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PRODUCTIVITY IN INNOVATION AND NEW PRODUCT DEVELOPMENT

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Abstract: *Current business environment tends to be rapidly and non-linearly changing. Thus, business objectives are extremely tied to management of unpredictability and chaos. Some of the changes in the market environment with the potential impact to the ways in which new product development (NPD) is practiced and managed over the past decade include increased level of competitions, in the same market are rapidly changing also customer needs and expectations. This research studies several aspects of NPD and innovation.*
Key words: New Product Development, Rapid Prototyping, Concurrent Engineering, Modularization, Data Mining, e-Manufacturing.

1. INTRODUCTION

It is known that Rapid Prototyping (RP) is being recognized as a significant technology for future product development. Today more and more manufacturers experience immense pressure to provide a greater variety of complex products in shorter product development cycle. The evolution of the market needs the time-to-market reduction, mainly because the product life cycle is shorter and also because it is important to produce more rapidly from an initial conception or 'idea' to a mass production product [1]. RP, as the name implies, should involve prototyping parts rapidly. Nevertheless, some RP systems are not rapid enough to compete with conventional machining systems [2]. Therefore, different case studies have been realized in this research in order to find the method for increasing innovation capacity in development of casing type details. Different RP technologies have been implemented and compared as one part of the whole new product development process. On the other hand, the case studies have been handled by taking into account Concurrent Engineering (CE) for launching efficiently to the final and desired result and modularization for simplifying and accelerating the speed not only for product development but for production as well. Additionally, different RP technologies have been compared and some useful tips for future NPD and RP has been investigated.

For today there is a new broad view of the innovation process – it is essential and needed that organizations are dealing with the educational dimensions of innovation. Now it is often not enough when firms are focusing only on R&D and on the technological aspects of innovation [3]. Thus organization's chiefs not only have to provide physical capital (R&D and technology infrastructure) but should also deal with enhancing human capital (training of workers) and social capital (i.e. encouraging the formation of trust based relationships between other firms). Therefore the innovation capacity of employees and entrepreneurs in the machinery, metal and apparatus engineering sector in Estonia, has been analyzed.

Finally, as it has been mentioned that novel applications to inventory management and Data Mining (DM) has showed great potential for engineering industry [4], DM

implementation for manufacturing area has been analyzed. Some solutions for the method implementations have been proposed and e-manufacturing together with e-solution opportunities has been handled together with DM opportunities. Therefore data warehouse creation was identified and needed data values were defined in order to investigate enterprise data more comfortably and effectively by using predictive data mining.
Thus, this research considers productivity investigations not only for innovation but for NPD likewise. This research has to provide additional surplus values for firms and helps to find useful methods for improving NPD process.

2. MAIN RESEARCH METHODS

The objective of research is to investigate productivity in innovation and product development and to find main factors that have positive effect for it.
For achieving the described objective, it was necessary to analyze CE impact for NPD process. Modularization was implemented into NPD and CE process in order to understand it effects for productivity. RP method was analyzed in practice in order to compare different RP technologies and find the most suitable one for further developments. Also DM possibilities were analyzed in production management and manufacturing. Finally, e-solution and e-manufacturing possibilities were investigated in industrial field in order to find out how they all would support and effect productivity in product development and innovation.

3. RESEARCH AND RESULTS

Different case studies have been performed by using different RP methodologies:
1. Radio Frequency Identification (RFID) reader housing was developed and compiled by using Inkjet Printing Technology (IPT) and Plastic Laser Sintering Technology (PLST);
2. Smart Dust housing (motes) was developed and compiled by using IPT and Soluble Support Technology (SST);
3. An autonomous robot device was developed and compiled by using PLST;
All three RP technologies have been compared based on the following criteria:
• uncertainty of arithmetic mean of printed detail dimensions
• speed of printing
• quality of printing (need for mechanical after treatment)
• preparatory works (e.g. 3D models created need to be carried into stereo lithography tessellation language (STL)
• physical properties of materials used choice of materials.
Comparison results of RP technologies are presented in Table 1.
The uncertainties of arithmetic mean of printed detail dimensions were also investigated in case of smart dust housing and RFID reader housing RP detail measurements (see Fig. 1).

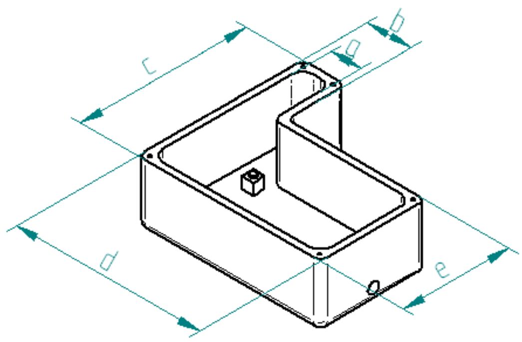

Fig. 1. Measured dimensions of housing in comparative 3D printing

Based on investigation of IPT, SST and PLST RP technologies, the following implications have been done. First of all, it is possible to avoid the differences between physical prototypes compared to virtual prototype (computer model).
It is good to know the arithmetic mean of printed detail dimensions. It gives the possibility to diminish detail’s dimensions before printing. The differences between physical prototype and virtual prototype can be decreased by using comparative pre-testing. Tensile strength analyze was

made, and several tests were conducted in order to find out the modulus of elasticity, elongation, tensile strength of the material.

Table 1. Comparison of RP technologies

Estimation criteria	3D Printing technology (printer)		
	IPT (Zprinter 310)	SST (Dimension SST 768)	PLST (Formiga P 100)
Un-certainties of arithmetic mean of printing results	Compared IPT with SST in one direction (a, b, d) the IPT uncertainties of arithmetic mean of printing results is bigger than another directions (c, e)		
	Compared IPT with PLST the IPT uncertainties of arithmetic mean of printing results is much bigger than in case of PLST		
Speed of printing	1 hour 10 minutes not including: - covering with glue - drying with compressed air	3 hours 23 minutes (smart dust housings detail) not including: - SST Station	
	30 minutes (RFID reader housings detail) not including: - covering with glue - drying with compressed air - mechanical treatment		8 hours and 6 minutes (RFID reader housings detail) not including: - cooling
Quality of printing	poor	good	excellent
Preparatory works	3D model into STL model; details optimal setting	3D model into STL model	3D model into STL model; check over of details
After-treatments	need for mechanical after treatment (polish and file of details)	SST Station automatically wash away the support structures	-
Cost of prototype	low	low	high
Cost of printer	low	average	high
Choice of materials	Fine powder and special glue (Cyano-acrylate (Z-Bond 101))	Fine powder and molten polymer	Fine powder

How infiltrating prototype parts with z-Bond resin affects its properties (see table 2).

Table 2. Tensile strength analyze results

	IPT			PLST		
	Force (N)	Tensile strength (MPa)	Elastic elongation (%)	Force (N)	Tensile strength (MPa)	Elastic elongation (%)
	Upright positioning, no post processing					
Average	21.3	0.591	0.109	2025	50.6	9.80
	Horizontal positioning, no post processing					
Average	58.2	1.617	0.091	2210	53.2	16.63
	Upright positioning, post processed					
Average	271.1	7.532	0.261			
	Horizontal positioning, post processed					
Average	218.4	6.066	0.391			

The study showed that prototype parts positioning during printing (IPT) affects greatly its physical properties. Upright positioning with post processing increases the maximum tensile strength about eight times and elastic elongation about three times. In case of PLST, detail positioning mainly affects the elastic elongation. The elastic elongation increased remarkably by positioning the detail horizontally compared to upright positioning. The tensile strength and elastic elongation were substantially higher with PLST compared to IPT.

CE was implemented together with modularization and simulation methodology in order to point out those impacts all together for NPD (see Fig. 2).

Investigation has proved that implementing CE into NPD has an important role for innovation and NPD productivity.

CE helps to get more correct product design at the start of the development process and reduces difficulties in future workflow.

CE enables to implement changes into product design simultaneously with product development. CE implementation in NPD case studies pointed out, that it is a business strategy that would have a positive effect for a whole product development process.

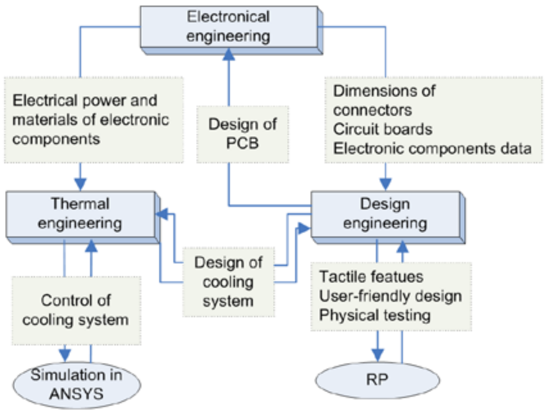

Fig. 2. CE in RFID reader housing development

Modularization was also implemented in housings development [5], as it enabled to make changes in module without affecting other modules. According to the figures 3 and 4, the modules were created and developed independently from other system.

Implementation of modularization showed that it can have positive effect not only for NPD, but also for RP. Based on modular structure each functional element can be placed into independent module which includes strictly defined interfaces with other modules. This enables to make changes in module without affecting other modules. Such approach is also suitable for apparatus industry where the variety of functions in electronic device can lead to need for changes. The modules can be created and developed independently from other system.

In case of RFID reader housing development, the target was to develop a housing that is modularized and compact. The reader is dedicated for passive Ultra High Frequency (860-950MHz) data interchange (40-640kbps) standard ISO18000-6B. The reader has working distance 2 m, and it belongs into "smart library" concept. As there was the need for cooling the device thermal analyze was implemented with an engineering simulation software ANSYS.

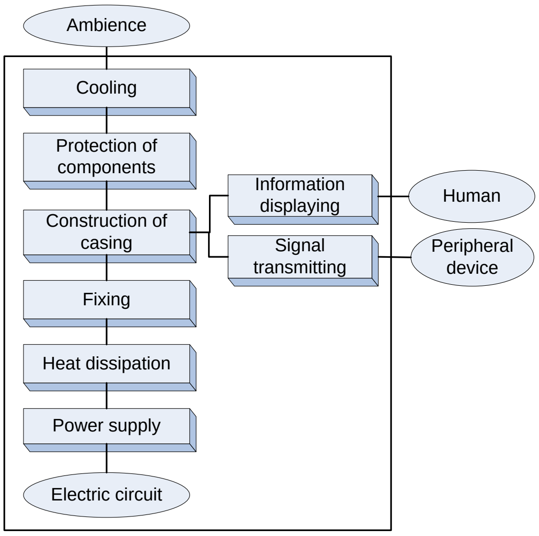

Fig. 3. Functional structure of electronic device

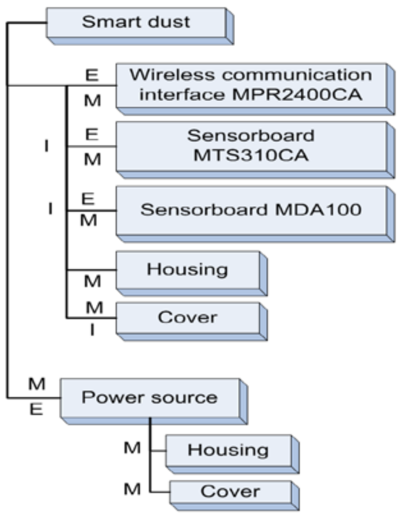

Fig. 4. Modular platform and interactions between the modules

Firstly, the developed cooling system was calculated by ANSYS. The warming printed circuit, aluminum plate and heat sinks were defined with ANSYS and the properties of materials were determined. The calculation results with the simulation program showed that the developed cooling method was suitable for heat rejection from the RFID reader. The highest quantity of heat was on the printed circuit, 0.662 W/mm^2 from where by the aluminum plate it was lead to the heat sinks and from there in turn out of device. Figure 5 presents that simulation confirmed that the developed device cooling assures the heat flow from the device.

Secondly, a whole set of housing, cooling and Printed Circuit Board (PCB) was built as RP model. The tactile features of the assembly were tested and thereafter PCB and heating replaced with real components. To test the developed cooling and also to become assured that device is not overheating, another tests with thermal camera Thermo CAM E45 was performed with RP model.

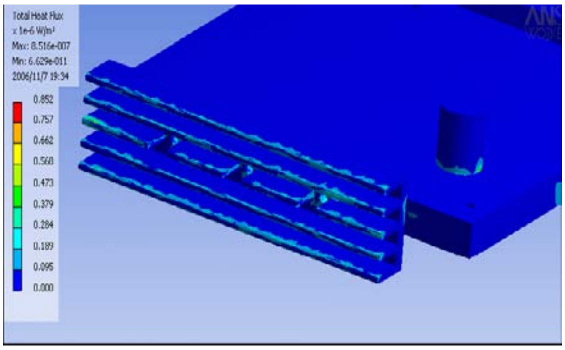

Fig. 5. Thermal dissipation from the heat sink

Test results showed that without cooling printed circuit's temperature run up during 30 seconds up to 85 degrees. With cooling, it stabilized on the level 58.6 degrees. The rest of heat was leaded to the aluminum plate and from there in turn to the heat sinks. Measurements proved that homogeneous heat dissipation was guaranteed with developed cooling method. Simulation utilization helps to assure the reliability of final product. It was found out, that the biggest quantity of heat was appeared on the printed circuit, from where by the aluminum plate it was leaded to the heat sinks and from there out of device. Simulation with ANSYS gave the certainty for future product development and producing.

Expert tool for innovation capacity estimation was also developed and implemented. The influence of human resources can be evaluated successfully when using proper taxonomy and expert estimations. In an effort to define the skill levels a number of taxonomies were studied [6-9]. All taxonomies are developed to describe goals/objectives of courses/education programmes in terms of knowledge and skills acquired by any student/participant fulfilling the course/programme requirements, but from slightly different viewpoints [10]. A comprehensive research was targeted to investigation of needed and existing competencies. Data about employees' existing and needed levels of competence was gathered and analyzed in case of 75 machine-building, metalworking and apparatus industry companies. In the elaborated model, the existing levels (EL) and needed levels (NL) were estimated in scale 0-5, where 0 means "the skill has no importance" and 5 means "the skill has high importance". It was found out that in the case of high-tech research, better results can be achieved when a team is selected according to expert evaluation of needed competences. The proposed expert tool solution is capable of monitoring the quality and quantity of technological resources in machine-building enterprises of the network.

The results were positive and the system elaborated has demonstrated the ability to enable competence development. Also e-solution and e-manufacturing possibilities in industrial field together with DM implementation have been analyzed. Toolset was created for integrating RP cost model into e-manufacturing system and for investigating service usability by companies using DM method. It was understood that the DM is proved to be promising method to handle the information thus increasing productivity of management and innovation in the collaboration network. Integrating a DM framework within the manufacturing information system can enable to analyze enterprises opportunities for manufacturing and its pre-calculations, find relations between enterprises, customers and subcontractors, and make consequences based on different data conjunctions. Therefore predictive data mining can facilitate to explore customer in more detail. For example, based on customer database it can be possible to investigate, which customers are interested of RP service or in which cases they gave up of offered services.

4. CONCLUSION

The main key factors, that can influence the company's productivity in innovation and NPD has been investigated. Suggestions for increasing innovation capacity and performance of NPD, is to follow sequent method:

- Analyze of needed competence for product development team with developed INNOMET expert tool.
- Implement CE and modularization in NPD and RP processes
- Build a CAD model and in case of need use computer simulation.
- Use RP by taking into account different investigated technologies advantages and disadvantages and possibility to diminish printable prototype part's dimensions
- Reckon with tensile strength analyze results
- Build the real experimental prototype by replacement of critical modules with experimental physical modules and test the critical characteristics
- Use provided e-solutions and DM methods for better accommodation of services

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6. REFERENCES

1. J.C. Ferreira, E. Santos, H. Madureira, J. Castro, Integration of VP/RP/RT/RM for rapid product and process development, *Rapid Prototyping Journal*, 2006, 12/1, Page: 45-52
2. R. Noorani, *Rapid Prototyping: principles and applications*, Hardback 2006.
3. B.A. Lundvall, *Why the new economy is a learning economy*, No 04-01, Aalborg University 2007
4. I. Liiv, *Pattern Discovery Using Seriation and Matrix Reordering: An Unified View, Extensions and an Application to Inventory Management*, TUT Press 2006
5. Matsi, B.; Otto, T.; Sarkans, M.; Roosimölder, L. Method for Increasing Innovation Capacity in Development of Casing Type Details. Bartolo, P. J. et al (Ed.). *Virtual and Rapid Manufacturing* (747 - 752). London: Taylor & Francis.
6. *Taxonomy of Educational Objectives: The Classification of Educational Goals*; pp. 201–207;B. S. Bloom (Ed.) Susan Fauer Company, Inc. 1957.
7. Anderson, L. W., & Krathwohl, D. R. (Eds.). *A taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of educational outcomes: Complete edition*, NY : Longman. 2001.
8. Boulton-Lewis, Gillian M. The SOLO Taxonomy as a Means of Shaping and Assessing Learning in Higher Education, *High.Ed. Res.&Devel.*, 1469-8366, Volume 14, Issue 2, 1995, pp 143 – 154.
9. Feisel, L., D.; Rosa, A. J. The Role of the Laboratory in Undergraduate Engineering Education. *J. Eng. Ed.* 94(1): 121. 2005.
10. Kjellberg, T., Larsson, M., Johansson, P., Wingård, L. Ontology of Terms and Definitions for Competence Management. *Innovative development of human resources in enterprise and in society* (38-46). Tallinn: TUT, 2007.