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Impact of human factors and errors for product quality and reliability in the integrated approach of product and process design, maintenance and production

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1. Introduction

Global manufacturing (GM) environment may be characterized by two main parameters: high level of competition and economy of labor. New product developers, producers, suppliers and customers are located apart within great distances. At the beginning of GM era, a lot of industrial production moved from the USA, Western Europe, Australia, and Japan to developing countries in South-East Asia and Eastern Europe, while in many industrialized nations the hollowing phenomenon of the manufacturing section is observed. A hollow company undertakes itself the functions of marketing, new product and process development, and production delivery to the customer. Strong relations, therefore, exist among customers, developers and producers of an end product or its parts and components [1]. The competiveness in product and process design, manufacturing cost, quality and delivery time is the main index of successful co-operation of such activity kind. Essential weakness of most products' producers is the fact, that when reducing manufacturing cost then requirements for quality are not fully realized, terms of usage and all the functional possibilities are not used well. Many end products' producers increasingly pressure the parts and components suppliers to decrease the manufacturing cost, yet have less security of supply and control of production. On the other hand, the manufacturing process maintenance and production itself is the systematical constituent together with product and process design. All four segments of mentioned different activity influence equally to the end quality and reliability of product and the humans' errors play a leading role in recited processes.

The integrated design of new product and its components together with manufacturing process at the early development stage applying concurrent engineering and innovative virtual reality methods, models and tools would be the way achieving required quality and reliability tasks of the end product. The integration of the product-process design in the development of a manufacturing system is emphasized in research [2] which had developed a virtual model for the production system design based on technical and temporal data such as work sequences, operations, components and product delivery time, and production resources. Minimizing manufacturing and quality cost is a risk to incur the process capability. An intelligent interfacing module of process capability between the product and process design systems in virtual prototyping environment is developed on the basis of the knowledge acquired at different organizations involved in new product and process development [3]. This research considers contradictions both in product design procedure when seeking its best performance and in the principles of design for assembling (DFA) and design for manufacturability (DFM), whereas, when facilitating the product assembling process, the fabrication process of product parts becomes more complicated. When product and process design is completed, assessing performance risk is checked by a simulation-based model [4]. Applying this model product and manufacturing process design could be limited by human factors and errors that have the following influence to the product quality and reliability in the next operation stages as maintenance and production. Assessment of human error in maintenance requires identification of the contributing factors that lead to quantification of human errors [5]. These factors are called human error inducing factors, which take into consideration both the active and latent error contributing aspects related to man, machine and environment. Product defect rate confidence bound with attribute and variable data in production line or cell evaluates the production process quality in industry being a last product evaluation and checking step. There are some methods for product defect rate evaluation [6] – bootstrap methodology to construct a upper confidence bound for the overall defect rate of a product whose quality assessment involve multiply pass/fail binary data and multiple continuous data. The technological scenarios of variation transmission in multistage machining processes [7] consider the possibility of variation reduction in key characteristics at the final production stage. It enables the understanding how variation is added and transmitted across the process stages; it helps to know and to identify the opportunities to reduce variation in key product characteristics at the final stage [8].

The main objective of this paper is to develop an integrated approach to achieve the least manufacturing cost and delivery time to the customer applying concurrent development of product and process keeping the onward end of the maintenance and production process. In this paper, the belief and plausibility computations and forecasting according to the evidence theory for classifying product and its parts failures are also carried out to highlight the capabilities of manufacturing system aiming the lowest cost and highest quality and reliability.

2. Acquisition and evaluation of engineer knowledge and creativity for product quality and reliability

Getting the right product at the right time to the customer is the main goal of every manufacturer for survival in marketplaces [9]. Competitive business priorities according to the opinion of most leading manufacturers are production cost, quality, flexibility, dependability and innovativeness. Quality and reliability of a product can be ensured only in the case, when it is foreseen and considered at the early product development and design stage. In this stage product properties and characteristics must be estimated and optimized interacting integrated product and process design with maintenance and production procedures.

Engineers and scientists participating in new product and process development tend to acquire a necessary knowledge and information related with appropriate engineering field as mechanical, electronical, informatical and so on. The development situation of innovative products is changed during past two-three decades because they became very complicated using knowledge and data of cross-disciplines area, i.e. contemporary product consists of all available components and parts involving above mentioned technical fields. Following this the developers of new products in nowadays must be able to work and make expertise in cross-discipline areas of their ideas and proposals.

The four fields of new product and process development at the early stage have been examined and checked in this research: 1) product design, 2) process design, 3) manufacturing process maintenance and 4) production and testing. All these jobs must be integrated in one entire and extremely made at the early design stage in virtual environment. The virtual reality methods and tools [10] are applied starting with development of product and process properties, characteristics, structure and manufacturing maintenance and production. The interactions among these fields and appropriate interfaces have to be created and used in particular applying rapid prototyping technique. Project manager has to foreseen objective and all tasks in the integrated development chain looking the end product quality and reliability.

In general the human knowledge at one or another field is classified into two groups [11]: 1) evolutionary infallible knowledge (*EIK*) and 2) reliable knowledge (*RK*). The intersection of *EIK* and *RK* represents infallible knowledge (*IK*); the knowledge of engineer or scientist involved in innovative product and process development generally mutates from *EIK* level to the *IK* sufficient level through scientific heuristic and specific engineering field knowledge acquisition and ignorance some knowledge and expertise of other experts. In the worst case $IK = 0\%$ while in the best case $IK = 80\%$ or even more. The *IK* level depends on the engineer or scientist skill, experience in field and working with minimum errors. Based on this representation, two primary types of ignorance can be identified: 1) ignorance within the knowledge base *RK* due to factors such as irrelevance, and 2) ignorance outside the knowledge base due to unknown objects, interactions, consistent patterns, and know-how.

New product and process design may come from external or internal sources [12]. External forcing for a new product may be due to an order from a customer, obsolescence of an existing product, availability of new technologies and change in market demands. Internal sources of new product ideas may come from new discoveries and developments within the organization as the need for a product identified by the marketing department. The stimulating of collaborative activity among various manufacturing and business people can help generating the new ideas for products and processes. A designer in general case uses trial-and-error method solving contradictions between new product performance and customer requirements. This approach needs adding resources and gives a bigger risk for product and process design errors. The production of new products' patterns and their thorough consideration and testing of properties and performance functions for clarification of errors and defects is necessary. The unnoticed design errors come to production process and finally products become non-quality. It is a long way, unfortunately, and new means of product and process development must be applied. One of the possibilities would be systematic work, clarification of contradictions among customers and developers, acquisition of knowledge and good practice, creation of knowledge base for new product and process development [13]. Another way could be statistics acquisition and analysis of new product and process, and application of the evidence theory calculating belief measure and plausibility measure for classifying product non-quality in accordance with the influence of product and process designer errors, maintenance errors and production errors [14].

Human factors and errors are one of the main reasons of non-quality product. These factors and errors can occur when humans are not sufficiently competitive, motivated and skilled in their work. There are main reasons, when employees are poorly trained in their area of responsibilities and duties, also when they are not motivated to do one or other job in the best way and salary is not related with the final job results, and when they do not feel social guaranties from the employer's organization. Human errors often upstart when employees are tired, when enforcement at the work is over their psycho physiological and physical possibilities.

Improvements of product and process quality and reliability must be implemented in all product life cycle phases beginning from the product concept formulation, validation, full scale development, maintenance, production and use, because they lead to product value enhance and lower manufacturing costs, and the qualitative product does not need to be repaired, corrected, and don't delays in delivery. When the cost is lower, productivity can be increased and manufacturer can cover a bigger part of the market and achieve more customers and bigger profit. Application theory of evidence and calculating the belief measure and plausibility measure for classifying product non-quality index in accordance with the influence of product and process design errors, maintenance and production errors is implemented in this research.

Evidence theory aims to evaluate the confidence of an expert infallible knowledge *IK* in the truth of the possibilities that are envisaged. The evaluation is summarized by a belief function for each four fields of above mentioned activities seeking product and process quality and reliability. It expresses belief in the hypotheses entertained by an expert. Evidence theory has the ability to express directly the uncertain information and knowledge. It allows expert to endow the probability in a single element or some elements affecting together. It is stated that product and process performance, quality and reliability ensuring, manufacturing cost reduction and work productivity improvement are the main tasks of surviving in Global manufacturing environment.

Forecasting methods for non-quality product reasons and its evaluation are created using statistical analysis and evidence theory. Evidence theory is a branch of the mathematics of uncertain reasoning that allows for novel possibilities to be conceived by a decision-maker. Data for these methods were gained from experiments and were calculated using parameter functions. Experimental research was performed directly studying and researching products and processes design, maintenance of manufacturing processes, used technologies, facilities and operations of product's parts and assembled product itself.

The evidence theory is used in this research for classifying of non-quality product. The underlying monotone measures for this theory are the belief measure (*Bel*) and plausibility measure (*Pl*). The belief measure should be defined on a universal set *X* (in this research *RK*) as a function that maps the power set of *X* to range [0, 1] of every considered field the infallible knowledge *IK*:

$$Bel : P_X \to [0,1], \tag{1}$$

where P_X is a set of all subsets of *X* and is called the power set of *X*. The power set has $2^{|X|}$ subsets in it.

The belief function has to meet the following conditions:

$$Bel(\varnothing) = 0; \tag{2}$$

$$Bel(X) = 1. \tag{3}$$

Bel and *Pl* functions satisfy the following condition:

$$Pl(L) \geq Bel(L), \tag{4}$$

for each *L* in the power set of the infallible knowledge *IK*.

In order to obtain a high quality product, the main factor for the design and manufacturing of a quality product and manufacturing process must be chosen and valued. These factors can be characterized:

$$m : P_X \to [0,1]. \tag{5}$$

This equation must satisfy the following conditions:

$$m(\varnothing) = 0; \tag{6}$$

$$\sum_{all L \in P_X} m(L) = 1. \tag{7}$$

The belief measure *Bel* and plausibility measure *Pl* can be computed according to a particular basic assignment *m*:

$$Bel(L_i) = \sum_{all L_j \subseteq L_i} m(L_j); \tag{8}$$

$$Pl(L_i) = \sum_{all L_j \cap L_i \neq \varnothing} m(L_j). \tag{9}$$

The three functions *Bel*, *Pl* and *m* can be viewed as alternative representations of the same information or evidence regarding to the element *x*. the basic assignment *m* for $L_i \in P_x$ can be computed according to the belief function as follows:

$$m(L_i) = \sum_{all L_{j \subseteq L_j}} (-1)^{|L_i - L_j|} Bel(L_j), \tag{10}$$

where $|L_i - L_j|$ is the cardinality of the difference between the two sets.

Basic assignments m_1 and m_2 produced by two experts on the same element and family of sets of interest can be combined using Dempster's rule [8] of combination to obtain a combined pinion $m_{1,2}$ as follows:

$$m_{1,2}(L_i) = \frac{\sum_{all L_j \cap L_k = L_i} m_1(L_j) m_2(L_k)}{1 - \sum_{all L_j \cap L_k = \varnothing} m_1(L_j) m_2(L_k)}, \tag{11}$$

where L_i must be nonempty set, and $m_{1,2}(\varnothing) = 0$. The term $1 - \sum_{all L_j \cap L_k = \varnothing} m_1(L_j) m_2(L_k)$ is a normalization factor.

The developed research has been tested both in laboratory and industry. The verification and validation tests for the developed approach applying better integrated product and process development with maintenance and production procedure in virtual reality environment have been conducted at the laboratory. Large Lithuanian company took a part performing the acceptance tests of that approach. The sub-chapter "Case study" illustrates how the developed approach works and some available results from its activity are presented.

3. Case study

The performed research is closely linked with the activity of a large Lithuanian enterprise *Y* that produces bicycles. Peculiarity of this enterprise is that bicycles are assembled, painted, tested and validated in Lithuania, but most of the materials, parts and components are purchased from suppliers located in various companies and countries mostly outside of Lithuania. It produces now close to 80 various types of bicycles including bicycles for children, urban and tourist and mountain bicycles and even special bicycles for sport race. The yearly output of bicycles at the enterprise is more than 350.000 units. Enterprise *Y* has close 4-6 good developed products types, which produces on a mass scale. Other types are made in batch or in small batch volumes according to the customers' orders. Just after privatization of the enterprise *Y* its owners launched incidentally search for the cheapest alternatives of manufacturing processes and cost. The make-or-buy decision has been applied outsourcing production to low cost sites. The problem of quality and reliability warranty, unfortunately, occurred because of non reliable suppliers – the material or parts and components for the bicycles not always satisfy quality requirements. Non-quality parts from the suppliers had inadequate design and manufacturing process, also quality control.

As things stand the shareholders of the company *Y* decided systematically analyze non-quality and manufacturing cost problems and initiated close collaboration with academia. The Centre of technological tests at the Šiauliai University was established for well-rounded experiments of bicycles and their parts and components. All tests of quality and reliability control are performed according to the requirements of appropriate standards. Tests are accomplished on more responsible parts of bicycles from every supply lot of products. These tests showed which parts, sections, assembling units and so on are improper and where risk of breaking can appear. List of the main bicycle parts, tested on initial analysis stage, is illustrated in Table 1. The only weakest data is presented in this table. Parts of bicycles, which didn't break during the tests detected that these parts are substantial, reliable and quality is quite enough.

Table 1

List of tests with bicycle parts and assembled products

Name of test	Number of tests	Below standards
Frame fatigue tests	122	2
Tests of brakes	63	31
Dynamics tests of pedals	12	2
Dynamics tests of wheels	57	3
Tests of saddle fatigue	14	1
Dynamics tests of carriers	28	18
Tests of front fork	65	4

According to the tests' results presented in Table 1 weakest parts of the bicycle are brakes and carriers. Of course, brakes of a bicycle are more important part to ensure safety of bicyclist, but total quality of the assembled bicycle depends on reliability and quality of the brakes and carriers. Formerly both the end bicycle producer and suppliers participated in product and process design applying trial-and-error method and some near-miss solutions have been left. Suppliers made production errors seeking the minimal manufacturing cost because not enough investments for innovative technologies and a big part of manual work have been used.

Summing-up the performed analysis it was stated that the main reasons of non-quality and reliability product and failures for bicycle manufacturing are:

1. Product design errors, when there are the human mistakes also not enough competence in design procedure or choosing the best design alternative for the product functionality, safety, quality, reliability and manufacturing cost.
2. Manufacturing process design errors as wrongly planned operations, facilities, tooling, work conditions, regimes and physical properties.
3. Maintenance errors expressed by human mistakes implementing robotic means and high productivity automatic machines, other initiative and motivation of techniques decreasing manual work and quality in company production lines and cells.
4. Production errors and defects as wrong materials, contravenes of parts' dimensions and tolerances requirements in drawings, geometrical form and other defects.

The methods of virtual reality environment and standard CAD software have been used for integrated bicycle and its manufacturing process development. It was decided to turn on systematic work going from "trials and errors" approach and clarifying contradictions among customers and suppliers and creating knowledge base for new product and process development avoiding errors. All integrated design functions of new bicycle and its components together with maintenance and manufacturing procedure have been undertaken to the end product producer. The developed integrated knowledge-based model in virtual environment of innovative product and process design has been applied at an early business engineering stage [16]. Product and its components have been tested virtually and employing physical prototypes at the early design stage. DFM and DFA methods concurrently have been used [3] and the best product and process design alternatives have been implemented. Special stands for laboratory and industrial testing and validation of assembled bicycles and their components (frames, brakes and carriers) have been developed and implemented.

Employing integrated design and testing procedures at the early stage, weaknesses of the bicycle and its components have been set. The special attention for the quality of braking and frame has been paid designing both mentioned components, while for carrier design the attention was paid for metal consumption decrease and welding manufacturability. Generally, for brakes design lever transmissions with the optimized transmission ratio and number of parts have been used. Ratio of the transmission must be high, while the number of parts in assembling unit must be low. Analysis of different lever constructions exhibited that the most effective is "V-Brake" design – ratio of the transmission for this design is the highest in comparison with other lever design alternatives.

Next reasons of bicycle non-quality and reliability are human factor and errors in the phases of process design, maintenance and production. For evaluation of influence the every failure cause on the quality of a bicycle, belief and plausibility measures for these failures have been calculated. According to evidence theory belief measure and plausibility measure have been set for the evaluation of reasons the non-quality bicycle. Two experts have been asked to review product and process design errors also errors of maintenance and production phase and to provide the assignments of these causes. For the first evaluation the person who is responsible for the total quality management and the methodology of testing and validation in the bicycle enterprise was chosen (Expert 1). Other expert (Expert 2) is the person, responsible for bicycle tests in the Šiauliai University Centre of bicycles' technological tests. He is responsible for the development of bicycle and its components design strategy including maintenance and production phases.

Bicycle quality and reliability can be incurred due to the human factors and errors of each above-mentioned cause. Each cause by two experts is valued separately (m_1 and m_2) and also rating of two, three and all four reasons originating together is fulfilled. Both experts evaluated the situation after implementation of systematic work clarifying contradictions among customers and suppliers in considered manufacturing system. The experts provided the assignments in Tables 2 and 3 for *D*, *C*, *H*, *E* also *D* U *C*, *D* U *H*, *D* U *E*, *C* U *H*, *C* U *E*, *H* U *E*, *D* U *C* U *H*, *D* U *C* U *E*, *D* U *H* U *E*, and *C* U *H* U E. The assignment for *D* U *C* U *H* U *E* was computed based on Eq. (7) to obtain a total of one for the assignments provided by each expert (Tables 2 and 3). Belief measure *Bel* of non-quality bicycle depends on the reasons – if there are some failure causes, the *Bel* will be higher. When all of the failure causes affect interact together and the belief measure m_1 and Bel_1 is the biggest (Table 2) defined by Eq. (8).

Table 2

Belief measure *Bel* of the non-qualitative bicycle

Subset		Expert 1		Expert 2		Combined judgment	
Failure cause	Notation	m_1	Bel_1	m_2	Bel_2	$m_{1,2}$	$Bel_{1,2}$
D – Product designer error	*D*	0.01	0.01	0.02	0.02	0.069	0.069
C – Process designer error	*C*	0.01	0.01	0.02	0.02	0.071	0.071
H - Maintenance error	*H*	0.02	0.02	0.03	0.03	0.085	0.085
E – Production error	*E*	0.02	0.02	0.01	0.01	0.072	0.072
D U *C*	*DC*	0.05	0.07	0.06	0.10	0.069	0.208
D U *H*	*DH*	0.05	0.08	0.06	0.11	0.067	0.220
D U *E*	*DE*	0.05	0.08	0.06	0.09	0.067	0.207
C U *H*	*CH*	0.05	0.08	0.06	0.11	0.067	0.223
C U *E*	*CE*	0.06	0.09	0.06	0.09	0.072	0.215
H U *E*	*HE*	0.06	0.10	0.06	0.10	0.070	0.227
D U *C* U *H*	*DCH*	0.08	0.27	0.08	0.33	0.054	0.481
D U *C* U *E*	*DCE*	0.08	0.28	0.08	0.31	0.054	0.473
D U *H* U *E*	*DHE*	0.07	0.28	0.08	0.32	0.051	0.481
C U *H* U *E*	*CHE*	0.07	0.29	0.08	0.32	0.051	0.488
D U *C* U *H* U *E*	*DCHE*	0.32	1	0.24	1	0.081	1

The plausibility measure shows data reliability, so it must be as high as possible. The plausibility measure defined by Eq. (9) for non-qualitative bicycle is shown in Table 3.

Table 3

Objective Plausibility measure *Pl* of the non-qualitative bicycle

Subset		Expert 1		Expert 2		Combined judgment	
Failure cause	Notation	m_1	Pl_1	m_2	Pl_2	$m_{1,2}$	$Pl_{1,2}$
D - Product designer error	*D*	0.01	0.71	0.02	0.67	0.07	0.51
C - Process designer error	*C*	0.01	0.71	0.02	0.68	0.07	0.51
H - Maintenance error	*H*	0.02	0. 70	0.03	0.68	0.08	0.51
E - Production error	*E*	0.02	0.72	0.01	0.68	0.08	0.52
D U *C*	*DC*	0.05	0.90	0.06	0.90	0.07	0.77
D U *H*	*DH*	0.05	0.90	0.07	0.90	0.07	0.77
D U *E*	*DE*	0.06	0.92	0.06	0.89	0.07	0.78
C U *H*	*CH*	0.05	0.91	0.06	0.91	0.06	0.78
C U *E*	*CE*	0.07	0.92	0.07	0.88	0.08	0.77
H U *E*	*HE*	0.06	0.93	0.06	0.90	0.07	0.79
D U *C* U *H*	*DCH*	0.09	0.98	0.06	0.99	0.05	0.92
D U *C* U *E*	*DCE*	0.08	0.98	0.08	0.97	0.05	0.92
D U *H* U *E*	*DHE*	0.07	0.99	0.07	0.98	0.05	0.93
C U *H* U *E*	*CHE*	0.06	0.99	0.08	0.98	0.05	0.93
D U *C* U *H* U *E*	*DCHE*	0.30	1	0.25	1	0.08	1

The quality must be ensured in every step of creating the bicycle. This means, that belief measure of non-qualitative product must be as low as possible. In such case failure causes will decrease and quality of the products will grow up. Experiments in bicycle enterprise *Y* showed that bicycle and its components design applying systematic work is the most effective, so it must be used for lesser product and process design, maintenance and production error.

4. Implementation and further research

The developed approach and its separate parts are implemented in industry of Lithuania. The implementation results in Large Company *Y* have shown that the approach is able to apply seeking a systematical job for increasing product and process quality and reliability. Systematical job on the new technical and economical knowledge acquisition and verification and close various specialists collaboration in cross-discipline environment is grounded. On the other hand the product quality and reliability with manufacturing cost and productivity is contemporized, therefore, the strategical decisions looking cheapest producer of different components on the methods of evidence theory could be grounded. Application of the approach developed in this research makes it possible to determine whether it is feasible to produce the component in local factory or shifting it to low cost sites. It means the ratio among component cost and quality has to be checked and evaluated.

It is planned to develop a knowledge base (KB) for rules, facts and regularities collecting the right decisions of product and process development also using a best practice in maintenance and production procedures. Above mentioned data must be evaluated and checked by available risk employing them in virtual reality environment of product and process design, maintenance and production phases. The research of this paper is useful tool because shows availability of decision making applying the methods of evidence theory avoiding influence of humans' factors and errors seeking product and process quality and reliability. For each product and process failure case, the case needs to be classified in terms of causes and entered in the KB. Failure cases have to be related with appropriate design features, materials and manufacturing processes. The maintenance of new innovative machines and processes in production and assembling lines and cells that could decrease the manual work is foreseen in the future research.

5. Discussions and conclusions

The research in this paper showed that the main reasons of non-quality and reliability product and its components are human factors, errors and defects of product and process design, maintenance and production procedure. Moreover, the interaction of different causes above mentioned activities enhances the probability to occur the non-quality product. The new product and process design is the essential task of the manufacturing organization that defines other areas of its activity and competitiveness. The integrated approach of product and process development in virtual reality environment has been applied and implemented in industry have increased the quality and reliability of production. It has been stated that the developed of integrated knowledge-based model is able to design innovative product and process in virtual environment at the early business engineering stage of the distributed manufacturing system. Belief measure and plausibility measure of non-quality product when one or some failure and defect causes of a product have been considered. The method that has been described in this paper accomplishes the objective of this research. The theoretical consumptions of this research have been checked and confirmed in case study – Large Lithuanian Company *Y* that develops and produces bicycles and their components.

Implication of this research with regard to close collaboration between academia and industry and implementing virtual reality is that an integrated product and process development with maintenance and production procedures is substantial for product and its components quality and reliability. This is illustrated and confirmed by bicycle and its components design and the application of belief theory. The experience of company employees and experts together with both universities researchers' achievements and further collaboration allow believing to achieve the constant enhance results of production quality and reliability in the company.

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ŽMOGAUS VEIKSNIŲ IR KLAIDŲ ĮTAKA GAMYBOS KOKYBEI IR PATIKIMUMUI, TAIKANT INTEGRUOTĄ GAMINIO BEI PROCESO, TECHNINĖS PRIEŽIŪROS IR GAMYBOS KŪRIMO METODĄ

R e z i u m ė

Veiklos globalizacija yra pagrindinis iššūkis organizacijoms, kuriančioms ir gaminančioms techninius gaminius.

Šis straipsnis skirtas sukurtam integruotam požiūriui siekti mažiausių gamybos sąnaudų ir gaminio pristatymo laikui vartotojui, naudojant vienalaikį gaminio ir jo gamybos technologijos kūrimą, siekiant tobulos techninės priežiūros ir gamybos. Šiame straipsnyje taikyta aiškumo teorija bei jos tikėtinumo ir patikimumo matų skaičiavimų bei prognozės metodai, klasifikuojant gaminius ir jų komponentus pagal tinkamumą ir gamybos sistemos galimybių atitikimą, siekiant aukščiausios produkcijos kokybės ir patikimumo. Teorinės šio mokslinio straipsnio prielaidos buvo patikrintos ir patvirtintos praktinėje studijoje, aprašančioje Lietuvos įmonės *Y* veiklą, kuriančioje ir gaminančioje dviračius ir jų komponentus. Ateityje moksliniame darbe planuojama sukurti žinių bazę (KB), kurioje būtų fiksuojamas kiekvieno gaminio ir proceso kokybės bei patikimumo nesėkmės atvejis, jie klasifikuojami pagal nesėkmių priežastis ir talpinami KB.

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IMPACT OF HUMAN FACTORS AND ERRORS FOR PRODUCT QUALITY AND RELIABILITY IN THE INTEGRATED APPROACH OF PRODUCT AND PROCESS DESIGN, MAINTENANCE AND PRODUCTION

S u m m a r y

Globalization is the main challenge for all organizations developing and producing technical products today. This paper deals with develop an integrated approach to achieve the least manufacturing cost and delivery time to the customer applying concurrent development of product and process keeping the onward end of the maintenance and production process. In this paper, the belief and plausibility computations and forecasting according to the evidence theory for classifying product and its parts failures are also carried out to highlight the capabilities of manufacturing system aiming the highest production quality and reliability. The theoretical consumptions of this research have been checked and confirmed in case study – Large Lithuanian Company *Y* that develops and produces bicycles and their components. At the further work it is planned to create for each product and process failure case, the case needs to be classified in terms of causes and entered in the knowledge base (KB).

Keywords: human factors, errors, product quality, reliability, evidence theory.

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