)	800–1000 km/h	1600–2000 km
	Air (regular)	400–800 km/h	800–1600 km
	Railway (fast)	120–180 km/h	240–360 km
	Railway (regular)	50–100 km/h	100–200 km
	Auto	60–120 km/h	120–240 km
< 5 hours	Air (fast)	800–1000 km/h	4000–5000 km
	Air (regular)	400–800 km/h	2000–4000 km
	Railway (fast)	120–180 km/h	600–900 km
	Railway (regular)	50–100 km/h	250–500 km
	Auto	60–120 km/h	300–600 km
< 12 hours	Air (fast)	800–1000 km/h	9600–12000 km
	Air (regular)	400–800 km/h	4800–9600 km
	Railway (fast)	120–180 km/h	1440–2160 km
	Railway (regular)	50–100 km/h	600–1200 km
	Auto	60–120 km/h	720–1440 km

Nevertheless, analysis of possible distances with respect to shortest elapsed time for the transportation reveals that less than 800 km distance allows satisfying supply demand with almost any type of transport. For the purpose of accuracy, one should consider also a cost of each type of transport. However, in case of our study we may disregard this cost as a yet unknown value for future robotic transport (like a drone air transport, or a railway robotic locomotive, or an autonomous truck).

Finally, to understand the system of railways and airports in Ukraine, one should consider Fig. 3 with the six divisions of Ukrainian national railways (named “UkrZaliznytsia”) and Fig. 4 with the seventeen international airports of Ukraine.

Answering all these questions requires a deep and detail analysis. We are conducting current research to clarify the vision of what should become the first step for Ukraine within the way to join “Industry 4.0” and to meet demands that could be the most valuable for European neighbors.

Fig. 3 Railways map of Ukraine (map retrieved from <http://railway.lviv.ua/info/maps/>)

Fig. 4 Airports map of Ukraine (map retrieved from Google Maps; airports list retrieved from Wikipedia [12])

First, Ukraine needs to make a tight economic connection with European Union. The best binds to any European country starts with a well-developed transport system. This point comes directly from discussion in previous section. As we have mentioned above, Ukraine may use a convenient geographic situation. One of the most promising routes goes between Baltic and the Black seas.

Unlike to other opportunities to cross the Europe from the North to the South (or vice versa from the South to the North) there is great advantage of the Ukrainian route – plain terrain with no mountains and seaports on both sides (see Fig. 5). The idea of using this route is not a new one. There was a “Sarmatia pipeline” (also known as Odessa–Brody) had been built with possible extension to Plock and Gdansk [13]. However, pipeline is a good example revealing the geographic convenience of the route. Another advantage to use the route Gdansk–Lviv–Odessa is that there is an opportunity to use sea transport on both ends of the route and only two countries (Poland and Ukraine) can be involved directly to control the whole route length (this may minimize political risks). Moreover, there is an existing railway connection. Due to examples of successful efforts in developing transport connections with Europe over the railways [14], Ukraine may keep going further and within “Industry 4.0” offer to develop a remote-controlled railway transport with robotic locomotives (we may call this an “autonomous railway transport”). Developing two new robotic railway hubs in Odessa and Lviv may provide European partners with a reliable, secure, fast and cheap transport corridor through Ukraine. Connecting Lviv railway hub to a Central European logistic hub in Austria [4] may boost creation of automated factories across the Central and Eastern Europe, while Ukraine may become a reliable supplier of resources over autonomous railway transport. Eventually, an autonomous railway is considerably more convenient and secure compared to autonomous vehicles. The idea of autonomous transport in Ukraine can be also developed in areas of air and river transports. Nevertheless, the railways now looks like a cheaper and easier way.

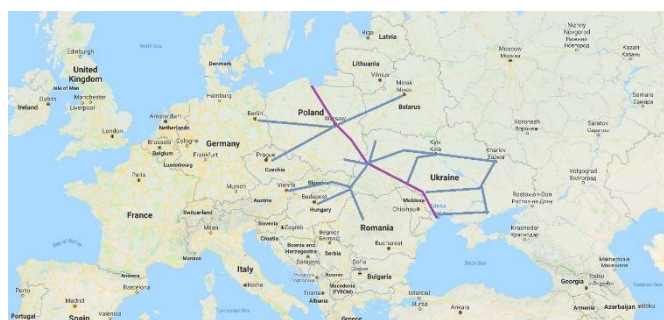


Fig. 5 Possible schema for Gdansk–Lviv–Odessa route (purple line) and its extensions (blue lines)

Second, Ukraine must offer some valuable own services and products to EU and, obviously, Ukraine have to consume some European services and products. Evidently, the use of autonomous railway transport allows Ukraine to join a brand new world of European “Industry 4.0” economy with its automated factories and European factories of the future. Meanwhile, Ukraine has a potential not only to build a railway locomotives, but also to make these locomotives smart with a support of its fast growing IT industry. Obviously, there is a need to rely on some best European technologies in locomotive building and railway transport, including IT infrastructure (datacenters services, cloud technologies etc.) and necessity of IT-support for autonomous railway transports. This cooperation of EU and Ukraine within “Industry 4.0” concept is supposed to become a great opportunity for both sides to develop new design of intellectually automated supply chains and to provide resources transition directly from areas of its origin to the factories to satisfy its demands “just-in-time”.

Third, Ukraine may offer an automated access to its agricultural regions and boost development of its food industry. Further development of autonomous railway may extend the ability both to use big agricultural areas in Ukraine and to support the exchange of food and agricultural products between EU and Ukraine. Another option for Ukraine is to support its metallurgy factories and mining facilities with a reliable transport to supply its products to their European partners and to the European future smart factories. Although, the current state of Ukrainian agricultural and food industry could be possibly more preferable to join new autonomous railway corridor at the first stage. At the same time, EU can be

interested in autonomous railway transport to use Odessa port to export products to Middle East, Caucasian Region and Central Asia.

4. Results and discussion

Implementation of the offered ideas allows expecting a deeper integration of Ukrainian economy to new coming EU economy of “Industry 4.0” era and strengthen the Ukrainian economy simultaneously. The solution looks evident and easy enough to develop successfully within existing circumstances.

5. Conclusion

The key result of present research is an idea to use autonomous railway transport. This may become both a simple and a cheap way for Ukraine to meet demands of supply for European smart factories (or “factories of the future”) within concepts of “Industry 4.0”. Implementation of the idea of autonomous railway in Ukraine we offer to start from construction of Trans-European autonomous railway “Gdansk–Lviv–Odessa” to connect Baltic and Black seas. Meanwhile, building the new robotic locomotives in cooperation with EU. Making locomotives smart can base on capabilities of a fast growing Ukrainian IT industry. Involving agriculture and food industry of Ukraine to exploit new autonomous railway transport may boost its development and become a great experience of implementation of “Industry 4.0” in Ukraine.

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ECONOMIC ASPECTS OF THE DEVELOPMENT OF INFORMATION AND COMMUNICATION TECHNOLOGIES IN UKRAINE

Экономические аспекты развития информационно-коммуникационных технологий в Украине

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Abstract: Information society is considered as a new stage in the human development, which is characterized by the dominance of information, information products, information technology and communications. The existence of interconnection of processes of globalization and informatization of social life are proved. The trends of information technology development and the main segments of the potential market of information technologies are determined. It is proposed to consider the use of information technologies as a complex of interrelated scientific, technological and engineering disciplines, that study the methods of efficient organization of labor engaged in the processing and preservation of information; computer techniques and methods for organization of their interaction with people and production equipment, and related social, economic and cultural issues. Virtualization has become the main trend that changes the IT infrastructure. The basic idea is to concentrate all resources of different physical systems in one large pool. As a result, there are various problems of information security, that should be taken into account. A number of business requirements that will increase demand and minimize costs to maintain the required level of service are proposed. The groups of factors that lead to an increase in economic benefits through the using of CALS-technologies are examined. The market of information infrastructure, dynamics of Ukraine's ranking on the level of development of information and communication technologies in the world are analyzed. It is determined that today in the information-telecommunication aspect Ukraine has no competitive advantages in international markets in comparison with developed countries. It is concluded about the main tendencies of the development of information and computer technologies and information and consulting services. The necessity of creating favorable conditions for the development of information and communication technologies in Ukraine is substantiated. This requires new approaches to the development of financial institutions that provide the accumulation and redistribution of financial resources for the implementation of effective structural changes. It is proposed to consider the fundamental economic strategy for the development of information and communication technologies in Ukraine not as a matter of public policy. Information and communication technologies should be transform into the subject of direct consumers', producers' and investors' interests. The state should create certain principles and conditions, diversify organizational forms and attract non-traditional sources for innovation in the field of information and communication technologies. The advantages that Ukraine can get through accelerated innovative development of information and computer technologies are determined.

KEYWORDS: INFORMATION SOCIETY, INFORMATION TECHNOLOGY, COMMUNICATIONS, ECONOMIC STRATEGY, VIRTUALIZATION, INFORMATION INFRASTRUCTURE

1. Introduction

Information society can be considered as a new stage in the human development, which is characterized by the domination of information, information products, information technologies (IT) and communications both in the field of production (Industry 4.0) and in the sphere of consumption, as well as the formation of the information industry as part of the national economy [1].

There is a close relationship between the processes of globalization and the informatization of public life. Such interdependence is obvious, because "on the one hand, information technologies cause "compression" of space, provide an opportunity for rapid interaction between different points of the globe, and on the other hand, there are global processes such as: liberalization, transnationalization, internationalization of production and capital allow the spread of the latest technology everywhere" [2].

Information technologies are the use of computer technology and communication systems for the creation, collection, transmission, preservation, processing of information in all spheres of public life [3]. Recognizing technological advances in the era of information technologies, one can identify the main directions of their development (Figure 1).

Ensuring the use of information technology is as a complex of interrelated scientific, technological and engineering disciplines, that study the methods of efficient organization of labor engaged in the processing and preservation of information; computer techniques and methods for organization of their interaction with people and production equipment, and related social, economic and cultural issues.

Globalization is directly related to the convergence that forms

today the potential market for information technologies, the main segments of which are the following elements [4]:

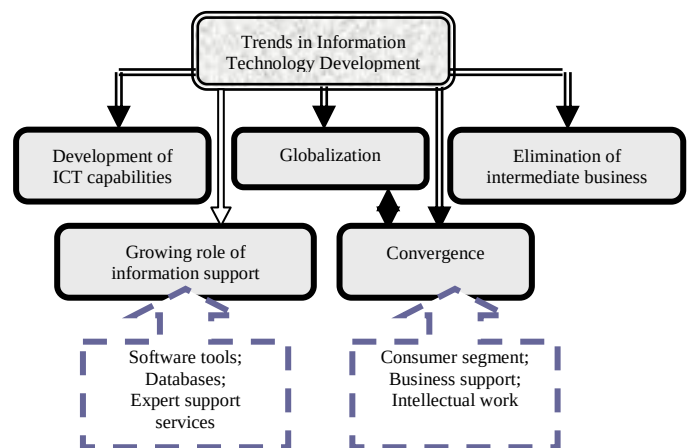


Figure 1. Trends in Information Technology Development

- consumer segment – it includes transfer of information to private individuals;
 - business support – it includes the use of products and services of information technologies in the implementation of various types of business activity;
 - intellectual work – it refers to the use and transfer of information among managers and other professionals.
- Information market through the use of information resources,

products, technologies and services and with the help of IT performs one of its main objectives – providing information in all spheres of public life.

It is well-known that IT and communications provide an opportunity for the rapid transfer of information, funds regardless of distances, and thereby ensure the creation of a global information space. Thanks to IT, it became possible for more free placement of production, without binding to developed countries.

2. Virtualization of IT technologies

The main trend that changes the IT infrastructure is virtualization. Virtualization technology makes information resources autonomous and independent. A global study by Penn & Berland Associates shows that 86% of IT executives plan to virtualize 75% of existing IT resources in the nearest future. According to CIO Research, 85% of companies use virtualization of servers, 37% - virtualization of storage systems, and 34% - virtualization of office systems [5].

Virtualization of storage of information separates physical storage systems from their logical representation. The basic idea is to concentrate all the resources of different physical systems in one large pool, from which it is easy to allocate storage space of different servers with different operating systems. The virtualization effect is especially noticeable where you need to replace a large number of physical servers. The cost structure of the virtualization project includes: equipment – 20-30%, software licenses – 30-40%, consulting and implementation work – 30-40% [6].

Cloud computing technology provides network access for each user to a flexible and defined set of physical or virtual resources at a certain scale, which can be independently used and regulated as needed. Referring these technologies to breakthroughs, experts and scholars predict that in the nearest future, their strong influence on markets, economics and society will grow [7].

In a cloud computing environment, all data is on many network resources that allows access to data through virtual machines. Since these data centers can be located in any part of the world beyond the reach and control of users, there are various security issues that need to be addressed.

At the same time, in terms of business, the following requirements are put forward:

- 1) the continuity of the service;
- 2) reservation;
- 3) scaling the data cluster;
- 4) automatization of technological operations.

The specified requirements allow to increase demand, and also to minimize expenses for maintenance of necessary level of service. At the same time, cloud providers have additional problems. After all, customers need a dynamic real-time scaling, which provides elasticity of replenishing or removing resources as needed. In turn, this process allows you to use a variable cost model and provide dynamic allocation of resources in real-time with correction for peak load, computing power, bandwidth and storage resources.

Virtual technology includes the CALS technology, which has emerged over the past 25 years in the United States and other developed countries. It is a paperless technology that embodies the electronic description of processes and products throughout their life cycle. It is their virtual, faultless and error-free support from development – to utilization. Products can be created by partners from different countries, language of communication – standards, means of communication – global computer networks.

The increase in the economic benefits of CALS-technologies is determined by five groups of factors [8]:

1. Intensification of the use of information resources due to the simultaneous multiple use of numerous users.
2. A record reduction in the time of release of products on the market and the conquest of the largest volume of market for a new product.
3. Decrease in the fixed costs due to the intensive involvement of fixed assets in the production cycle.

4. Significant decrease in the value of inventories and working capital.

5. Improving the quality of products at the expense of: reducing to 40% of the number of products that are lacking in the company's technical control department; reduction to 80% of the amount of processed products.

The problem of data integration and integrity is solved at all stages of the product life cycle at the same time. This radical distinction has caused the main economic advantage of CALS-technology.

Today there is a tough competition for the redistribution of world market space in the field of information and computer technology. Due to the spread of "cloud technologies", that were previously in different business segments of the market, the interests of the largest global companies are confronted and aggravated.

Internet is a universal communication space, in which very different interests and values coexist. Of course, the spread of information and communication technologies is uneven across countries and sectors of society. It should be mentioned prospect of transition to the information age depends primarily on the availability of education for all segments of the population, as well as the opportunities of operative learning and processing information [9].

3. Development of information infrastructure in Ukraine

The formation of the information society and infrastructure has played an important role in the innovative activity of the developed countries, as the key to the active introduction of innovation in the economy is the exchange of information. All this requires the further development of information infrastructure.

According to the Global Information Technology Report, 2016, published by World Economic Forum, Ukraine ranked 64 position among 139 countries, improving its results by 7 points in a year.

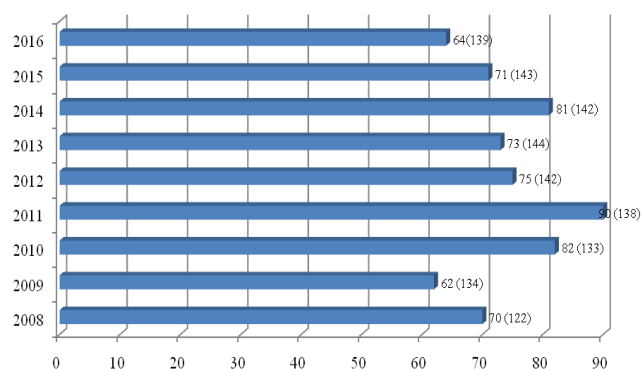


Figure 2. Rating Ukraine on the level of development of information and communication technologies [10]

International Scientific Congress "Information Society in Ukraine: The Current State of the IT Segment and Its Development Trends", held in Kyiv on October 25, 2012, formulated the main thesis for the further development of the information economy: "The development of "a new economy" was impossible without the telecommunications sector – the main instrument of management of the information flows of modern society and the basis of the economy in its modern sense".

However, the section "Information Society" appeared on the official web-site of the State Statistics Service of Ukraine (www.ukrstat.gov.ua) under the heading "Publications" only in the Statistical Yearbook of Ukraine for 2015 (for example, in the United States, regular IT surveys of companies on IT spending started with 2003).

According to the Table 1, it can be seen that in the field of informatization in 2016 there were 11932 enterprises and organizations, the main type of activity of which was the provision of services. That indicator was by 5.6% less than in 2010. The total number of IT specialists in Ukraine at the end of 2016 was 157.1 thousand people, which was 31.2% less than in 2010.

For 2016, the sales of services in the spheres of information and telecommunications are 117407.2 million UAH. The operating profit margin of the information and communication enterprises in 2016 increased by 1.1 percentage points compared to 2010.

Table 1

Key structural indicators of enterprises about providing information and communications in Ukraine [11]

Indicators	2012	2013	2014	2015	2016
Number of enterprises, units	13448	14885	13319	13617	11932
Number of employed workers, thsd. persons	219,5	218,1	192,7	166,4	157,1
Sales of goods and services, mln. UAH	79354,9	80410,4	84103,6	100590,4	117407,2
Computer programming consulting and related activities, mln. UAH	11654,2	14486,9	18547,3	29670,6	31550,1
Telecommunications, mln. UAH	44574,5	44088,7	44832,7	47650,8	48330,1
Earnings before tax, mln. UAH	6300,1	6817,7	-15379,9	-10166,6	4197,9
Operating profit margin, %	10,5	11,8	-1,6	0,5	8,5

Access to information for the public is becoming more and more accessible. Number of users of computer communication, including Internet, is growing at a fast pace (Table 2).

Table 2

Number of Internet users in Ukraine [11]

Indicators	2012	2013	2014	2015	2016
Internet subscribers, thsd. persons	4904	5435,3	6122,5	6000,6	14203,2
including home internet	4432	5002,4	5645,5	5557,3	13122
Computer communications services, mln. UAH	5401,6	5697,2	6190,4	7144,3	9101,8
including providing access to the Internet	4673,1	4908,5	5348,9	6130,5	6054,6
including public	2925,3	3284,7	3733,9	4125,7	6476,8

In the information and telecommunication aspect, Ukraine today has no competitive advantages in international markets compared to developed countries. This applies both to qualitative and quantitative indicators that characterize the relevant segment of the domestic market at the present stage. The greatest cumulative value for the development of the domestic economy is concentrated in the telecommunications sector of the following types of communication: mobile, satellite, as well as computer, which is responsible for incorporating the Ukrainian economy into the global Internet information space.

Table 3 illustrates the use of personal computers (PCs) and computer networks of the investigated enterprises of Ukraine (according to the results of the monitoring of the State Statistics Service of Ukraine).

The development of information and computer technologies and information and consulting services in Ukraine reflects the following trends:

- a rapid decline in the price of Internet access;
- mobile communications covering information processing and electronic document transfer services;

- information exchange moves from a centralized and hierarchical model to decentralized, horizontal, evenly distributed and democratic;

- the transition from the sale of computers to their free transfer or sale for a nominal fee with monthly payment for access to services;

- distribution of computerized interactive TVs;

- creation of clusters or zones of universal access to Internet services with the help of wireless technologies;

- development of electronic document circulation in all spheres.

Table 3

Use of computers and computer networks by enterprises, Ukraine, 2016, units [12]

Indicators	Investigated enterprises			
	total	including		
		small < 50 workers	medium-sized 50-249 workers	large > 250 workers
The number of enterprises used PCs during the year	39540	29073	8339	2128
Number of PCs at enterprises	1199001	260174	301080	637747
Number of PCs with internet access	38825	28428	8277	2110
The number of enterprises used internal computer network	24727	16387	6387	1953
The number of enterprises with Intranet network	25937	18396	5916	1625
The number of enterprises with Extranet network	3665	1898	1136	631
The number of enterprises used wireless access to the internal computer network	27907	19483	6531	1893
The number of enterprises with mobile Internet connection	9723	6414	2450	859

4. Prospects for the development of information and communication technologies (ICTs) in Ukraine

The formation of a national strategy for the development of the ICT sector in Ukraine will lay the foundations for an integrated national strategic management system aimed at ensuring achievement, and then long-term retention, a high level of global economic competitiveness of the country. Creating favorable conditions for the development of this area requires new approaches to the development of financial services institutions that provide the accumulation and redistribution of financial resources for the implementation of effective structural changes.

The basic economic strategy for the development of the sphere of ICT in Ukraine is to not first consider ICT as a subject of state policy, but to turn ICT into the direct interest of consumers, producers and investors by:

- 1) encouraging the subjects of the national economy to invest innovatively in order to increase the supply of innovative products, technologies and knowledge (investing directly in the sphere of ICT and in introducing elements of ICT into traditional branches of economy and spheres of life);

- 2) creation of conditions for the domestic enterprises to implement an offensive strategy in foreign markets, support of constructive competition in the domestic market, which will encourage enterprises to innovate;

- 3) the diversification of organizational forms of the national economy functioning, the provision of cooperation between small, medium and large enterprises in the field of development, implementation, production and sales of ICT products, development of scientific and production cooperation, industrial and financial integration, venture business, including the international level;

- 4) the transformation of "shadow" capital and the involvement of the "shadow" sector in investing, and expanding on this basis own enterprise resources for innovation activity in ICT.

5. Conclusion

Information technologies are not the main reason for the changes that society is experiencing at the present stage of its development. However, such changes would not have been possible in the absence of new information and communication technologies. Moreover, our planet is incorporated in the global telecommunication computer network, which is the basis for local information systems and communication processes.

Accelerated innovation development of information and computer technologies will allow Ukraine to:

- create new jobs and increase the level and quality of life of the population;
- balance interregional disproportions;
- ensure sustainable economic growth;
- enter the international markets of information products;
- integrate into international organizations;
- increase the inflow of foreign investments;
- accelerate economic reforms in Ukraine;
- build an information society.

Information nature of the present stage of civilization evolution determines the situation when no country without an effective entry into the world information space can't successfully compete in the sectors of high and medium technology not only on external but also on the domestic market. Today it is not enough to link the development of the information society only with the solution of problems transmission, access, processing and storage of information or information products. Strategic planning processes of producing information in the form of new knowledge and the mass production of information technologies, which determine the modern condition of the productive apparatus and social-economic development of the country.

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SERVICE SIMULATION IN INDUSTRY 4.0: A COMPARISON OF SIMULATORS

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Abstract: Web services are application components that can be linked together for creating new functionality. As such, they support industry environments by binding together inhabitant services with distributed on demand services for implementing the business strategies. However, web services are operating in dynamic environments and an important issue during the composition process is change management either at the local or at the web, in general. Therefore, service changes together with other nondeterministic behaviours must be efficiently propagated to ensure the validity and consistency of the enterprise plans. Simulations are effective tools for enhancing factory competitiveness. Simulating the operation of a developed composite service for verifying the developed product could be a solution to this problem. The results of the simulation will allow to predict and react to such behaviours before applying the developed service in real production. As such, this paper describes and compares the existing service simulators that could be used in smart industry environments in terms of their functionality. Based on this review, the identification of gaps in performing simulation of service composition in industrial environments is presented, and challenges to be met on the field are outlined.

Keywords: SIMULATION, WEB SERVICES, EMBEDDED SYSTEMS, INDUSTRY 4.0, COMPOSITION OF SERVICES

1. Introduction

Automation of the industry includes automation in binding together local, cloud and web services to provide support for its inhabitants. Services technologies offer applicable solutions for service composition that can be exploited for automated planning and composition. In many cases the composition process produces a system of systems that might be quite complex. The better comprehension of the functionality of these complex systems along with the prediction of unwanted results during their execution is challenging.

However, there are practical issues that industry environments will face when automation of services is involved in testing, monitoring and verifying their performance in such systems.

The utilization of simulations tools that give the ability to evaluate the hypothesis prior to the application of the developed service could be a solution to the above problem. Simulation studies are obtaining popularity and they are used in many scientific fields. An environment that mimics as closely as possible the real setting, such as a service simulator can play an important role in evaluating the quality of a service, before its actual execution [1]. A domain that have the ability to use a service simulator can discover and evaluate which combinations of individual services cause what positive and negative results and avoid costly and error prone process.

Composite service simulation of the execution enable developers to understand performance issues that might occur and ensure that a service will meet the expected performance. Based on the simulation output, it is possible to verify the composition process and perform more experiments.

Choosing a simulator in order to perform functionality testing in services architectures is not a trivial task [2]. Simulators offer different facilities to assists users and applications to test the new developed services and obtain results for performing evaluations.

This paper contributes with a survey on existing simulators and makes a comparison based on specific properties with reference to industry 4.0 environments.

The survey offers an overview and comparison of six simulators for service systems, describing for each: (i) the main objective, (ii) the latest release of the simulator (iii) the service modeling approach it supports, (iv) the use of evaluation method for services, (v) the communication platforms or languages are used, (vi) the semantic web technologies support, (vii) potential behavioral observation, and (viii) whether the simulator has been validated.

The rest of this paper is organized as follows: Section 2 describes the selected service simulators, in Section 3 we compare them according to specific characteristics defined with reference to

industry 4.0 environments, while the last section presents the conclusion of the research on service simulation.

2. Background

An important aspect of simulation is the ability to experiment with alternative arrangements (Shannon, 1975; Sol, 1982). The idea is to develop a model of the existing situation and, based on a diagnosis, develop one or more alternative models and find improved arrangements using ‘what-if’ analyses. Simulation can thus be used to test and analyse various scenarios and decide which scenario is most promising. According to [3], the disadvantages of using a simulator are: (i) potentially long time of model preparation, (ii) every simulation model is unique – its solutions cannot be used for analyzing other decisional issues, (iii) it allows for preparing alternative decisional solutions in subsequent experiments, but these are not optimal solutions for all conditions, (iv) simulation models generate answers to the questions related to specific and changeable conditions.

A service’s simulator main goal is to facilitate the planning and development of atomic and composite services. They present the results of the execution and predict the performance of the tested system under various parameters of the system and workloads[4].

A wide range of service simulators implementation environments were reviewed. This review is intended to examine only service simulators platforms are available today. Hence, in the following, we present six simulators that were selected as more compatible for simulating services in academia and industry environments and their development progress have not stopped. Initially we shortly describe each simulator while a pivot table with a comparison is presented at the end of the section.

2.1 Planning and Execution for Experiments in Service Oriented Systems (PEESOS)

PEESOS [4] is a tool that aims to perform capacity-planning tests for end-to-end SOA applications. The tool provides a collaborative workload generator based on a Client-Server model to establish a realistic load test environment for capacity planning test. It makes functional testing and can capture the results from the simulations to predict the performance of the target system, under different resource configurations. It is also capable to predict non-functional metric such as QoS for clients in different environments. It includes facilities that assist developers to test new service based applications.

The latest version of the simulator is PEESOS-Cloud [5], it enables cloud services to be evaluated as well as to improve the ability of the workload so that it conforms to their described

characteristics. In this version, experiments in a cloud environment were conducted that present how PEESOS-Cloud validate its capabilities.

2.2 Devices Profile for Web Services Simulator (DPWSim)

DPWSim is a simulation toolkit enabling the simulation of DPWS devices and protocols [6]. It enables developers to prototype, develop, and test IoT applications and services without the presence of the physical devices. It mimics all the software and protocol features and provide a way to simulate and manage DPWS devices. It is especially useful when developers want to focus on designing the business logic of IoT applications rather than the physical performance of devices.

It simulates the environment where DPWS devices exist by creating virtual devices that can be discovered on the network and can communicate with other devices or clients via DPWS protocols. It also provides management of new and existing simulations created with which, it offers a high flexibility for users. It also provides a graphical interface designed in Java Swing that users can interact with the virtual devices.

2.3 Services-Aware Simulation Framework (SASF)

The SASF [7] is a suite of tools supporting the modeling of a service-oriented system and the execution of this model in a virtual environment. Its intended use is to predict the behavior and the performance of a software system, under different resource configurations and workloads. Some features of the SASF simulation framework are:

- (i) it generates simulated services from WSDL documents and a performance profile, thus, it reduces the development effort required
- (ii) it provides recording and visualizing behavioral metrics of interest, supporting special-purpose metrics and visualizations
- (iii) it supports automatically generating executable service simulations, based on existing data about the services of interest, including their WSDL specifications and their implementations
- (iv) has the ability to receive interactive input from users and external programs, thus enabling the simulation of systems evolving at runtime and the integration of real and simulated services
- (v) has extensibility both in terms of the implementations of the simulated components and the data collected during simulation.

The intended use of the simulator is both in the pre-deployment and the post-deployment stage. Simulations for new implemented services are created to support the process of better understanding, and systematically analyzing them in the pre-deployment stage. On the other hand, after deployment, the simulation can be improved using the SASF tools by capturing more accurate performance profiles. With simulation, alternative configurations can be tested to improve specific aspects of services. In addition, all this reasoning about the service performance happens offline, without interfering with it.

2.4 PlanetSim

PlanetSim [8] is an extensible and scalable service simulator that supports simulation of peer-to-peer systems and services. The simulation is developed in three layers: (i) the network layer, (ii) the node and (iii) the application layer. The network layer manages the node inter-communication, the node layer deals with the implementation of peer-to-peer overlay protocols while the

application layer is focused on services running at existing peer-to-peer overlay protocols. All entities within the simulator are defined through separate interfaces. The simulator dictates the overall life cycle of the framework by calling the appropriate methods and obtaining information to dispatch messages through the Network. It provides only basic statistics as part of the simulator in order for the tool to be efficient for large-scale scenarios as well.

The simulator is a Java framework while the main entities are separately defined and permit extension. It provides algorithm-based implementation of all the peer-to-peer protocol into the Node entity, answering correspondingly to any incoming message and behavior-based implementation, which encapsulates any individual part of the protocol into a Behavior entity, processing the incoming messages as expected by the protocol.

2.5 Service Composition and Execution Tool (SCET)

SCET [9] enable users to compose and simulate services. It is capable of monitoring a service that is being executed and captures bottlenecks and performance problems in the service components, suggesting reordering. It visually shows the number of service invocations at the host and evaluates the execution and performance of services under various hypothetical conditions while presenting statistical performance estimates. These results approximate the actual invocation and allows decisions to be made based on the behavior of the simulated services without actual execution.

The definition of the statically composed services is made using the Web Service Flow Language (WSFL). It integrates the JSIM simulator [10], therefore it converts the WSFL specification to a model that the JSIM simulator can interpret.

2.6 CloudSim

CloudSim [11] is a framework for modeling and simulation of cloud computing infrastructures and services. It has become a popular open source cloud simulator in the research and academia. It is an extensible simulation framework that enables modelling, simulation, and experimentation of Cloud computing infrastructures and application services. By using CloudSim, developers can focus on specific system design issues that they investigate, without getting concerned about the low level details related to infrastructures and services.

The framework has the following features: (i) support for modelling and simulation of large scale Cloud computing infrastructure, (ii) it is a self-contained platform for modelling data centers, service brokers, scheduling, and allocations policies, (iii) provides availability of virtualization engine, which aids in creation and management of multiple, independent, and co-hosted virtualized services and (iv) offers flexibility to switch between space-shared and time-shared allocation of processing cores to virtualized services.

It is customizable tool, thus allows extension and definition of policies in the components and this helps developers to handle the complexities arising from simulated environments. It is written in Java and it is using existing libraries such as GridSim and SimJava to handle low-level requirements of the system. An extended version of CloudSim which is CloudReports[12] have a graphical user interface and offer a GUI for CloudSim simulations.

3. Comparison of Service Simulators

The subject of research is to compare the selected simulators according to the specific properties are chosen as relevant to the intended environment of use, i.e. the industry 4.0 domain.

Simulator / Characteristic	PEESOS	DPW SIM	SASF	PLANET SIM	SCET	CLOUD SIM
Objective	Focus on capacity planning	Supports simulation for the development of IoT services	Virtual model of an application, focus on capacity planning	Supports simulation of peer-to-peer systems and services	Compose and simulate services	Simulation of Cloud infrastructures and application services
Latest release/ Open Source	2016 No	2014 No	2013 No	2009 No	2003 No	2016 Yes
Service Modeling	SOA entries	DPWS	WSDL services profiles	Platform defined syntax	WSFL language	Platform defined syntax
Evaluation	Validate workflows	No	Statistical metrics	Basic statistical metrics	Statistical metrics /Time Analysis	Yes
Communication	Platform defined	SOAP	SOAP	Platform defined	SOAP	Platform defined
Platforms/ languages	Web tools	Java	Java	Java	Java, Perl	Java
Semantic Web technologies support	No	No	Yes	No	Yes	No
Behavioral observation	No	No	Yes	Yes	Yes	No
Validated	In presented case study.	IoT application scenario.	In presented case study.	Used in scientific projects.	Real Web service scenario.	Used in cloud environments.

Table 1: Comparative matrix of simulator properties.

3.1 Criteria for comparing the tools

We first describe the properties defined to compare the deferent simulators:

Objective	:The objective of each simulator is described and if its use is specific to services or other systems can also be simulated.
Latest release	:The year of the latest release. As it is already mentioned only in use simulators are included.
Open Source	:Whether a simulator is open source or not.
Service Modeling	:The language/model in which services are defined.
Evaluation	:The evaluation method that provides the simulator to evaluate participant services and how it does this.
Communication	:The protocol/language is used for communicating simulated services.
Platforms	:The platforms or languages the simulator is build on.
Semantic web technologies support:	Whether semantic web technologies are used during interaction or semantically meaningful information derive.
Behavioral observation:	Whether the composite behavior of the services being simulated is taken into account or only the atomic responses to a specific call.
Validated	: Under which circumstances the simulator is validated.

3.2 Discussion

The basic characteristics of each simulator are presented in Table 1. Based on our review, we discuss our observations for each characteristic.

We notice that PEESOS and CLOUD SIM simulator have the most recent versions while only the Planet simulator is open source.

The performance of an atomic service has the potential to affect the performance of a composite service. Performance evaluation in a simulator of services can help implementers understand the behavior of the atomic services and the composed services under specific application and workload. We notice that the majority of simulators offer performance evaluation with some of them offer more sophisticated by using graphical interfaces.

Regarding the communication protocols are used to communicate services we see that PLANETsim and CLOUDsim use platform defined syntax language while all others follow standard protocols.

Furthermore, our intention is to study which simulator platforms can be used in the Web, hence we tried to figure out which of them support semantic web technologies. From the potential of a platform however could not conclude the simulators ability of modeling semantic web services. However, SASF and SCET have the ability to simulate services by semantically describe them.

The simulators that provide connections, which link the behavior of the individual components to the resulting system effects, are SASF, PLANETsim and SCET.

PEESOS and SASF simulators are using a case study to prove the validation of the system while DPWsim, PLANETsim, SCET and CLOUDsim are used in real word scenarios to be validated.

4. Conclusion

Industry is an increasingly complex environment. Systems and models that are used are continuously becoming more complex and difficult to analyse. In this context, simulation technology could be a powerful and useful tool for developers.

In this article, we have presented six available simulators that are or could be used in simulating service oriented systems in

industry. Ultimately, the goal of the study is achieved since the table in section 3 analyzes nine properties of the described service simulators and figures out that there exist simulators partially ready to be used in industry environments. This finding is really hopeful since service simulators have potentials in industry 4.0.

Our research agenda includes experimenting with the aforementioned simulators especially those that support semantic web technologies.

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GOVERNANCE OF *INDUSTRIE 4.0*. CONTRIBUTION TO THE DISCUSSION

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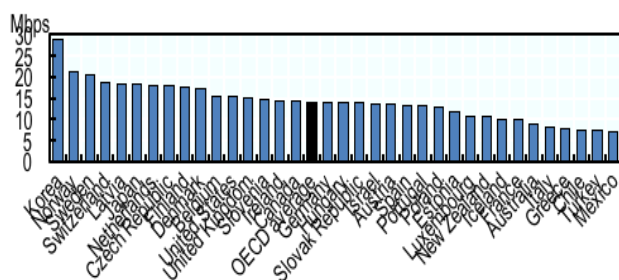
Abstract: This paper is the endeavor to present the concept of *Industrie 4.0* in terms of its governance prerequisites. On the one hand, there is a need to boost the innovation and productivity of the enterprises. On the other one, the technological changes are expected to respect not only economic, but also social and ecological security of citizens. The analysis drawn in the paper is based on the economic consequences of disruptive technological changes especially in their features concerning the need of governance in the light of the dilemma between the imperative of business effectiveness maximization and the necessity of social security.

Keywords: ICT SECTOR, REGULATION 4.0, ICT INNOVATION-DRIVEN ECONOMY, SECURITY OF USER INTEREST

1. Introduction

An overwhelming pressure generated by the recent technological revolution in information and communication sector challenges the mode of behavior of every single individual, business and society across the world. The prior objective of a developing digital economy – aiming to growth and employment, is to provide access to high-speed broadband networks as well as to overhaul the law in that respect. The backbone of well prospering digital economy is efficient access as the conductor of effective use of information and communication infrastructure and services.

Figure 1. Average Speed, 2016¹



The leading advertised download speed in the countries under analysis was 10 Gbps but it generally still remained a challenge for majority of countries as average speeds varied substantially across OECD countries.

Connectivity remains as one of the main building blocks (followed by effective use, skills, review of policies, security and privacy, strategic coordination) for a digital transformation supporting well-being. The growth in this area has been observed very clearly, but lagging especially in the access to fibre networks².

The tremendous pace of technology innovations (mobile devices and applications, social networking, cloud computing) needs to be accompanied by permanent assessment of the implications of these disruptive technologies³. The technologies that are characterized by the features representing the most disruptive technologies are mobile (communications, commerce, software and applications) and cloud (software as a service, infrastructure as a service, platform as a service). They are perceived as the drivers of the meaningful transition of consumer technologies, business models and industry ecosystems (new products, applications, services – mainly based on the Internet of Things, Big data analytics, Artificial Intelligence, Blockchains).

Converged broadband networks (NGN, Next Generation Networks) through the convergence of media, Internet and communications services generate new market players (therein new content and application providers - over-the-top) and new services (including the ones concerned with connectivity of things), as well as the change of consumer style of living, working, relaxing. These

trends call for ubiquitous access to ICTs (Information and Communication Technologies) and put pressure on the adjustment of the rules of the game and business practices. Drastic increase of data flow caused by ease of access to information, development of new services and applications (cloud services, mobile applications) together with increasing complexity of the ICT markets challenge the traditional role of regulation and call for rethinking of the existing approach to regulation in a digital ecosystem.

The enormous necessity to leave the techno-economic decisions of economic agents free, on the one hand, and, the imperative to secure the balance between the interest of consumers and suppliers, on the other hand, generates the dilemma concerning the regulatory aspects of *Industrie 4.0*.

The main analytical problem faced herein is the effectiveness-driven versus security-driven facets of *Industrie 4.0*. The main objective of the paper is to spotlight on the governance of *Industrie 4.0* as an attempt to embrace the key elements of nowadays techno-economic revolution in ICT for the well-being of the societies around the world. The structure of the paper is imposed by the analytical frameworks based on the chief role of technology-driven determinants of regulatory transformation in the ICT and the followed economic adjustments, including the normative adaptation. Then, structure goes through the revealing of the notion of Regulation 4.0, and aims to the presentation of the dilemma between productivity and safeguarding as the proposed essence of the problem of the *Industrie 4.0* governance.

2. Economic character of technological transformation – the conceptualization of the problem

Upper level of industrialization characterized by the technology relying on self-service of users and highly standardized service offers calls for radical service innovation⁴. The 4th Industrial Revolution is described as the phase of techno-economic evolution directed toward integration of technology at physical, digital and biological areas. Therefore, there is a critical dilemma opening a wide area of discrepancy between pro-productive possibilities and a new range of impediments focusing mainly in consumers security and intellectual property rights.

The governance of *Industrie 4.0* appears as the efforts to advance the neutralization of the tension between the urgency toward economic efficiency and immanent requirement to make the human activities socially and ecologically secure. Herein, regulation is forced by the processes taking place in technology-driven economies, fields of human work and life. Digitalization and interconnection, data-driven innovation, and application and service convergence emerge as the possible areas to analyze the determinants of the regulation of economy in the 4th technological revolution.

Table 1: Technology-native and economy-native determinants of next generation regulation of an economy⁵

	Digitalization and interconnection	Data-driven innovation	Application and service convergence
Technology	cooperation of researchers and operators	importance of global, market-relevant technical standards	platforms potential to large scale, data acquiring and analyzing
	dispersion of infrastructure innovation	high-speed broadband connectivity	platforms potential to decentralization, complication of enforcing social protection (inc. working conditions)
	advancement of digital applications	Internet openness	threat of privacy deprivation
Economy	innovativeness of services	new business models	sufficiency of ICT skills of workers and citizens
	economic power of market players	digital inclusiveness of society (in respect to the development of new markets, new jobs)	proficiency of workers in problem solving and communications skills
	dynamics of market players adaptability	intellectual property protection	privacy risk and digital security in the network and the proficiency in managing them
	dispersion of infrastructure investment		consumer trust
			effects of scale, effects of scope, network externalities as the potential of market concentration and market entry blocking
consumer patterns such as “sharing” and “on demand”			

The nature of digital transformation of the economies worldwide is mainly operational, i.e. using and applying invented technologies within the interplay between technology and business. The potential of every single technology and business process is multiplied by the integrated techno-economic approach of deploying the sensors, social media, cloud, analytics, mobile, Artificial Intelligence and many more throughout the economy. These trigger the potential to economic cooperation across the industries and regions to create new partnerships oriented towards unifying experience to standardized offerings according to the responsiveness of customer's demand. All that requiring interoperability, the freedom of choice, as well as privacy and security and protection of consumer rights.

Adaptation of companies is additionally required in the face of growing transparency, consumer awareness and engagement, as well as new patterns of behavior such as “sharing” and “on demand”.

Digitalization and interconnection, empowered by high computing power, together with “ecosystem of inter-related technologies” are

listed as technological pillars of digital transformation⁶. In between, innovations that are data-driven accelerate the development of techno-economic ecosystem meant as the range of new products, applications and services (The Internet of Things, Big data analytics, Artificial Intelligence, Blockchain). Digitalization as the protection of data from degradation and as the means of communication by very high speeds at almost zero marginal cost⁷ eliminates the physical constraints to information sharing and exploitation. Interconnection as the consequence of the growing importance of the Internet restores patency of its operations on the inter-company/operator and global scale. Data-driven innovation based on the movement of socio-economic activities to the Internet, the decline of the cost of data (“big data”) operations aim to create the key assets in the economy, create new industries, processes, products to generate unique competitive advantage. Application and service convergence profoundly affects industries in their sale, development formula and market redefinition. The phenomenon is rooted in the design of the systems dealing with multiple technologies, set to meet entrepreneur and consumer utility expectations.

Digitalization, data-driven innovation as well as service and application convergence reformulate the functioning of many sectors and masses of employees. Digital innovations are mostly perceived as forming the basis to innovation networks, access to finance or the use and reuse of data, as well as the foundations of investment in ICT, knowledge-based capital or data analytics. New work patterns, the creation and disappearance of different sectors and jobs, reshaping trade agreements and labor law are the consequences⁸.

3. Main prerequisites for exploring the potential of disruptive technologies - Regulation 4.0

The main drivers of communications markets expansion are demand empowered by technology innovations and adjusted regulatory frameworks (competition-, innovation- and investment-friendly) in particular jurisdictions.

The disruptive character of innovations rooted in recent technological advancements transmuting the trajectory of decision processes in every single factory and industry (Industrie 4.0) calls for the regulatory assistance in its role of the neutralizer of the divergence between efficiency impulses and security need and the engine of sustainable growth of well-being for all. The governance of *Industrie 4.0* emerges as the prerequisites of the exploiting the potential of the immense technological expansion.

The key means to diffuse innovation are **standards**. Therein are regulators featured by efficiency and effectiveness, ready with regulatory standards and good governance inevitable to administer and enforce regulations. Regulators are pivotal element of regulatory system to create pro-development regulatory regime addressing the wider objectives of sustainable growth and just society⁹. The regulatory role is mostly attributed to national regulatory agencies and International Telecommunications Union as ICT standardization global leader, intensively dealing with standardization gap between developed and developing countries, whose role is particular in case of scarce resources such as spectrum for mobile and wireless technologies or when Quality of Service is important.

Regulatory policy (licensing, standardization, managing the spectrum, interconnecting, providing universal access and service) is designed to **remove uncertainty and regulatory risk for service providers and their investors** by authorizing the provision of services, the operation of facilities or the use of radio spectrum (general authorization regimes). These determine the market structure and level of competition, and then the efficiency of supply of the ICT services to the public. But, as regulation is an art it is impossible to prescribe exhaustive policy for particular situations in the world of above-average dynamics, there are general objectives

and policy frameworks desirable as well as the mechanism of their consequent execution.

Currently, there is no concept of the regulatory approach that could result in the positive impact on the ICT sector and be accepted worldwide. First generation regulatory approach aimed to unravel the problem of monopoly which devoured the socio-economic potential of communication sector. Second generation of regulatory policy represented the proposals of liberalization and privatization. The regulation of third generation is concerned with preserving and managing the competition. Fourth generation regulatory endeavors to incorporate their own objectives in the frames of wider socio-economic policy goals¹⁰, and are even more anchored in the specificity of a particular country than the previous generations of regulation.

The dynamics of innovation of digital technologies stands in stark contrast to the pace of regulation. There is a pressing need emerging in the digital world to react faster than classical instruments of regulation allow. This regulatory landscape represents a unique challenge for regulators to respond not too early (and stymie innovators) or not too late (and expose consumer to risks) and calls for regulatory decisions to be adequate, not to lose its relevance.

The concept of Regulation 4.0 characterizes regulatory approaches that promote innovative and apt solution for ensuring level-playing field for all market participants, stimulates the spillover of services and access to services and applications without imposing excessive burden on operators and service providers (co-regulation, self-regulation, “smart” motivation etc.) for the well-being of all societies across the world.

The main drivers of Regulation 4.0 are technological transformation (services and networks convergence), and socio-economic transformation (consumer behaviours), as well as political objectives such as social inclusiveness and development. The perception can further be highlighted in the aspects of digitalization and interconnection, data-driven innovation, and application and service convergence (Table 1).

Regulation 4.0 is being designed to draw out the opportunities and challenges brought by digital transformation of economies and societies in the frameworks of whole-of-government approach policy¹¹. And, the regulation’s role is perceived as the critical in creating the incentives structures for business to consider the value to society.

4. Between productivity boosting and security safeguarding – the essence of dilemma

ICT plays a key role as a driver of innovation, as it accounts for the largest part the OECD businesses expenditure on research and development and over thirty percent of patent applications worldwide¹². At the same time, users and consumers are exposed to the unprecedented risks often not even conceptualized.

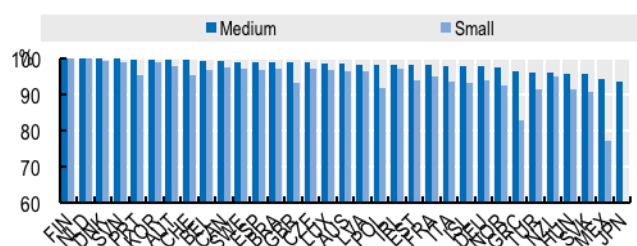
Business benefits

Leverage from cloud technology for computer systems and storage, big data navigation, tagging, searching, visualization to help people manage with the mass of information more quickly. Information technologies function as the back office resources that result in driving the rest of the business world forward. The processes foster innovation in the unprecedented manner. Broadband enables the business processes to be more efficient and increase productivity. The new applications and services accelerate innovation. The clear-cut relationship between ICT and productivity is perceived through the rise of more complex production processes, as a result of economic growth, and the demand for labor force concerned with the flow of information for the purposes of production organization whose need for the ICT technology becomes more and more intense with the rising complexity of

information processing. Information processing and provision of communication services attract employment through outsourcing¹³.

There is considerable increase of enterprises getting connected to broadband networks, but out of them few make effective use of advanced ICT especially such as cloud computing and e-sales (lowest percentage of enterprises with ten or more employees in OECD respectively Poland and Mexico). Workers insufficiently use office productivity software (from nearly 15% of all users in Netherlands or Canada to less than 10% in such countries as Sweden, Japan, Finland)¹⁴.

Figure 3. Small and medium enterprises with broadband access, fixed and mobile, 2016 (% of enterprises in each employment size class)¹⁵



Digital gap is much less drastic, spreading from 100% of broadband access of medium and small enterprises in Finland, Netherlands to around 94% (medium) in Mexico and Japan and 77% (small) in Mexico. However, applying indicator of small and medium enterprises broadband access and as percentage of total businesses with ten or more employees the digital gap extends from 2,6% in Australia to 31,4% in Switzerland.

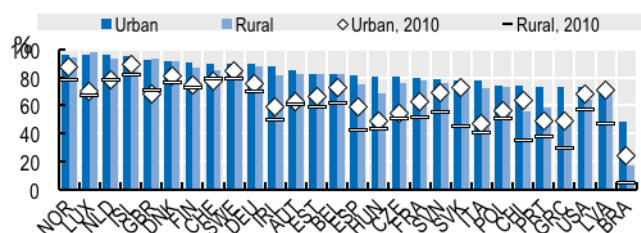
Social benefits

Consumer benefits come down mostly to easier access to personalized real-time information, increased personal productivity, ability to manage personal information online, improved connectivity with family and friends, greater convenience and more saving making through online purchases etc. Fundamentally new way of communication which is social media (Instagram, Twitter etc.) add great amount of dynamism to stay connected. The main barriers that arise are security and privacy governance and problems with customer adoption¹⁶. The threats emerging from security and privacy issues are balanced out by the benefits of adopting the new technologies. There are business models that are highlighted as the ones build on the necessity of transparency from technology vendors which is indicated as a key factor to build the customer trust and loyalty in the markets.

Positive impact of broadband access on consumer surplus (consumers’ willingness to pay for the broadband services and actual prices) is the effect of efficient access to information, savings in transportation, gains in health care and entertainment.

And what is even more challenging and prosperous, the right to the broadband access has been approved as the fundamental citizen right¹⁷.

Figure 2. Households with broadband connections, urban and rural, 2010 and 2016 (% of households in each category)¹⁸



Broadband access in the households for Norway surging over 96% to Brazil reaching less than 50% in urban areas in 2017 depicts uneven chances in the societies worldwide to tap the potential of

broadband. The picture of the digital gap in the world amounting (according to the above data) to almost second so much in the least connected households of the world in comparison to the most connected.

Security still remains a growing challenge with the digital security incidents experienced by individuals (aged 16-74) reported from nearly 30% of all individuals (Luxembourg, France, Hungary, Denmark) to less than 5% (Mexico, New Zealand)¹⁹.

5. Conclusion

The opportunities and challenges arising in the transformation to cyber world call for permanent policy reviews and strategic coordination within national strategy governance to ensure the optimal participation of all enterprises, individuals and governments. Out of the them, fibre connectivity for all, effective use of digital technologies on every-day basis at work and at home, strengthened skills, adjusted legacy frameworks shape the next generation of regulatory approach as a whole-of-government strategy coordinated across countries. The prospective of *Industrie 4.0* are to be explored through the governance tuned toward fostering potential of digitalization while neutralizing social costs.

In the face of the immanent tendency to monopolize market power among market agents, the problem of security in the network, the development of intellectual property and intellectual capital, employee's promotion, patent award system (cash reward), acquisitions (IBM) form the foundation issues of regulatory platform to secure and stabilize these techno-economic trends of *Industrie 4.0*.

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¹⁸ OECD Science, Technology and Industry Scoreboard 2017, chapter 6, graph 6.1.2

¹⁹ OECD Digital ... op. cit., s. 260.