Analytical Tools in an Industrial Enterprise

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INTRODUCTION

The vision of the digital enterprise concept focuses on the integration of methods and tools available at different levels for product planning and testing and related production. And integrates the following processes (Kuehn, 2008):

- ✓ product development, testing and optimization,
- ✓ design of the production process and optimization,
- ✓ workshop design and optimization,
- ✓ operational planning and production management.

The concept of a digital enterprise can be considered as a business and information strategy for the management and cooperation of business processes in global networks. It offers methods and software solutions for product, portfolio planning, digital product development, digital manufacturing, sales support that provides faster time to create value, collaborative solutions to support people and processes in every major product and production phase. Therefore, the concept of a digital enterprise integrates databases for models, advanced visualizations, simulations and documentation of products, processes and plants in order to improve the quality and dynamics of products and production processes (Šišan and Majdan, 2011).

The digital enterprise integrates three main elements (Gregor and Medvecky, 2010):

- ✓ digital product, with its static and dynamic properties,
- ✓ digital production planning and,
- ✓ digital production, with the possibility of using planning data to increase the efficiency of business processes.

The main benefits of implementing the digital business concept are in particular in achieving organizational, technical and economic goals, communication, knowledge management, reducing confusion, using standardization, various methods of tools and processes, saving time and costs, flexibility and quality improvement, eliminating risks before introducing new production, verification of

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processes before their start, possibilities of employee education and offline programming, ergonomic analyzes and the like (Beňo and Jakábová, 2014; Mingaleva et al., 2019). The concept of a digital enterprise is based on five basic areas (Furmann, 2010):

- ✓ digitization of halls and production equipment using 3D laser scanning technology,
- ✓ process planning, creation and analysis of time management,
- ✓ 3D design of production and logistics systems,
- ✓ detailed design of workplaces and ergonomics,
- ✓ simulation and optimization of production and logistics systems.

DIGITAL ENTERPRISE AND ERGONOMICS

In the process of digitization of the workplace, it is possible to abstract and transfers important features of a real workplace into a virtual model, which forms the basis for the implementation of ergonomic studies in the workplace. Digitization of the workplace can be realized on the basis of manually measured values obtained from a real workplace. These are then used for manual modelling of the entire workplace. However, the workplace is increasingly using 3D laser scanning to create a digital model. Using a 3D scanner, the data is transferred to the computer environment in the form of a point cloud, which is then modified and a virtual model of the workplace is created (Bozek and Chmelíková, 2011). Ergonomics is a body of knowledge about human abilities, human limitations, and other human characteristics that are relevant to design. Ergonomic design is the application of this body of knowledge to the design of tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use. The underlying philosophy of ergonomics is to design work systems where job demands are within the capacities of the workforce. (Board of Certification in Professional Ergonomics 21000)

Ergonomics is seen today as a vital component of the value-adding activities of the company, with well-documented cost–benefit aspects of the ergonomics management programs (Gao, 2007). A company must be prepared to accept a participative culture and utilize participative techniques in implementation of work design principles. The job design-related problems and consequent intervention should go beyond engineering solutions and include all aspects of business processes, including product design, engineering and manufacturing, quality management, and work organizational issues, along the side of task design or worker education and training. (Karwowski and Salvendy, 1999; Genaidy et al., 2004)

For the comprehensive digitization of the workplace, the modelling of the employee's work activity is presented as the next step in the overall sequence. We adapt the properties of the human model to the real human person by using an anthropometric atlas, which is directly built into the software of the digital enterprise. The anthropometric atlas makes it possible to adapt anthropometric characteristics (dimensions, gender, nationality) to a specific person who actually works at the workplace. Subsequently, a person is assigned work tasks and simulation of work activity is created (Tabaková, Hulín and Štefánik, 2009). The simulation is used both in the design of a non-existent workplace and in the evaluation of an existing workplace. The workplace can be assessed from the point of view of reach zones and the angle of view of the worker, the height of the working space, the handling of the load, or the size of a load of individual parts of the body when performing work tasks. Based on the results, it is possible to adjust the workplace, determine the necessary rotation of workers, or design elements of automation to increase productivity and prevent the emergence of permanent work consequences (Furmann, 2010).

Digital human modelling enables engineers to address ergonomics and human factors in product development in the early stages of the development process. In the field of research and development, commercial human models are already in use. Two frequently used human models are JACK and RAMSIS (Naumann and Rötting, 2007).

Jack makes it possible to improve the safety, efficiency and comfort of the working environment using digital human models. The work environment can be analyzed using virtual human models, using a database that includes characters typical of other populations. When designing work environments, we can test the impact of work and work environment factors, including the risk of injury, user comfort, accessibility, line of sight, energy expenditure, fatigue limits, and other important parameters. These products offer recommendations for more user-friendly designs throughout the design process, helping to save costs and time (Plm.automation.siemens, 2015).

JACK TASK ANALYSIS TOOLKIT

Designing work areas that enable workers to more safely and effectively perform industrial tasks can be a sign can’t challenge. The Jack Task Analysis Toolkit enables to evaluate human performance from an in-depth ergonomics perspective early in the product lifecycle before designs are frozen and change re choir costly rework. The toolkit allows evaluating tasks using the Jack and Jill human models, without ever putting real workers at risk.

The Jack Task Analysis Toolkit (TAT) provides analytical tools to help you design manufacturing workspaces for optimal human performance. TAT is an add-on module to Jack, Siemens PLM Software’s widely-used human simulation and ergonomics analysis software. (www.geoplm.com)

What is the Task Analysis Toolkit? Manual work gives rise to numerous human performance concerns that need to be taken into account during the analysis, including working postures, part weight, and task frequency. The Task Analysis Toolkit enables you to perform ergonomic compliance checks directly within a 3D virtual environment. You can leverage TAT tools to quantitatively review manual tasks, such as lifting and carrying and to assess strength capabilities, joint forces and postural demands (Supsomboon, 2019).

Benefits (www.geoplm.com):

- ✓ advance your current human performance studies in Jack by putting a complete set of performance analysis tools to work;
- ✓ diminish quality issues related to human performance;
- ✓ identify potentially injurious situations and reduce the risk of worker injury;
- ✓ improve the efficiency of workstation layouts;
- ✓ help integrate ergonomic compliance into the design process;
- ✓ reduce worker compensation costs;
- ✓ avoid costly physical prototyping studies.

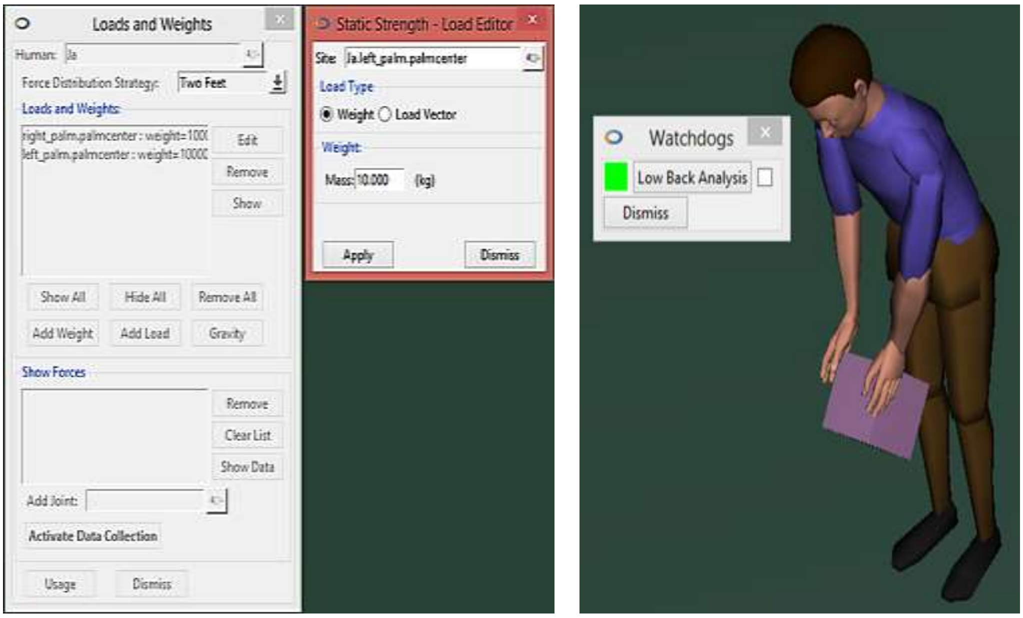
Features:

- ✓ TAT assessment tools are linked directly to the human figure, minimizing user inputs and standardizing assessment results between users;
- ✓ TAT tools can be run interactively, enabling real-time results during animations and motion capture sessions;
- ✓ TAT tools are based on recognized data sources endorsed by the ergonomics community;
- ✓ Analysis reports are available for TAT tools, enhancing communication of results;
- ✓ TAT includes simplified screening tools, as well as complex quantitative analysis options, facilitating easy use and interpretation.

SELECTED TOOLS FOR ANALYSIS

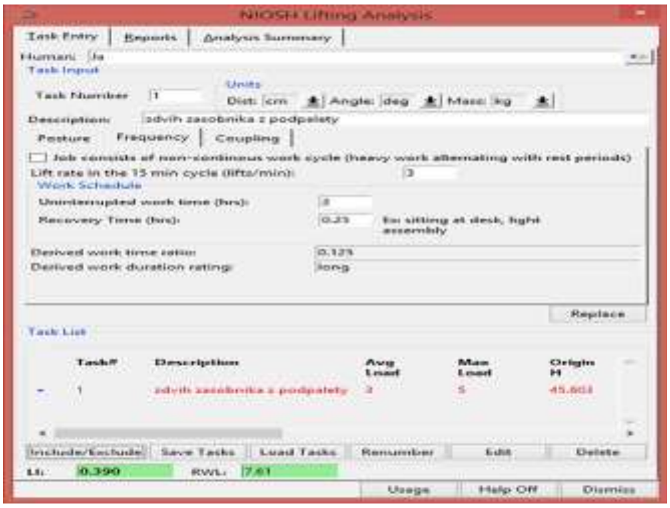
Selected ergonomic tools enabling better design and evaluation of workplaces and evaluation of physical work.

1. *Lower Back Analysis Tool*

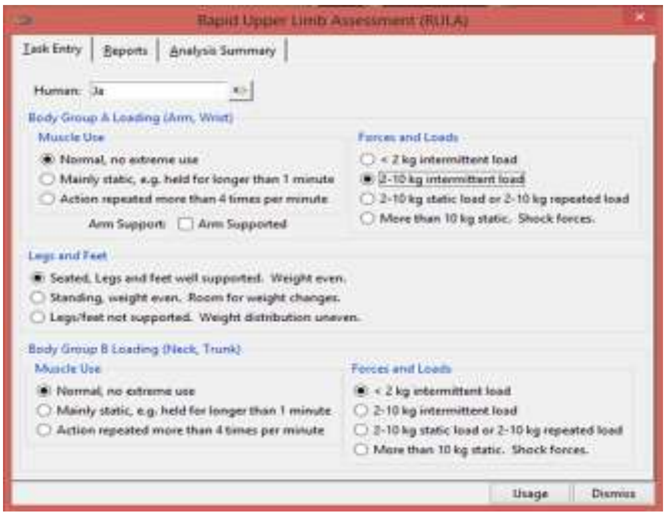


2. Static Strength Prediction

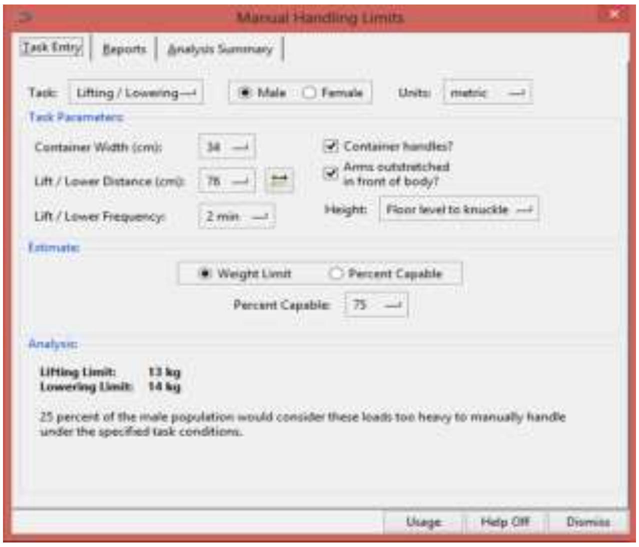
3. NIOSH



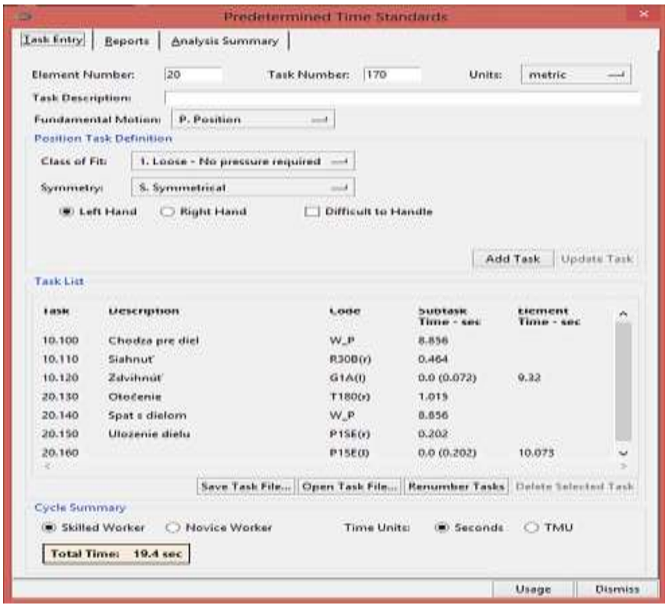
4. RULA



5. Manual Handling Limits



6. Predetermined Time



7. OWAS

The OWAS method is the most commonly used method for evaluating a person's working position during manual handling of loads. The principle of the method is the observation of the employee at regular intervals and subsequent evaluation using indices and evaluation tables. Ergonomic analysis using the OWAS method is performed using Jack software from Tecnomatix. The ergonomic analysis itself using the OWAS method is preceded by several steps that need to be performed.

The first step was to digitize the workplace, ie to create objects (devices) located at our selected workplace in a 3D module (Straka et al., 2018).

The second step is to transform objects in the 3D module into Jack software and, based on manually measured workplace dimensions and distances of individual objects, in Jack software to place objects in the 3D module into real distances so that work process simulation and ergonomic analysis are as objective as possible.
In the third step, Jack selects the human-employee biomechanical model in the Jack software and the simulated work operations of the actual employee at the selected workplace based on the sequence of steps resulting from the workflow. When simulating individual work tasks, care must be taken to capture movements, postures, gripping, carrying or pushing objects as faithfully as possible. From the workflow, we simulate all activities of the employee.

Method:

- run the OWAS tool via the command from the main menu Analysis > Task Analysis Toolkit > However, Working Posture Analysis;
- select a human model and define his stand_relaxed position;
- click on the Activate button;
- change the position of the human model by turning the torso to the side 23° with a slight inclination of 11°;
- the WatchDog, Reports and Loads & Weights commands work the same as in the previous cases;
- outputs from reports are generated in a web browser and also provide brief suggestions for corrective measures;
- click on the Dismiss button.

a) Simultaneous removal of left and right components (Petráš, 2015)

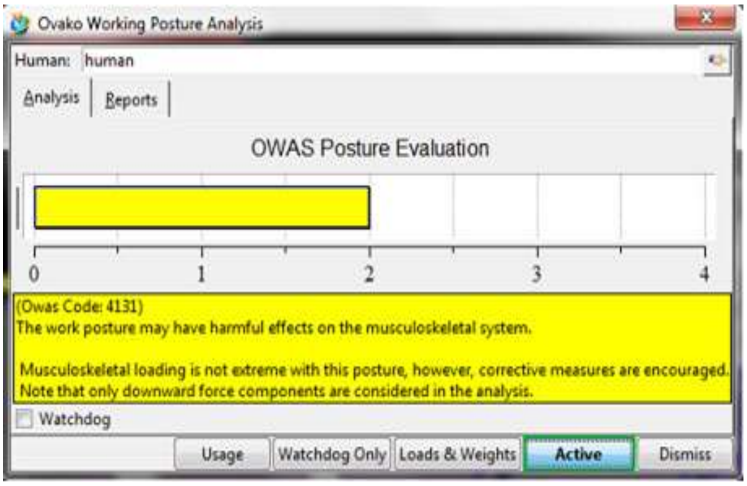


Fig. 1 Resulting graph OWAS 1

OWAS analysis: Resulting action index 2. The job position can have detrimental effects on the musculoskeletal system due to the need for the employee to tilt slightly when removing components from the bottom of the bins.

- In this position, the load on the musculoskeletal system is not extreme, but corrective action is recommended.

Visual analysis: The height of the trolley with small bins is relatively high, the possibility of discomfort when removing components from the bottom of the bin.

b) Suspension of the right component (Petráš, 2015)

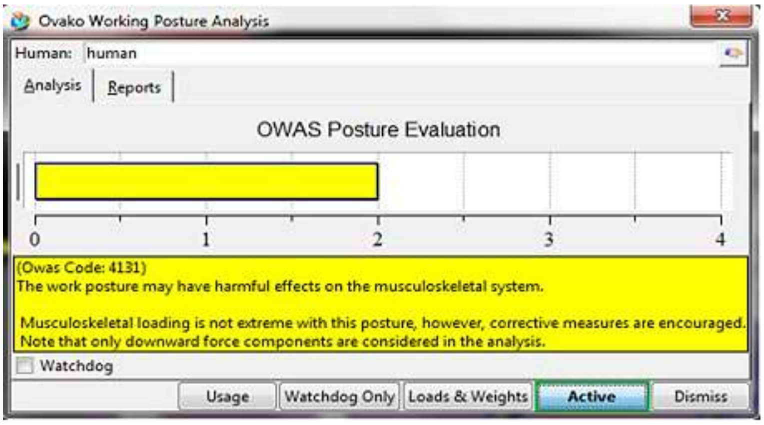


Fig. 2 Resulting graph OWAS 2

OWAS analysis: Resulting action index 2. The job position can have detrimental effects on the musculoskeletal system due to the need for a slight forward bending of the employee when hanging the component at a designated location on the robot.

- In this position, the load on the musculoskeletal system is not extreme, but corrective action is recommended.

Visual analysis: Necessary forward bending of the worker when hanging the component at a designated location on the robot.

c) Component removal (Petráš, 2015)

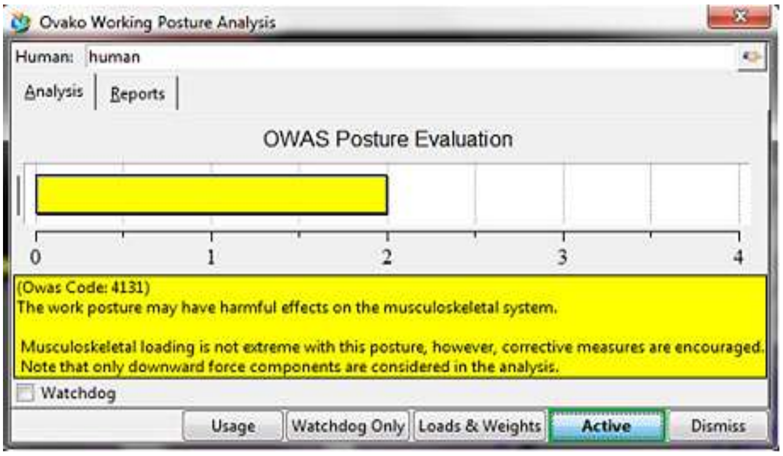


Fig. 3 Resulting graph OWAS 3

OWAS analysis: Resulting action index 2. The working position can have detrimental effects on the musculoskeletal system because both hands are at arm level, ie too high, when removing the component from the hopper.

- In this position, the load on the musculoskeletal system is not extreme, but corrective action is recommended.

Visual analysis: No deficiencies related to the job position in performing this activity were noticed.

d) Component transfer (Petráš, 2015)

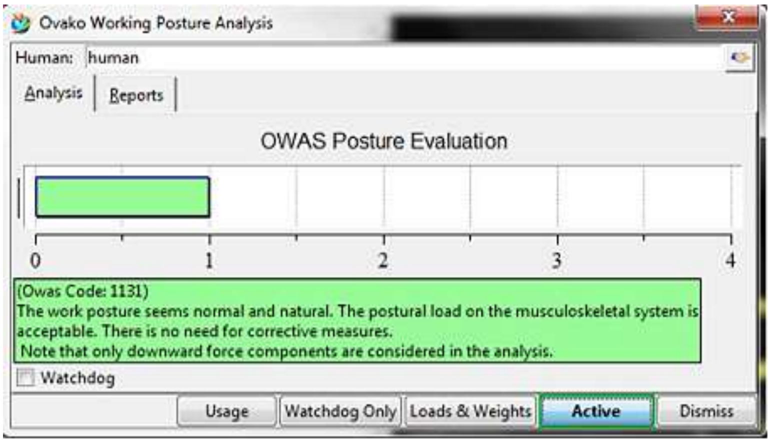


Fig. 4 Resulting graph OWAS 4

OWAS analysis: Resulting action index 1. The working position looks normal and natural, the back is straight, both hands are below the level of the shoulders.

- The positional load on the musculoskeletal system is acceptable. No corrective action is required.

Visual analysis: The working position in this activity seems to be optimal.

e) Component suspension (Petráš, 2015)

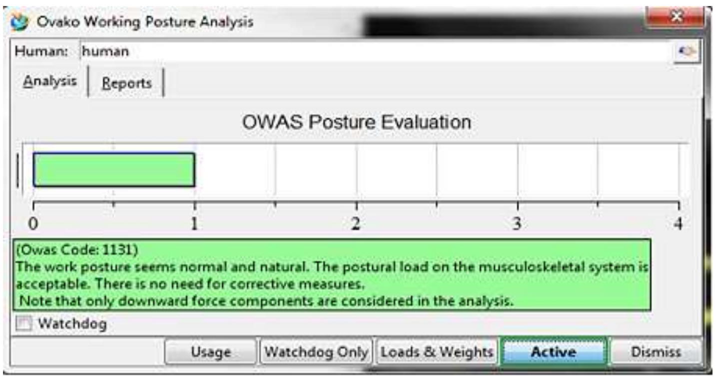


Fig. 5 Resulting graph OWAS 5

OWAS analysis: Resulting action index 1. The working position looks normal and natural, the back is straight, both hands are below the level of the shoulders.

- The positional load on the musculoskeletal system is acceptable. No corrective action is required.

Visual analysis: The working position in this activity seems to be optimal.

CONCLUSIONS

Ergonomics is a scientific discipline dealing with the adaptation of the working environment and means of production to human needs. Its primary goal is to preserve a person's physical, mental and social satisfaction, to create conditions for optimal human activity, but also to create a feeling of well-being in the workplace. The purposeful application of knowledge of ergonomics can bring for the organization a reduction in the incapacity for work of employees and occupational diseases, an increase in work performance, a reduction in error rates. For the employee, the effective application of knowledge of ergonomics can bring improvement of physical and mental condition, minimization of manifestations of mental and physical fatigue and benefits in the social field (improved self-realization, teamwork, motivation for better performance).

The aim was based on the obtained theoretical basis of physical load and ergonomic analysis of manual handling processes and based on the results of the analysis of the current state of manual handling of loads in the company to propose measures to optimize manual handling using selected methods of physical load assessment in the company. (Petráš, 2015)

Using the available literature, the basic concepts of ergonomics, manual handling of loads, methods of measuring the physical load of workers and assessing ergonomic risks and the concept of the digital enterprise were theoretically defined. Based on the information provided in the company, an analysis of the current state of manual handling in the company was performed using the ergonomic OWAS method. The result of the ergonomic analysis of manual handling did not prove an increased physical load of employees during the work, nor any other negative effects of the workplace on the support system of employees.

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REFERENCES

Beňo, R. and Jakábová, M., (2014). Use of the concept of "Digital Enterprise" in the field of ergonomics in the context of sustainable work performance of employees. Výkonnosť podniku, 4(1), pp. 6-21. ISSN 1338-435X

Bozek, P. and Chmelíková, G., (2011). Virtual Technology Utilization in Teaching. In ICL 201, 14th International Conference on Interactive Collaborative Learning and 11th International Conference Virtual University. Piešťany, Slovakia, Piscataway: IEEE, pp. 409-413.

Furmann, R., (2010). Digital enterprise - an innovative solution for you. Produktivita a inovácie, 11(2), pp. 3-5. ISSN 1335-5961

Gao (2007), ‘‘Worker Protection: Private Sector Ergonomics Programs Yield Positive Results,’’GAO/HEHS-97-163, U.S. General Accounting Office, Washington, DC.

Genaidy, A., Karwowski, W., and Christensen, D. (1999), ‘‘Principles of Work System Performance Optimization: A Business Ergonomics Approach,’’ Human Factors and Ergonomics in Manufacturing, Vol. 9, No. 1, pp. 105-128.

Gregor, M. and Medvecký, S., (2010). Digital factory – theory and practice. In: Engineering the Future. InTech, pp. 355-376. ISBN: 978-953-307-210-4

Karwowski, W., and Salvendy, G., Eds., (2001), Design of Work and Organization, John Wiley & Sons, New York.

Kuehn, W., (2000). Digital factory – Integration of simulation enhancing the product and production process towards operative control and optimisation. International Journal of Simulation: Systems, Science & Technology, 7(7), pp. 27-39. ISSN 1473-8031

Mingaleva, Z. Zhulanov, E. Shaidurova, N. and Vukovic, N. (2019). Economic Transformation of a Mining Territory Based on the Application of a Cluster Approach. Acta Montanistica Slovaca, Volume: 24, Issue: 3, pp. 257-268.

Naumann, A. and Roerring, M., (2007). Digital human modeling for design and evaluation of human - machine systems. MMI Interaktiv, 1(12), pp. 27-35. ISSN 1439-7854

Petráš, R. (2015). Optimization of manual handling of loads by using the selected methods for the assessment of physical load in the selected workplace in the company VOLKSWAGEN SLOVAKIA, a.s. [Graduate Thesis] - Slovak University of Technology in Bratislava. Faculty of Materials Science and Technology in Trnava; Institute of Industrial Engineering and Management.

Straka, M. Rosová, A. Lenort, R. Besta, P. Šaderová, J. (2018). Principles of computer simulation design for the needs of improvement of the raw materials combined transport system, Acta Montanistica Slovaca Volume 23 (2018), number 2, pp. 163-174

Supsomboon, S. (2019). Simulation for jewelry production process improvement using line balancing: a case study, Management Systems in Production Engineering 2019, Volume 27, Issue 3, pp. 127-137, DOI 10.1515/mspe-2019-0021

Šišan, D. and Majdan, M., (2011). The concept of the digital enterprise - as a tool for improving production processes. In: Modelování, simulace a optimalizace podnikových procesů v praxi. Praha: ČSOP, pp. 442-449. ISBN 978-80-260-0023-5

Tabaková, M., Hulín, M., Štefánik A., (2008). Healthy workplaces with the support of a digital enterprise. Produktivita a inovácie, 9(6), pp. 4-6. ISSN 1335-5961

PLM.AUTOMATION.SIEMENS, (2015). Jack a Process Simulate Human. [online]. http://www.plm.automation.siemens.com/cz_cz/products/tecnomatix/assembly_planning/jack/index.shtml

www.geoplm.com/knowledge-base-resources/GEOPLM-Siemens-PLM-Tecnomatix-Jack-Task-Analysis-Toolkit.pdf

Abstract: Manufacturing companies operate on data from production, operation and trade. The strategy of creating and collecting data at the centre of production processes has significantly improved in recent years. Manufacturers are now collecting and storing vast amounts of data from their manufacturing facilities, both online and offline, from multiple geographic locations and with a growing number of separate data repositories. The design of workplaces and products continues to migrate from paper to the computer, where analysis accuracy, visualization, and collaboration utilities allow designs to be realized much faster and better than ever before. As the pace of this development accelerates with the increased capabilities of the software design tools, less time is spent on physical prototyping, allowing for shortened time-to-market for new products. Ergonomists, who in the past used the physical prototypes to perform human factors analyses, are now challenged to move the analysis into the virtual domain using new tools and methods. Usability, maintainability, physical ergonomic assessments, psychological perception, and procedural training are some of the human factors issues that might benefit from analysis prior to the first physical incarnation of the design.

Keywords: analytic tools, ergonomic, digital factory, Jack