

**INTERNATIONAL JOURNAL FOR SCIENCE
AND INNOVATIONS FOR THE INDUSTRY**

INNOVATIONS IN DISCRETE PRODUCTIONS

**YEAR IV ISSUE 2/2016, SOFIA
ISSN 1314-8907**

Publishers:



SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING



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AUTOMATION IN DISCRETE PRODUCTIONS**

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ON DESIGNING OF A TECH-HUB FOR STRENGTHENING THE MANUFACTURING SECTOR IN DEVELOPING COUNTRIES

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Abstract: In this paper, we want to show ideas on how building a Tech-Hub for boosting and strengthening the manufacturing sector in developing countries. We think this goal can be attained by creating a network composed of universities and enterprises between developed and developing countries, we think that this method will make more effective, easy and fast the process of creation of new products or processes by start-ups or enterprises of developing countries.

Keywords: TECH-HUB DESIGN; TECHNOLOGY TRANSFER; INNOVATION NETWORKS; MANUFACTURING; DEVELOPING COUNTRIES

1. Introduction

The scientific community has highlighted the importance of clusters and the role played by the central hub in their governance and dynamics inside and outside them, usually with large-sized companies to expand its influence beyond its borders for the creation, distribution, dissemination and skills development to strengthen its value chain. However, there are not enough studies that explain the limited creation and maintenance of clusters in the manufacturing sector, where the productive structure of a country is based mainly on the extraction and export of raw materials or products with low added value. As we see in Fig. 1, it is the case of almost all the Latin American countries; with some exception like Mexico, Brazil and Argentina.

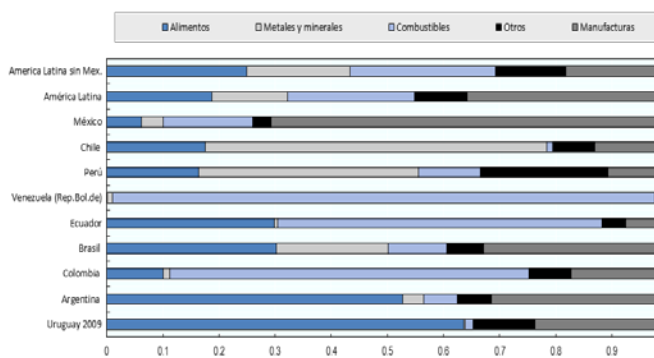


Fig. 1 OECD, CAF, & ECLAC. (2013). *Perspectivas económicas de América Latina 2014. Logística y competitividad para el desarrollo* (p.38); elaborado con datos de CAF (2013).

Some economic studies have been suggesting policies to promote innovation systems at national and regional levels in developing countries; but despite government efforts, it had not been boost the sector neither improve their poor competitiveness, productive diversification and sophistication indicators. Manufacturing is an industry strongly based on experience and tacit knowledge, which certainly requires promotion policies and public funds for technology transfer and innovation, but also an important proximity between local stakeholders and a specialized international network. Therefore, in this article we advocate on the relevance and feasibility of a Tech-Hub Peru, working on design issues and modeling its structure.

2. Literature Review

The scale of analysis applied in Latin America, was mostly related to the national and regional innovation systems and firms cluster inward and outward delimitations. However scholars like Kaumann (2001, p.4) suggest that there are at least three different social systems that interacts in the process of product (goods and services) innovation – ‘business’, ‘science’ and ‘policy’- interacting with a different modes of interpretation, decisions rules, objectives, and specific communicative standards. This clearly suggests an

extended ecosystem going beyond the specific national, regional or industrial sector. The process of collaboration between actors belonging to different systems are based on diversity playing different roles, where individuals are not the specific elements of systems, but communications is (2001, p.4). Thus, as he remarks, “in the particular case of industry-science interaction this might, among other things, result in product innovation”.

The scholars use the term innovation when they are referring to new products, services, process, materials or organizations forms that arrives to the market, or create new markets, regardless of their successfulness; because the newness become attractive more widely, usually, after a process of broader use. In an industrial context, most innovations are based on some kind of problem solving, when firms facing a particular problem turns to a supplier, or some other related actor, to get help in specifying the problem and defining procedures for its solution.

However, it is not a straight line; it is necessary a firm’s ‘absorptive capacity’, term coined by Cohen & Levinthal (1990 p.128), which is “the ability to exploit external knowledge as a critical component of innovative capabilities” that are “largely a function of the level of prior related Knowledge”. That includes “basic skills or even a shared language... of the most recent scientific or technological developments in a given field”.

In addition, the manufacturing sector presents a complex interaction environment, with multiple layers, and fuzzy boundaries; thereby, the processes of technology transfer and innovation should be incubated and developed taking account of these dynamics. Because the combined forces of globalization of markets and deepening divisions of labor, make knowledge creation and innovation increasingly important. As Bengt-Åke Lundvall (2007) state “the most important resource in the current economy was knowledge and the most important process was learning” (p.99).

In the arena of clusters, Malmberg & Power (2006) emphasizes that “knowledge in clusters is created through various forms of local inter-organizational collaborative interaction; increased competition and intensified rivalry; spillover following from the local mobility and sociability of individuals” (p.411).

Also Bengt-Åke Lundvall (2007) discuss the limits of national, regional, sectoral and technological innovation systems highlighting that “the innovation process may be seen as an intricate interplay between micro and macro phenomena where macros-structures condition micro-dynamics and vice versa new macros-structures are shaped by micro-process” (p.101)

In a more social system view, Bengt-Åke Lundvall (2007) summarizes that a series of empirical studies demonstrates that “a key to transform technical innovation into economic results is training and organizational change”. However, he claims that “the impact of innovation on economic performance will typical depend upon change in ‘people’, ‘orgware’ and ‘socware’” (p.101), the last

two words referring to how people interacts each other inside and outside their organizations.

There were Malmberg & Power (2006) that pointed out that industrial systems should be assumed to have a distinctly localized component, where the interactive processes of innovation and knowledge creation, goes necessary in a spatial proximity for intensified face-to-face interaction, shortened cognitive distance, use common language, consolidated trustful relations between the actors, promote easy observation and immediate comparison. Thus for them *“there are reasons to believe that the knowledge-enhancing structures of a given geographical territory are more important than other characteristics (such as general factor supply, production costs, etc.) when it comes to determining where we should expect economic growth and prosperity in today’s world economy”*.

3. The Peruvian Context

In this chapter, we propose to understand the contextual factors that firms encounter in their innovative activities, as Bengt-Åke Lundvall (2007) suggest, those have an important impact in their style and mode of innovation and learning, and in turn, affects the country's competitiveness. Becoming a kind of feedback loop, ranging from micro (firms) to macro (nationwide), and back again to micro.

Productive Structure and Product Markets

The Peruvian productive structure is mainly the same since 1950 (see fig.2), it is based on services that counts for over 60%, followed by agriculture and mining within an average of 15%, manufacturing 14% and other (construction; electricity and water) that change mostly from 4% to 9% basically for the boom in building constructions.

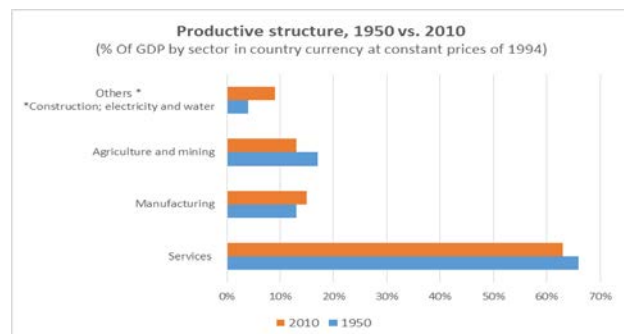


Fig. 2: Peruvian productive structure 1950 vs. 2010. Data from BCRP (Central Reserve Bank of Peru)

If we go inside the manufacturing category, we found is almost the same through the last years; being the food industry the first contributor, followed by chemical, textile and leather, fabricated metal products, manufacturing non-metallic products and paper industry the most relevant as we can see in the Fig.3.

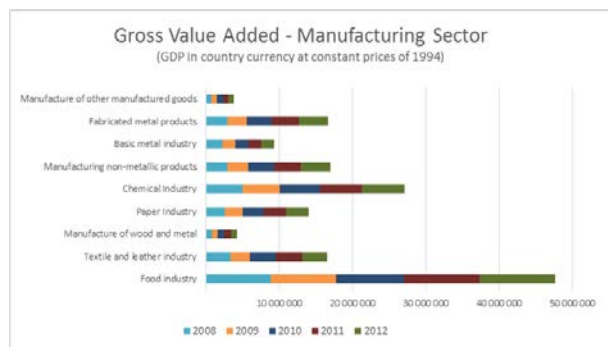


Fig. 3: Gross Value Added - Manufacturing Sector, 2008 to 2012. Source: CEPLAN (2013) - Report of the productive structure of Peru, for 2021 and 2050

Competitiveness Index and Products Sophistication

In 2013, according to the Observatory of Economic Complexity (OEC), created and supported by the "MIT Media Lab Macro Connections group" (AJG Simoes, CA Hidalgo, 2011) Peru had an index of -0553 (ECI) being ranked in 85 of 124 countries. This atlas describes an economic complexity index (ECI) according to the level of complexity of the products each country is able to do and export, analyzing a multiplicity of knowledge, know how, networks people and organizations that are embedded in the manufacture of this products.

The main products exported in 2013 were gold (\$ 8.29B), copper ore (\$ 7.79B), petroleum refining (\$ 3.17B), refined copper (\$ 2.12b) and gas oil (\$ 1.65B); and the main imported products were petroleum refining (\$ 3.2B), crude oil (\$ 3.08 B), automobiles (\$ 1.8B), truck load (\$ 1.57B) and informatics (\$ 959M). Equally that weak productive sophistication we can see in a non-traditional exports reported by the Central Bank in 2012, that reached 21%, the composition was Agricultural (28%), Textiles (20%), chemical (15%), Sidero-metallurgical (11%), Fishery (9%), Non-metallic Mineral (6%), Metal-Mechanics (5%) and others (2%).

Likewise, the last ranking of the World Economic Forum 2016-2015 ranks the Peruvian economy 69 of 140 countries giving an overall value of 4.2 (scale 1- 7). Based on twelve pillars of global competitiveness and its interrelations with 113 indicators, we can see in the Table 1 that despite the middle position, the pillar are mostly in the lower third worst countries. Especially on indicators relevant for this study, as those of innovation, business sophistication, technological readiness, higher education and training.

Table 1: Peruvian pillars of global competitiveness 2016-2015 vs. 2015-2014. Source: Translated and prepared with data from the Global Competitiveness Reports - World Economic Forum (WEF)

Nº	Pillars	2015-2016		2014-2015		Change Position
		Rank	Value	Rank	Value	
1	Institutions	116	3.3	118	3.3	2
2	Infrastructure	89	3.5	88	3.5	-1
3	Macroeconomic environment	23	5.9	21	5.9	-2
4	Health and primary education	100	5.3	94	5.4	-6
5	Higher education and training	82	4.1	83	4.1	1
6	Goods market efficiency	60	4.4	53	4.5	-7
7	Labor market efficiency	64	4.3	51	4.3	-13
8	Financial market development	30	4.5	40	4.5	10
9	Technological readiness	88	3.4	92	3.3	4
10	Market size	48	4.4	43	4.5	-5
11	Business sophistication	81	3.8	72	3.9	-9
12	Innovation	116	2.8	117	2.8	1

Going a Little further on innovation pillar, the fig. 4 shows the poor performance in all the indicators, being the worst ones applications for PCT patents, company spending on R&D, Gov't procurement of advanced tech products and quality of scientific research institutions.

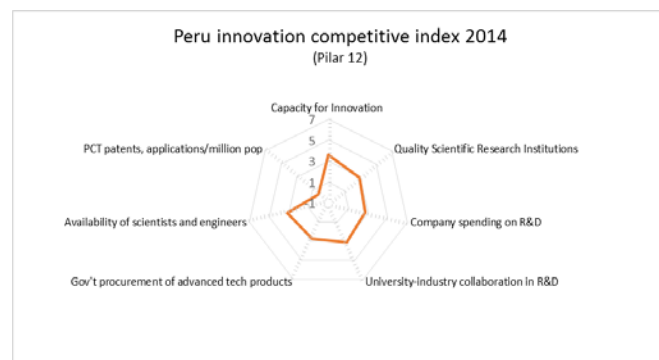


Fig. 4: Innovation Competitiveness Index (pillar 12). Source: Translated and prepared with data from the Global Competitiveness Report 2016-2015 - World Economic Forum

Labor Markets

According to the National Institute of Statistics and Information (INEI 2011) of a total of 15.3 million workers, 74% belongs to a Micro and Small Enterprises (MSEs), they are mainly located in the region of Lima (98%). As could see in the distribution of employment by economic sector for 2010 (Fig. 5) the 33% are on primary activities, followed by 28% in services and only 6% and 4% in low and high tech industries respectively. On the other hand, labor productivity is weak and vulnerable, with high levels of informality, underemployment and self-employment; in 2011 the INEI reported an increased rate of suitable job (46.7%) having been only 23.5% in 2010. The index of informality since 2002 is over 65%.

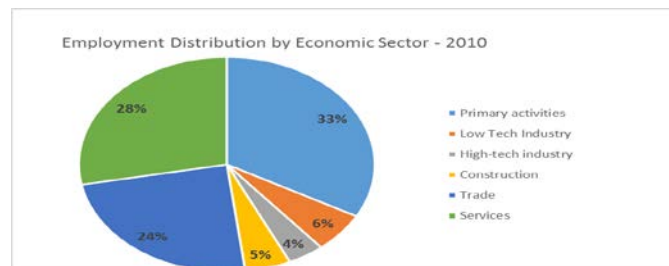


Fig. 5: Distribution of employment by economic sector - 2010
Source: CEPLAN (2010)

Financial Markets

By 2013, Peru was already very attractive for international investors, and is usually grouped with Mexico, Panama, Colombia and Chile as one of Latin America's high-growth economies. Nevertheless, in words of Miguel Castilla, Peru's finance minister for almost a decade, the financial market, is failing to meet demands from both issuers and investors. *"this is partly due to "excessive regulation" and partly because of a shortage of investable assets, so the reform will encourage the offer of hybrid instruments"*.

Currently, most of the local investment is from pension funds, Peruvian companies get 70% of their finance from the banking system and just 30% from capital markets. However, about 90% of that took the form of foreign currency bond issued overseas, which are only available to the biggest corporate names. Between 2009 and mid-2013 Peru has experienced significant inflows from foreign investors into local currency government bonds (BTP). Regarding the Global Financial Development Report 2011-2013, Peru financial system is characterized in the Table 2. The overall economy value was below the 25th percentile.

Table 2: Peru and Their Financial System Characteristics (av. 2011-2013).
Source: The World Bank

Financial institutions				Financial markets			
Private credit by deposit money banks to GDP (%)	Account at a formal financial institution (% age 15+)	Bank lending-deposit spread (%)	Bank Z-score	Stock market capitalization + outstanding domestic private debt securities to GDP (%)	Market capitalization excluding top 10 companies to total market capitalization (%)	Stock market turnover ratio (%)	Stock price volatility
26.2	20.5	15.8	16.6	61.7	36.2	5.2	23.1

National Educational System

Education in Peru is divided into three levels of mandatory basic education: preschool (3 to 5 years), primary (3 to 5 years) and secondary school (3-5 years). It has improved its coverage levels, especially in primary education; however, there are serious problems regarding the quality of education, as most primary school students does not achieve the expected learning, in 2009, only 23.1% of students in second grade achieved the expected learning in reading comprehension and only 13.5% in math. The completion rate in secondary education also had an increase in the range 17-19 years (60.7%) and 20-24 years (73.9%).

Many of technological colleges (IST) do not have trained teachers in pedagogical neither with updated specialties; their students develop their practices with obsolete and shabby

equipment. Most technical careers offer consists of accounting, secretarial, computing, administration and nursing; however, the labor market for these specialties are saturated, without the rivalry that are made with the same graduates specialties at local universities.

The average annual expenditure on state universities in Peru is less than US\$1600 per student. Additionally to deficiencies in quality, there are a low demand-oriented in engineering and science careers. Thereby, the distribution of professionals by main occupation has not changed in decades, and remains concentrated in the professions of law, social sciences and humanities, which despite being saturated remain the most demanded and supplied.

Intellectual Property Rights

The ninth edition of the International Property Rights index (IPRI) which ranks countries on three main components: Legal and Political Environment (LP), Physical Property Rights (PPR), and Intellectual Property Rights (IPR), ranked Peru in 79 of 129 countries in 2015. Table 2 shows the position within a global and regional scale (Latin America and Caribbean).

Table 1: Peruvian rank in International Property Rights Index. Source: website of the 2015 International Property Rights Index

	Score	Globally	Regionally
Peru overall IPRI	4.6	79 of 129	12 of 22
Overall Intellectual Property Rights	4.5	77 of 129	12 of 22
Protection of IPR	3	110 of 129	18 of 21
Patent Protection	6.9	52 of 107	7 of 18
Copyright Protection	3.5	62 of 105	7 of 22

Welfare Regimes

For Wellbeing in Developing Countries (WeD), the research group funded by ESRC and published by the Centre for Development Studies at University of Bath, *"the distribution of income and wealth in Peru is one of the most unequal in the world"*. Because of the perpetuated inequality, affecting different measures of wellbeing. Or as Wood and Copestake (2007, p.8) says *"Peru is an 'unsettled' society in welfare/wellbeing regime terms"*.

Peru is considered by the World Bank as a mega-diverse country with a geography that in their three regions (coast, highlands and jungle) has a great diversity of climates and microclimates that favor biodiversity. This diversity is also social, with races, languages (Spanish, Quechua, Aymara) and lifestyles adapted to each region. However, this geographical diversity and remoteness is not the fundamental source of Peru's social stratification, in fact, since the colonial times there is a cultural dualism, with highly unequal ethnically diversified society with culturally structured forms of social exclusion, which is translated into political exclusion, economic inequality and a fundamental problem of institutional legitimacy. Thus, the preconditions for a political settlement capable of delivering universal improvements in wellbeing are weak. Rather, it is a society dominated by strong ethnic and cultural identity, social closure and mutual exclusion.

4. On Tech-Hub Peru design

Our Tech-hub concept

Tech-Hub Peru will be a physical place where we:

- Evangelize and build firm's absorptive capacity: by developing international high-level postgraduate courses in engineering, technology and innovation. The courses must be hands on, market and industry oriented, with an international value from academic and practitioner point of view.
- Develop an ecosystem: as a cluster facilitator, building an international network that includes micro, small and medium-sized enterprises, universities or other research and

technological center; initially between Europe and Latin America.

- Do research and development: as a business support and facilitator for knowledge creation, technology transfer and innovation in manufacturing sector

The hub extends

Using a rich picture technique, we propose the following design for the Tech-hub ecosystem, there are represented in the upper middle-left corner the Degli Studi of Salerno University within the networks of business and industries that could be already interested in this enterprise, as well as other international universities; symbolizing the scope of these relations the globes within the continents. In the opposite side, represented by Peruvian flag, are the local universities, businesses within their extended value chain, the professional, labor and trade associations, the government institutions related with manufacturing and science and technology promotion. In the middle, the 'hub' leader within a committee that is tied initially with Salerno University (see Fig. 8).

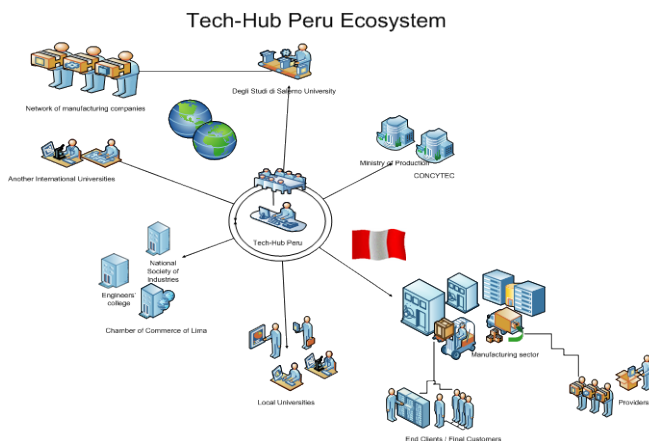


Fig. 8: Rich picture of Tech-Hub Peru ecosystem

Describing the ecosystem

As we could see, we already use the term ecosystem, as a system of systems, trying to symbolize the Kaumann (2001) social systems that interacts in the process of product innovation – ‘business’, ‘science’ and ‘policy’-. Going beyond national innovation systems, we are incorporating from the very beginning a more experience and industrialized country, that has knowledge explicit and tacit, different kinds of technologies for manufacturing sectors and the experience in business-university innovative projects, and last but not least funding experience from government and European community.

From Peruvian ecosystem, we will begin to search stakeholders from public and private sectors looking to get interested in being part of this project from the very beginning, as sponsors or allocating funding resources. Particularly those institutions related with the promotion of science, technology and innovation like CONCYTEC or sectorial and professional associations as SNI (Industrial National Society) and Engineering College in Lima (CIL). Then, we will continue with the evangelization on technology transfer and technological innovation for competitiveness through talks, conferences, seminars in collaboration and with the support of our first members and stakeholders. Subsequently, we will design special middle and high level international training courses for the preparation of technicians and professionals in areas of industrial, mechanical and electronics engineering; based on hands on with an international travel and work experience. In parallel, we will organize in-house meetings to collect needs and expectations of executives, entrepreneurs and associations in the manufacturing sector.

Governance and Organization

The Oversight Board will have an important role in supervision and opening national and international network of companies and contacts at the highest level to position the hub. The center directors are executives responsible for driving the hub, one at local place in the role of general manager and another one with the role of international manager. They will have two areas of counseling, one related to the expertise in industry and technology and the other with internal and external communication, both been key elements in the conception of this center. The layout of organization is presented in Fig. 9, the key roles here below:

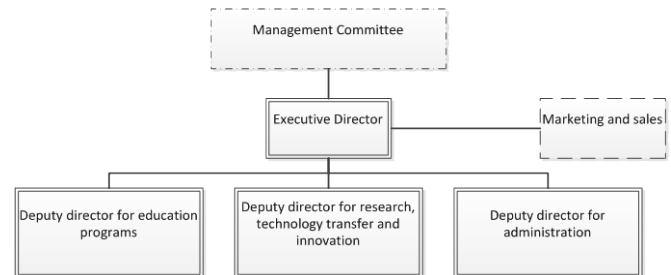


Fig. 9: Organization chart of Tech-Hub Peru

The key roles and decision makers:

Board of Directors

- Local Chair
- International Chair
- Chief Executive Officer

The operational and support roles:

Marketing and sales

Deputy Directors:

- for education programs
- for research, technology transfer and innovation
- for administrative stuffs

In order to manage and funnel these flow of information and knowledge from the international partners and expectations, inquires and needs of information, knowledge and technology from local businesses, institutions or government, we will have a stablished permanent committee which have a regular weekly meetings in order to prioritize projects and activities. To provide the services, the hub will have three executive branches, a central research, technology transfer and innovation, one for training and one for training and administrative support. The head quarter will be located in Lima.

Building a common understanding

Following Kaumann (2001), we will put communications as a central and specific elements of our ecosystem; what these mean is we will use specific communication methods and channels in order to spread our vision, mission and values inside and outside the cluster, to motivate individuals, institutions, and public audiences about important competitiveness in manufacturing industry through technology transfer and innovation.

- **Mission:** Provide an international cluster environment in which old, new and emerging companies can develop and grow, building the best combination of cutting-edge knowledge, dynamism, technology infrastructure, funding opportunities and innovative approaches, relevant to their business and profitable for manufacturing industry
- **Vision:** Stimulate and manage the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; being a trusted key stone in international cluster building for manufacturing industry in developing countries.
- **Values:** Cutting-edge knowledge and technology, passion, engagement, innovation, leadership, trustfulness, reliability, valuable networks.

Goals

Capacity-building and international contacts will be the core of our proposal; we propose five goals to respond to the need of technology transfer and innovation in Peru:

- Development of applied research; oriented to the solutions of practical problems, both of industry and society
- Training and high level education; based on projects in abroad industrial locations
- Technological development and innovation in industry;
- Introduction of new technologies in the country; and
- Creation of knowledge-based industries (spin-offs)

Sectors of intervention

Tech-Hub will start by launching high levels of learning programs in engineering, technology and innovation, in partnership with Salerno University and their Italian cluster. The courses will be hands on, market and industry oriented, with an international value. Those will be useful also as an evangelization stuffs and Firm's absorptive capacity development, thus immediately after we could start working on science, technology transfer and innovation projects in three areas, those are:

- On design, construction and / or adaptation of machines for agribusiness, metalworking, public transport. To have a positive and significant impact on improving the competitiveness of the Peruvian productive sector, we will choose the right scope (national, regional or sectoral).
- On aeronautics related services, not in the design or construction of ships, rather in the maintenance and logistics around the air transport; as well as in training and EASA / FAA certification.
- On design and construction of boats and yachts to enjoy all Peruvian sea and large coast as a tourism potential. Until now, the population lived on backwards to these rich possessions; thus, sailing could be an important sector for the economy of Peru and will have certainly a future.

Financing

We will do initial orientation seminars to familiarize potential sponsors with the concept of Tech-Hub Peru, giving information objectively on characteristics and objectives, its problems and potentials, and the responsibilities and obligations of the key player. Being a private initiative, we will need to look actively for funds to cover operational and developing expenses:

- By selling international high-level postgraduate courses in engineering, technology and innovation, paid either by people taking those or by their enterprises. We will try to have the sponsor of government, professional associations or international organizations
- By submitting research, technological and innovative projects to national or international grant funds aimed to promote innovation in developing countries. Also, partnering projects looking for government programs that usually demand co-financing through the allocation of facilities, man-hours, equipment and experts of the participating entities, through a win-win business models
- By selling services of consultancies in research, technology transfer an innovation for manufacturing; or helping to formulates and manages projects.

5. Discussion

A wide range of studies suggest the importance of innovation as a competitive trigger especially in a knowledge economy, but, in a developing countries there is also a high need of evangelization and building of firm's absorptive capacity. This is almost a fact in manufacturing of high tech with innovation in all channel value; also, it is an industry highly linked to experience and tacit knowledge, which refers to a knowledge difficult to communicate to

others via words and symbols, thus, there is a need of face-to-face and hands-on learning experience.

Following the literature review, we propose an ecosystem for Tech-Hub Peru, in order to include the dynamics of broad social environment where we will introduce new ways of production, anchored in a more productive and competitive manufacturing through technology transfer and innovation. In addition, our strategy takes care of firm's absorptive capacity through proximity to capture tacit knowledge from most developed and experienced economies. However, it is not without significant risks.

The first steps until the consolidation heavily depends on the capacities of the cluster facilitators in a local front, engaging stakeholders, getting government support, building trust relationship and maintaining a long, solid and profitable relationship with Salerno University. Deploy a platforms like this requires interdisciplinary perspective and different fields of knowledge, thus, it could be costly and hard to engage all professionals and stakeholders needed. Another risks is the no consecution of financial funds to lunch the high-level educational programs, to start building testing and reverse engineering labs for research and technologies adaptations, as well as for operational and initial projects.

6. Conclusions and Recommendations

The design of Tech-Hub Peru proposed here, defines its scope, vision, missions, goals, network cooperation and governance, organizational structure, physical (geographical location of local office), services offers and initial sectors of intervention. Being proposed as a private initiative, it will be necessary to get government support to finance the initial activities, and to contact all Peruvians stakeholders who may be interested in joining this initiative, both in public and in private, directly or indirectly.

As Tech-Hub Peru is a private initiative, it will be convenient to be managed as an adaptive ecosystem. Thus, we could capitalize on field studies in order to build a model. We also encourage to have more studies and suggest to build consistent data of clusters life cycles, especially on birth and development phases.

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THE IDEA OF CREATIVE WORKSHOPS AS AN INSTRUMENT OF AN ENGINEER'S EDUCATION IN THE CREATIVITY-BASED ECONOMY

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Abstract: *The purpose of the paper is to identify the role of the engineer in the evolution of the market economy. This identification made it possible to present the engineer's new roles in the creativity-based economy emerging in the first decade of the 21st century. These roles require changes in the widely understood engineering education process. We believe that one of the fundamental tools in this education should be a creative workshop, being the space for shaping innovative, enterprising and social competences, attitudes and behavior. The evolution of the engineer's role is the natural consequence of changes taking place in the economy. More and more significance in various domains of the economy is played by information techniques, the transfer of technology, integrated management systems, the need to increase quality and productivity as well as the workplace culture. This evolution forces the need for a comprehensive education for engineers who will have a substantial impact on the level of innovativeness and competitiveness of the Polish economy.*

KEY WORDS ENGINEER, EDUCATING, MARKET ECONOMY, ENTREPRENEURSHIP, CREATIVITY

Introduction

The dynamic changes in the global economy result in the need for a new outlook on the engineer's role and tasks in a company. Research conducted between 1986 and 1993 in the group of 15,000 managers from various countries shows that engineers in the USA and in Great Britain were not a group actively participating in the management of companies and their impact on the workplace culture - as compared to lawyers and economists - was significantly lower than it could be expected. In turn, engineers in Germany, the Netherlands, Sweden and Japan – due to historical and economic conditions, were the dominant group and had a substantial impact on the workplace culture and environment¹. It turns out that the future engineers in these countries received managerial knowledge in the process of education – apart from technical knowledge. The education of engineers-specialists focused only on production processes and hard skills was recognized as a unique relic. Therefore, the problem of the managerial preparation for engineers is still valid, also with regard to Central and Eastern European countries, especially those that went through political and economic transformations in the 1990s. Poland belongs to this group of countries that began the process of creating foundations for the creativity-based economy. The determinants of this new concept of economy emerging from the knowledge-based economy include: the creative class, *smart technologies* and the tolerance towards diverse attitudes and behavior².

The purpose of the paper is to identify the engineer's role in the evolution of the market economy. This identification made it possible to present the engineer's new roles in the creativity-based economy emerging in the first decade of the 21st century. These roles require changes in the widely understood engineering education process. We believe that a creative workshop should be one of the fundamental tools in this education, being the space for shaping innovative, enterprising and social competences, attitudes and behavior. The evolution of the engineer's role is the natural consequence of changes taking place in the economy. More and more significance in various domains of the economy is played by information techniques, the transfer of technology, integrated management systems, the need to increase quality and productivity as well as the workplace culture. This evolution forces the need for a comprehensive education for engineers who will have a

substantial impact on the level of innovativeness and competitiveness of the Polish economy.

From mass production to mass creativity

Requirements set for engineers by contemporary companies are completely different than those formulated by industrial companies in the 20th century (see Table No 1). They are manifested on the background of new phenomena in the economy, such as: the growing importance of ethics and responsibility, working with people in decentralized management systems (network structures), shorter and shorter as well as faster and faster life cycles of products, production diversified to the maximum etc. In this situation, it seems justified to pose a question about the engineer's education model which needs to meet new requirements in the creativity-based economy, also market requirements. In practice, this means extending the technical education (age of mass production) and the economic education (age of mass marketing) with creative, enterprising and innovative content (age of mass creativity).

¹ Ch. Hampden-Turner, A. Trompenaars, *The seven cultures of capitalism, Value system for creating Wealth in the United States, Japan, Germany, France, Britain, Sweden and Netherlands*, Charles Hampden-Turner, 1993.

² These determinants were specified in the works by R. Florida. (See R. Florida, *The Rise of the Creative Class*, New York Basic Books 2004; R. Florida, *The Flight of the Creative Class*, New York Harper Business 2005).

Table No 1. Features of development phases in the market economy

PHASE OF DEVELOPMENT	NATURE OF THE MARKET	NATURE OF COMPETITION	DOMINATING ROLES OF ENGINEERS
Age of entrepreneurship until 1900	Exceptionally receptive, but with poorly stimulated needs. Stimulated needs on the basis of inventions from the 19th century.	"Predatory" competition, aiming more at domination or stealing the competitor rather than at direct meeting on the market.	Engineer inventor
Age of mass production 1900-1930	Receptive and hardly discriminating market with regard to the diversity in the utility parameters of products and services. Pursuit of the satisfaction of basic needs	Boundaries of industrial activities are clearly identified. The winner is the one who offers the product for a lower price (production line). Pursuit of achieving the benefits of a large production scale (<i>Economics of Scale</i>).	Engineer specialist, inventor
Age of mass marketing 1930-1960	Demand close to saturation. Customers demand the satisfaction of more sophisticated needs. Market segmentation appears.	The emergence of sales focus. Growth in the importance of distribution, market research, promotion and advertising.	Engineer designer-salesman, specialist, inventor
Age of mass customization 1960-2000	The emergence of wealth on the market. Customers demand diverse products, even within specific market segments.	Cost competition loses significance for the benefit of capacity and the speed of adjustment to changes on the market (operational flexibility). Focus on the economics of a group of goods (<i>Economics of Scope</i>). Growth in the importance of symbols, brands, signs.	Engineer manager, specialist, salesman innovator, stylist
Age of mass creativity from 2000	Development of economy on knowledge and creativity. Development of <i>smarts products</i> . Socially responsible company. Protection of intellectual property.	Turbulent changes in the environment. The competition moves to the area of innovations and skills, creating new market niches and their deep penetration. Competition - <i>winner takes all</i> . Global, glocal and local strategies.	Engineer manager, specialist, salesman, innovator, stylist, entrepreneur, creator

Source: prepared by the author (columns 1-3 were prepared on the basis of Ansoff H. I., *Strategic Management*, Macmillan, London 1984).

In contemporary circumstances, it is necessary to educate not only engineers-technical specialists, designers and salesmen, but also engineers-creators and engineers-entrepreneurs. Such education requires the search for new forms of education at technical universities. According to the authors of this paper, one such form is "*the creative workshop*" which creates the space for confronting theoretical and practical content, confronting individual and team work, as well as is a place for creating social responsibility and the formation of new, creative concepts and values converted into new products, technologies and start-ups.

Creative workshop as an instrument for engineers' education at the Wroclaw University of Technology

The problem of engineers' education in the field of entrepreneurship is truly complex, requiring introduction of practical elements linked with theoretical issues.

Experience-based teaching methods are crucial for developing entrepreneurial skills and capabilities. Traditional teaching methods (e.g. lectures) do not match entrepreneurial thinking development. Approaches involving more interactive teaching (workshops, laboratories projects, interactive games), with the teacher being a moderator rather than a traditional lecturer, are demanded. Entrepreneurial skills rely mainly on crossing boundaries between disciplines, multi-disciplinary cooperation and collaboration with entrepreneurs.

The first attempts of the WUT in this respect are highly

satisfactory, due to the achieved results and benefits. (i.e. regional project "Shaping creative market attitudes in engineer education in the years 2010-2011"). Entrepreneurship knowledge is demanded among students. We believe that an effective solution to this problem is launching, for all WUT students, a creative workshop for shaping innovative, entrepreneurial and social competences, attitudes and behaviours.

Therefore, we offer introducing creative workshops to the engineers' education system. We treat them as a space for shaping innovative, entrepreneurial and social competences, attitudes and behaviours of technical students. Validity and usefulness of organizing such workshops were evaluated in a survey. The survey was to identify the degree of demand and preferences for such education among students and employers. The first – pilot study covered a group of 30 WUT students, and a group of 24 Lower Silesian employers. Survey interviews were conducted in June 2015 using CAPI methodology (Computer Assisted Personal Interviewing), - a variety of classic questionnaire survey (PAPI) in which a paper questionnaire is replaced with a laptop.

Validity was assessed according to needs' measurement principles, with three degrees of observing the examined phenomenon:

- level of needs of a statistical individual (in our case - a student)
- level of needs of a population (all students)
- level of needs of the population's environment (employer's expectations for a student as a future candidate)

An adequately designed questionnaire helped obtain information as to:

- technical university graduate's profile,
- graduate's skills expected by employers,
- methods of recruiting graduates,
- evaluation of current WUT educational programs,
- proposed modification and changes in the WTU curricula.

The survey results expressly indicate consistency of assessments of individual needs and environment's needs. The analysis indicates the need for radical changes in the university's education system, especially as to the issues of curriculum changes.

The most relevant and effective teaching tools/methods for programmes and subjects related to entrepreneurship, in particular for non-economic major students, are those based on "group and team techniques of generating new business ideas" and on "case studies". Considering the results of the surveys conducted among entrepreneurs, apart from the above tools, also "workshops on business plan preparation" (partially consistent with the first proposed category, confirming selection of group techniques and brainstorm, as well as new ideas' creation) "inviting guest speakers" (entrepreneurs) and "business simulations" prove effective.

The workshops prepared by us rely on the above methods, and we also highlight effectiveness of methods based on undertaking certain practical business activities, as well as creative exercises for development of ideas. In our opinion, traditional teaching methods are not synchronized with development of entrepreneurial features and attributes. On the other hand, multi-disciplinary cooperation is vital in building entrepreneurial capabilities. These unconventional or untraditional methods of education of students of WUT are treated by us as a tool for shaping

active entrepreneurial attitudes and behaviours. Such attitudes and behaviours meet expectations and needs of the labour market, not only in Lower Silesia.

Conclusion

Analysing the data from the survey, we recommend our workshops for crossing the boundaries between disciplines, and as a form of a team work. We intend to teach entrepreneurship by connecting students of economic and non-economic majors. Considering the employers' opinions obtained in the study, we would like to direct workshops participants to work on real business ideas. Our point is creation of a new learning platform through practical learning of management skills in cooperation with leading innovative companies and entrepreneurs in Lower Silesia.

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APPLICATION BUSINESS INTELLIGENCE TOOLS IN MULTICRITERIAL DIAGNOSTIC PROCESS

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Abstract:

Business Intelligence is set of techniques and tools for acquisition and transformation of raw data into meaningful and useful informations. Multicriterial diagnostic is approach to obtain real status of machining proces just in time and produce a big group of raw data. We want to prepare application business intelligence tools in multicriterial diagnostic process to obtain results of diagnostic process and find "hiddenly" influence the result

Keywords: MULTICRITERIAL DIAGNOSTIC, BUSINESS INTELLIGENCE, DATA MINING

1. Introduction

Currently we are seeing a significant rise in the modernization of processes and procedures across the whole spectrum of manufacturing companies in the engineering industry. This is a natural consequence of efforts to increase the efficiency of production processes primarily due to a reduction in production cost, reduction in energy consumption with emphasis on reducing environmental impacts caused by production itself, but also other dependent aspects, and also the efforts of manufacturing companies to ensure optimization of the indirect costs associated with human resources, that are an integral part of costs. Another very important reason for modernizing production processes are continually increasing demands of customers for increasing the quality of production with demand for delivering in the required time and the required quantity. Engineering production companies are due to diversification of customers largely focused on the automotive industry and thus is also the associated requirement of their customer base to conform to standards as defined by ISO/TS 16949, which entails very high expectations for the quality of production. Because of this multi-criteria diagnostics is very beneficial, based on analysis of the results obtained from manufacturers exact information about weaknesses in the processes of production and proposed solutions to existing or predictable problems can be made. An indirect consequence of globalization trends, is evident from all sectors of industry and economy, it is manifested by combining the small and medium manufacturing enterprises to large structures that are decentralized in geographical nature, but have shared leadership and shared the same level of process control. This creates multinational corporations influencing several countries and their production is influencing the economy at international level. In such enterprises original manufacturers are transformed from autonomous production structures with complex production to highly specialized manufacturing units.

The reason for the creation of specialized units is to ensure the maximum possible level of production quality and optimization of logistic processes within the group. However, this causes a new complication in the production process, the formation of hierarchical dependence of the manufacturing process where successive stages of production within the company are dependent on the production of the previous stages in the life cycle of production. For this reason, the occurrence of random and sudden interruptions of production or unplanned production decline is undesirable phenomenon with potentially serious repercussions for the entire production group. Prediction of the problems determined by the analysis of information obtained in production by obtaining measurable data is very beneficial method of eliminating the aforementioned problems of manufacturing. Production processes

are complex in nature with a large number of interacting actors. Results of mono-criteria diagnostics are useful only in analyzing an isolated property of the production process, or in the case in mono-criteria diagnostics of more complex property (e.g. vibrations) the result have broader scope, but are susceptible to errors due to misinterpretation of the results analyzed or the emergence of errors in cases where the process is affected by new actor that did not appeared previously and then "hiddenly" influence the result.

Our aim is to as much as possible get a realistic and comprehensive view of the manufacturing process and obtain measurement results that their analysis produce results with high diagnostic value with accurate description of the state of the manufacturing process. Data obtained through multi-criteria diagnosis have a very large content value. Depending on the way in which we look at the data, in way of their further processing and, depending on the interpretation of the results obtained by the analysis of the collected data we can not only predict failures and need of scheduled maintenance, and also predict other phenomenon related to the production and manufacturing process. With correct data analysis and correct interpretation of data we can create very precise results for optimization of energy requirements and environmental impacts of manufacturing processes, also we can optimize usage of human resources, and material flow, and other important factors. Because of wide application opportunities of the proposed multi-criteria diagnostics, and analysis of the results obtained by it we can apply the research results in a wide variety of manufacturing companies at the international level.

Aim of our research is to ensure the development of analytical tools that process the data obtained through multi-criteria diagnostics to obtain the required answers to specific questions defined by mechanical engineering companies in the topic of increasing efficiency and optimizing production processes. The resulting data set has a very large scope and the maximization of the content value, is however dependent on a thorough knowledge of its structure and in particular in accordance with the dependencies observed in gathered data. Production process is a continuous sequence of tasks and the various actions in the production process are not an isolated factors affecting the final product, but are an integral set of mutually interacting factors that have both a direct impact on final product manufacturing, and also often lead to mutual interaction between each parameter by means of a visible but also hidden dependencies that need to be understood before of the processing and interpretation of data obtained thru multi-criteria diagnostics.

2. Multicriterial diagnostic

With multi-criteria diagnostics of the production process we are collecting in a relatively short time an extensive set of data. We need very powerful analytical methods and tools to obtain applicable results in real time. Therefore, we will focus our research on the implementation of advanced analytical methods for processing the large data set on commodity computing devices. We plan to achieve the desired performance when storing and subsequently processing data collected from the production process by implementing the tools on top of database systems and subsequently ensure progressive implementation of data processing methods presently known under the term Data Mining. These methods and approaches are significantly contained in the tools some times known under the name of Business Intelligence, the application of the general principles under which they carry out their tasks we already know, we will be able to deploy and modify them in order to achieve our goals with high efficiency.

The essence of multicriterial diagnostics is simultaneous usage of multiple methods of diagnostics in order to gain effects such as simplification of measurement, reducing time and costs necessary to perform measurements or to increase accuracy of measured data. Therefore, one of our aims is selection of suitable diagnostic methods in order to gain synergic effect as result of combination of conventional methods of technical diagnostics utilized for certain group of production machines, and monitoring of technological and non-technological parameters related to production processes. Each method of technical diagnostics and monitoring of production process is characteristic not only by measured parameters but also physical phenomenon used for its measurement and also by characteristic and volume of measured data and signals that have to be stored for evaluation. The purpose of integration of multicriterial diagnostics is optimization of diagnostics of production processes and setting of diagnostic processes in production in way that allows maximal positive effect on stability of production processes thru maintenance planning.

Keeping availability of diagnostic tools in mind, we expect usage of multiple available methods such as measurement of vibration in various places of production device, in multiple axes during its operation and taking sources of mechanical wave motion and it's spreading into consideration. Vibrodiagnostics as part of multicriterial diagnostics offers significant amount of information about state of monitored object such as changes of state, its character and localization. Same time, vibrodiagnostics allows certain amount of automatizability, what simplifies its implementation to long-term and short-term monitoring and also into multicriterial diagnostics. Particularly interesting results can be gained by measurement and analysis characteristic vibrations of spindle of machine tools. In terms of methods of signal processing and volume of data gained during measurement, vibrodiagnostics is similar to noise analysis, which differ mainly by used sensors, where microphones are used instead of vibration sensors. The recorded sound is processed through the various filters in order to extract usable signal which can be scanned for distinctive patterns afterwards. Such patterns allows to determine corresponding events. Vibrodiagnostics provides wide range of information about condition of machinery, but it is unable to reflect the condition completely. Vibrodiagnostics is specific by significant amount of measured data what can complicate the processing.

Another methods with high potential in multicriterial diagnostics, we determined, the thermography and measurement of temperature of constriction nodes of monitored objects. The increased thermal emissions and related increase of temperature of the component is usually directly related to increased friction, load or electrical resistivity as result of mechanical or electrical failure of monitored device. The first analysis allows to identify the nodes where change of temperature can occur as result of various events and localize positions where temperature sensors can be placed in order to perform long-term monitoring and diagnostics. Measurement of temperature of individual nodes can be relatively

easy to implement into common production devices with no effect to its original purpose and functionality. The measured data can be easily analyzed directly in real time or in the context of activities carried out by monitored devices with further increase of the reliability and sensitivity to changes that may occur at various different levels and type of loads on monitored device.

The engineering industry uses dimensional geometric accuracy as one of the most important parts of quality of production. Accuracy of products, not only machined parts, is directly linked to precision of production device and therefore precision of positioning and its analysis should not be neglected in field of multicriterial diagnostics, even though it can be hardly implemented directly into autonomous systems. The alternative to fully automated system for monitoring is the implementation of measurement of positioning precision at regular intervals or at occurrence of event of change of monitored parameter or parameters. This requires specification of certain limits for monitored parameters that requires to repeat measurement of positioning precision. The implementation of precision measurement of production devices anticipates usage of laser interferometer and device for analysis of precision of positioning during circular interpolation. Described measurements gives information about complex technical state of observed production device as technical system and it's subsystems that are involved in positioning.

Precision of machinery is closely related to wear. The wear usually is not uniform along all effective workspace of machine tool and therefore it is possible to say that precision is function of position. The wear is directly linked to usage rate, so maximal wear is usually localized at most exposed places and vice-versa, the less used parts of workspace should keep maximal precision longer. The mentioned facts indicates that the monitoring of the working space of production device can be used as base for prediction of future wear of movement mechanisms based on usage rate of different parts of workspace. Besides of position there are other factors that have considerable impact to wear rate of machine such as forces produced during normal operation of device and therefore it is important to monitor other parameters such as spindle speed and federate in individual axes. Next parameter suitable for long-term monitoring which can easily reveal some aspects of machine state is amount of electric energy consumed to perform specific. If amount of electricity necessary to perform specific action rises it is usually caused indicates that energy is consumed to overcome previously absent resistance or obstacle. Data received by described monitoring will be included into basis of analyzed data. Important part of following analysis will be revealing of correlations between parameters obtained by multicriterial analysis and optimization of data harvesting processes accordingly.

Base methodology to deal with the second objective is the implementation of method to preserve data obtained in the process of multi-criteria diagnostics, implementation of relevant tools and consequently processing and evaluating the obtained data thru analytical tools. The results will be presented to final customer through suitable informative views.

Given the scope and nature of the data obtained during the implementation of multi-criteria diagnostics while respecting the need for rapid storage and processing measured data we propose to use database application approach. If deployed into the production environment on the corresponding sufficient hardware, it give us high-performance set of tools that will allow us to perform all the required tasks associated with storage of the measured (raw) data without restrictions due to different structuring of stored data and it will allow us to back up all the required data, and pre-processing of data on the data server, without sacrificing performance on computers that will implement the analytical processes, enabling us to flexibly create and modify the rights to stored data, and allow us to be very responsive when providing a response to a query processed by set of data analysis tools. An important part of the database system to allow processing of high volume data is a tool

for data optimization and data processing tools to maintain data integrity.

The complexity of multi-criteria diagnostics is proportionally depending on the number of data collected in the production process. They are the parameters describing the status of individual elements that are part of every process of production (machinery, tools, workpiece, etc.), but also elements indirectly affecting the production process (alignment of machines, cutting tool abrasion, state of coolants, etc.), and elements that externally influence the process of manufacture (ambient temperature, ambient humidity, the state of power network, etc.). As the number of monitored elements is growing, proportionally increases the number of endpoints and this causes proportional increase in data acquisition.

The data obtained during the multi-criteria diagnostics in the manufacturing process are usually very large in volume. Likewise, we can say that, when monitored data is properly defined data obtained during the multi-criteria diagnostics give us very large amount of usable informational. Our role is to provide an understanding of the data obtained in contexts of the monitored production process, detect cross-correlation between the parameters of the production process and enable to the user of our system to optimality access the presented information, by correctly defining the set of interpretation rules. To achieve these objectives, we need to have powerful analytical tools that allow us to process all necessary steps with the available data obtained by the multi-criteria diagnostics.

3. Application of Business Intelligence

For this reason, we propose to use in obtaining the necessary information tools designed to analyze large volumes of data, this tools are sometimes known as Business Intelligence tools. They can be defined as tools that arose from a set of concepts and methodologies for improving decision-making process based on the use of metrics and use of systems-based metrics. Business Intelligence (BI) is an important factor affecting the quality of business informatics processes in the competitiveness of enterprises. The basic principles of BI include data transformation from databases and production systems to the analytical data. BI solutions are based on multidimensionality in stored and manipulated data.



Fig. 1 Tools of Business Intelligence in Enterprise

The focus of our research in the transformation of data collected from multi-criteria diagnostics to information presented to the end user will be primarily done by using tools for parallel processing on multidimensional data of BI tools. From OLAP tools we will focus on defining data structures that are also known as OLAP cube, that allow us to carry out necessary analysis on the data gathered by multi-criteria diagnostics, for effective business planning.

Planned analytical process will be carried out through data mining. Data mining will be realized through statistical methods and artificial intelligence, that will allow us to find correlations and other hidden or unknown dependencies between data acquired by multi-criteria diagnostics. Subsequently, the results of analysis will be processed through predictor models or segmentation models and then presented in the form of the results to the end user.

On the basis of the described methodology to deal with defined roles and selection of tools that we plan to apply in our research we are confident to say that they are designed competently and with emphasis on the ability to meet the declared objectives in full.

We hope that our approach is right to obtain our intended aims.

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DEVELOPMENT, MANUFACTURING AND INTRODUCTION OF NEW CONSTRUCTIVE SOLUTION OF TRANSMISSION MECHANISM

РАЗРАБОТКА, ИЗГОТОВЛЕНИЕ И ВНЕДРЕНИЕ НОВОГО КОНСТРУКТИВНОГО РЕШЕНИЯ ПЕРЕДАТОЧНОГО МЕХАНИЗМА.

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Abstract: It was developed, studied, manufactured and tested new designs of multistage gearboxes on the two shafts with cylindrical gears, providing virtually unlimited value ratios. This reduces metal consumption, improved reliability and efficiency by the eliminating in the mechanical system of the intermediate shafts and their support units, to provide a set of agreed most effective technical solutions and create new machines and units at the level of the best world samples

KEYWORDS: TRANSMISSION MECHANISM, PACKET GEAR, SCHAFT SPEED

1. Introduction.

Gear reducers are widely used in machines and units in almost all branches of modern engineering.

The use of low-power and high speed electric motor drives, allowing to reduce energy consumption as a whole, and by the extreme operating conditions of machines and units depends on the number of stages and gear ratio value of gear reducers.

Therefore it is very important to finding the most efficient kinematic scheme of multi-gear reducers, taking into account not only the external (consumer) characteristics, but also its cost [1-3].

The department "Machine parts" of Azerbaijan Technical University developed, studied, manufactured and tested new designs of multistage gearboxes on the two shafts with cylindrical gears, providing virtually unlimited value ratios, which originality was confirmed by the Eurasian patent. This reduces metal consumption, improved reliability and efficiency by the eliminating in the mechanical system of the intermediate shafts and their support units, to provide a set of agreed most effective technical solutions and create new machines and units at the level of the best world samples [4-7]

To confirm the theoretical assumptions were made laboratory working model of a new constructive solution to single-threaded five-step gearbox with a total transmission ratio $U_{\Sigma}=243$ (Fig. 1)

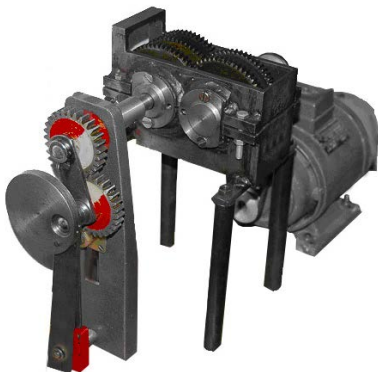


Fig. 1. Laboratory sample of the new constructive solutions of three-stage cylindrical gear reducer with a gear ratio $U_{\Sigma}=243$

A distinctive feature of the proposed gear is that all the intermediate shafts are eliminated in this mechanical system, in all stages drive and driven gears are the same size, that it provides increased reliability and manufacturability. The structure of the gear working as a coaxial transmission mechanisms includes, freely rotated on the driving and driven shafts, one three and two double corona gears, mounted in the form of a "packet". The rotation direction of three and double corona gears wherein respectively coincide with the rotation direction of the driving and driven shafts.

Due to the specific useful direction of the friction force of lubricating fluids on the cylindrical and side surfaces of the structural parts of "packet" gear its efficiency is increased up to 8%, and thus achieved a reduction of electricity consumption.

The proposed transmission gears in the future called "packet reducers" that has been recognized in several international conferences [8, 9].

Further, according to initial data of the drive rod pumps and based on normative requirements for water wells depth of 40 m and an oil well to a depth of 1,500 m (for sucker-rod pump SKD3-1,5-710) have been designed, manufactured and successfully industrially tested two double-flow three-stage cylindrical gear reducers on two shafts, with the transmission ratio $U_{\Sigma}=64$ (Fig. 2, 3).



Fig. 2. Mechanical drive rod pumps for water wells depth of 40 meters with a new constructive solution double-flow three-stage cylindrical gear reducer with a gear ratio $U_{\Sigma}=64$.



Fig.3. Mechanical drive rod pumps for oil well depth of 720 meters in relation to the SKD 3-1,5-710 with the new double-flow constructive three-stage cylindrical gear reducer $U_{\Sigma}=64$.

2. Methods

For the using in mechanical drives of machines and units of relatively high-speed and low power consumption electric motors significant practical importance has the evaluation of critical rotational speed of the drive shaft of the new constructive solutions of three-stage double-flow “packet gear”.

We consider the drive shaft gear batch on two bearings with a rotating speed n_1 . The drive shaft is represented as a stage rotor with a fixed gear and symmetrically arranged double corona gears rotating around its geometric axis and downloaded randomly distributed masses and moments of inertia [10].

Approaching of the shaft rotation frequency to the critical can be dangerous, so the rotation frequency from $0,7n_{kr}$ to $1,3n_{kr}$ not recommended for the operating modes of packet gear. In this connection, in all cases it is desirable to provide an operation of packet gear with a rigid drive shaft and $n < 0,7n_{kr}$.

To check the reliability of the basic scientific statements made numerical experiment – calculation of the drive shaft of two-stage double-flow packet gear for the sucker-rod pumps SKR3 and SKDR with the following input data:

- Nominal torque at the output shaft $T^* = 7100 \text{ Nm}$;
- Actual gear ratio of the reducer $u_z = 64$, the gear ratio of one stage of package reducer $i_n = 4$;
- Output shaft diameter $d' = 90 \text{ mm}$;
- Based on design reasons the diameter of input shaft on its mid taken $d_1 = 0,5d' = 45 \text{ mm}$; thereafter $d_2 = 40 \text{ mm}$; $d_3 = 40 \text{ mm}$; $d_4 = 35 \text{ mm}$;
- Diameter of the initial circle of gear $d_{w1} = 117 \text{ mm}$;
- Coefficient characterizing the ratio of the width of the respective stages of the output shaft $v = 0,5$;
- Torsion stress of the output shaft $[\tau]_k = 40 \text{ Mpa}$.

The first approximation for the critical speed of the drive shaft is determined according to the formula

$$n_{kp} = C \left(\frac{y(0)}{K_{y(0)}} \right)^{\frac{1}{2}} \bigg|_{x=\frac{1}{2}} = 9,55 \left(\frac{1}{367,2773} \right)^{\frac{1}{2}} 10^4 = 4983,18, \text{ rpm}$$

Recommended rotation frequency of the drive shaft of packet reducer

$$n < 0,7n_{kr} = 3488,23 \text{ rpm}$$

Where

$$y(0) = -\frac{1}{L} \int_0^{x_1} \int_0^{x_2} \frac{M(x_2)}{EJ(x_2)} dx_2 dx_1 - \frac{x}{L} \int_0^{x_1} \int_0^{x_2} \frac{M(x_2)}{EJ(x_2)} dx_2 dx_1$$

$$K_y = \left| \int_0^{x_1} \int_0^{x_2} \frac{A_y(x_2)}{EJ(x_2)} dx_2 dx_1 - \frac{x}{L} \int_0^{x_1} \int_0^{x_2} \frac{A_y(x_2)}{EJ(x_2)} dx_2 dx_1 \right|$$

$M(x)$ - discrete mass, $EJ(x)$ - stiffness of the shaft section in bending.

3. Conclusion and results

1. Compared with the existing multi-stage cylindrical gears classical performance in the proposed new designs of multi-stage packet gearboxes operational and technological parameters (reliability level increased up to 8%, efficiency - up to 9%, metal content reduced up to 30%) are improved.

2. A new analytical expression to determine of critical rotational speed of the drive shaft of the new constructive solutions of three-stage double-flow “packet gear” have been improved, which has undoubted practical value by the using of low-power motor with high rotational speed of the drive shaft $n = 3000 \text{ rpm}$.

3. Kinematic and design features of packet gear boxes allow to obtain the minimum value of the output shaft speed ($n = 1 \text{ rev/day}$), which enabled their widespread use in the mechanical drives of monitoring systems and radars.

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ON EXPERIENCE OF MODELING OF HYDRODYNAMIC PROBLEM USING COMBINED NEURAL NETWORK AND DYNAMIC MODEL

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Abstract: Solution of gas-dynamics problems containing different fine structures (shock waves, boundary layers, traces, jets, etc.) as well as areas within which the flows are described by different models of turbulence by traditional grid methods is quite difficult. These tasks are encouraged to address, using neural network technology in the analysis and grid-analytical form by stochastic optimization. The proposed method is demonstrated on the problems of mixing jets. Numerical experiments have shown several advantages of this approach: reducing the cost of computer time, good accuracy, the connection of patchy pattern of flow in a single unit.

Keywords: turbulence model, random search, neural network interpolation, combining simulation and dynamic models, non-grid methods for field tasks.

1. Introduction

The use of neural network technology can provide substantial assistance in solving the problems of continuum mechanics, containing different fine structures: boundary layers, shock waves, traces, separation points, the coverage of different turbulence models [1].

The essence of the proposed computing technology is convenient to demonstrate on the problems of mixing of supersonic streams. Such problems arise, for example, in developing high-power gas lasers stirring [2]. On fig.1, 2 the schemes are shown with the longitudinal and cross-reactive blowing environments and their respective designs. Obviously, the flow patterns are very complex. They include various fine structures of shock waves, boundary layers and their interaction fields. In addition, you can specify the subfields in which various semi-empirical turbulence models are preferred.

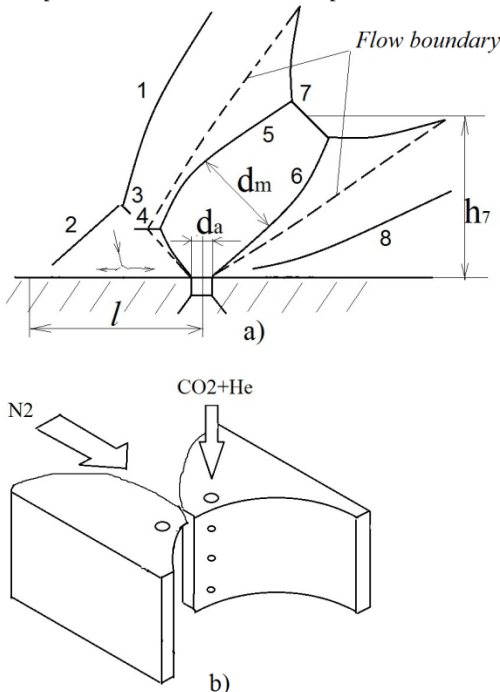


Fig.1. Cross blowing of the reacting environments: a – scheme; b – constructive solution
1 – main jump; 2 – skew jump; 3 – closer jump; 4 – jump in place of abrupt break; 5, 6 – barrel jump (inside flow); 7 – central jump (Mah's disk); 8 – jump, formed by the flow, gone around jet, inleaking on the wall; l – length of the separation zone; h_7 – distance to the Mah's disk center; d_m – diameter of the barrel jump; d_a – diameter of the injection hole.

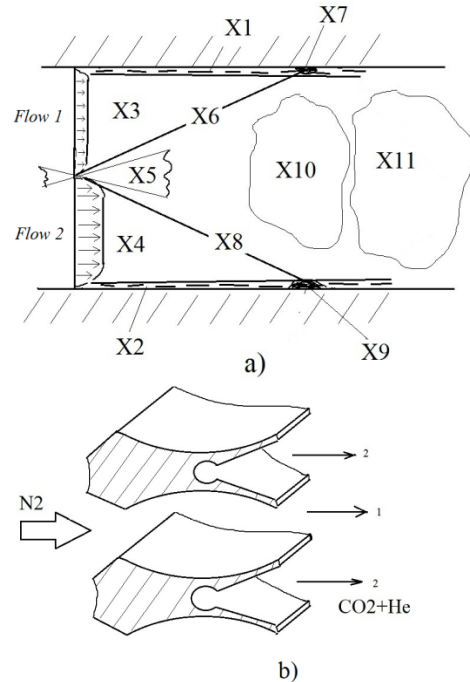


Fig. 2. Longitudinal blowing of the reacting environments: a – scheme; b – constructive solution
X1, X2 – turbulent boundary layers; X3, X4 – flows, entering the mixing chamber; X5 – boundary layer between the flows; X6, X8 – shock waves; X7, X9 – fields of the shock-wave interaction with turbulent boundary layers; X10 – field of the K-E turbulence model; X11 – field of A.N. Sekundov's model.

2. Hydrodynamic problem

As is well known, solution of the specified problems by means of purely grid methods is difficult. Indeed, the turbulent viscosity near the solid walls conveniently calculated using formulas of Prandtl and Spalding (1). Hereinafter A. Einstein's record of the field differential equations generally accepted:

1) index after the decimal point indicates the derivative on the corresponding coordinate.

2) the summation is performed according to the twice repeated index, although the sign of the sum is not specified.

$$(1) \quad \nu_t = l^2 \sqrt{(u_{1,2})^2 + (u_{2,1})^2},$$

where l – the length of the mixing path

$l = k \cdot L_{min}$,
 $k=0,41$ – Karman constant, L_{min} – the shortest distance to the nearest hard surface.

It is also not difficult to find v_t in the initial sections of flows. But in the area of the mixing flows we have to use either the K-E model (2):

$$(2) \quad \begin{aligned} \frac{\partial K}{\partial t} + u_i K_{,j} &= \left(\frac{\nu}{\sigma_K} K_{,j} \right)_{,j} + S_K, \\ \frac{\partial E}{\partial t} + u_i E_{,j} &= \left(\frac{\nu}{\sigma_E} E_{,j} \right)_{,j} + S_E, \\ S_K &= \nu_m D - E, \quad S_E = (C_1 D - C_2 E) \cdot E/K, \\ D &= (u_{i,j}(u_{i,j} + u_{j,i}))^{1/2}, \\ \nu &= \nu_t + \nu_m, \\ \nu_t &= C_\mu K^2/E, \end{aligned}$$

here ν_m, ν_t, ν - molecular, turbulent and full kinematic viscosity, K, E - kinetic energy of fluctuations and their dissipation rate, $\sigma_K, \sigma_E, C_1, C_2, C_\mu$ - semi-empirical constants,

either model of G.N. Abramovich and A.N. Sekundov is applied (3):

$$(3) \quad \begin{aligned} \frac{\partial v_t}{\partial t} + u_j v_{t,j} &= ((\nu_m + \kappa v_t) v_{t,j})_{,j} + v_t \cdot f \left(\frac{v_t}{8\nu_m} \right) \cdot D - \\ &\quad - \gamma \cdot L_{min}^{-2} (\nu_m + \beta v_t) \cdot v_t \\ f(z) &= 0,2 \frac{z^2 + 1,47z + 0,2}{z^2 - 1,47z + 1}, \end{aligned}$$

κ, γ, β - empirical constants.

The most difficult area is the interaction of shock waves with turbulent boundary layers. It is proposed to present such a motley picture of flows in one piece with the following neural network technology.

3. Neural network synthesis

Let us select the areas X_s ; $S = 1, 2, \dots, N$, each of which is characterized by its apparent specificity (shock wave, turbulence of a certain type, flow boundary layer, shock wave and boundary layer interaction zone and so on). Each of the mentioned fields X_s is fixed by the plurality of signal points $\vec{X}_{sr}; r = 1, 2, \dots, N_s$; N_s - the number of signal points in the field X_s . For each field X_s the potential of Braverman is introduced (4):

$$(4) \quad \varphi_s(\vec{x}) = \sum_{r=1}^{N_s} \|\vec{x} - \vec{X}_{sr}\|^{-m_s},$$

m_s - positive value. $m_s > 1$

If a random point $\vec{x}$ falls in the field X_s or approaches it, then the potential φ_s increases or takes the greatest value. We need to introduce some small constant protection from zero in the denominator in (4). Its neural function is introduced for each area X_s , for example, such (5):

$$(5) \quad g_s(\vec{x}) = \frac{1 - \exp(-\alpha_s \varphi_s(\vec{x}))}{1 + \exp(-\alpha_s \varphi_s(\vec{x}))},$$

which refers to the number closest to the one in the field X_s and tends to zero outside it.

The transition rapidity of $g_s(\vec{x})$ from one to zero is regulated by constants m_s, α_s .

Now turbulent viscosity can be calculated throughout the study area as (6):

$$(6) \quad \nu_t = \sum_{s=1}^N g_s \cdot \nu_{ts}.$$

Neural interpolation will fill ν_t value for those areas for which there is currently no corresponding semi-empirical model. A similar technique can easily be extended to determine the position of the shock waves, satisfying the boundary conditions, etc.

Since the solutions are presented in an analytical form, then there is no need to split the grid steps in the field of sharp

transitions. This is achieved by using the properties of neural functions g_s . Let the equations of gas dynamics system be presented (7):

$$(7) \quad F(\vec{x}, U(\vec{x})) = 0,$$

F - some linear operators, $U(\vec{x})$ - the required fields, $\vec{x}$ - point of the real space field Ω , where the process is considered.

Equations (7) are joined by the boundary conditions (8):

$$(8) \quad f(U)|_\Gamma = f_\Gamma(x'),$$

Γ - boundary of Ω , $x' \in \Gamma$, f - boundary operators.

We seek a solution in the form of constructions (9):

$$(9) \quad U(\vec{x}) = \Phi(\vec{x}, A) = \sum_{s \in \Omega} g_s(\vec{x}, \alpha_s, m_s) U_s(\vec{x}, \beta),$$

here U_s - special solutions for different subdomains X_s , $A \equiv (\alpha_s, m_s, \beta)$ - free constant, from the selection of which depends the approximation quality. U_s can be both analytical and grid approximations. Желательно при конструировании $\Phi(\vec{x}, A)$ удовлетворить граничные условия. It is desirable to satisfy the boundary conditions in the design of $\Phi(\vec{x}, A)$. This can be done by means of already mentioned neural functions g_s . In the region Ω the system of control nodes is selected. Each node represents a basic point, surrounded by a system of additional. It is possible to calculate the values of the fields U_s in each node at random, but specific parameters A and find all the partial derivatives by means of the difference method.

It should be noted that one should not equate such a calculation of derivatives with the traditional grid method. The control nodes may be spaced apart by a substantial distance, and auxiliary points are concentrated near the main central, that provides high accuracy and does not affect the stability of the calculations. The discrepancies F for equations are calculated in control nodes for any A (10):

$$(10) \quad F_i(\vec{x}_j, A) = F(\vec{x}_j, \Phi(\vec{x}_j, A)), i = 1, 2, \dots, N.$$

Of these the proximity measure $Q(A)$ of the approximate solution to the exact is constructed. For example, in such form (11):

$$(11) \quad Q(A) = \sum_{i=1}^{\bar{N}} \sum_{j=1}^M \gamma_i |F(\vec{x}_j, A)|^{p_i},$$

where $p_i > 0$; $\bar{N}$ - the number of discrepancies; γ_i - their weights; M - the number of control nodes, their number is considerably smaller than the number of nodes in the grid method.

Do other designs are possible to measure proximity. For optimal values A such values of A^* are taken, which deliver a minimum of the objective function $Q(A)$. As a tool of minimization the random search is used in the form, presented in [3]. An important advantage of random search in the ability to get out of local minimum and its insensitivity to non-smooth surface $Q(A)$.

Comment.

To determine the position of the shock waves and the zones of their interaction with turbulent boundary layers is convenient to take the continuity equation in the following form (12):

$$(12) \quad \dot{\rho} + (\rho u_i)_{,i} = \sigma \cdot \rho_{,ii},$$

here σ - constant, allowing to change the shock wave, increasing its thickness. The resulting field ρ is then approximated by the surface $Y(x)$ with the appropriate neuro constructions. During the iterations parameter σ decreases, and the shock wave sharpens. With such an arrangement is possible to model the zone of the shock wave interaction with a turbulent boundary layer. With

neuro approximation the boundary conditions are satisfied automatically. If this fails, then the measure of closeness Q is added by the penalty function.

4. Conclusion

The proposed method of solution of gas- and hydrodynamic problems, the foundation of which was laid in the works of Academician G.I. Petrov and his school, can be extended to a wide range of applications, where traditional grid approaches face major difficulties. Development of the system, consisting of neural network and dynamic model looks promising. Combination of dynamic model and neural network will allow to study physical processes more fully and quickly, to determine the unknown hidden parameters and initial conditions. These capabilities allow to apply the proposed method in many application areas.

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AUTOMATIC DESIGN OF GEARS AND THEIR MECHANICAL DRIVE IN BLENDER

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Abstract: Creation of different types of simulations of moving mechanisms with involved elements as gears is widespread. Depending on the specific needs different techniques which enable the accomplishment of the assignment are applied. Of particular importance is the selection of suitable software system that contains the necessary tools, functional qualities, set of features for automating the drive mechanisms, simulations and animations. Furthermore, it is important to determine the accessibility to such resource. Under these conditions a very good solution is the system with open source Blender.

Keywords: BLENDER, GEARS 2.0, SIMULATIONS, ANIMATION

1. Introduction

In the design of gears and other machine elements it is accepted to use CAD systems [1 - 3]. According to the functionality the CAD systems are divided into three classes: low, medium, and high [4]. Respectively each of these systems is specific in many indicators. Often developers of software products allow programs to be supplemented with additional capabilities such as: database, specifications of standards, used materials, graphic symbols and characters, as well as ready set of elements, components, and mechanisms. With the rapid expansion of the 3D system Blender, mainly due to the rich set of functionality and free GNU license [5 - 8] there are opportunities wanted for quick design of machine elements, mechanisms, and simulation of various types of mechanical systems and animating processes [9]. This study aims to clarify possible ways of quick design of gears and their drive with subsequent animation.

2. Prerequisites and ways to solve the problem

Blender 3D system itself allows a high-quality design in mesh mode (main difference with Solid CAD systems). When an individual design is applied to gear design it is necessary to consider many basic requirements and mechanical laws typical for machine elements. This design process can be facilitated as to the basic software Blender a specialized Addon - Gears 2.0 is integrated. Typical for Addons in Blender is that they are designed for the relevant version of the program. At this point the actual version is Blender 2.76 (2015). Gears 2.0 is developed in 2014 and is made completely free for use by the developer [8]. Fig.1 shows the path of generating gear models in Blender in sequence of integrating Gears 2.0 Addon to the activation of the application in add/mesh.

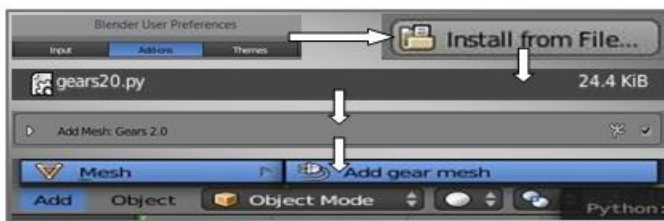


Fig. 1 Integration of Gears 2.0 Addon in Blender

When generated the initial mesh 3D gear model comes with advance (default) set parameters. Thus facilitates the further definition of the automatic gears model. Fig. 2 shows default 3D generated mesh gear model.

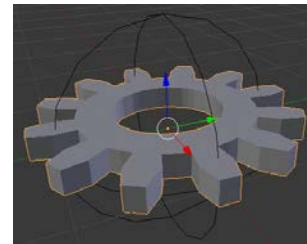


Fig. 2 Default 3D generated mesh gear model

Possible parameters for the automated design of gear models are shown in Fig. 3. Panel settings are located in Modifiers.

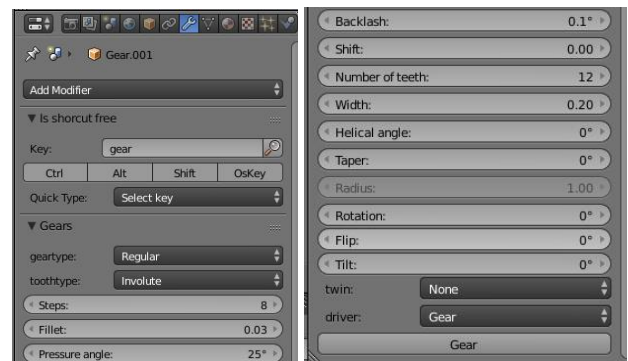


Fig. 3 Possible parameters for the automated design of gears

Gears 2.0 Addon allows a precise automated design of Tothing, [10] trough defining the parameters of Pressure angle and Backlash (Fig. 4).

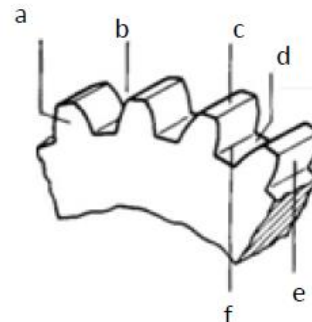


Fig.4 Tothing (a) tooth (b) tooth space (c) tip surface (d) root surface (e) tooth flank (f) fillet surface

Fig.5 shows versions of cylindrical, bevel, and helical gears automatically generated in Gears 2.0.

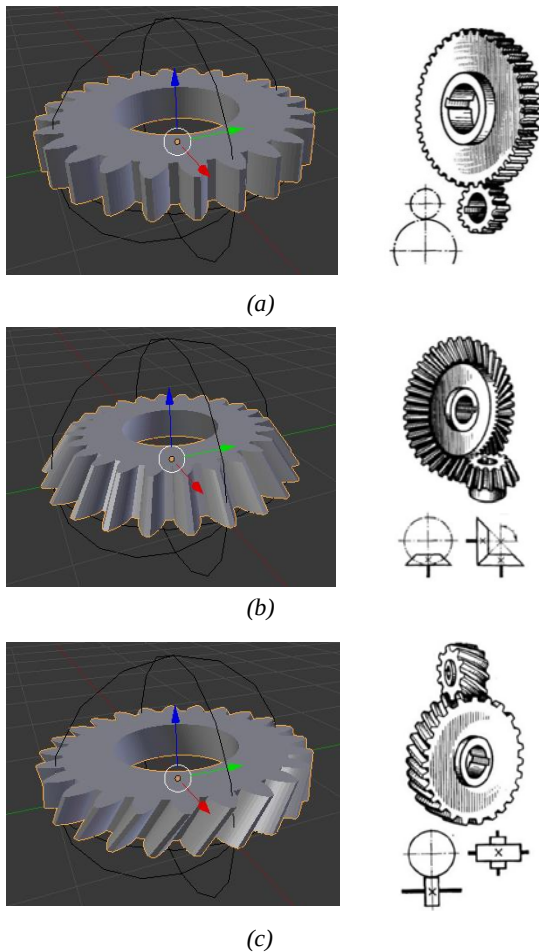


Fig.5 3D Gears: (a) cylindrical (b) bevel (c) helical

3. Solution of the research problem

This study's goal is to explore the possibilities of designing gear elements in an environment of Blender software, as the process of creating design of 3D models of gears, simulation and animation is supported automatically. Fig. 6 shows the defined configuration of the simulation of driving the cylindrical gears.

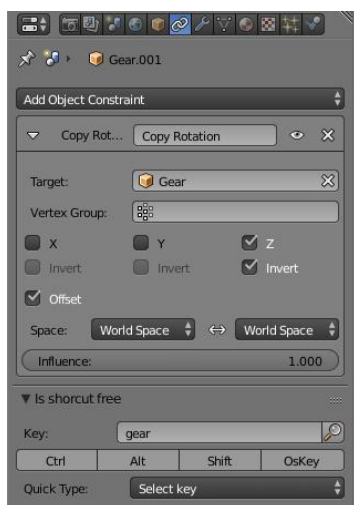


Fig. 6 Configuration of mechanical cylindrical gearing simulation

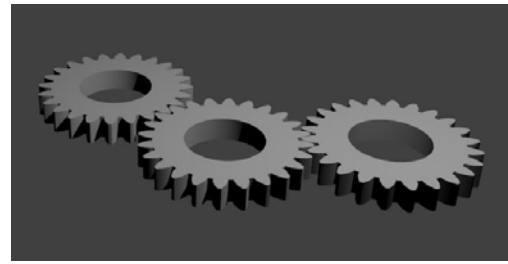


Fig. 7 Simulation of 3D model cylindrical gearing

4. Results and discussion

The resulting simulation of drive of cylindrical gears is made in a relatively short time. The possibilities of computer aided design through additional tools help constructing 3D models of gears in a more effective way. According to the assignment the cylindrical gearing system is textured and animated, using the powerful resources of Blender software.

5. Conclusion

In the present study a simulation of driving cylindrical gears is generated, using the specialized module for automatic support in the design of gears "Gears 2.0" Addon. The generated simulation is subsequently animated by rigging of 3D models. The final version of the resulting model is used to support engineering design, through quality visual presentation of powered mechanical gears elements.

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INNOVATIVE SYSTEM OF INTERACTION BETWEEN THE DRIVER AND VEHICLE. THE FANCI PROJECT WITHIN EUROPEAN COMMISSION'S HORIZON2020 FRAMEWORK PROGRAM

Alessandro Mecocci, Moshe Shahar, Per Ericsson, Sébastien Piccand, Daniel Van Nieuwenhove, Tim Llewellyn, Davide Di Censo, and Itsik Arbel

Abstract— The system described in this article has been developed within the consortium of project FANCI (Face and body Analysis Natural Computer Interaction) project. One of the main scope of the project is to give a better support to the driver's capabilities using some of the most advanced technologies in the field of intelligent user sensing methods, including eye tracking, face analysis, emotion recognition, intention & authentication, voice tone analysis, hand gesture recognition and head gesture & pose analysis. All these technologies will be integrated in a unique platform which is always-on, real time, low consumption and low cost. The information collected by this platform will be used as input of smart user intention or distraction estimation and system reaction methods, supplying visual (HUD, etc.), voice and haptic feedback as well as autonomous system actions.

KEY WORDS: EVENT DETECTION, HUMAN COMPUTER INTERACTION, USER INTERFACE.

I. MOTIVATION

HE know-how of the technologies involved in the project is spread in different research field. There are relevant publications related to the single technology. [1], [2] on modeling and emotion recognition software, [3], [4], [5] on biometric face detection software, [6], [7] on gesture recognition 3D sensor, [8], [9] for infotainment and audio solution are just some of the main publications.

Unhappily there is little work on the integration of these technologies in automotive field. This is why different partners in different technology field start to think about a common project which could lead to a new paradigm of interaction between driver and vehicle. There is an enormous innovation potential for advanced HMI based functionalities in the car: detection of drowsy or distracted drivers, driver recognition, gesture recognition, and personalization of in-car experiences.

The target of the system is to integrate existing and advanced technologies in order to help the driver's experience and also some other aspects related to the driver's management like usage based insurance and teenagers curfew. Eye tracking, hand gesture recognition, emotion detection and biometric authentication have been integrated with visual & infotainment systems through a platform solution in order to develop a meaningful system which could have a real impact in the automotive market. The integration of multi-modal human-machine technologies on a single platform allows a significant cost and power savings for the implementation of these functions in embedded products with relevant real time constrains.

The work has been focused on researching, innovating, architecting, designing and developing innovative multi-modal face and body analytics and Natural Computer Interfaces (NCI). The project will deliver these capabilities in a developer reference platform, demonstrated by building a creative Automotive Application-suite Demonstrator.

To achieve these goals multi-modal sensor data has been combined in a platform to enable robust operation in natural environments, sensing explicit, implicit, and emotional actions of the user in a simple, yet powerful extensible software architecture.

II. OUTLINE OF THE WORK

In the following subsection is briefly presented the skeleton of the work done so far.

A. Concept

This section will describe the aim of the work and the development and integration of novel methods of user sensing involving multi-modal, multi-level fusion. This involves extracting

information arriving simultaneously from different sensor modalities (audio and image) and combining them into more unified and coherent representation.

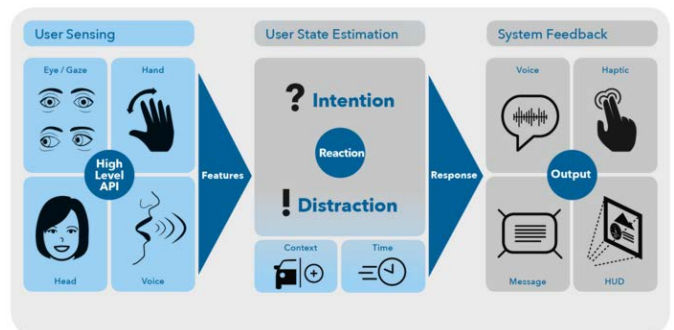


Fig. 1. Platform concept

The goal is to improve the user experience and comfort in the car while simultaneously improving security and safety.

B. System implementation

This section will describe deeper the technical implementation of the work. Here several aspects will be described such as the sensors which have been used, the multi-modal data fusion and the hardware prototype platform used. In the above pictures is highlighted the overview of the pipelines and algorithms of the system.

The full system block diagram and system capabilities will be described. Also the single components will be defined (intuitive chip, intuitive platform, ToF module, eye tracking sensor, camera) in order to give a full overview of the developed system. We will describe deeper the technologies behind the sensors, also related to the biometric authentication and mood recognition. The paper will describe also the connectivity between all components and to the host system.

The system will be integrated in a modular, low power, low cost, reference automotive platform with advanced HMI functionality.

This is the general architecture of the user sensing and face analytics software components.

- Red blocks consist of sensors and firmware components. The yellow boxes inside are the output delivered by the sensor.

- Grey blocks consist of the software components which will be implemented during WP4.
- Blue blocks consist of the applications which will be implemented on the PC.

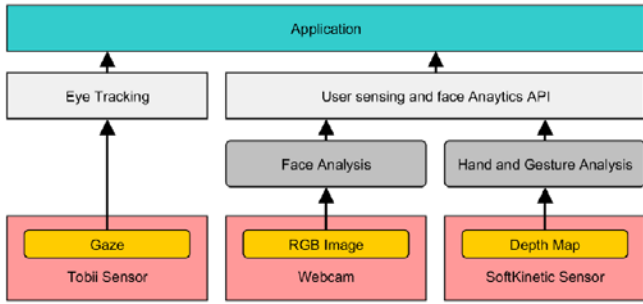


Fig. 2. Pipeline and algorithms

The software architecture consists of three main modules:

- FANCI control program (acting as the central communication instance between the other software modules and the sensors)
- instrument cluster application visualizing data in the instrument cluster screen
- infotainment HMI visualizing data in the infotainment screen

C. Prototype

The platform used for the system validation will be described. Beside the analysis core system, there are also the user interfaces used in automotive context:

- Instrument cluster display behind the steering wheels, mainly used for displaying driving information to the driver: navigation instructions, fuel level, temperature level, etc.
- Infotainment HMI display in the center console, used for controlling vehicle sub systems (media center, navigation control, phone, ADAS functionalities, etc.)

D. Use cases description

The system is intended to serve specifically for demonstrating automotive infotainment and safety applications, so the system will be finally evaluated in some meaningful use cases. The use cases are only a subset of the scenario which can face the platform. Depending on the use case, the input of the sensors are handled separately or combined to achieve the described results.

Some of the use cases are:

- User Authentication / User Profile
- Interaction with the Infotainment Display
- Select Music depending on the Driver's Mood
- Dimming Infotainment Display
- Live Eye Tracking
- Live Mood Detection

In this section will be described the detailed features of each Use Case.

E. Evaluation

The system will be validated concerning capabilities in automotive infotainment user experiences. It will demonstrate the validity of the system in automotive end-user scenarios, leveraging an integrated head-unit demonstrator, which will combine driver

assistance functionalities with infotainment components like navigation, connectivity, media, etc. The various sensors used to detect and analyze the user's face, gaze and gestures will be linked to the head-unit, and each scenario will involve the creation of a use-case specific application for the device.

During the evaluation phase both a Technical Validation and a Human Factors Evaluation will be done.

The ultimate goal of technical validation was to assess to which level requirements and specifications were met. Examples of indicators that were measured are the precision and the reliability of the sensors in automotive configuration and the capacity of the system to run in real-time.

Human factors will be studied by means of questionnaires to assess user acceptance and workload.

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IV. SHORT BIOS

Following the list of the authors with a short description.

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OPTIMAL BACKSTEPPING CONTROL FOR DUFFING CHAOTIC SYSTEM

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Abstract: This paper has presented chaos synchronization in the Duffing system using the backstepping approach. Backstepping approach consists of parameters which accept positive values. The parameters are usually chosen optional. The system responses are differently for each value. It is necessary to select proper parameters to obtain a good response because the improper selection of the parameters lead to inappropriate responses. Genetic algorithm can select appropriate and optimal values for the parameters. GA by minimizing the fitness function can find the optimal values for the parameters. This selected fitness function is for minimizing the least square error. Fitness function forces the system error to decay to zero rapidly that it causes the system to have a short and optimal setting time. Fitness function also makes an optimal controller and causes overshoot to reach to its minimum value. This hybrid makes an optimal backstepping controller.

Keywords: DUFFING SYSTEM, BACKSTEPPING METHOD, GENETIC ALGORITHM

1. Introduction

Control for Duffing chaotic system is one of the main approaches in control engineering that deal with uncertain systems. Over the last few years, control for Duffing chaotic of nonlinear systems has emerged as an exciting research area, which has witnessed rapid and impressive developments leading to global stability and tracking results for a large class of nonlinear systems; strictly feedback. Genetic algorithms have been extensively applied to the off-line design of controllers [1].

In this paper, is showed a simple and efficient approach for the revealing of all the unknown parameters and the estimation of the velocity state for the Duffing system by using a genetic algorithm (GA). Loosely speaking, the role of a GA in any application is to evolve a chromosome population that codifies several possible solutions of the problem using genetic operators like selection, crossover and mutation. The goal of GA is the optimization of a fitness or cost function that depends on the problem to resolve. In our case, we must minimize the norm of a quadratic function that depends on the unknown parameters and successive integrations of a suitable output.

Several possible methods, depending on the desired behavior of the system, have been developed (see, for example, the review in [2]), but a complete analysis of the resulting closed-loop system has been given only in a few cases. In particular, satisfactory state feedback control results for the controlled forced Duffing equation are given, for instance [3-5]. Since the periodically forced Duffing equation exhibits chaotic motion for suitable parameter settings, this system forms an important illustration for controlling a chaotic system. Chronologically, a tracking state feedback controller was established in [3] and extended to an output feedback tracking controller in [5], which also deals with the case of parameter uncertainties. See also [4], where a "speed gradient" adaptive controller was proposed. [6] showed that a number of long term stable and chaotic motions exist for systems governed by the Duffing equation. In [7] the solution was extended to Duffing equation for forcing amplitudes between 20 and 80. They found new regions with deterministic chaos consistent with the results of our research [7].

2. Duffing Chaotic System

Chaotic dynamic systems have been studied and known to exhibit complex dynamical behavior. The interest in chaotic dynamic systems lies mostly upon their complex, unpredictable behavior, and extreme sensitivity to initial conditions as well as parameter variations. Consider a second-order chaotic dynamic system, the Duffing equation, which describes a special nonlinear circuit or a pendulum moving in a viscous medium under control. We have already seen that chaotic behavior can emerge in a system as simple as the logistic map. In that case the "route to

chaos" is called period-doubling. In practice one would like to understand the route to chaos in systems described by partial differential equations, such as flow in a randomly stirred fluid. This is, however, very complicated and difficult to treat either analytically or numerically. Here we consider an intermediate situation where the dynamics is described by a single ordinary differential equation, called the Duffing equation. The dynamics of Duffing's equation is described as [8].

$$\ddot{x} = -p\dot{x} - p_1x - p_2x^3 + q \cos(\omega t) + u = f + u \quad (1)$$

where $t, \omega, f = -p\dot{x} - p_1x - p_2x^3 + q \cos(\omega t), u, p, p_1, p_2$ and q are time variable, frequency, system dynamic function, control effort and real constants, respectively. We choose initial condition as $(0.2, 0.2)$ and $p = 0.4, p_1 = -1.1, p_2 = 1, \omega = 1.8, q = 7$.

$$\begin{aligned} x_1 = x &\Rightarrow \begin{cases} \dot{x}_1 = x_2 \\ \dot{x}_2 = -px_2 - p_1x_1 - p_2x_1^3 + q \cos(\omega t) + u \end{cases} \quad (2) \end{aligned}$$

Before controlling $u=0$ the nonlinear Duffing given by (2) exhibits varieties of dynamical behaviour including chaotic motion is shown in Fig.1.

3. Backstepping for Strictly Feedback System

Consider the strict-feedback nonlinear system as

$$\dot{x}_i = f_i(x_1, \dots, x_i) + g_i(x_1, \dots, x_i)x_{i+1}; \quad 1 \leq i \leq n-1 \quad (3)$$

$$\dot{x}_n = f_n(x) + g_n(x)u$$

Where $x = [x_1, \dots, x_n]^T$, $f_i(0)$ and $g_i(0)$ are smooth functions with $f_i(0) = 0$ and $g_i(0) \neq 0$.

Step 1.

Considering the first subsystem of (3), we take x_2 as a virtual control input and choose

$$x_2 = \frac{1}{g_1(x_1)}[u_1 - f_1(x_1)] \quad (4)$$

The first subsystem is changed to be $\dot{x}_1 = u_1$. Choosing $u_1 = -k_1x_1$ with $k_1 > 0$, the origin of the first subsystem $x_1 = 0$ is asymptotically stable, and the corresponding Lyapunov function is $V_1(x_1) = x_1^2/2$, (4) is changed to

$$x_2 = \Phi_1(x_1) = \frac{1}{g_1(x_1)}[-k_1x_1 - f_1(x_1)] \quad (5)$$

Step 2.

Considering (x_1, x_2) , x_3 is a virtual control input.

$$x_3 = \frac{1}{g_2(x_1, x_2)}[u_2 - f_2(x_1, x_2)] \quad (6)$$

The (x_1, x_2) subsystem is changed to:

$$\begin{aligned}\dot{x}_1 &= f_1(x_1) + g_1(x_1)x_2 \\ \dot{x}_2 &= u_2\end{aligned}\quad (7)$$

Which is in the form of integrator backstepping, so the control law u_2 is as follow

$$u_2 = -\frac{\partial V_1}{\partial x_1} g_1(x_1) - k_2[x_2 - \Phi_1(x_1)] + \frac{\partial \Phi_1}{\partial x_1} [f_1(x_1) + g_1(x_1)x_2] \quad (8)$$

Where $k_2 > 0$. This control law asymptotically stabilizes $(x_1, x_2) = (0, 0)$ and Lyapunov function is as

$$V_2(x_1, x_2) = V_1(x_1) + \frac{1}{2}[x_2 - \Phi_1(x_1)]^2 \quad (9)$$

Substituting (8) into (6) gives

$$x_3 = \Phi_2(x_1, x_2) = \frac{1}{g_2} \left[-\frac{\partial V_1}{\partial x_1} g_1 - k_2(x_2 - \Phi_1) + \frac{\partial \Phi_1}{\partial x_1} (f_1 + g_1 x_2) - f_2 \right] \quad (10)$$

The remaining step can be deduced by analogy. Until step n , we shall determine the actual control law $u = \Phi_n(x)$, which can asymptotically stabilize (3).

4. Design Controller with Backstepping

During the last few years, backstepping-based designs have emerged as powerful tools for stabilizing nonlinear systems both for tracking and regulation purposes. The main advantage of these designs is the systematic construction of a Lyapunov function for the closed loop, allowing the analysis of its stability properties.

The backstepping is used to bring the states x_1, x_2 to the desired references via the torque u calculated with four steps.

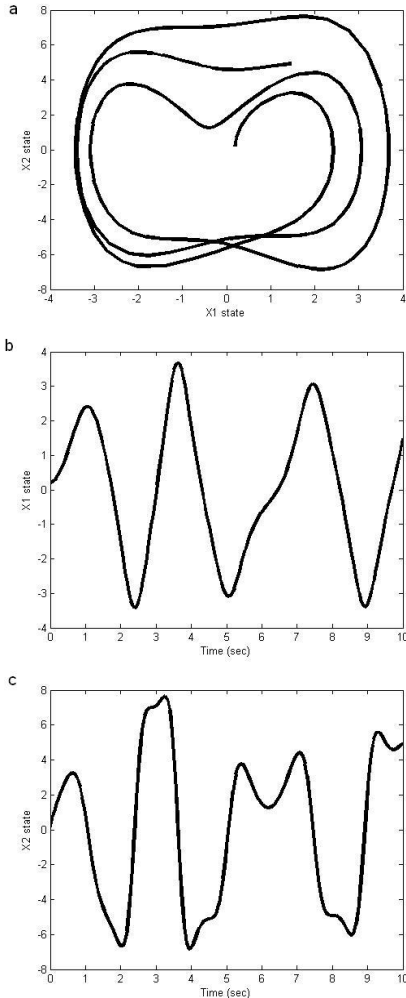


Fig. 1 (a) Phase portrait, (b-c) State trajectory variation for duffing system

Step 1.

Considering the first subsystem of (2)

$$\dot{x}_1 = x_2 \quad (11)$$

Construct the joint Lyapunov function.

$$V_0(x_1) = \frac{1}{2} x_1^2 \quad (12)$$

Take x_2 as a virtual control input and choose.

$$x_2 = \Phi_0(x_1) = -x_1 \quad (13)$$

Step 2.

Considering all system

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = -px_2 - p_1x_1 - p_2x_1^3 + q \cos(wt) + u \quad (14)$$

Take u as an actual control input and choose:

$$u = \Phi_1(x_1, x_2) = -(x_1 + x_2)(1+k) + px_2 + p_1x_1 + p_2x_1^3 - q \cos(wt) \quad (15)$$

And take the Lyapunov function as

$$V_1(x_1, x_2) = V_0 + \frac{1}{2}(x_2 - \Phi_0)^2 \quad (16)$$

Before using the GA the result estimated are shown in Fig.2.

5. Genetic Algorithm

The most of optimization algorithms are based on the gradient of the cost function, so for the ill choice of the initial point or the interval search. these algorithms can be misled on the locally optimum and can't achieve the globally optimum. For this problem, a class of optimization algorithms, like genetic algorithms, is developed to avoid this constraint.

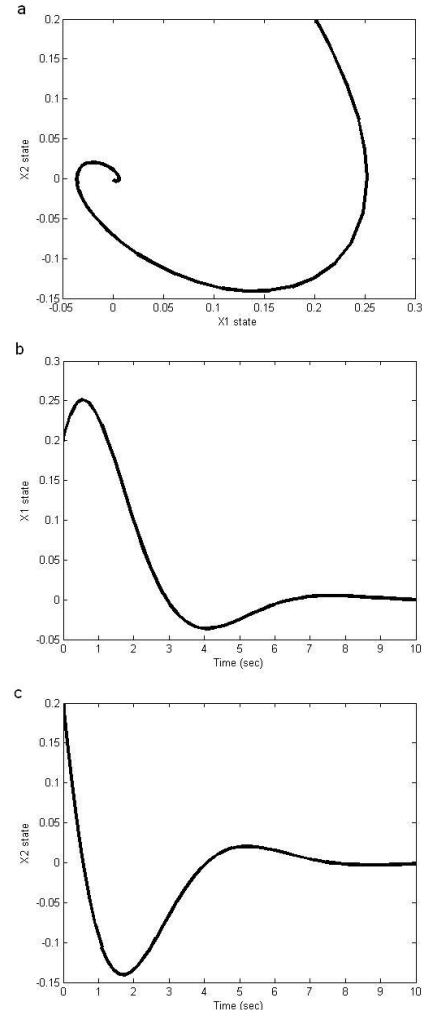


Fig. 2 Response of system with controller and without GA; (a) phase portrait; (b-c) state trajectory

In its most general usage, genetic algorithms refer to a family of computational models inspired by evolution. These algorithms start with many initial points in order to cover all search interval and encode a potential solution to a specific problem on a simple chromosome like data structure and apply recombination operators to these structures so as to preserve critical information. An implantation of genetic algorithms begins with a population of chromosomes randomly bred. We evaluate each chromosome by using the objective function called Fitness function. In order to apply the genetic reproductive operations called crossover and mutation, we select, randomly, two individuals called parents and we apply the crossover operation, if its probability reaches, between parents by exchanging some of their bits to produce two children. A mutation is the second operator applied on the single children by inverting its bit if the probability reaches. After this stage we obtain two population : a parent population and a children population, the individual who has a goodness solution is preserved [9].

The genetic algorithms are used to search the optimal parameters k_j in order to guarantee the stability of systems by ensuring negativity of the Lyapunov function and having a suitable time response. The fitness function used is

$$f = \frac{1}{n} \sqrt{\sum_{i=1}^n (x_i - x_{di})^2} \quad (17)$$

x_i is system state and x_{di} is favorit mood for x_i . Based the system purpose for placing the states at zero value; $x_{di} = 0$. By the training, can be obtained optimal parameters as $k = 9.878$.

The fitness function before and after using GA is shown in Fig.3. Fig.4a shows the phase portrait of duffing system. Fig.4b-c show the state trajectory variation for duffing system.

6. Step Response Tracking

Suppose, the x_1 state would be output of the system and it would track the input response. In this case by using the change of variable $y = 1 - x_1$, (2) would be converted to (18).

$$\begin{aligned} \dot{y} &= -x_2 \\ \dot{x}_2 &= -px_2 - p_1(1-y) - p_2(1-y)^3 + q \cos(wt) + u \end{aligned} \quad (18)$$

Step 1.

Considering the first subsystem of (18)

$$\dot{y} = -x_2 \quad (19)$$

Construct the joint Lyapunov function.

$$V_0(y) = \frac{1}{2} y^2 \quad (20)$$

Take x_2 as a virtual control input and choose.

$$x_2 = \Phi_0(y) = y \quad (21)$$

Step 2.

Considering all system

$$\begin{aligned} \dot{y} &= -x_2 \\ \dot{x}_2 &= -px_2 - p_1(1-y) - p_2(1-y)^3 + q \cos(wt) + u \end{aligned} \quad (22)$$

Take u as an actual control input and choose:

$$u = \Phi_1(y, x_2) = -(x_2 - y)(1+k) + px_2 + p_1(1-y) + p_2(1-y)^3 - q \cos(wt) \quad (23)$$

And take the Lyapunov function as

$$V_1(y, x_2) = V_0 + \frac{1}{2} (x_2 - \Phi_0)^2 \quad (24)$$

The system response for step tracking is shown in Fig.5.

7. Conclusion

This paper has presented a new hybrid backstepping approach with genetic algorithm that is demonstrated to have more optimal

behavior when compared with previous methods. This approach is used for chaos synchronization in the Duffing by using backstepping method for controlling of Duffing chaos. The designed controller consists of parameters which accept positive values. The controlled system presents different behavior for different values. Improper selection of the parameters causes an improper behavior which may cause serious problems such as instability of system.

Table 1: Genetic Algorithm Parameters

Parameters	Values
Size population	100
Maximum of generation	300
Prob.crossover	75
Prob.mutation	0.001
k_j search interval de	[0.1 10]

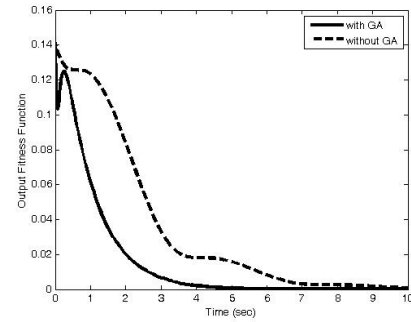


Fig. 3 Fitness function before and after optimization

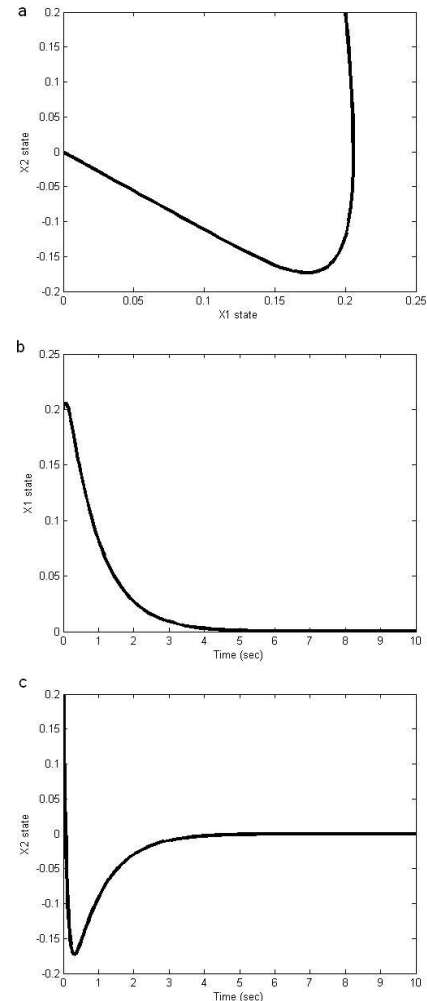


Fig. 4 Response of system with controller and GA; (a) phase portrait, (b-c) state trajectory variation

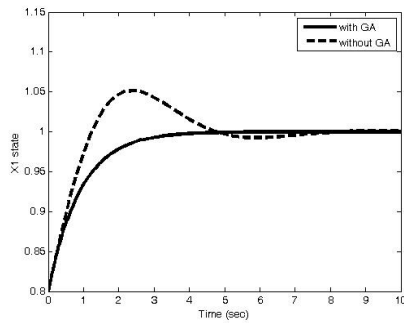


Fig. 5 Step input tracking by Duffing system

Genetic algorithm optimize the controller to gain optimal and proper values for the parameters. For this reason GA minimize the fitness function to find minimum current value for it. On the other hand fitness function finds minimum value to minimize least square errors.

By this approach the setting time and overshoot reach to their minimum values that is demonstrated to have more optimal values when compared with previous methods. Also by selecting different fitness function can have other appropriate results.

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COMPUTER DESIGN OF PRECISE SPECTROMETRIC EQUIPMENT WITH INNOVATIVE COOLING SYSTEMS

КОМПЬЮТЕРНАЯ РАЗРАБОТКА ПРЕЦИЗИОННОЙ СПЕКТРОМЕТРИЧЕСКОЙ АППАРАТУРЫ НА ОСНОВЕ ИННОВАЦИОННЫХ СИСТЕМ ОХЛАЖДЕНИЯ

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Abstract: *The small and efficient Stirling electrical coolers, which recently appeared on the market, are opening the wide perspectives for the development of precise spectrometric equipment based on semiconductor detectors for nuclear radiations cooled by innovative cooling systems. The development of such equipment is impossible without efficient computer software packages, intended for the equipment design, simulation of different solutions and preparation of design drawings and/or technological documentation. The greatest problem at the development of cooling systems based on Stirling electrical coolers is their acoustic vibrations, which impact the spectrometric performance of semiconductor detectors. Recent results of computer design of precise spectrometric equipment with Stirling electrical coolers for laboratory, field and space applications are presented.*

KEYWORDS: SPECTROMETRIC EQUIPMENT, DESIGN SOFTWARE, COOLING SYSTEMS, NUCLEAR APPLICATIONS.

1. Introduction

High Purity Germanium (HPGe) detectors for nuclear radiations require cooling till liquid nitrogen temperature to provide the best performance [1]. The small and efficient Stirling electrical coolers, which recently appeared on the market, are opening the wide perspectives for the development of precise spectrometric equipment based on semiconductor detectors for nuclear radiations cooled by innovative cooling systems [2]. Such systems can be build based on Stirling electrical coolers with different cooling power and allow to create precise spectrometric equipment for different applications without liquid nitrogen.

The development of the precise spectrometric equipment at the present is not possible without application of the modern Computer-Aided Design (CAD). Modern application software packages provides not only the reduction of the development terms for the design and technological documents, but also lower the expenses for the prototypes manufacture up to their complete exclusion in the development process.

The objectives of the present work was to design a modern spectrometric equipment based on innovative cooling systems for HPGe detectors using modern computer software package for design and simulations.

2. Equipment Functional Structure Features

The precise spectrometric equipment [3,4] generally comprises the HPGe detector of X- or gamma-radiation, vacuum cryogenic system for the detector cooling based on liquid nitrogen, passive shielding and collimation system, electronics for the detector signals processing, computer with analytical software for the calculations and results display. All these systems have own design-technological peculiarities, which should be taken into account during computer simulation and design:

- vacuum-cryogenic system for detector cooling – it requires the development of the cryostat which could provide the effective cooling for the detector up to liquid nitrogen temperature, low leakage of the residual gases in vacuum volume over the operation process. The development requires simulation of the gas leakage processes from the cryostat materials and detector holder as well as heat transfer due to heat conductivity of materials, gas convection and infrared radiation. Applied materials are stainless steel, aluminium, copper. The weight of the details could be varied within several to hundreds grams. The details are made on

CNC machines which provide the surface purity of Ra1.6. The further technological processes are the clean welding, vacuum annealing and vacuum pumping. The designer-technologist makes the calculations for strength and gas-dynamic in the documentation development as well as analysis of design processability.

- system for passive detector shielding and collimation - comprises the development of effective radiation shielding and collimators set. Only radiation pure certified materials such as lead, tungsten, copper are applied in the production process. The weight of the shield elements and collimators could be varied within several to hundreds of kilo. The machining process is made with turn/mill equipment. The designer-technologist makes the strength calculations, analysis of design processability, optical calculations for optimal radiation shielding and effective collimators set.

- electronics for detector signals processing - comprises the design of the printed circuit boards topology, design of radioelectronic units and assembly of radioelectronic equipment (REE). The designer-technologist creates the model with volumetric assembly and apply it for the further heat calculations, as well as solves the tasks of the optimal cooling for REE. The same way electromagnetic calculations are made.

- various accessories – in dependence of the type of the developing device.

The manufacture technologies of semiconductor detectors, circuit engineering solutions of low noise electronics and analytical software for the calculation and results display are rather specific products of not design features and are not discussed in the present paper.

3. Choice of Design Software Package

It's impossible to develop innovative product without innovative computer-aided design. Each of the listed system is a functionally completed one with its design-technological features and, usually, is developed in the projects by a various designers, specialized particularly in such developments. Alongside, the designed documents of the device should present the unified documentation set made in the accordance to the international standards as the result of the development and ready for the production. That is why it's very important to choose the soft package optimally

feasible for the design of all systems of the developed spectrometric equipment.

Market analyses shows that among the design software packages the most popular today are Solidworks, Autodesk Inventor, KOMPAS-3D, ADEM CAD/CAPP/CAMM, Solid Edge [5]. And the first two are the absolute market leaders. Both software Solidworks and Autodesk Inventor maintain Unified Standard for Design Documents and comprise the base of the most widely spread world standards: ANSI, ISO, DIN, JIS, BSI, GOST, GB. Both software packages are widely used in the design and their advantages and drawbacks are well known [6]. Nevertheless we have carried out rather large volume of the practical test for various applications of both software packages in the different systems and assemblies of the analytical equipment. As the result of the analysis of all advantages and drawbacks of all studied packages as well as their separate units on the specific systems and assemblies of our equipment, the choice was made for Solidworks [7]. The main reason in that choice was the presence of analytical modules in Solidworks, which allow to simulate different technological processes and to design virtually different variants of device designs without prototyping. The present advantage is highly imperative when scientifically advanced analytical equipment which requires various physical technological processes is under development.

4. Computer Design of Equipment with Stirling Electrical Coolers

Stirling electrical coolers of different cooling power allow to design modern precise spectrometric equipment with innovative cooling systems without liquid nitrogen. At the beginning in development we design Solidworks computer general model and then make a full detailing.



Fig.1. Laboratory HPGe gamma-spectrometer with shield: 1 - with liquid nitrogen cooling and 2 - with cooling system based on Stirling electrical cooler LSF9340-02 (Thales, France).

Fig.1. shows laboratory HPGe gamma-spectrometer with shield for analysis of radionuclide pollutions in liquids, powders, gas and solid samples, the most widely used in environment monitoring practice. Fig.1.1. shows the spectrometer with HPGe, cooled by liquid nitrogen, produced by our company more than 20 years already. Designed spectrometer (Fig.1.2.) has innovative HPGe

detector cooling system based on Stirling electric cooler LSF9340-02 (Thales, France) with cooling power 9W at the temperature 80K. The system of the passive shielding (weight ≈ 600 kg) was made from lead with radiation purity less than 50 Bq/kg with copper cylindrical inserts, coated with galvanic nickel. In modern spectrometer detection limit for radionuclide Cs-137 is less than 0.5 Bq/kg at the acquisition time 1 hour. The energy resolution of the spectrometer at present is approximately 10% worse than with liquid nitrogen cooling due to Stirling electrical cooler vibration.

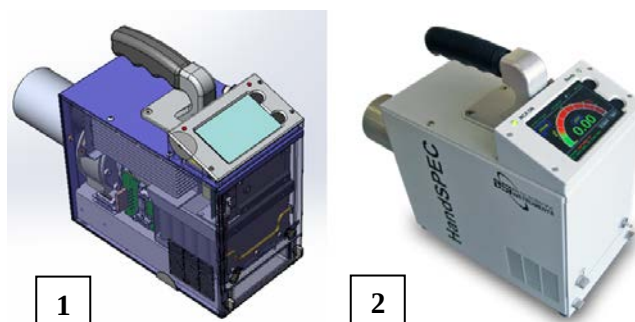


Fig.2. Portable hand-held gamma-spectrometer HandSPEC with electrical cooling: 1 – computer 3D assembly model in Solidworks; 2 – spectrometer photo.

Fig.2. presents portable HPGe gamma-spectrometer for field applications - analysis of the radionuclide pollutions on the nuclear enterprises, at the environment monitoring and inspections on the border. The spectrometer has a complicated cooling system for HPGe detector based on Stirling electric cooler SL-400 (AiM, Germany) with cooling power 4W at the temperature 80K [8]. Weight and overall parameters of the spectrometer has important value for portable device and its inner assembly has been modeled several times to get the optimization. The optimization has been carried by Solidworks Professional + attachment Solidworks Simulation (machine dynamics for strength, stability, deformation systems dynamics, thermo elasticity). The weight of spectrometer is 12 kg. Energy resolution of spectrometer is less than 1.0 and 2.0 keV on energies 122 and 1332 keV correspondingly. Worsening of energy resolution of spectrometer, compare to equipment with liquid nitrogen cooling, generated by acoustic vibration of Stirling electric cooler.



Fig.3. Miniature HPGe gamma-spectrometer for space applications

Miniature gamma-spectrometer for space applications is presented on Fig.3. Spectrometer is designed based on N-type HPGe detector with 30% efficiency registration, cooled by miniature Stirling electric cooler K508 (Ricor, Israel). Miniature electric cooler has cooling power 0.5W at the temperature 80K. The spectrometer weight is 2.9 kg, consumable power is less than 10W. We obtained energy resolution ~ 4 keV on energy 1,33 MeV, when Stirling electric cooler was switched off and $\sim 5,9$ keV when it was switched on. Energy resolution on energy 122 keV was found to be $\sim 2,0$ keV when electric cooler was switched off and ~ 4.0 keV when it was switched on. Testing results demonstrated significant influence of electric cooler Ricor K508 vibrations on developed spectrometer performance.

5. Conclusion

As result of computer design modern precise spectrometric equipment with innovative cooling systems for laboratory, field and space applications were developed. Innovative cooling systems were designed based on Stirling electrical coolers of various cooling power produced by different companies. Such innovative cooling systems can be the bases for creation of wide range of spectrometric equipment with HPGe detectors for many nuclear applications. Acoustic vibrations of applied Stirling electrical coolers worsening energy resolution of HPGe detectors remain the biggest problem of precise spectrometric equipment based on such cooling systems until now. The next steps of development should lead to significant decreasing of such vibration influence. Solidworks application results in our project have demonstrated its optimal feasibility for the design of all systems of the developed spectrometric equipment.

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AUTOMATED PASSING OF SPECIAL CONTACT ELEMENTS FOR ELECTRONIC ASSEMBLY

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Abstract: Electronic assembling is strongly automated. In 1980 the use of SMD technology for electronic assembly began on a mass scale. This technology is currently used in more than 90% of the cases. It requires a precise passing of SMD components so that it can assemble with high speed and precision. The technology is hardly applicable for non-standard component such as contact components. In the production of flame detectors by the firm of “UniPOS” non-standard contact components are used. These components have to be positioned and soldered precisely because after that there will be no opportunity for automated assembling of the final products. At first these components were put by hand and they were soldered by SMD technology. This led to a lot of labor expense, a low quality and a lot of rework, which made the products more expensive. By a vibration and a specially created strip for leading and positioning the contact elements conditions for automated SMD assembly were created. This enabled a large decrease in the prime cost of the products and an increase in the productivity of the whole production.

Keywords: SMD, contact, vibration, assembly, position

1. Introduction

The assembly of non-standard components is a problem for every automated technology [1]. In the electronic technologies for assembling components packages such as reel, stick and tray are mostly used. For components with special forms a tray is used but the assembly is slower and it requires specialized (optional) equipment.

In the firm of “UniPOS” specialized contacts (a contact component) are used. Their form is shown on fig. 1.

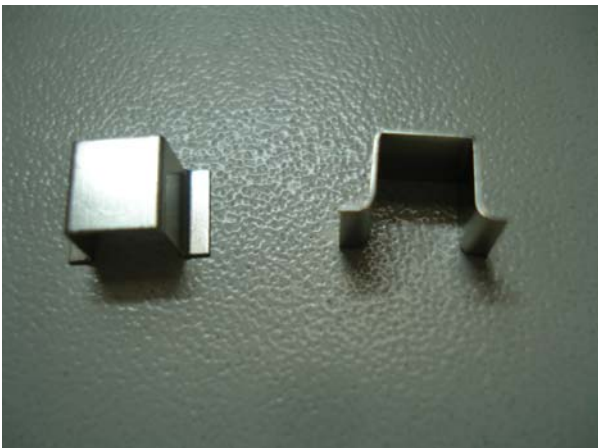


Fig.1. Contact components for UniPOS products

On fig. 2 a plate (PCB) with assembled (soldered) contact components is shown.

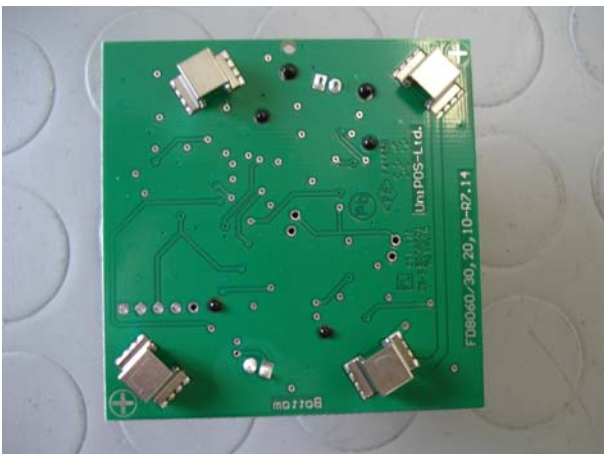


Fig.2. PCBA with contacts

On fig. 3 a final product with assembled contact components is shown.



Fig.3. Product with contacts

At first this contact component was assembled by hand and it was soldered automatically by reflow process. This led to its imprecise positioning and to a lot of repairs, respectively.

As the volume of the production increased, it was necessary to automate the mechanical assembly of the products [2]. The main reason for its development was the wrongly positioned contact component, which required a lot of repairs because of the impossibility of assembling the final product in moving the contact component on PCB (printed circuit board) by more than 0,2 mm.

We decided to accomplish it by SMD technology [3]. We had to decide how to pass the contact component to pick position of the machine.

We directed our attention to the use of a tray. It turned out that it was impossible because of the following reasons:

- The trays cannot be loaded with contact components automatically;
- The pick of the contact component from the tray is unreliable because it is difficult to carry out precise positioning and the edges of the tray catch the contact component;
- A change of the place and the position of the contact component when it is transported.

Putting in a reel tape was impossible because the contact component didn't have a shifted center of gravity and it was positioned with difficulty.

The possibility of passing from a tube left. It turned out that the use of strips and tubes didn't give a result because of:

- Stopping the motion in the tube due to heaping the components one on top of the other and fixing the components on the walls of the tube/strip;
- Difficult filling of the tubes/strips.

It was necessary to design a special strip and to decide its filling.

2. A strip and vibrobunkers for passing a contact component

It was necessary to create a strip which can adapt to a linear vibratory feeder of SMD automatic machine.

After a lot of trials an optimal form and corresponding dimensions for a strip were found. The strip is shown on fig. 4.



Fig.4. A strip for passing contact components.

On fig. 5 the initial part and the end part of the strip are shown. The strip is suitable for assembling a linear vibratory feeder.



Fig.5. Start and end of a strip

On fig. 6 a strip which is adapted to a vibratory feeder is shown.

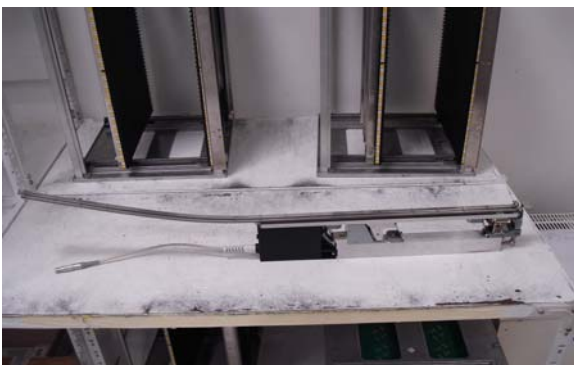


Fig.6. Vibratory feeder with a strip

The next task was the construction of a device which filled the strip with bulky contact components. Trials were made and the decision that included a vibrobunker turned out to be successful.

After a lot of trials an optimal leading construction for arranging the components was chosen. Also, it had to serve as a gauge that didn't miss components with dimensions and didn't remove them from the vibrobunker. This vibrobunker is shown on fig. 7.

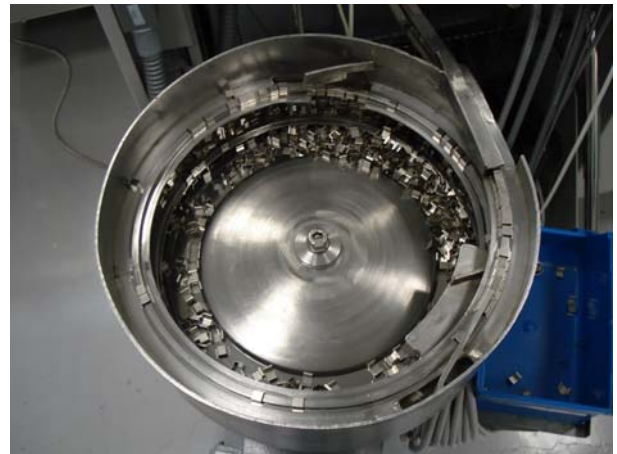


Fig.7. Vibrobunker

The blue box is the place where the components with unsuitable size are put.

The controller that controls the vibrobunker is shown on fig. 8 and a change of the frequency and the amplitude is envisaged in it.

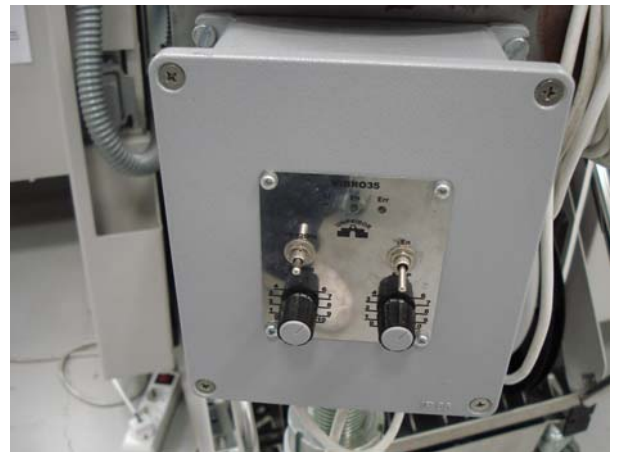


Fig.7. Vibrobunker control panel

An optimal frequency and an optimal amplitude for achieving a stable and fast passing of components in the strip. A speed of 120 components per minute was reached, which was enough for the case.

3. Adaptation of a strip and a vibrobunker to SMD vibrofeeder

The described modules were adapted to SMD vibrofeeder through appropriate stands and connections between the modules. It turned out that a vibrobunker and a vibrofeeder work with different frequencies and for this reason there shouldn't have been a mechanical connection between them. A construction was created. This construction allows an adjustment of the distance between them so that there is a stable motion of the components. In the adjustment of the system it turned out that a lot of components didn't have to be heaped on the strip because this led to its blocking. An optimal filling was determined and an automation that was capable of supporting it was created.

On fig. 8 the described system is shown.



Fig.8. Vibrobunker system

On fig. 9 the strip with the components, which are passed to pick position of SMD placer ASM Siplace D1, is shown.

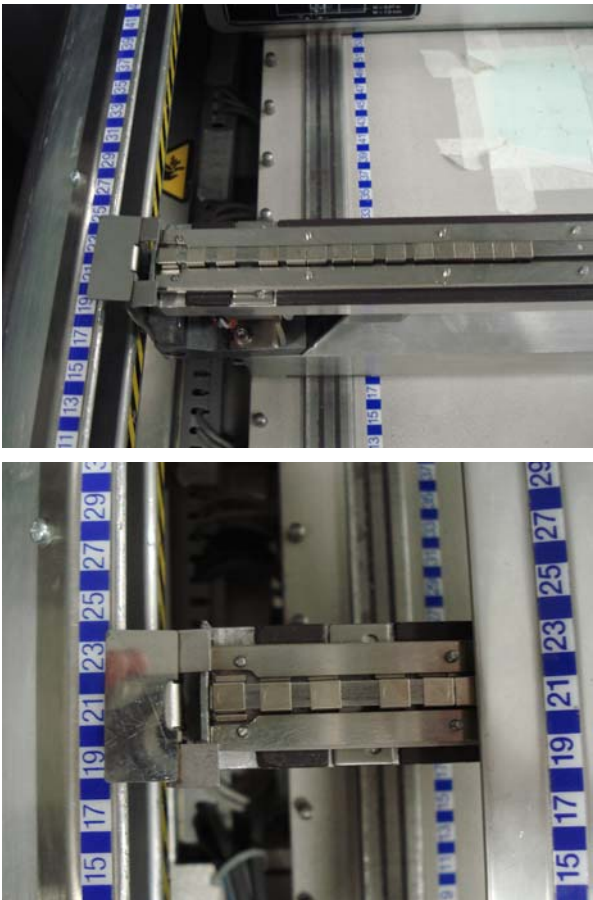


Fig.9. ASM Siplace D1 pick position

4. Results

The results of the described automation of the process of passing the components are:

- a system of a strip and a vibrobunker for a stable passing of components for SMD assembly was created;
- an optimal frequency and an optimal amplitude for work of a vibrobunker were determined;
- the optimal connections between the strip and the vibrobunker for a maximum speed of passing and moving the components were determined;
- an additional automation for a stable filling of the strip with components was created.

5. Conclusions

The conclusions of the system for an automatic passing of components are:

- An automatic assembly of final products was possible as the problem regarding the precise assembly of contact components was solved;
- The productivity increased 8 times, which enabled the accomplishment of the increased volume of production;
- The labor considerably reduced, which reduced the prime cost of the product considerably – the cost of an assembly reduced 40 times;
- The rework rate considerably decreased (200 times). This guarantees a lack of refusals among the clients;
- The possibility of stopping work of an assembly line decreases.

Acknowledgement

I express my gratitude to UniPOS Ltd. for creating and financing this project.

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ENERGY FACTOR OF TECHNOLOGY OF NANOCOMPOSITE MATERIALS BASED ON POLYMERIC MATRICES

ЭНЕРГЕТИЧЕСКИЙ ФАКТОР ТЕХНОЛОГИИ НАНОКОМПОЗИЦИОННЫХ МАТЕРИАЛОВ НА ОСНОВЕ ПОЛИМЕРНЫХ МАТРИЦ

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Abstract: *There were considered physical preconditions of appearance of dispersed particles activity in the process of the high molecular matrix modifying. The existence of a non-linear function $S(r) = f(r)$ defining the dependence of the parameters of the characteristic physical properties of the particle of its geometrical parameters was shown. The expediency of use as modifiers dispersed particles with developed morphology of the surface layer, which provides a special energy state, was shown. Methodological approaches the optimum choice of effective modifiers while creating functional composites were developed. Practical applications of the developed approaches were exemplified.*

KEYWORDS: *DISPERSED PARTICLES, MODIFYING ACTION, MATRIX, ENERGY STATE, NANOSIZED CRITERION.*

1. Introduction

In a wide range of engineering materials a special place occupy composites of various purposes, which are obtained by modifying the matrix polymer, oligomeric and combined bindings by target components based on silicon, carbon, metal-containing compounds with a given dispersion and form [1-4].

As a rule, when creating composites is realizing the traditional labor-intensive approach based on the use of the results of experimental studies to determine the modifying effect mechanisms of components of different composition, structure, particle size and obtaining technology. The practical implementation of this approach is not only costly, but also, as a rule, does not provide an achievement of the optimal technical effect. Moreover, in some cases are forming conditions of the "structural paradox" manifestation, the essence of which is inadequate change the service characteristics parameters of an composite materials, even when using high-efficiency, including high strength and heat resistance, components. An example of a manifestation of such structural paradox is given in [4].

The obvious is the need to develop criteria for reasonable choice of components to create functional materials that take into account the most common features, characteristic for all types of condensed matter, which form the physical paradigm of modern materials science.

The aim of this work was to analyze the possibility of assessing the effectiveness of the modifiers in the macromolecular matrix on the energy state criteria.

2. Methods of research

As binders for composites were used thermoplastic polymers - polyamide 6 (PA 6) and polyamide 11 (PA 11), low-density polyethylene (HDPE), polypropylene (PP), polytetrafluoroethylene (PTFE) in the industrial delivery state. To control the parameters of energy state and dispersion of components used technological methods based on mechanical dispersion, mechanochemical combining, the impact of energy flows in the heat treatment, exposure to a corona discharge, microwave and laser beam using the original settings. Selection of the energy impact type and modes for carrying out the activation process was due to the composition, structure and chemical and dimensional parameters of components, the functionality of the coatings or products.

3. Results and discussion

An analysis of the literature sources devoted to materials science and technology of polymeric composites [1-4], shows promising

use of modifiers that are in the nanometer range, so-called nano-sized particles of different composition, structure and technology. In the presence of a large number of studies on the mechanisms of modifying action of nanoparticles in the polymeric, oligomeric and combined matrices, it is necessary to underline the ambiguity of the results and the lack of common concepts that define the dimension and concentration ranges of the optimal effective operation of the dispersed particles in the matrix binders, differing in molecular weight, chemical structure of macromolecules, peculiarities of structural organization under the influence of technological factors - temperature, pressure, exposure time, etc. The most effective multi-purpose modifiers are natural silicon compounds - clays and zeolites, fine products of detonation, thermo gas dynamic and plasma chemical synthesis - nanoceramics, sialons, nano-diamonds, diamond-containing burden, fullerenes, nanotubes, thermally split graphite, mica, clays, and nanosized particles of metals and oxides obtained by thermolysis of metal-containing precursors in molten thermoplastics. Meanwhile set features a number of modifying effect of nanoparticles of different composition, structure and obtaining technologies that determine the efficiency of use. These features can be systematized by the characteristic features [1-4]:

- 1) increasing the dispersion degree nonlinearly effects on the energy state of the particles and the effectiveness of their modifying action;
- 2) when increasing the degree dispersion of the particles increases the tendency to the formation of cluster structures of different structure;
- 3) modifying effect activity nonlinearly depends not only on the composition, structure and technology of dispersed particles, but also external, including process, factors acting on the components in the process of receiving, storing, processing and manufacture of composite materials;
- 4) increasing the dispersion degree of the particles causes nonlinearity of economic costs of their production, storage and practical use;
- 5) fine-grained particles of the modifiers of high-molecular matrix are generally necessitated the development of special technologies and equipment for their practical application;
- 6) superfine (including nano-sized) particles have a negative impact on the environment and require special measures to comply with safe conditions of their production and use;
- 7) long-term (long-acting) effects of the action of fine-grained (including nanosized) particles on the mechanisms and kinetics of physical and chemical (including biochemical) processes studied not in full;
- 8) the effectiveness of modifying action of fine-grained (including nanosized) particles in some cases, inadequate forecasts due to technological constraints of the optimal (calculated) conditions of interfacial interactions at various levels of the structural organization of the composite material.

Distinctive features of the practical application of nanoscale modifiers indicate the need for systematic analysis of their action mechanism, which will establish the most characteristic features of their effective action and conditions for their manifestation in practical technology of polymer nanocomposites.

In order to establish these common characteristic studied of the morphology of dispersed particles of different composition, structure, and obtaining technology, widely applied in practice. The presence of nanoscale components in the surface layer of all modifiers is established.

The presence of such nanoscale components in the structure of the dispersed particles causes the manifestation of the characteristic energy state of the surface layer, which causes the structuring of the surrounding binder macromolecules to form a quasi-crystalline structure [3-4].

The research allowed offering effective approaches to optimal selection of high-dispersed particles of modifier of high-molecular matrices:

1. It is advisable to use fine particles of micron range mainly with developed morphology of the surface layer formed by nanoscale components of different composition and structure;
2. The ratio of geometrical parameters of the surface layer components and volume of dispersed particle must be determined by physical criteria which characterize nanostate of selected material objects (matrix and modifier);
3. In order to ensure effective modifying action fine particles need to give particular energy state due to the combined effect of structural, chemical, dimensional and technological factors. Selecting the prevailing factor determined by a combination of operational, energy, economic and environmental parameters that determine the effectiveness and appropriateness of industrial application in accordance with the terms of reference;
4. When choosing a method of activation of fine-grained particles, providing optimal modification, it is necessary to establish the prevailing mechanism of formation of a transitional (the boundary) layer of a given structure and parameters of deformation strength and adhesion characteristics and unconditional implementation of

"reasonable sufficiency" principle for a particular combination of materials science, environmental and economic factors;

5. The most perspective when creating functional composite materials and large-tonnage production on the basis of high-molecular matrices are dispersed particles derived from natural compounds laminate, frame, chain structure and fibrous natural, synthetic and artificial semi-finished products using traditional and special technologies, providing formation of surface layer morphology with nanoscale components with an optimal level of energy activity;

6. For composites based on high-viscosity and high melting matrix preferably using technology joint mechano-chemical activation of components and multi-level modification using particles of different composition, structure and dispersion.

4. Conclusion

Practical testing of the proposed methodological approaches have been implemented to create composite materials based on thermoplastic matrices and greases for heavy-duty friction units of machines and technological equipment used at the enterprises of mechanical engineering, building industry, chemical and mining industries.

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INNOVATIVE FORM OF LEARNING PHYSICS IN ENGINEERING STUDY PROGRAMS

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Abstract: This research paper demonstrates the use of experimental problem based learning tasks which students of computer science and information technology study programs realized through a semester in physics study course. In this course students had to master how to use several sensors and how to connect them to Arduino and acquire proper measurements and save them in a memory card. Students admit that in most of the experiments using Arduino as a data logger gives advantages to more easily deal with experimentation. Students appreciate that this kind of mastering physics is more related to their specialty and future work. It becomes more significant to use measuring devices not only in laboratories but also in different environments where specific data acquisition systems are necessary. Therefore with this teaching method students realize the real life needs and conditions.

Keywords: PROBLEM BASED LEARNING, SENSORS, ARDUINO, DATA LOGGING, LABORATORY WORKS, PHYSICS

1. Introduction

To engineering students physics has to be taught differently than with classic methods of teaching. Physics in fact is basis of every further research and study so it must be taught properly and adapted to specific study programs. Based on research and observations technology instructions in physics should make scientific views more accessible and meaningful. The main goal is that technology should be used in teaching and learning of science as one of learning possibilities and not to have less effective results than other learning styles [12].

Problem based learning (PBL) is known as highly effective type of learning and is by far considered as one of the best methods in education. Especially combined with specified technologies that can be used with commonly known sensors and measuring methods. Most commonly known appropriate reasons when studies are provided by technology are: a) to use computer interfacing equipment to collect and process data of a measurement or experiment; b) to perform experimental or theoretical modelling and to use computer simulations; c) to use research and presentation programs for gathering and displaying information [4].

Common interfacing devices, which are used in the study process, are probes that are plugged into graphing calculators or measuring interfaces that are usually connected to computers. With aid of these devices students are capable of collecting and analyzing data of several measurements [9].

Usually all measurements in physics in Liepaja University are realized with aid of measuring interface Cobra3 – basic unit, provided by PHYWE. A lot of measurements can be taken with this interface, but there exist certain problems, that prevent students from using it. To use the interface in specific experiments a special measuring module has to be used which has to be purchased and does not come in the original packaging. Another considerable fact is that using the original packaging experimentation cannot be done in places where there is no electricity.

In year 2015 from September to December computer science and information technology students studied physics course using experimental PBL and microcontroller Arduino to solve complex problems. These students had previous knowledge about electrical components and Arduino programming basics.

Adapting classic physics course in the interest of computer science and information technology students is definitely a challenge to deal with.

2. Materials and connections

A wide range of microcontrollers are available in the market. Because of the price and other available parts and sensors Arduino

was chosen over others offers. The Arduino is open source, which means hardware is reasonably priced and development software is free. The Arduino platform consists of a set of microcontrollers, a programming language and an integrated development environment. The language is based on the Wiring and Processing languages, which were created to teach core programming and computing concepts through electronics and visual arts respectively to nonprogrammers. With the Arduino board, you can write programs and create interface circuits to read switches and other sensors and to control motors and lights. The Arduino language is syntactically similar to C and its platform has wide-spread open source community support, numerous projects, and is easy to use. The challenge from a teaching perspective is to bring all this hardware and software into a cohesive platform for computer science pedagogy. An important feature of the Arduino is that user can create a control program on the computer, download it to the Arduino and it will run automatically. For stand-alone operation, the board can be powered by a 9 volt battery for example [8].

There are countless examples of Arduino being used to log weather conditions, atmospheric conditions from weather balloons, building entry data, electrical loads in buildings, and much more. Because of the small size, low power consumption, and ease of interfacing with a lot of sensors, Arduino is a considerable choice for building data logger, which is a device that records and stores information over a period of time. Data logging systems are very simple. They generally consist of some kind of acquisition system, such as analog sensors, to obtain data. They also contain some kind of memory for storing data over a long period of time [10].

A large number of sensors are available to monitor and measure many types of environmental parameters or physical processes. The rapid advances and usage of programmable microcontrollers have brought an increase in the availability and ease of use of sensing physical phenomena. The sensors operate on low voltage [11].



Fig. 1 BTA male and female connectors (from left side). First pin of the male BTA connector is marked with black arrow.

Most of the sensors that students had to use were provided by Texas instruments that were used before with interface Coach Lab II. All of these sensors have British telecom analog/digital connectors (BTA/D) according to sensor. Connectors have six pins and their usage depends on the sensor that is used (Fig. 1). Vernier provides protoboard adapters which can be used when connecting sensors and other necessary equipment for measurements to breadboard. Breadboard connections for students were taught before

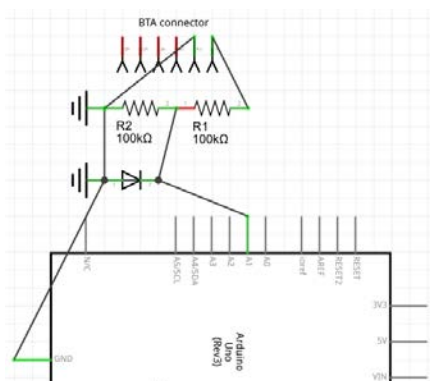
in other courses. Students used simple BTA/D connectors with necessary resistors for each sensor (Fig. 1).

For connection of Arduino and Vernier sensors students used universal connection principles (Table 1) which can be fitted for specific sensor because not all of them use all six pins (for example Fig. 2). For all occasions connector can be connected to the Arduino in such a manner. But in most cases Vernier sensors especially analog sensors use only three pins and they don't need the others to operate properly.

Table 1: Sensor and Arduino connections.

Number of connectors Pin	BTA to Arduino	BTD to Arduino
1	Pin A1	Pin 2
2	Pin GND	Pin 3
3	Pin A4	Pin 4
4	Pin A5	Pin 5V
5	Pin 5V	Pin GND
6	Pin A0	Pin 5

One of the most important things in physics is capability to measure voltage because in most of experiments which includes electricity this kind of measurement is important. Arduino analog inputs can be used to measure direct current voltage up to 5 volts therefore for higher voltage measurements a simple voltage divider is necessary. The analog sensor on the Arduino board senses the voltage on the analog pin and converts it into digital format that can be processed by the microcontroller. For voltage measurements students used simple sensor from Texas instruments. Experimental setup is shown (Fig. 2).



sensors were given. As it was mentioned these students know at least programming basics. Sample programs of each sensors, SD card and timer were given but the working program they had to create by themselves.

Working at the second part of work students realized the necessity of data loggers. They could leave the data logger alone when the measuring process took a longer time. The measured data was easily processed afterwards through graphs and tables.

4. Results and discussion

Advantage of using experimental PBL is that students feel responsible for providing answers to the problems provided in the laboratory instructions, and those they encounter themselves. They develop skills to solve these problems, and therefore become more competent. Also laboratory time is used efficiently, with all participants fully engaged in the learning process. Students leave the lab more mature and confident about their skills. They know they can solve other problems when they encounter them in other classes or later in industry. Students develop understanding of how data acquisition system works and develop their own skills to solve hardware and software problems [2]. They also learn data acquisition techniques and software applications to solve real world problems.

Disadvantage is that students may initially struggle with PBL when this approach is new to them. They may not be prepared to answer questions posed by the instructor, they may want the instructor to solve all problems for them. Students may struggle with software and hardware for data acquisition. Learning how to use new software in one lecture can be a challenge also laboratory assignment may not be completed during the given time.

Data acquisition systems are used for laboratory research and are necessary more frequently in scientific research fields that are developing in Liepaja University. Data acquisition systems are interfaces between the real world of physical parameters, which are analog, and the artificial world of digital computation and control [3].

Many data acquisition systems are used in scientific application to acquire data and transfer it directly to computer memory. Data acquisition boards are general-purpose instruments that are well suited for measuring voltage or current signals or resistance that can include some form of signal conditioning [4].

Data acquisition and control system consist of sensors which measure physical variables such as temperature, pressure force, motion, voltage and current, signal conditioning, to convert the sensor outputs into signals readable in the PC. Analog input board, to convert these signals into digital format usable by the PC [6].

Capabilities and the accuracy of data acquisition systems can be founded from analog input specifications. Basic specifications are number of channels, sampling rate, resolution, and input range. Usually there is necessary a computer with appropriate application software to process, analyze and display data [5].

Student results were higher than previous years. Through these laboratory works they got deeper understanding about physical processes and how computer science is based on physical principles.

5. Conclusions

Different teaching strategies can be used to provide suitable education support to enhance the effectiveness of learning. Technologies are often used by teachers to improve teaching and learning process.

Data acquisition systems have always been used in education to measure physical phenomena [1]. Therefore the right choice of data acquisition system is critical. Due to the development of informatics, microelectronics and mechatronics there can be

observed a revolution in mechanics and measuring methods and technologies.

It becomes more significant to use measuring devices not only in laboratories but also in different environments where specific data acquisition systems are necessary. The Arduino platform is suitable for data logging and is considered very easy to use in physics and programming. Arduino can be used for many different purposes. This kind of studies demonstrate usefulness of automated measurements, and offer guidance for other researchers in developing inexpensive sensing and monitoring systems to do other researches [11].

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INVESTIGATION OF THE TRIBOLOGICAL CHARACTERISTICS OF THE STAINLESS STEEL X20Cr13

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Abstract: For the purposes of testing tribological characteristics of the stainless steel X20Cr13 designed for the parts of process industry plants for the production of sunflower oil, test samples were made and heat treatment by improving on different hardnesses was performed. Final machine processing of the samples was performed out by grinding and polishing. This way, the different characteristics of the surface layer and the different surface topography were achieved. The paper presents the results of the impact of the hardness on characteristics of the stainless steel X20Cr13. By examining the resistance to the adhesion wear it was concluded that the higher wear was on the test samples which have been in the raw condition and who were also loaded by higher forces. Therefore, the quality of the surface wear greatly affects the surface roughness and the coefficient of friction.

Keywords: STEEL X20Cr13, TRIBOLOGY, ADHESION WEAR, TOPOGRAPHY, COEFFICIENT OF FRICTION

1. Introduction

Tribology is not a science „for the sake of science“. Tribology is scientific approach by extending and solving problems of parts which are exposed to wear. The aim is to reduce costs and losses of tribological nature [1]. The paper presents the results of the impact of topography surface and coefficient of friction on the characteristics of the stainless steel X20Cr13. Steel X20Cr13 is the martensitic stainless steel resistant to water and water vapor and the organic acids. It is widely used in making surgical instruments and household accessories, to the creation of machine parts such as eg. shafts, turbine blades, etc. [2]. The equipment for testing tribological characteristics were examined for resistance to adhesion wear of the test samples. For the purposes of the testing „block on the disc“ method was used. When examining the lower sample (disc) is rotated and the sample has on the top (block), which is loaded by a certain force. Mutual contact of the test samples is performed by the peripheral surface of the lower sample (disc) and the lower surface of the upper sample (block) [3]. The aim is to analyze the change of surface roughness, the coefficient of friction and quality in terms of wear surface of the test samples.

2. Equipment for investigation of the tribological characteristics

Tests of the tribological characteristics of the stainless steel X20Cr13 were conducted on improved and computer supported tribometer TR-95 in contact „block on the disc“ (Figure 1) at the Faculty of Engineering, University of Kragujevac.

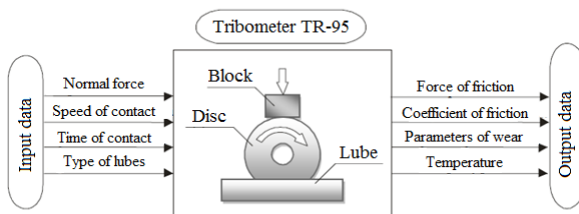


Fig. 1 Input and output data of tribometer TR-95 [4].

Tribometer TR-95 allows varying conditions of contact in terms of shape, dimensions and materials of contact elements, the normal contact load and speed skating. Tests can be performed in conditions with lubrication and without lubrication. The basic configuration of the tribometer consists of: a drive system, system load, the system for managing, lubrication system, the system of self-adjusting blocks and measuring system, Figure 2.

The drive system consists of an electrical motor with pulleys, belts and variator that allows varying of the speed from 100 to 1200 r/min. There is a rotational disc on the main shaft. The system of loads by weight or steam allows load from 0 to 500 N.



Fig. 2 Tribometer TR-95 [4].

The system for managing is realized by means of linear rolling bearings, in which stress is eliminated backlash. Lubrication system consists of a variety of containers for lubricant or the system for the supply of lubricating oil in the contact zone. The system of self-adjusting block and drive has a duty to at all times ensure the transfer of the normal load in the direction of the axis of the disc and contact throughout the length of the block on the disc. This system realized the construction of a special rotating carrier of the block, Figure 3.



Fig. 3 Carrier of the block [4].

3. Experimental investigations

Tests samples in the form of discs dimensions $\phi 35 \times 6,3$ mm and blocks dimensions $6,3 \times 15 \times 10$ mm, made of stainless steel X20Cr13 (according to AISI 420). Declared and tested the chemical composition of steel is shown in Table 1.

Table 1: Chemical composition of the steel X20Cr13 [5].

	Chemical composition, %					
	C	Cr	Mn	P	S	Si
Declared	0,16 ÷ 0,25	12 ÷ 14	max. 1,5	max. 0,040	max. 0,015	max. 1,0
Tested	0,21	12,8	0,6	0,031	0,013	0,67

After test samples were made heat treatment by improving on the different hardnesses was performed. Hardened test samples are arranged in pairs so that a disc and a block in mutual contact consisted a tribometrical pair, Figure 4.

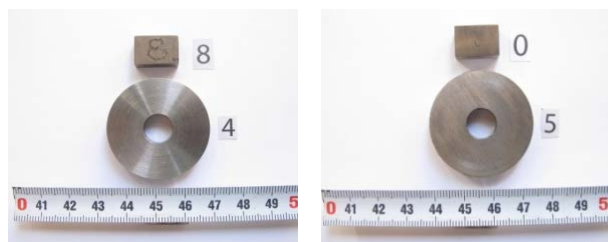


Fig. 4 Representation of the tribometrical pairs.

A total of nine tests for resistance to adhesive wear and investigation plan is presented in Table 2.

Table 2: The investigation plan of the samples on the tribometer TR-95.

Investigation	Disc	Block	Force, N	Speed, m/s	Duration, h
T1	1 ^S	5 ^K	100	1	1
T2	2 ^S	3 ^S	100	1	1
T3	3 ^S	11 ^K	50	1	1
T4	4 ^S	8 ^K	100	1	1
T5	5 ^K	0 ^K	300	1	1
T6	7 ^K	1 ^S	300	1	1
T7	12 ^K	7 ^K	200	1	1
T8	13 ^K	10 ^K	200	1	1
T9	14 ^K	12 ^K	50	1	1

* K – tempered condition, S – raw delivery condition.

3.1. Investigation of resistance to the adhesion wear

Test of resistance to the adhesion wear of the samples was performed on tribometer TR-95 in contact „block on the disc“, Figure 5.

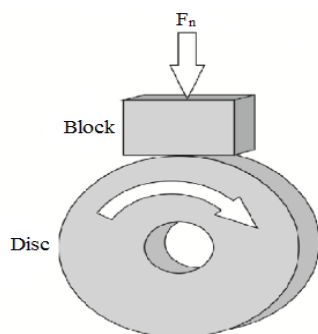
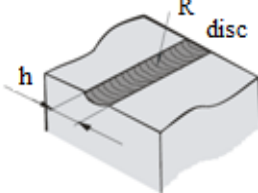


Fig. 5 Sketch of the method „block on the disc“ [4].

Each individual test lasted one hour. The investigation was conducted with lubricated sunflower oil where the samples of discs were partially submerged. Blocks are placed on the discs and their mutual contact came to the appearance of the adhesive wear. Speed of disc was 1 m/s, or 554 r/min. After testing the blocks, traces of wear were analyzed, Table 3.

Table 3: Value width of the traces of wear blocks and coefficient of friction.

Block	Width of the traces of wear, mm	Coefficient of friction
5	1,775	0,024
3	1,088	0,008
11	0,678	0,012
8	1,868	0,023
0	7,478	0,13
1	6,015	0,08
7	4,256	0,068
10	4,461	0,068
12	0,669	0,014



Test samples for testing resistance to the adhesion wear are loaded by forces from 50 to 300 N. It is important to highlight the fact that in two tests, test samples during wear did not withstand the power load of 100 N so the referred tests were performed with a load force of 50 N, tests T3 and T9 in Table 2.

Table 3 shows that the higher wear of the block came with the load forces from 200 to 300 N, while less affected were blocks which were loaded by forces from 50 to 100 N. Also in these blocks is not observed a large difference in the widths of traces of wear, in contrast to the blocks that have been loaded by greater forces. Traces of wear on the blocks was recorded on a light microscope „Leica DM 2500 M“ with different increases, Figure 6.

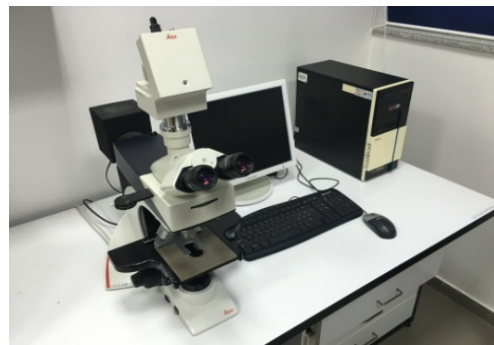


Fig. 6 Microscope „Leica DM 2500 M“.

Traces of wear of the block 8 are shown in Figure 7, while traces of wear of the block 0 are shown in Figure 8.

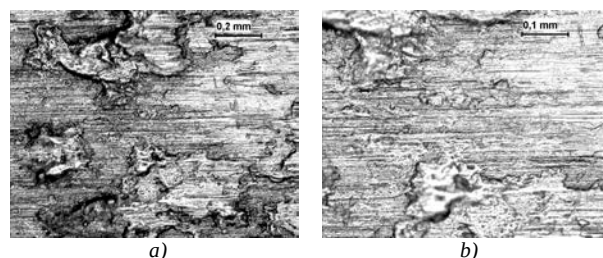


Fig. 7 The characteristic traces of wear of the block 8.
a) magn. 100x; b) magn. 200x.

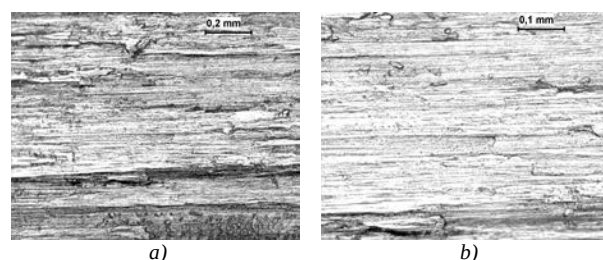


Fig. 8 The characteristic traces of wear of the block 0.
a) magn. 100x; b) magn. 200x.

Figures are showing bigger wear of the block 0 compared to the block 8. The reason for this lies in the fact that the block 0 was wasted by disc 5 which has been hardened in a condition with extremely higher hardness compared to the disc 4, which was in the raw delivered condition, from which block 8 was wasted. Also during the wear block 0 was loaded with force of 300 N, unlike the block 8 where the loading force was 100 N.

3.2. Investigation of topography

After the test for resistance to the adhesion wear was performed, the surface topography of test samples was conducted. Heat and final machining obtained different characteristics of the surface layer and the different surface topography of the test samples. Figures 9 and 10 are showing the different topography surface of the disc 4 in the new condition and disc 7 in the condition of the wear. Worn part of the disc and the topography of used parts can be seen.

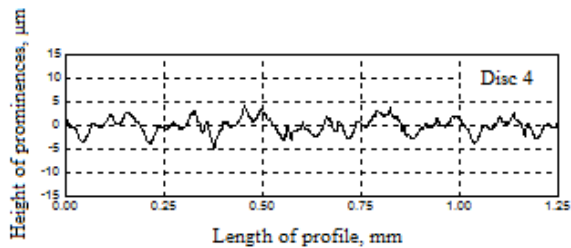


Fig. 9 Representation of topography of the disc 4 in the new condition.

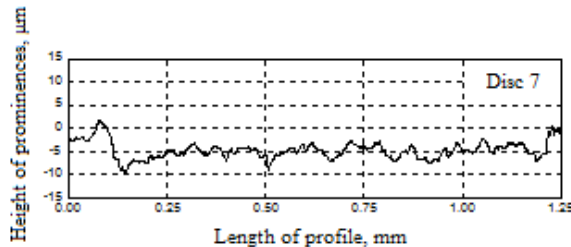


Fig. 10 Representation of topography of the disc 7 in the worn condition.

Figures 11 and 12 are presenting different surface topography in a new block 0 and block 6 in the wasted condition. In place of wear of the blocks width, depth and area of the worn part can be measured.

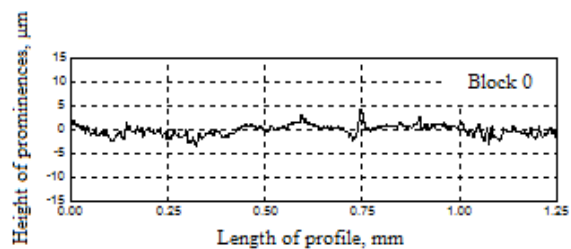


Fig. 11 Representation of topography of the block 0 in the new condition.

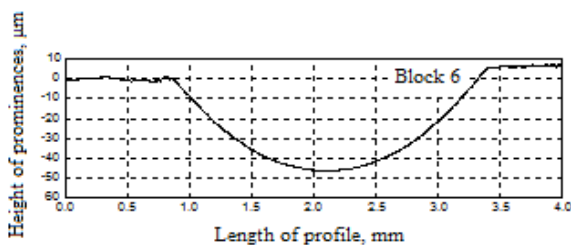


Fig. 12 Representation of topography of the block 6 in the worn condition.

3.3. Investigation the coefficient of friction

In Figures 13 and 14 are shown signals changes in the coefficient of friction during the test period for test T4 and T7.

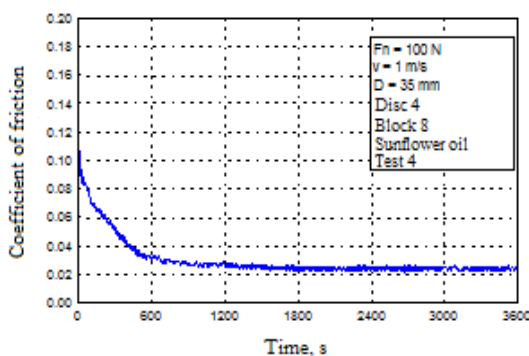


Fig. 13 Value of the coefficient of friction for the investigation T4.

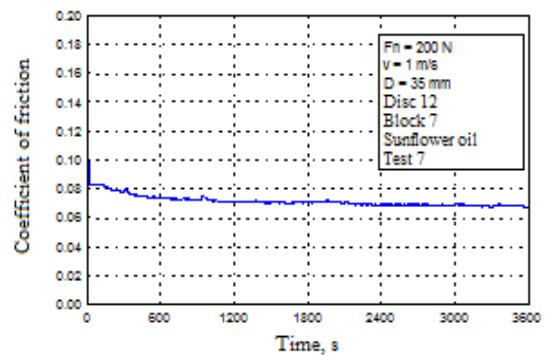


Fig. 14 Value of the coefficient of friction for the investigation T7.

It can be noted initial running period which is lasting up to 15 minutes, and then an approximately constant value of the coefficient of friction. Table 3 shows the mean value of the coefficient of friction after running. It can be concluded that with increased load the coefficient of friction is significantly increased. This because sunflower oil has a poor lubricating characteristics.

3.4. Investigation of hardness

Hardness tests are performed using the method Rockwell (HRC) with a load of 1500 N. Results of measuring the hardness of discs and blocks are shown in Table 4. Hardness of discs that were in the raw or delivered condition is around 25 HRC, while the hardness of hardened discs is around 52 HRC. Hardness of blocks that were in the raw or delivered condition is around 19 HRC, while the hardness of hardened blocks is around 48 HRC.

Table 4: Results of measuring the hardness of discs and blocks.

Disc label	Hardness HRC	Block label	Hardness HRC
Disc 1	25	Block 0	49
Disc 2	25	Block 1	19
Disc 3	27	Block 3	19
Disc 4	26	Block 5	47
Disc 5	53	Block 7	49
Disc 7	53	Block 8	48
Disc 12	50	Block 10	44
Disc 13	52	Block 11	50
Disc 14	52	Block 12	50

4. Analysis of the results and conclusion

The aim of this paper was to analyze the change of surface roughness, the coefficient of friction and quality in terms of wear surface of the test samples. By examining the resistance to the adhesion wear it was concluded that the higher wear was on the test samples which have been in the raw condition and who were also loaded by higher forces. The measured coefficients of friction indicate that increasing the load comes to a significant growth of the coefficient of friction. Therefore, the quality of the surface wear greatly affects the surface roughness and the coefficient of friction.

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NOVEL DIGITAL PIEZO VALVE USED FOR HIGH-RESPONSE HYDRAULIC LINEAR DRIVE POSITION CONTROL

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Abstract: Main purpose of the paper is to present high-response hydraulic linear drive, which is controlled with new digital piezo valve and where the new position transducer is integrated as a part of hydraulic cylinder. The new linear drive has great potential for the use in modern adaptive position control systems integrated into the smart machines. Hydraulic digital piezo valve with main static and dynamic characteristics as well as its functionality is presented in detail. The main static and dynamic characteristics of digital piezo valve which influence directly on the linear drive performance are high resolution of the volume flow rate and high response of the valve. Beside valve characteristics the new integrated position transducer, the digital controller and control method, presented in the paper, have major impact on linear drive performance. At the end of the paper the step response and position resolution of the hydraulic linear drive controlled with the new digital valve is shown and compared with the results of reference hydraulic drive controlled with high response proportional valve.

Keywords: HYDRAULIC LINEAR DRIVE, DIGITAL PIEZO VALVE, HIGH RESPONSE, INTEGRATED MOTION SENSOR

1. Introduction

Advanced applications of handling and assembly which demands high dynamic positioning becomes a real challenge today [1], [2]. These applications demands high response, high position accuracy as well as low energy consumption which can be achieved with the use of high-response hydraulic linear drives controlled with new digital piezo valves [3], [4].

Most of the above mentioned industrial applications use servo hydraulic linear drives controlled with the conventional high-response proportional valves or servo valves. Dynamic characteristics of the proportional and servo valves, even in the range of small control signals, are limited up to 200 Hz [5], [6]. The main reason for limited dynamic response of the valve represents the valve construction and the use of conventional actuators. Optimization and development of new advanced control valves took place step by step and is mainly focused on the development of individual components of the servo valves [7], [8]. The earlier researches are focused on the geometry optimization of the hydraulic spools in terms of mass reduction and internal flow force reduction [7], [9], [10], [11]. Further on, the conventional actuators of proportional and servo valves are replaced with the high-response piezo actuators [12], which increased the dynamic characteristics of the valves significantly (up to 600 Hz at phase shift of 90°). The step response of the valve is reduced from 7 to below 4 ms [13]. A 3D CAD data of a part are imported into the procedural software of the printer EOSINT M 270¹. Software designed to the data preparation allows choosing the appropriate thickness of production layers with regard to accuracy / resolution and speed of production (0.020 mm or 0.040 mm – thinner layer means higher accuracy, but longer production time).

Based on the fact that conventional servo valves with limited dynamic characteristics, high failure sensitivity and high manufacturing costs, are not always the best choice for use in high-response applications. Therefore the market demands new high-response, robust and low cost hydraulic valves which can be used as control components in modern linear drives. The use of high-response Digital Fluid Control Units (DFCU) presents one of the alternative approaches [14]. With the development of new spools materials and advanced high-dynamic valve actuators, and in particular the development of advanced digital electronics and new control methods have opened up new guidelines for the development of digital hydraulic valves and linear drives. In the beginning the DFCU-s consists of several parallel connected conventional solenoid on/off seat valves. Pulse number modulation (PNM) and pulse width modulation (PWM) are the most common used control technique [15]. In the beginning the conventional low-cost switching valves were used and were not suitable for the high-

response hydraulic linear drives due to low dynamic characteristics [16]. In the last decades these valves use new actuators based on piezo technology [17] and are therefore more suitable for the use in high-response hydraulic linear drives.

The paper deals with the high-dynamic hydraulic linear drive controlled with the new digital piezo valve. New digital electronics and control method in combination with integrated position transducer allows high response closed-loop position control.

2. Hydraulic linear drive controlled with digital piezo valve

2.1. Hydraulic linear drive

Hydraulic scheme of the linear drive where the conventional proportional valve is replaced with the new digital piezo valve shows Figure 1. Functionality of the 4/3 spool valve is achieved with the use of four digitally controlled on/off valves (functional states: P-A, B-T and P-B, A-T). The major advantage of the new digital piezo valve, compared to proportional and servo valves, is the step response below 0.3 ms, even at 100% control signal. The construction of the seat valve results in robustness and has lower sensitivity to oil contamination. The advantage can be seen in control method. Control electronic and control method allows controlling the flow rate (from 0.08 to 20 l/min at pressure drop per metering edge $\Delta p=3.5$ MPa) of individual on/off valve independently which results in high flexibility of the digital piezo valve.

The second important component of the hydraulic linear drive presents position transducer installed directly into the hydraulic cylinder as it is shown in Figure 1 and Figure 2. The position transducer consists of encoded cylinder rod and incremental absolute linear shaft encoder placed in cylinder head /18/. Encoder with the proper electronic parameters operates with high frequency up to 4 kHz and allows measuring the cylinder rod displacement up to 0.2 μm , which is important to perform high-dynamic and precise closed-loop position control.

The real picture of the prototype hydraulic linear drive shows Figure 2. Conventional two stage one rod hydraulic cylinder PARKER HMI ISO is used (D/d/s: 25/12/200). Digital piezo valve DPVL-20 is composed of 4 on/off seat valves which are controlled with piezo actuators. Each piezo actuator has several piezo elements in order to achieve proper spool stroke of the valve. Control electronic and method allows controlling up to 12 piezo elements independently. Nominal flow rate of the valve is $Q=20$ l/min at pressure drop per metering edge $\Delta p=3.5$ MPa. Switching response time of the valve is $t_{\text{resp}} < 0.3$ ms (0-100 % control signal). Absolute

linear incremental position transducer RLS LinACE™ is integrated as a part of hydraulic cylinder [18]. The cylinder rod presents encoded shaft while the encoder is placed into the cylinder head.

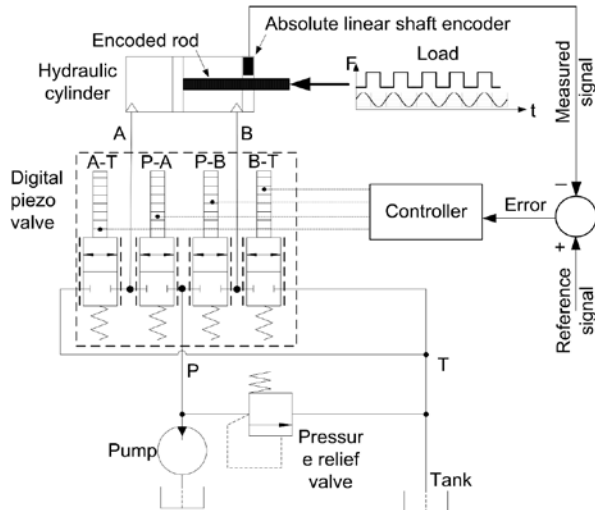


Fig. 1 Scheme of hydraulic linear drive controlled with digital piezo valve.

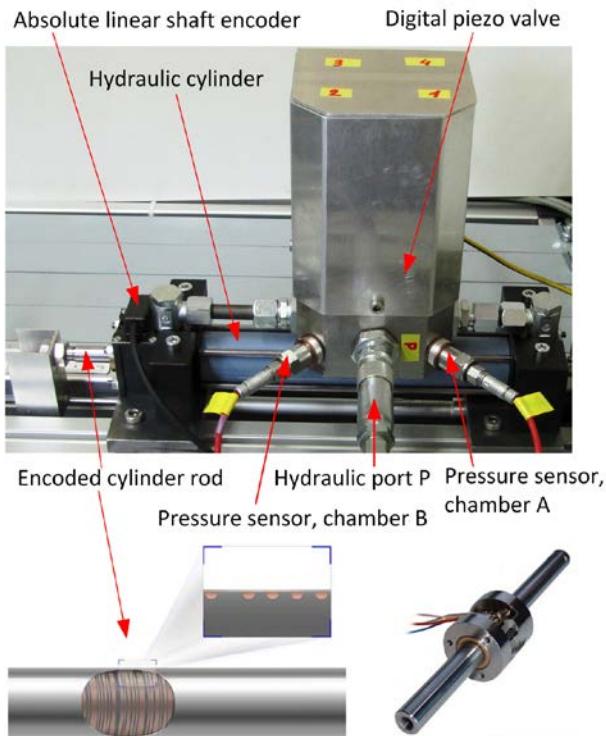


Fig. 2 Real picture of prototype linear drive controlled with digital piezo valve.

2.1. Control method

Beside above mentioned mechanical components also the quality of the control has major influence on closed-loop position control. New control electronic and control method is specially developed for the digital piezo valve. It is based on two control methods, pulse number modulation and pulse width modulation method. It allows controlling several piezo elements placed into valves actuators totally independently. The maximal control voltage is $U=200$ V. Block scheme of the position control method is presented in Figure 3.

Micro controller is used to perform the PID closed-loop position control. The actual and real cylinder position is compared and the position error is calculated which presents the input parameter of

the control method. The position error is amplified (e_{oj}) and the proper valves (V1, V3 – for the positive error and V2, V4 – for the negative error) are activated based on negative or positive error. Further on, the method defines the number of activated piezo elements of the active valve actuators. If the error is big the valve is totally opened (all piezo elements of the actuator are activated) and if the error is small only one piezo element of the actuator is activated. After the number of piezo elements is defined the parameters of PWM method is calculated (generation of PWM signal) for two signals (ON - PWM signal for piezo element activation and OFF - PWM signal for piezo element deactivation). The minimal time period of PWM signal is limited to $t=10$ μ s. Closed-loop control is performed with the frequency up to 4 kHz (compatible with the position transducer frequency).

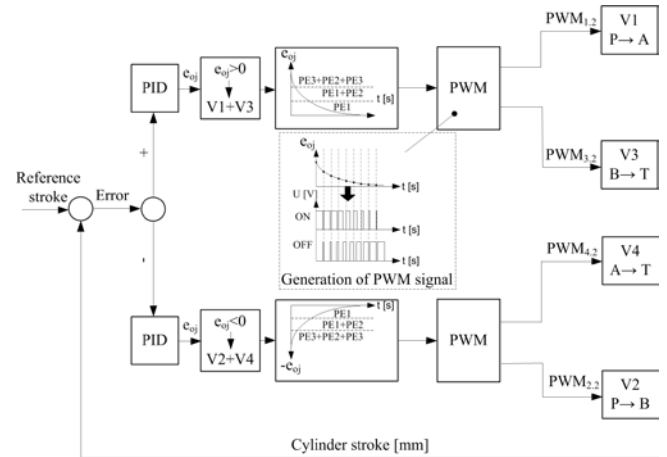


Fig. 3 Block diagram of control method valve.

3. Experimental investigation of digital piezo valve and hydraulic linear drive

Dynamic characteristics of the hydraulic linear drive depend on characteristics of the control components (hydraulic valve). Therefore the main valve characteristics are presented first followed with the dynamic characteristics of the linear drive. The step response of the digital piezo valve for different control signals is shown in Figure 4 and Figure 5. Measured step response gives the response time below 0.3 ms (spool movement from initial position to 100% position), while the step response of the valve flow rate at hydraulic port A is around $t=2$ ms.

By using the proper control method the minimal step size of flow rate is around 0.08 l/min which results in flow rate characteristic close to linear (Figure 6).

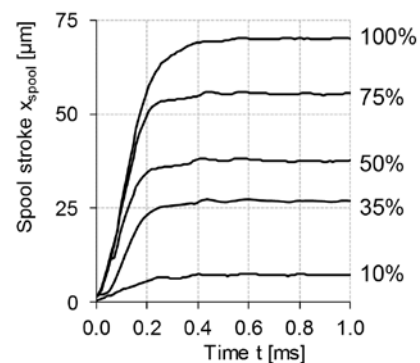


Fig. 4 Response of digital piezo valve.

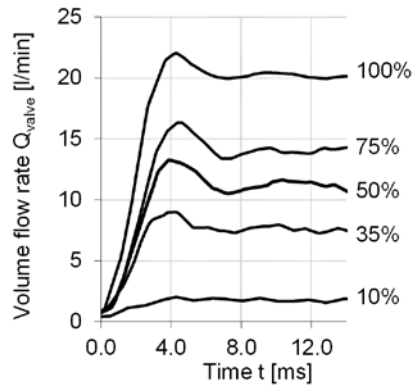


Fig. 5 Response of digital valve flow rate.

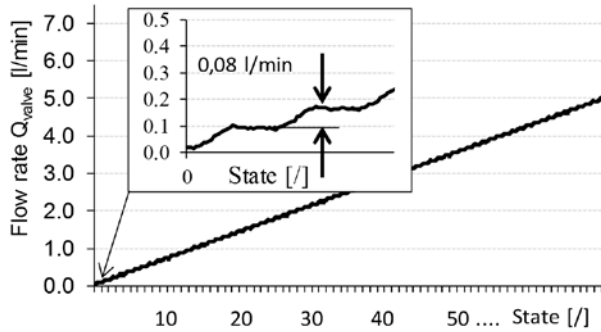


Fig. 6 Flow rate characteristics of on/off piezo valve and the step size (state P-A).

The results of the experimental tests for hydraulic linear drive are presented in Figure 7 and Figure 8. Figure 7 shows the position resolution of the hydraulic linear drive. The position resolution is depended directly on the valve flow rate resolution. By using the digital piezo valve and the proper control method we are able to control the position of the hydraulic drive up to 1 μm in both directions, forward and backward (Figure 7 and 8). The control method and the parameters should be set separately for forward and backward direction due to unsymmetrical hydraulic cylinder chambers.

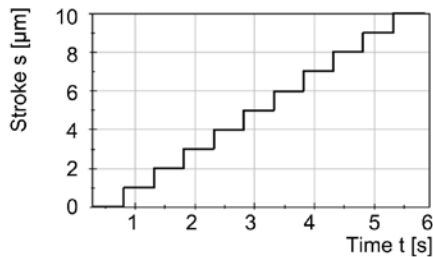


Fig. 7 Position resolution in forward direction.

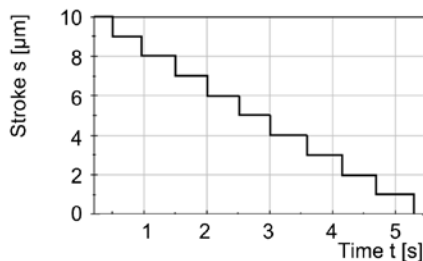


Fig. 8 Position resolution in backward direction.

The test of dynamic step response involves two different control valves; high-response proportional valve Moog D633 as a reference and new digital piezo valve. The step response curves are measured

at inlet pressure $p=6$ MPa. The black dotted curve shows the step response of the linear drive controlled with proportional valve while the solid curve shows the step response of the linear drive controlled with digital piezo valve. It can be seen that linear drive controlled with digital piezo valve has much lower time delay at the beginning and determines higher stiffness of the hydraulic system which can be seen as smaller overshoot. To confirm the influence of new digital piezo valve on the dynamic characteristics of the linear drive deeper analysis and optimization processes will be performed in the future research work.

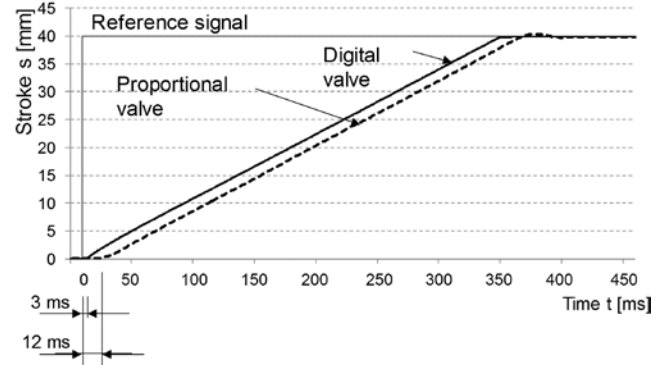


Fig. 9 Step response of hydraulic linear drive controlled with proportional and digital valve.

4. Conclusions

In this paper high-response hydraulic linear drive controlled with new digital piezo valve and integrated position transducer is presented. The research work is focused on the possibility of replacing the conventional proportional or servo valves with the new digital piezo valves. One of the main components that influence directly on dynamic characteristics of the linear drive and low energy consumption present high-response digital hydraulic piezo valve. Static characteristics as well as dynamic characteristics of the hydraulic valve and linear drive show that the use of new digital piezo valve is sufficient. The use of advanced piezo actuators in hydraulic on/off valves and its mechanical construction results in better step response. The response time of the valve is reduced to 0.3 ms while the response time of the linear drive is reduced to 3-4 ms. Proper control electronics and control method also have major impact on dynamic characteristics of the linear drive. Combination of PNM and PWM methods results in high resolution flow rate of the valve and therefore flow rate characteristics close to linear. In this way the number of on/off valves in DFCU unit is reduced. First results of the energy consumption measurement tests, which will be analyzed in detail in the future, shows that the use of piezo actuators can reduce the energy consumption up to 15% compared with the conventional high-response proportional valve Moog D633 of the same size.

The future research work is focused on further experimental analysis and characterization of the hydraulic linear drive (disturbance response, position resolution of the linear drive, etc.).

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INNOVATIVE PROCESSES FOR RAPID PROTOTYPING: CASE OF 3D PRINTER'S DIMENSIONAL QUALIFICATION (DQ).

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Abstract: - This work implements for the first time a dimensional qualification procedure for an open access 3D printer, the authors propose a new methodology to measure the prototype part as a mean to achieve the qualification procedure. Experimental results are compared with the specifications of the designer from a Fused Deposition Modelling (FDM) 3D printing. The quality of the machine recommended by the manufacturer and data are used to obtain its qualification. Then, this work aims to evaluate the quality of the machine through a comparison between the design's data and the measurements taken from the prototype part (the piece test). So, the results have confirmed and validated the dimensional quality of the machine that was randomly taken from a series of commercial printers.

Keywords: Qualification, 3D, Piece test, prototype part, Quality insurance, Rapid, Prototyping.

1. Introduction

Rapid prototyping is a technology that allows any manufacturer, artist, researcher, professional designer ...to transform digital designs into 3-dimensional solid objects (Figure 1). However, these prototypes, moulds, machine parts or models or any other product must be qualified and improved by quality insurance. Hence, the ultimate aim of developers and product designers is to come out with better quality products. So, a qualification procedure is needed.

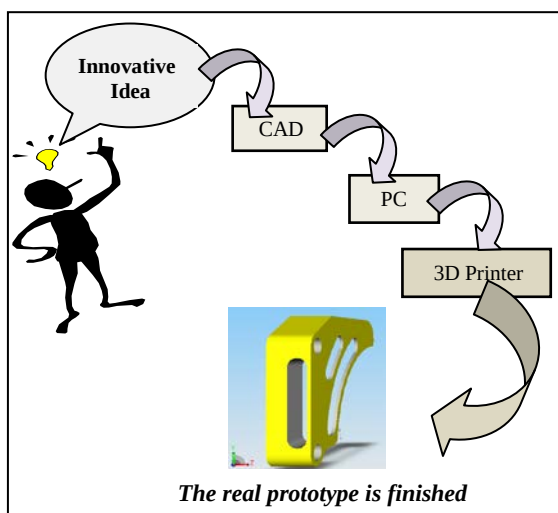


Fig.1. The process 'FDM' of prototype in Rapid Prototyping

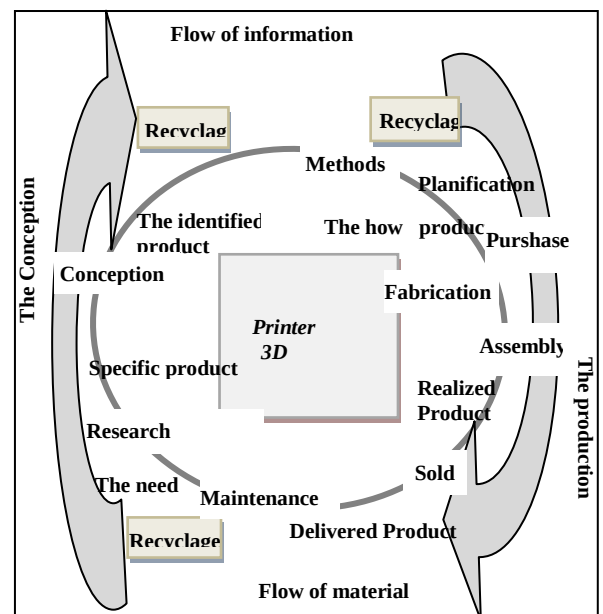


Fig.2. Cycle of 3D Product Elaboration.

In recent years, the 3D printer has been implemented in many spheres of industry and it becomes possible to Small and Medium Enterprise (SME) to provide a microenvironment research and development as an innovation tool. This tool is sometimes a survival device. The use of Open Access at low cost printers in the field of 'SME' allows reducing the costs of research and development (R & D) by mobilizing scarce resources especially for the 'START UP', spin off, and also it is implied for artists, inventors, craftsmen, etc ...). It is important to note that this paper does not attempt an exhaustive review of

research literature related to the topic of types of 3D printers, its benefits or its future. Rather, the intent is to provide a qualification process of a 3D printer by using a finished prototype part as a sample to test its quality. Further, this latter is more than just the shape of the finished prototype part, it is about a part's ability to perform the task for which it was designed.

2. Methodology

The qualification procedure is done through the realization of prototype parts and then getting the record of their measures to be analyzed and validated with the specifications of the machine. This research focuses on 3D printing using FDM (see Figure 4).

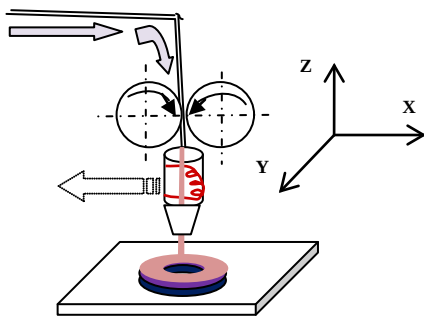


Fig. 4. 3D printer (FDM)

Figures 5.a and 5.b show the material that is going to be used for the qualification procedure which is an *open access at low cost machine*.



Fig.5-a. The 3D printer in the realization process of the prototype part (by the FDM).

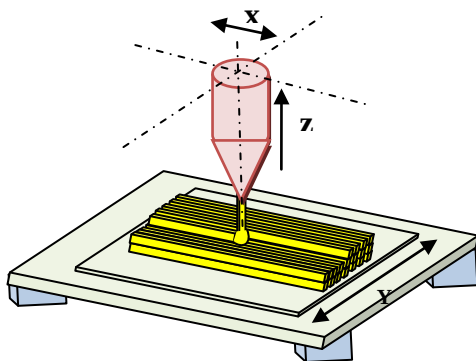


Fig.5-b. FDM process of 3D printer

In practical term, the metrology allows determining the compliance of the product with the quality claimed

by the manufacturer. This involves the description of the design and the modeling process with an empirical approach. Resources have been designed for the intended control operation to reject or accept the product, according to the general representation of the new product design process [4]. It is dimensional qualification of the 3D printer () See Figure 6.

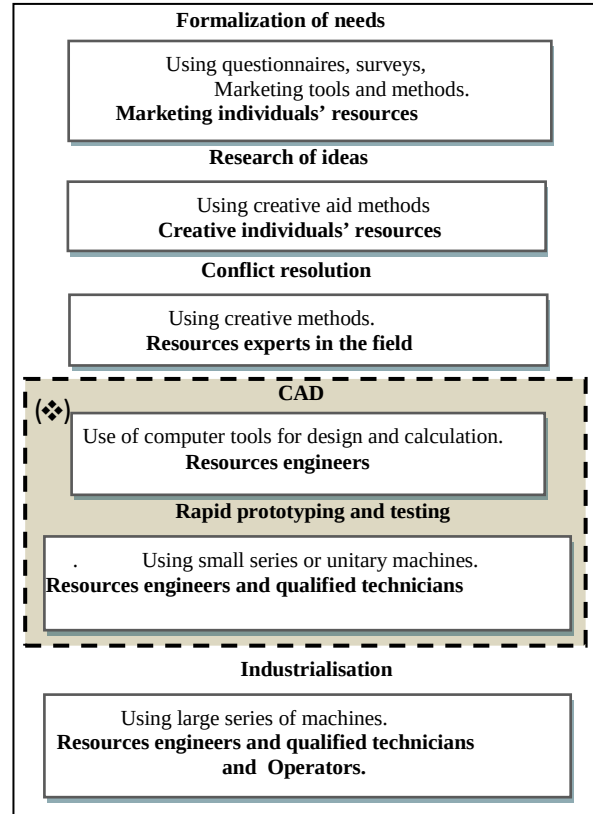


Fig.6. Chart of the process design of new products [4]

3.1 The Implemented Qualification Methodology

The Implemented Qualification Methodology compares the results of the finished prototype parts which are made according to the specifications of the machine data. The metrology analyzes and verifies the results obtained by executing three-dimensional measurement tasks. The author refers to the three approaches shown in the following points, figure 7:

- a- The determination of the machine geometry,
- b- The achievement of a permutation to separate the contribution of all fixed defects,
- c- The realization of a comparison between the value of measurements made on the finished part and those given by the manufacturer [5].

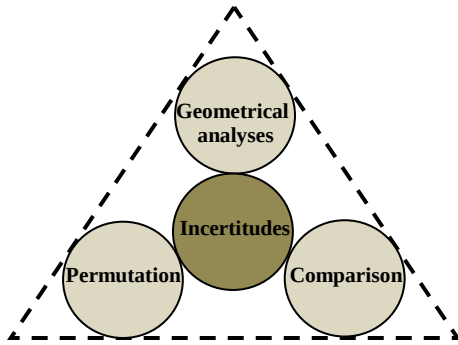


Fig.7. The verification triangle methods [5]

Measures and Dimensions.	
Width	480mm
Length	455mm
Including height	455mm
Weight	14kg
Temperature extruded	270 °C (s / type of filament)
Print Volume	230mm x 210mm x 190mm
Maximum print speed	15mm ³ / seconde and 50mm/min
Movement X-Y	50 microns,
Minimum print thickness (Z)	100 microns
Materials	PLA, ABS, Nylon, Lay Wd & Brick
Nozzle diameter	0.4 mm
Filament diameter	3 mm
Steering and connectivity	USB and Carte SD
System Compatibility	Windows, Mac, Linux
Alimentation	110/220 (V) @ 50/60(Hz)

The quality control does not involve the maximum performance, but compliance with its specified standards. Figure 8 provides a flowchart of the qualification process.

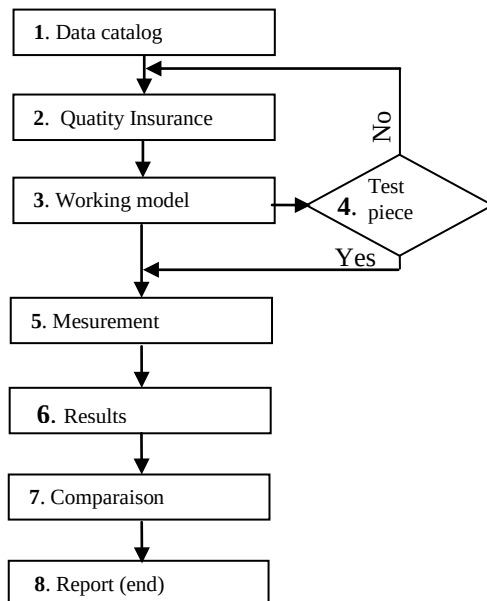


Fig.8. The theoretical description of the qualifying practice

1- Data Catalog

Data collection will be based on the input data available to the user by the manufacturer.

2- Quality insurance

The qualification procedure for Rapid prototyping means a verification of compliance with a standard already adapted in place . After assessing compliance, we make our judgment on the recognition of the capability of the process of production chain, supplier, component, etc...[6].

3- Working Model

The dimensional measurements are performed in the laboratory of metrology Therefore ambient conditions (baseline $T^{\circ} 20^{\circ} \pm 1^{\circ} \text{C}$, relative humidity 55% and pressure at 101325 Pa) should be subject to monitoring devices.

4- Prototype Part

Describe the prototype part with its design and material. It should not require post-processing or manual intervention or the supports to facilitate its control .

5- Measurement

The measurement method of the prototype part is done by a control which allows verifying compliance of the figures contained in the tender specifications (document) of designer (manufacturer). In view of the importance of the measurement errors' influence on the accuracy of pieces dimensions; we have chosen the three-dimensional measuring machine.

6- Results treatment's methodology

A series of measurements on the test piece will be performed to determine the uncertainty by statistical magnitudes as well as comparing the results with a tolerance interval.

7- Comparison and validation

It is required to make a comparison between the theory and the results of the various points of the qualification process which was conducted.

8- Report (end)

The end of the qualification procedure must lead to the systematic generation of a final report which must decide on the acceptance of the FDM printer's qualification.

3.2 Application

The developed methodology has been applied on a FDM 3D³ machine and has given the following results:

1- Data catalog

The data is directly taken from the machine's catalog and available on paper or electronic support, see table 2 (specifications)

Table 2. The 3D printer characteristics [7]

2- Quality Insurance

The printer under test showed compliance with the characteristics presented by the manufacturer on items 1, 3, 4, 5, 6 and 7, of the present methodology

3- Working sample

In laboratory, dimensional measurements were identified which are adapted to the ambient conditions of T ° were of 20 ° ± 1 ° C, 53% relative humidity and pressure at.10100 Pa.

4- prototype part

The *prototype part* realized on 3D printer with ABS3 base is a chain guard's crankcase of a sports bike (Figure 9-a and b).

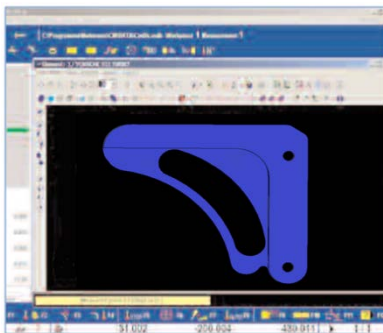


Fig .9-a. Prototype part defined by CAO

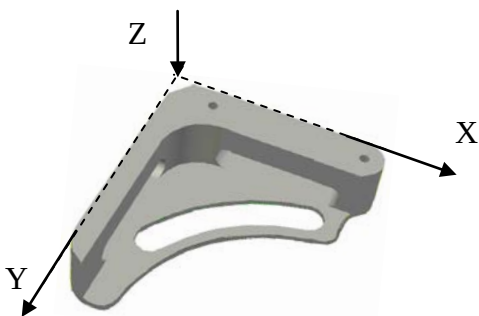


Fig .9-b. Prototype part obtained by 3D.

5- Measurement

The measurement was carried out on all functional dimensions & bulkiness of the test piece.

The measurement ranges are:

X=400; Y=350 and Z=300.s

Volumetric accuracy/ functional is:

ISO10360/2= (2,8+3L/1000) micron

There are many forms to be controlled, inter alia, the rectitude of the piece contact plane with the motor surface and the distance between the two holes 'Ø6' (See figure 10).

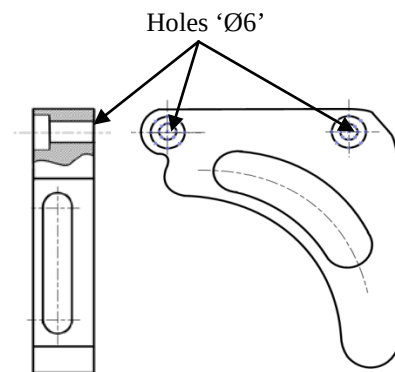


Fig.10. Diagram of the piece (crankcase/casing)

The measurements are taken in such a way to avoid the defects of the probe, (see figure 11a).

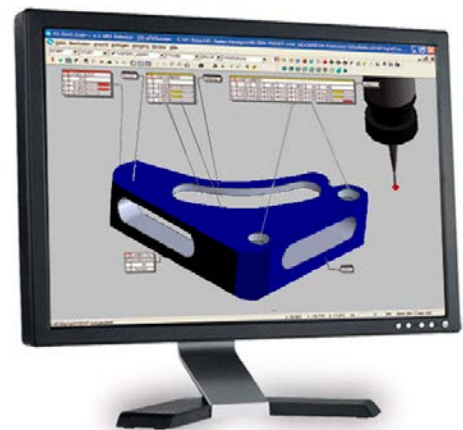


Fig.11a Prototype part's Position relative to the MMT probe

Each time, the measurement is done in triple points (Figure11a, 11b).

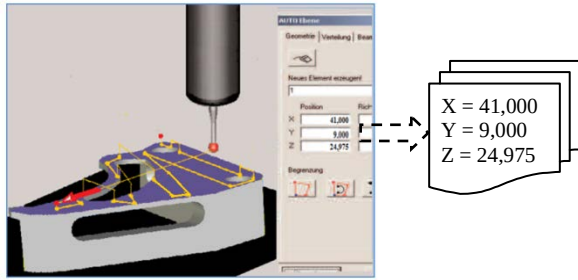


Fig.11b. Prototype part control operation on the MMT.

6- Treatment of results

The results are obtained by measuring the variances of the finished prototype (test piece) on the three-dimensional measuring machine (MMT) to determine the uncertainty of magnitudes in a statistical manner. It was measured the variances and found 3D printer errors.

7- Comparison and validation

A validation of the results is given at the end of this work (see § VI1).

Guidance according to:	chosen Cotes	Relative error (no unit)	Plotting of Graphs Average gap (mm)
X	70 ± 0.05	0,0025 ou 0,25% 0,0035 ou 0,35% 0,0030 ou 0,30% 0,0039 ou 0,39% 0,0031 ou 0,31%	
Y	110 ± 0.045	0,0030 ou 0,30% 0,0035 ou 0,35% 0,0032 ou 0,32% 0,0038 ou 0,38% 0,0035 ou 0,35%	
Z	25 ± 0.09	0,0025 ou 0,25% 0,0020 ou 0,20% 0,0028 ou 0,28% 0,0025 ou 0,25% 0,0030 ou 0,30%	

7.1. Results

The determination of uncertainty requires performing measurements series on the same piece and to draw any statistical magnitudes.

7.1.1. Measures identified gaps and errors Printer '3D'

The execution of a three-dimensional measurement range encourages performing by the use of prototype parts allowing a correlation matrix establishment. This work is carried out under the conditions imposed by the drawing definition (table 4).

Table 4. Correlation matrix reduced for dimensional inspection [8]

Five measures have been identified from the same side on each of the five pieces according to the axes (X, Y and Z).

a. The calculation of the identified dimensions' terminals [9]:

- Upper terminal = Systematic error – Mini error
- Lower terminal = Systematic error – Max error

• Along the X axis:

$$70 \pm 0.05 \text{ (r)} \text{ and } 70 \pm 0.007 \text{ (m)}$$

• Along the Y axis:

$$110 \pm 0.045 \text{ (r)} \text{ and } 110 \pm 0.004 \text{ (m)}$$

• Along the Z axis:

$$25 \pm 0.090 \text{ (r)} \text{ and } 25 \pm \begin{smallmatrix} +0.0044 \\ -0.0056 \end{smallmatrix} \text{ (m)}$$

b. The calculation of the arithmetic mean ($\bar{X}$) of statistical series [10]:

The arithmetic average calculation $\bar{X}$ of statistical series.

Either:

$$\bar{X} = \frac{1}{n} \sum_{i=1}^n x_i, \quad \bar{Y} = \frac{1}{n} \sum_{i=1}^n y_i \text{ and } \bar{Z} = \frac{1}{n} \sum_{i=1}^n z_i$$

Or: $n=5$ (❖)

We conclude that these values are all included as well as their average, within the tolerance interval imposed by the designer, and that following the specification condition ± 0.05 expressed by the following formula:

IT = upper tolerance-lower tolerance

$$IT = 0,05 - (-0,05)$$

$$IT = \underline{0,1\text{mm}}$$

The measures' survey is according to X, Y and Z (with $n=5$) (Table 5).

Table 5. Measures identified gaps and errors of 3D Machine

PARAMÈTERS PROCESSÉ	LOKED. POSIT.	0/1	REMOVIN	THICKNESS LAYER Z
DIRECTIONS FOR OBDERVATION				
Dimensions between plane X & Dimensions between Plan Y	⊗	⊗	⊗	
Thickness according to X & thickness according to Y	⊗	⊗	⊗	
Thickness according to Z & dimensions between plane Z			⊗	⊗

The measured deviation or the absolute error is equal to the final:

The final dimension (measured)–the ideal dimension (drawing definition)

$$\begin{aligned} \text{Measured Gap or (absolute error)} &= \\ \text{final rating (measured)} - \text{Ideal dimension} &= \\ \Rightarrow 24,9750 - 25 &= -0,0250(*) \text{ (mm)} \end{aligned}$$

Evidence :

Average value retrici. = Error .system.

$$\Rightarrow \sum_{n=1}^{\infty} (\text{error } i + \dots + \text{error } n) =$$

error1 + error2 + error3 + error4 + error5 =

$$\begin{aligned} &(-0,025 + 0,02 + 0,028 + 0,025 + 0,03) = \\ &= -0,128/5 \end{aligned}$$

$$\Rightarrow \text{average. v. r} = -0,0256 \text{ (mm)}$$

The final graph represents the three selected ratings (according to X, Y and Z) and visualizes the uncertainty and the deviation measures of the five pieces compared to those recommended by the manufacturer (figure 12).

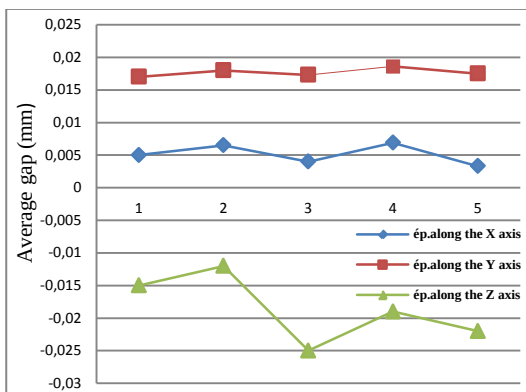


Fig.12. Evolution of the gap 'theory-based measure thickness'

8. Report (end)

The qualification of the 'FDM 3D' printer is verified. The product design is accepted for printing a multitude of plastic prototypes. The result is then, the acceptance of XXX 3D' printer's qualification after verification.

VI. Conclusion

The present work aims to qualify an open source product-design in a laboratory. This qualification is based on the verification of 3D machines' limits and it integrates the quality aspect on the *prototype part* around the identification of the flaws possible sources. The procedure has allowed us to verify the measured

values and compare them with the designer's data on the drawing. Our aim was first, to examine if the obtained values are in accordance with the tolerance indicated by the designer as well as to conclude whether the FDM process is qualified or not. Further, the obtained results have demonstrated that the methodology developed for qualification is reliable thanks to two simple tests (piece test, machines test) so as to decide on the quality of a low cost 'Open Source' machines.

In perspective, a geometric qualification will be the concern 'the second "stage"' of our next research. This work is a foundation stone for a better organization of product quality and opens up the possibility of ensuring low cost Open Access products, download directly open web-sites. This paper puts 3D printing in the field of both 'quality and reliability' investigation since printing has entered a historical phase.

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