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PARALLEL APPROACHES IN THE PRE-MANUFACTURING PHASE - PROCESS OF THE TECHNICAL PREPARATION OF MANUFACTURE AND RISK ASSESSMENT OF TECHNICAL SYSTEMS

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Professional paper

The possibility to identify and subsequently to react to the bottlenecks of the new proposed technical systems in pre-manufacturing phase, based on the principle of concurrent engineering, brings a number of positive effects on financial savings by improving the quality of the finished product. An important feature of the new product is that during its technical life it will not be the source of adverse events, whether in the form of injury or harm on other technical system or environment. The process of risk assessment must therefore be an integral part of all creative activities, resulting in a functional, reliable and safe product. These were the reasons for our development team to attempt to create an intelligent computer system that performs the chosen method of risk assessment in close cooperation with the selected computer aided process planning systems (CAPP). The aim of this article is to present a modern process of digital information processing in pre-manufacturing phase in terms of predicting security features of the new system through the knowledge system that we proposed.

Keywords: *Concurrent Engineering, risk analysis, risk valuation, technical preparation of production*

Paralelni pristupi u fazi prije proizvodnje - Proces tehničke pripreme proizvodnje i procjena rizika tehničkih sustava

Strukovni članak

Mogućnost identificiranja, a potom reagiranja na uska grla novih predloženih tehničkih sustava još u fazi prije proizvodnje, temeljena na načelu simultanog inženjerstva, donosi niz pozitivnih učinaka na financijske uštede poboljšanjem kvalitete gotovog proizvoda. Važna značajka novog proizvoda je da tijekom njegovog tehničkog života on neće biti izvor negativnih događaja, bilo u obliku ozljede, ili štete na drugi tehnički sustav ili okoliš. Postupak procjene opasnosti, dakle, mora biti sastavni dio svih kreativnih aktivnosti, rezultirajući funkcionalnim, pouzdanim i sigurnim proizvodom. To su bili razlozi da naš razvojni tim pokuša stvoriti inteligentni računalni sustav koji odabranu metodu procjene rizika izvodi u uskoj suradnji s odabranim računalno potpomognutim sustavom planiranja procesa (CAPP). Cilj ovoga članka je predstaviti suvremeni proces digitalne obrade informacija u fazi prije proizvodnje u smislu predviđanja sigurnosnih značajki novog sustava kroz sustav znanja koji smo predložili.

Ključne riječi: *analiza rizika, procjena rizika, simultano inženjerstvo, tehnička priprema proizvodnje*

1 Introduction
Uvod

Modern principles of construction of new products are based on the philosophy of concurrent engineering tasks which are applicable even in pre-manufacturing phase in order to minimize potential collision and critical states in terms of construction and also in terms of technology. Concurrency in designing of new technical systems must be based on principles of close cooperation and mutual exchange of information among employees participating in a common goal, which is a functional, reliable and safe final product. The effect of this approach is not only in the shortening of the development time, but finally, in cost savings - not only in its pre-manufacturing phase, but also during technical life of the product with possible elimination of any undesirable behavior, inappropriately chosen construction and/or technology. Characteristic for the concurrent engineering is the consideration of all aspects of production and functions of the component's technical life even in the development phase of the component. This procedure is also called integrated design of component. With conventional approach, the continuity of operations from initial idea of new product through implementation of development, planning of the process until introduction into production takes place sequentially – although with the use of tools for computer aid, modern approach must assume the cooperation and data sharing of all creative capacities. Intelligent formats for data exchange are used in the CAD - CAM - CAE systems and also data formats readable by other CAPP systems in accordance with the concept of computer integrated manufacturing CIM [3]. Some of the operations and processes must be carried out in parallel, or partially in parallel to achieve positive effects. By this the transversal times for individual phases are shortened, while the responsible coordinator records the comments from expert in each field. Any structural design and each structural and also technological change is consulted [8].

The effect of parallel access of development processes and procedures consists not only in the shortening of transversal times of the product development, but also in cost saving, such as in the elimination of faults and errors. Known theorem is applied giving into the context the fact of generating the errors of new products and possibilities of their detection. While about 75 % of potential errors arises in the phases of the concept of new product, development and production preparation, the most usual possibility of detection of these errors, up to 80 % takes place in stages of control and marketing. With the parallel access the process of bottleneck detection moves substantially from the control stage and marketing to the stages of technical preparation of manufacture – to structural, technological or constructional preparation of production.

During the global industrial recession, the success of any business in the area of market competition depends more than ever on the quality and efficiency of its products and services. A system which is functional, technically reliable cannot yet be regarded as good, if during its installation, operation, or stages of maintenance and repair it represents a source of adverse events for any element of the system human - machine - environment.

The issue of technical and human security, in addition to the requirements of current European or national legislative regulations and standards must therefore be a priority concern of every company and business that would like to succeed with its product in the market. By selecting of the appropriate risk assessment methods it is possible to move the process of managing for both the technological systems and departments, but also for the newly designed equipment and systems.

Technical Standards and applicable legislative regulations constitute the required product characteristics, among which there are: level of quality, performance properties, safety, size, product testing and so on. Standard EN ISO 12 100-2:2004 prescribes general principles of machinery construction, so that they do not constitute a source of risk not only for involved employees, but also for hands-off personnel that is in interaction with the device during its operation. These requirements have led members of the team participating in the development of the system of computer-support of risk assessment at technological workplace to draft a comprehensive knowledge of the system, where outcomes could be integrated to the production documentation executed by CAPP and CAD systems, so that in conjunction with the corporate information system they would present an overall source of management quality for the new technical product.

2 Computer system of risk assessment - HAZOP method

Računarski sustav procjene rizika – HAZOP metoda

The logical architecture of the system for computer-aided risk assessment was designed to integrate not only the selected risk assessment method applicable to the assessment of security of existing technology department, but also the method usable for safety assessment in the early stages of the technical life of the examined technological unit.

Therefore the method called HAZOP (Hazard Analysis and Operability Study) was chosen. The method was designed primarily for chemical operations – for the reason of its development in UK after an industrial accident in petrochemical factory in 1974. The method is applicable for risk assessment of individual plants too. The considered system is divided into sub-subsystems. This division is always intentional, while the main aim is to create simpler subsets which have a clear purpose. The following procedure is shown in these steps [10]:

- **description of the purpose (function) of the system (subsystem)**
- It is assumed that one subsystem has one essential function.
- **creation of a working group**
  Working group consists of specialists responding to the type of analyzed system.
- **description of deviations from the desired purpose**
  Usage of listed, defined keywords.
- **recovery of the cause or combination of causes that led to deviation**
  Looking for answers to the questions "***what happens if*** ..." "***What could cause that...***", for example:
  What happens if the temperature is lower than it should be?
  What are the consequences of the fact that the temperature is lower?
  Are consequences of lower temperature dangerous, do they impede the smooth and effective operation?
  If yes, how can we prevent the drop of the temperature? (change of the process, change in operating conditions, installation of technical measures, doubling of the heat source, installation of an emergency alarm, etc.)
  In accordance with the level of threat is it appropriate to increase operating costs by implementing of arrangements? Is the risk acceptable?
- **determination of potential impacts and operational problems**
- **proposal of remedies.**

In this study a small team of experts is drawing up a critical assessment of the project (operation or the system). Each section will be assessed systematically using a series of keywords. A series of keywords is used so that team members can immediately get an idea and based on this they would be able to identify the probable deviations from the required conditions. Consequently, it is necessary to determine whether there is a condition that could lead to such a deviation. If this cause exists, it is necessary to examine its consequences [6].

In computer system for application of the given method that was designed by our team a dialogue form was proposed that contains sections in the form of bookmarks for description of the system for the application of key words and guide words and for determination of the deviations from the required values and determination of the results of adverse events.

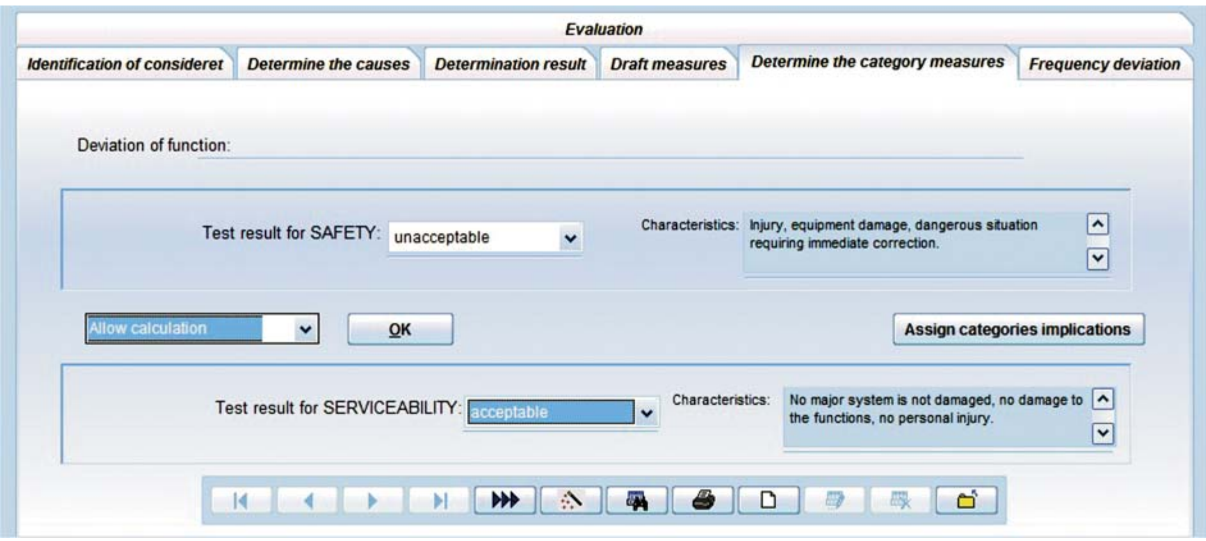

Figure 1 *The determination of category of consequence for the safety and serviceability criteria*
Slika 1. *Određivanje kategorije važne za kriterije sigurnosti i uporabljivosti*

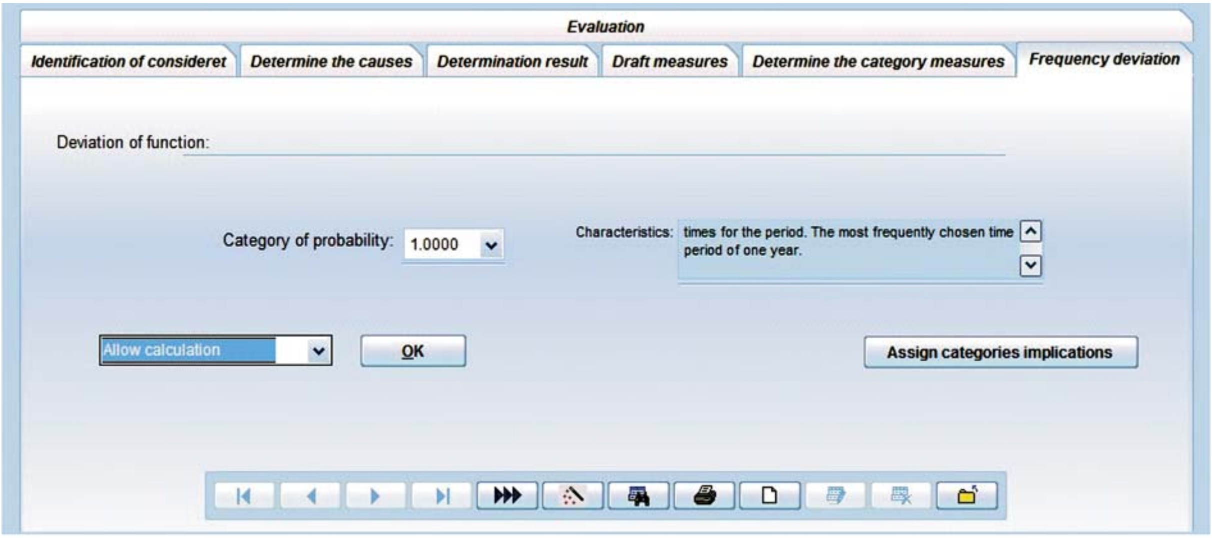

Figure 2 *Estimation of probability given by frequency of examined deviation*
Slika 2. *Procjena vjerojatnosti dana pomoću učestalosti ispitivanih odstupanja*

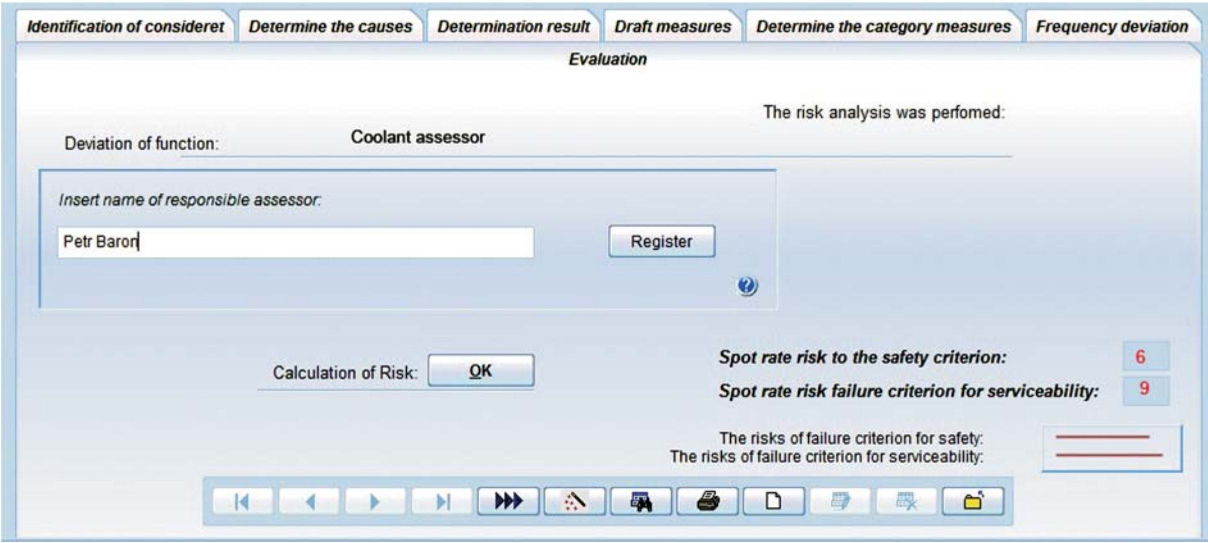

Figure 3 *Calculation of the risk for category of security and serviceability*
Slika 3. *Izračunavanje rizika za kategoriju sigurnosti i uporabljivosti*

Risk assessment is carried out for identified deviations while taking into account the criteria of safety and serviceability (Fig. 1). The consequence of the given criterion was expressed by the word variables:

- Low
- Acceptable
- Larger
- Unacceptable
- Catastrophic.

The *low* consequence reflects the fact that no major system is damaged, there was no personal injury, implying that there is no need for immediate correction. At the other hand the *catastrophic* consequence represents a disastrous loss of system or facility, multiple injuries or death.

Estimation of probability was being executed on the basis of the frequency of observed deviation. 5 numerical variables representing categories of probability were used. For example, variable 1 indicates that the observed deviation ranges 1-10 times in the period, while most elected period is 1 year (Fig. 2) [10].

Thanks to the logical procedure the computer system realizes the construction of risk matrix, which links into a reciprocal relation the categories of probability with categories of consequence. Hazard ratio for individual segments of the considered system is graphically illustrated in a form of application separately for the criterion of safety and of serviceability (Fig. 3).

When applying this procedure by the HAZOP method we proceed in the following steps [6, 10]:

- Identification of functions for a sub-system of technical unit (piping, valves, equipment, tanks, pumps, etc.)
- Operating mode (normal operation, start-up facilities, decommissioning, inspection and maintenance)
- Triggering events (failure of handling, failure of equipment, of machinery, dangerous incidents involving the causes of abnormal operation and instrumentation solution, unsafe conditions, changes in inventories, changes in physical conditions) corrective actions (changes to the draft process, changes of operating limits, changes in the reliability of systems, changes in the composition of the material - in the chemical and physical terms)
- Detection of dangerous conditions during normal operation after failure of operator, after failure of technology or other cases
- Security remedies for improvement of current state - basic options to reduce risk can be summarized into the

following groups of applied rules:
- redundant (multiple) systems
- diversity of systems - different physical principles
- principle of Fail-Safe (safe while fail)
- spatial separation
- separation of safety and operational systems
- inherent safety (while reaching a dangerous state the equipment turns itself off)
- repeated testing
- automation - separation of human from the machine.

Application environment of the knowledge system includes a section for management of printouts of the used methods of risk assessment. As the optimal output format, processable by other applications for OS Windows the form of PDF output was used. It is a common format for sharing documents, allowing easy interaction to manufacturing documentation realized for example with CAPP system.

3
Integration of exits from the assessment of risks to the environment of the CAPP system SYSKLASS
Integracija izlaza iz procjene rizika prema okolišu CAPP sustava SYSKLASS

In addition to generating the output in the form of PDF document with a fixed layout the designed computer system also carries out export of internal databases that are converted into tables of Excel type - XLS documents. In this case, the database record is converted to a record where each cell represents a separate statement. In some way a "devaluation" of logical record of consideration system occurs here, but this deficit is eliminated by processing of the PDF output [7].

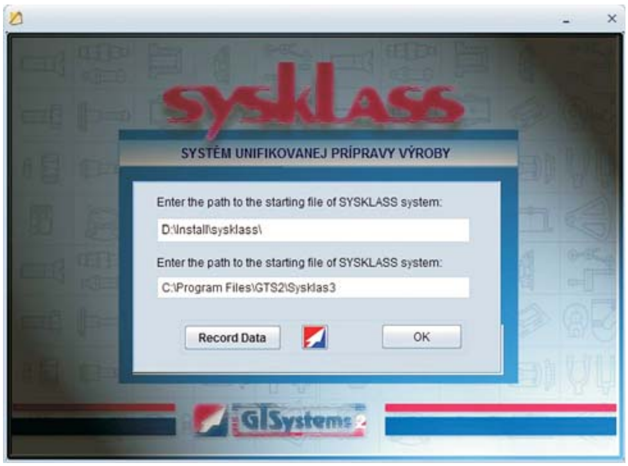

Figure 4 *Configuration of access to the CAPP of system SYSKLASS*
Slika 4. *Konfiguracija pristupa CAPP-u sustava SYSKLASS*

The system was primarily designed to interact with the CAPP system SYSKLASS (the most comprehensive and widely used system for CAPP in countries of Visegrád Group). It allows running of the application SYSKLASS directly from the environment of the knowledge system. A user, within settings for configuration of mutual connectivity, sets the memory variable paths to the working directory of SYSKLASS system, as well as to its console EXE application (Fig. 4).

CAPP system is activated through the Icon button directly from the configuration form, respectively icon-based toolbar button from the knowledge system. The SYSKLASS system has a fundamental feature - the report of external documents that can be connected to the documentation of technological preparation of production - to the form of change, structural header, technological

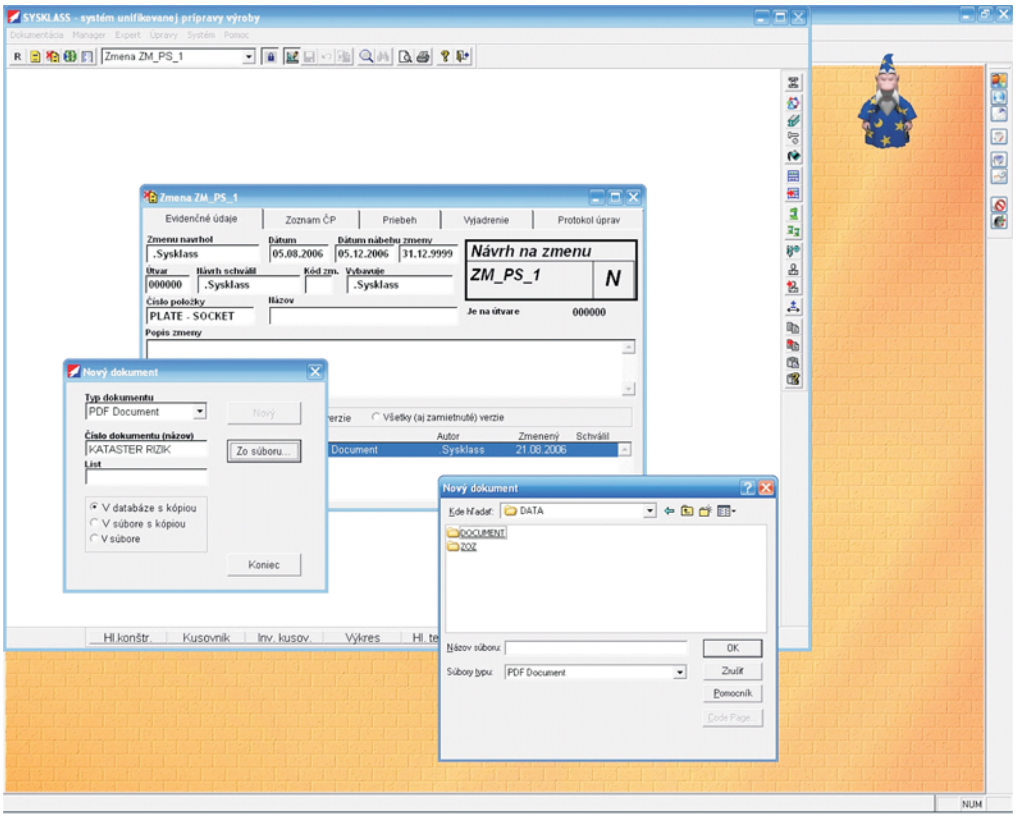

Figure 5 *Report of external documents in TlgPV documentation implemented by the SYSKLASS system*
Slika 5. *Izvještaj vanjskih dokumenata u TlgPV dokumentaciji provedenoj pomoću SYSKLASS sustava*

header, as well as the header of the contract. As the external document for the CAPP system is considered document accounted by one computer file of any pre-defined format (Excel, Word, Corel Drawing, Raster, etc.). The document can be also represented through multiple files. External documents have relatively independent report (i.e., archiving, assigning new releases, search), which is implemented separately from the working objects of SYSKLASS. The user can edit the document only if it is assigned to the given object, i.e. user sees documents as an integral part of the data of that object to which they are attached. In the dialog box for the document over which an option *Assignment to objects of SYSKLASS* was used, a list of objects to which the document is attached is displayed in the local menu.

4 Conclusion
Zaključak

The purpose of efforts of the implementation team while programming the knowledge system that realizes the HAZOP method was to develop a support system for management of decision-making in the process of risk management so that the continuity of production documentation conducted through advanced CA systems would be an information base created for quality decision-making in pre-manufacturing stages in order to minimize potential bottlenecks in drafts of new technical system. This approach is based on mutual cooperation and exchange of information among developers that affect the concept of final product, so that it meets all specified requirements and is implemented with minimal time deviations. By these means inclusion of manufacturing aspects is expected in developing of new product, not only in the area of its functional properties, but also in terms of its technical and human security. By this procedure the objective of philosophy of concurrent engineering is attained, which is based on cooperation of multidisciplinary team of experts, who in real time make a draft of new technical system.

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5 References
Literatura

[1] Baron, P. Začlenenie systému posudzovania a manažérstva rizika do procesu technologickej prípravy výroby, Habilitačná práca, FVT TU Košice so sídlom v Prešove, Prešov, 2007., 97 s.
[2] Baron, P.; Brázda, P. Application of Computer Aided Risk Valuation Using Scoring Method. In: Scientific Bulletin, 6, 2006., ISSN 1224-3264. str. 33- 36.
[3] Brázda, P.; Janák, M.: Computer aided selction of suitable manufacturing strategies, In: Scientific Bulletin : fascicle: Mechanics, Tribology, Machine Manufacturing Technology. - ISSN 1224-3264. - Vol. 22, serie C (2008), p. 53-58.
[4] Hrubina, K.; Hapáková, A. On Algorithms for Solving Optimal Control Problems for Systems with Distributed Parameters. In: Proceedings of the Scientific Conference with International Participation "Řízení procesů '98", Katedra řízení procesů a výpočetní techniky, Fakulta chemicko-technologická, Univerzita Pardubice, Česká Republika, 1998, ISBN 80-7194-138-7, p. 165-170.
[5] Lihou, M. Hazard & Operability Studies http://www.lihoutech.com/index.html
[6] Kandráč, J.; Skaraba, D. Metodický postup na hodnotenie rizík nebezpečných prevádzok a štúdia o podnikoch v Slovenskej republike, http://www.lifeenv.gov.sk/minis/chem_latky/prevencia/metodika/risk.htm
[7] Kočiško, M.; Janák, M.: Workshop documentation for CNC machning and CAD/CAM/CAE system NX. // In: Inteltrans 2009 : Jakość, innowacyjność i transfertechnologii w rozwoju przedsiębiorstw / 5. Konferencja Naukowo-Techniczna : Kraków, 21-22 października 2009. Kraków : Politechnika Krakowska, 2009., ISBN 978-83-7242-512-6, p. 211-216.
[8] Kuric, I.; Košturiak, J.; Janáč, A.; Peterka, J.; Marcinčin, J. Počítačom podporované systémy v strojárstve. EDIS - vydavateľstvo ŽU, 2002. ISBN 80-7100-948-2
[9] Sinay, J. Riziká technických zariadení – manažérstvo rizika, TU Košice - VSŽ Košice, OTA Košice, 1997, 212 s., ISBN 80-967783-0-7
[10] Sinay, J.; Pačaiová, H.; Oravec, M. Present state of machinery safety assessment. // In: DAAAM : Annals of DAAAM for 2005 : Proceedings of the 16th international DAAAM symposium "Intelligent manufacturing & automation: focus on young researches and scientists". 19-22nd October 2005, Opatija, Croatia. Viedeň : DAAAM International Vienna, 2005. s. 347-348. ISBN 3-901509-46-1.
[11] STN EN ISO 12 100-1:2004 Bezpečnosť strojových zariadení. Základné termíny, všeobecné zásady konštruovania strojov. 1. časť : Základná terminológia, metodika.
[12] STN EN ISO 12 100-2:2004 - Bezpečnosť strojových zariadení. Základné termíny, všeobecné zásady konštruovania strojov. 2. časť: Technické zásady
[13] Tomková, M.; Kopas, M. Použitie katalógových listov pre analýzu rizika oceľových lán. In: Zdvihací zařízení v teorii a praxi, Elektronický odborný časopis o konstrukci a provozu zdvihacích, manipulačních a transportních zařízení a dopravních prostředků. no. 1 (2007), p. 63-65. Internet: <http://www.id.vsb.cz/zdvihacizarizeni/> ISSN 1802-2812

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