Received: 14 Oct. 2016
Accepted: 29 Nov. 2016

ERGONOMIC EVALUATION OF PHYSICAL LOAD BY SIMULATION SOFTWARE IN ENGINEERING

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Keywords: ergonomics, simulation, Tecnomatix Jack, engineering
Abstract: In ergonomics, the evaluation of physical load is possible to do by various methods, calculation, assessing tables, etc. Recently, the evaluation by different ergonomic simulation tools is very widespread. Presented article is focused on introducing the application of simulation in the field of ergonomics. This article presents the practical example of physical load evaluation by simulation software Jack in engineering – the workplace of component packaging. In the simulation software, there is created the simulation model of the working environment and working activity. After that it is evaluated by means of three ergonomic methods – RULA, OWAS and SSP.

1 Introduction

Every kind of work performed by the employee is physiologically outcome of nerve, sensory and muscle activity of human. In the company focused on engineering production, there is a working load in the sphere of muscular activity. The employees are exposed to physical load. Physical load is defined as factors relating to biomechanical forces generated in the body. In the literature this has also been defined as "mechanical exposure", to indicate that the full working environment (i.e. lighting, noise, the thermal environment, work organization, psychosocial factors, etc.) is not considered [15]. The physical load is mainly influenced by the range of muscle activation because every working activity needs the muscles and energy [14].

The determination of the body part that is exposed during work activity, the physical load can be divided as follows:

- *General physical load* – the load of muscles of the upper and lower extremities,
- *Local physical load* - the load of muscles of the little muscles - the hand or forearm muscles

The measurement of physical activity is nowadays possible to solve differently [8]. The basic measurement types of the load are presented in the following table.

Table 1 The most common method of physical load measurement [11]

Methods of physical load measurement	Description of methods of physical load measurement
Tabular estimation	use of tables with the energy consumption (minutes or hours) for work of different muscles
Calculation	use of technical mechanics principles
Calorimetry	lab-methods, the measurement of heat expenditure during the work
Biomechanics	analysis of changes of specific substances in the human organism
Electromyography	the measurement of electric potential in the muscles
Changes of pulse frequency	by palpation or by pulsometers
Changes of blood pressure, quantity of discharged sweat, etc	these methods are used in the combination

The physical load is possible to measure and evaluate by various type of checklists. These checklists are divided by kind of load. The particular types of checklists are presented in the following figure.

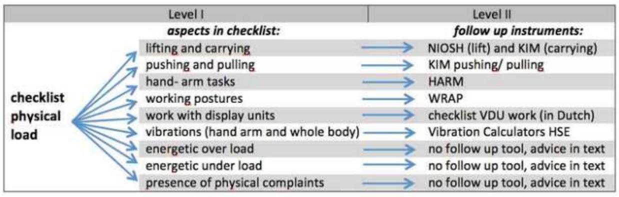

Figure 1 Checklists of physical load [5]

In the engineering production there is noticed the lower-back load during the sedentary working activities. The measurement and evaluation of this type of load is very difficult and it is possible to determine it by subjective evaluation, special methods or simulation tools. Certainly, this evaluation is not still reliable and exact. Physical loading on the back is often assessed using different design criteria such as spinal compression (biomechanics), oxygen consumption (physiology), and the percentage of the population that finds a task acceptable with respect to fatigue and stress (psychophysics). Although these criteria are assumed to prevent low-backdisorders, epidemiological evidence is sparse. However,these criteria have substantial application to job designer,which is rarely differentiated from risk assessment. The following table presents the advantages and disadvantages of use of various methods for the determination and evaluation of lower-back load.

Table 2Advantages and disadvantages of load determination of lower-back [3]

Assessment Method	Major Advantages	Major Disadvantages
Biomechanical Model	1. Appropriate for jobs requiring high forces, handling of heavy loads 2. Quantitative 3. Covers lifting, lowering, pushing and pulling	1. Practicality limits application to static analyses in the workplace 2. Fairly expensive 3. Fairly high expertise required 4. Carrying is excluded
Psychophysical Tables	1. Easy to use 2. Inexpensive 3. Extensive data available 4. Covers lifting, lowering, pushing and pulling	1. May ingnore high biomechanical and physiologiocal demands 2. Based on subjective responses
Energy Expenditure Models	1. Appropriate for high frequency tasks 2. Usually the only practical method of assessing energy expenditure	1. Validity of available models is questionable 2. Relationship between energy expediture and health effects has not been demonstrated
1991 NIOSH Equation	1. Captures major risk factors associated with lifting and lowering 2. Is a useful toll for training non-ergonomists on how different parameters affect lifting capacity	1. Has not been validated 2. Applies to few MMH jobs 3. Only applies to lifting and lowering

Physical load requirements and the methodology of evaluation are defined by Decree No. 542/2007. The basic requirements are the following [14]:

- General physical load of worker has not exceed the limit values of general physical load of worker which are given considering the energy expenditure and heart rate
- Local physical load of worker has not exceed the limit values of local physical load in relation to muscular forces and frequency of working moves which are given in the individual attachment

To prevent the increased physical load during the work are carried out the technical, organization and other arrangements [14].

The basic technical arrangements are the following:

- ergonomic modification of workplace
- limitation of application of products, tools, devices, machines and technical procedure causing the increased physical load during the working activity
- adequate microclimatic conditions

The basic organization arrangements are the following:

- working mode and recreation mode
- organization of work

The other arrangements are the following:

- continuous evaluation of health risks to workers working in risk of excessive physical load
- evaluation of worker health capability to the working performance including the realization of medical routine checkups in relation to work

One of the ways to identify and eliminate the physical load in the workplace is the use of ergonomic simulation tools especially in the sedentary activities [4]. The simulation is possible to define as a numerical method of complex dynamic systems by experimenting with computer model.

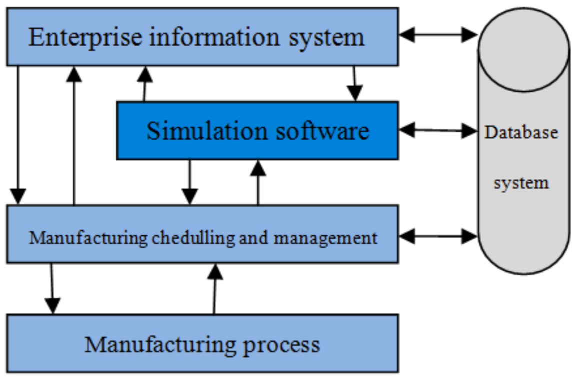

Figure 2 Integration of simulation in the systems [2]

At the basic categorization of simulation, it is possible to classify the experimental method and the essence of simulation consists in the fact that studied dynamic system simulator and replace it with him then conduct the experiment in order to obtain information about the original investigation system. Simulation can be read from the following aspects [7]:

Acta Simulatio - International Scientific Journal about Simulation
Volume: 2 2016 Issue: 4 Pages: 1-5 ISSN 1339-9640

- Economic aspect - simulation serves for identification and skipping the objects which are in the system moreover
- Controlling aspect – simulation serves for prediction of impact of accepted decisions

Simulation has found the application in the field such as space flights, military operation, urbanistic systems, computer systems, logistic and manufacturing systems, financial models, ecolology and environmental protection, ergonomics, etc. [6].

Process and system simulation should include the following stages [2]:

- System analysis and defining the issue, formulation of simulation targets
- Collection and processing of information, estimation of parameters and types of random variables.
- Creation of abstract logical model
- Construction computer model
- Verification and testing of model
- Planning and preparation of simulation experiments
- Realization of simulation experiment, changes of elements in the model, correction of model
- Evaluation and processing of simulation results, final report

Simulation according to the nature of changes in the model over time is possible to divide [9]:

- Discrete event simulation
- Continuous simulation
- Combined simulation

A discrete-event simulation models the operation of a system as a discrete sequence of events in time. Each event occurs at a particular instant in time and marks a change of state in the system. Continuous Simulation refers to a computer model of a physical system that continuously tracks system response according to a set of equations typically involving differential equations. [10]

According to the type of model is possible to divide the simulation into [9]:

- Determinist simulation
- Stochastic simulation

All of simulation tools like any other real tools have several advantages and disadvantages. The overview of the basic advantages and disadvantages are presented in the following table.

Table 3Advantages and disadvantages of simulation [1]

Advantages	Disadvantages
choose correctly	model building requires special training
compress and expand time	results may be difficult to interpret
explore possibilities	modeling and analysis can be time consuming and expensive
diagnose problem	simulation may be used inappropriately
visualize the plan	

2 Tecnomatix Jack – ergonomic simulation tool

Jack is a human modeling and simulation tool that enables to improve the ergonomics of your product designs and to refine industrial tasks. Jack, and its optional toolkits, provides human-centered design tools for performing ergonomic analysis of virtual products and virtual work environments. Jack enables you to size the human models to match worker populations, as well as test your designs for multiple factors, including injury risk, user comfort, reachability, line of sight, energy expenditure, fatigue limits and other important human parameters. Using Jack facilitates significant cost and time savings by enabling you to improve product quality and process feasibility early in the product lifecycle [13].

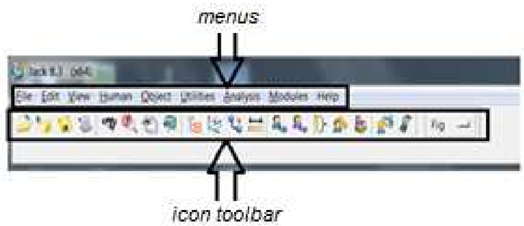

Figure 3 Control bar – Tecnomatix Jack

Jack provides a complete environment for all ergonomics and human factors needs, offering a comprehensive suite of analysis capabilities [12]. It enables to uncover human performance and feasibility issues early in the design process, allowing for big savings from a small investment. Simulation software Jack has 4 basic application:

- Create a digital human
- Posture the manikin or create a simulation
- Analyze human performance
- Experience virtual reality

3 Evaluation of physical load – Tecnomatix Jack

Ergonomic tool Jack is possible to use during the evaluation of load in the various fields. One of them is the application in the mechanical engineering, particularly for packaging works. These working activities produce the big static load to the lower back. In the following part of this article it is presented the possibility of application the ergonomic simulation tool for determination and evaluation of this type of physical load. This ergonomic simulation is implemented into the practice. The evaluated working posture is presented in the following figure.

Figure 4Working posture

In the ergonomic simulation software Tecnomatix Jack, it was created the model according to the previous figure. In the first step, there were defined the anthropometrical data of worker and then it was created the working environment. Defined worker was implemented into the working environment in the specified working posture. The created model of working posture is presented in the following figure.

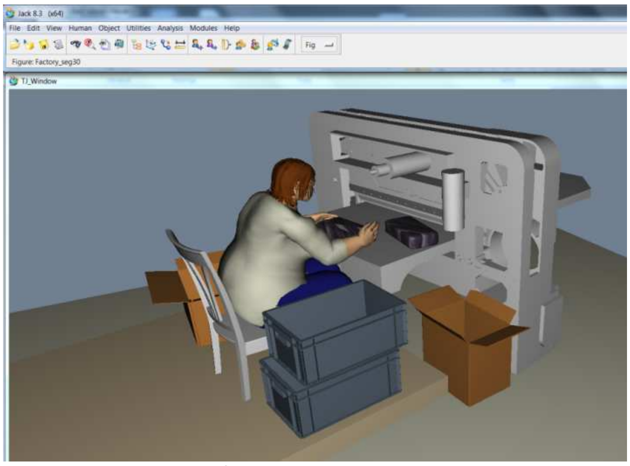

Figure 5Model of working posture – Tecnomatix Jack

After the creation of virtual model of working posture it was applied the evaluation methods – RULA, OWAS and SSP. First of all, it was applied the evaluation of physical load by RULA method. The final score of this method is 3- further investigation needed and it may be required the changes.

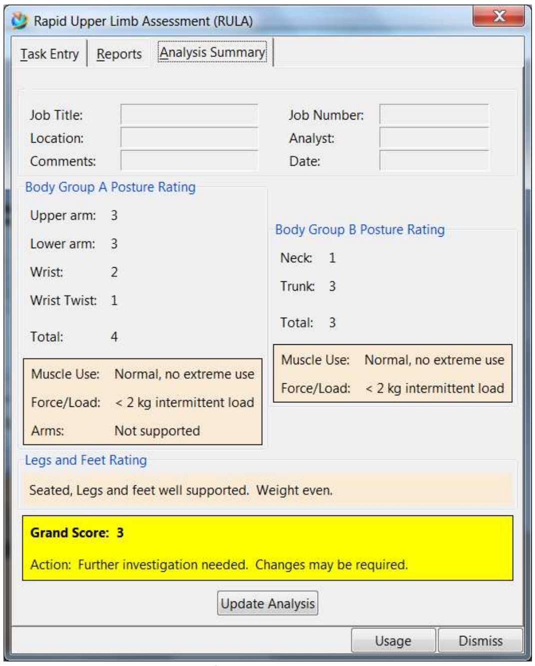

Figure 6Evaluation of physical load by RULA method - Tecnomatix Jack

To the evaluation of working posture it is suitable to use the OWAS method, too. The final score of this method is the value 3 – work posture will case harmful levels of stress on the musculoskeletal system. The system also warns that it is necessary to perform the optimization at the earliest possible time.

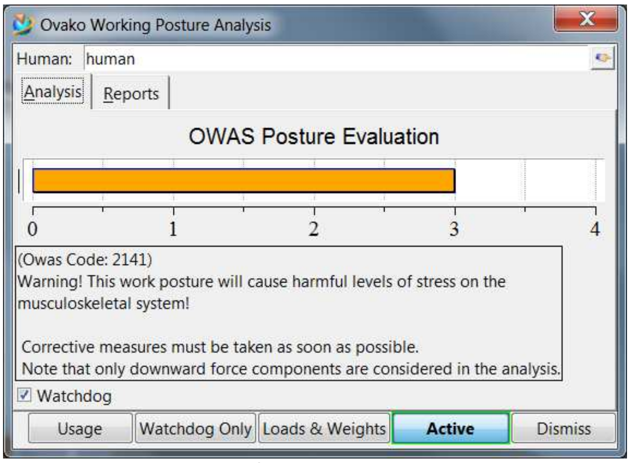

Figure 7Evaluation of physical load by OWAS method – Tecnomatix Jack

The final evaluation of the possibility to carry out an analysis through a SSP. Results can be found in the following figure in graphical and tabular form.

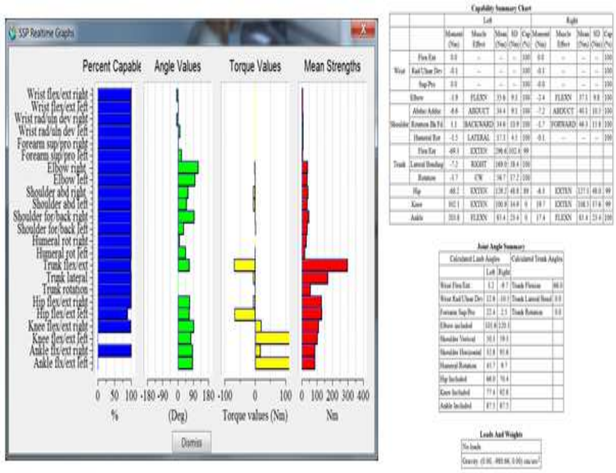

Figure 8Evaluation of physical load by SSP method – Tecnomatix Jack

The evaluation by individual methods showed that the static load of worker is inadequate and consequently it is necessary to perform the optimization of working posture or working environment for compliance with the required limits.

Conclusions

Nowadays, simulation ergonomic software Jack is possible to apply in the different industrial branches for evaluation of dynamical and static load of worker during the realization of various working activities. On the previous practical examples it is presented the ergonomic evaluation of the static load that impacts the worker involved in packaging components. In addition to the above mentioned analyses it is possible to realise the in time evaluation during the realisation of working activities. This evaluation requires the compilation of an accurate model and then compiling the working moves via Task simulation builder. The simulation is an essential part of small and medium-sized enterprises that use it in solving various tasks.

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Review process

Single-blind peer reviewed process by two reviewers.