Ľuboslav DULINA

THE USE OF TRACKING SYSTEMS FOR ERGONOMICS ANALYSIS

1. Detailed design using Tecnomatix Jack

Tecnomatix software is a product package developed by the company Siemens PLM Software. Tecnomatix includes software solutions from different production areas that are mutually connected. This software helps to prepare manufacturing and assembly processes quickly and precisely. Thanks to the simulation and optimisation in a development phase high quality product can be assured, without need to additionally apply expensive and time-consuming changes. [1]
Tecnomatix Jack is one of several modules. It was developed at the University of Pennsylvania. It is focused on ergonomics analysis and a correct working environment proposal. In this software a workplace can be created from the individual components. Simple 3D models can be created directly in Jack and complex 3D models can be imported in several formats. The best compatibility is achieved when *.jt format is used. 3D models in *.jt format can be created in other modules of Tecnomatix, e.g. NX or FactoryCAD. Disadvantage is that it is impossible to copy 3D models, so if the same 3D model should be used several times it has to be imported more times or with the use of a special plug-in which is designed especially for it, but has to be downloaded from the community page. The fact that TX Jack is open source software is a great advantage, because if certain functionality is needed, very often user can code it himself. [8]
In Jack a workplace at required dimensions is prepared and then an anthropometrically and biomechanically accurate mannequin of a man with natural human motions and joint range is put in. Ranges and dimensions were taken from NASA studies. The mannequin consists of 71 segments and 69 joints, some of them have several degrees of freedom. The mannequin figure has 135 degrees of freedom. Dimensions of the mannequin body can be selected in an extensive library of exact anthropometric dimensions from different areas of the world.
Any detail of the mannequins can be changed, for example: colour of hair, eyes, and clothes. The mannequin in version 6.0 has „plastic skin" and because of that it is very similar to the real man and aesthetically pleasing; previous versions worked with a segmented mannequin.
Software provides several options for adjusting working postures. It is possible to use library with 30 basic postures and 27 basic grips. Alternatively, it is possible to modify these basic postures in several ways. The program enables to adjust the mannequin posture to the last fingertip. When the posture is set, it is possible to evaluate the visual field, view cone for one or both eyes or evaluate reach-zones of the operator based on several rules. [2]
All well-known ergonomics analyses as OWAS, RULA, NIOSH, Low Back Analysis, Static Strength Prediction or MTM can be found in Task Analysis Toolkit. For example, RULA is analysis which does not give specific advice how to change the work procedure. It is designed for quick assessment of a working posture and determination whether it will be necessary to use more detailed analysis of the evaluated work. An OWAS-based analysis shows the four-place code indicating the back position, hands position, feet position and load level for the selected working posture and shows result of corrective recommendations. [3]
Occupant Packaging Toolkit module is specifically designed for automotive industry. It includes further analysis, e.g. a detailed assessment of the visual area, colour recognition, visibility of selected objects.
Software can also create animations of movements to evaluate the load of operator continuously in motion. There are two ways how to make movements manually. Animation and simulation mode can be used. These ways of movement's creation are very time consuming because every simple movement through joining static postures must be created.

2. Tracking systems

Another possibility how to move a figure in the virtual environment is to use tracking systems. These systems deal with movements recording. There are several categories of these technologies. The first category is tracking of one point.

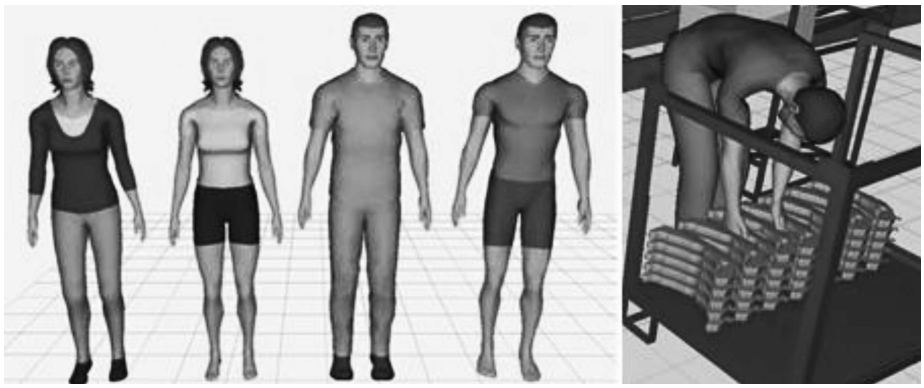

Figure 1. Mannequins with plastic skin

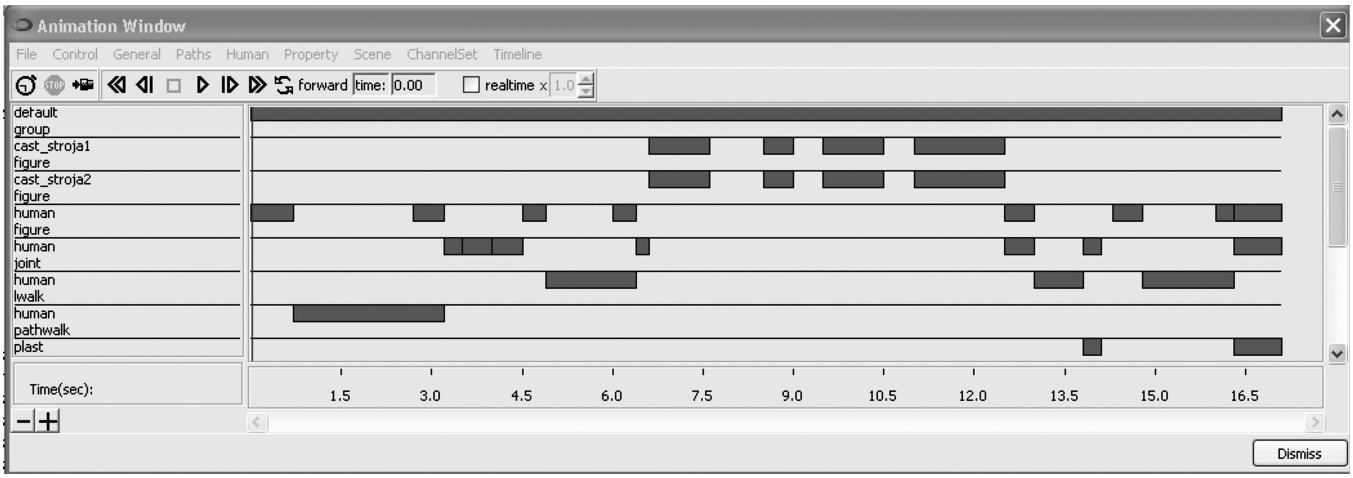

Figure 2. Sequences of movements in animation mode

Only a position of the beholder is tracked. The movement is saved in three axes x, y, z. The second alternative is to track the users whole body. This is called body tracking. The whole body can be tracked with scene identification systems (for example Microsoft Kinect) or by adding several markers on the users body. This method is usually done via a special Motion Capture suit with precise disposition of markers. The final alternatives are special tracking systems focused on special areas of tracking as the eye or face tracking. [4, 9, 10]

In the next part two of these technologies, i.e. Motion Capture and Microsoft Kinect and their interference with Tecnomatix Jack will be introduced.

2.1. Motion Capture

With the use of Motion Capture device the movements of the operator can be recorded very accurately. This technology is however very expensive. Its costs about 15000 – 40000 €. The special suit can work on few technologies, for example, on the optical principle. When the man has a suit with optical sensors, he is tracked with more than two special cameras detecting his position at the workplace.

Another tracking technology is provided by the company Animazoo. Motion Capture from this company was used in connection with TX Jack for the first time in Škoda Mlada Boleslav in Czech Republic. For connection with Jack it is necessary to use special software, IGS Jack. It is part of the Motion Capture package. This Suit works on detecting position of sensors consisting of a gyroscope and accelerometer. A gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum. Mechanically, a gyroscope is a spinning wheel or disk in which the axle is free to assume any orientation. At present it can be based also on electronic or fibre optic principles. [11]

An accelerometer is a device that measures proper acceleration. Motion Capture IGS 180 has 18 movement tracking sensors.

2.2. Microsoft Kinect

It is a device used for body tracking. It was originally developed for a game console Xbox 360. But some people started thinking about its industrial usage too. The first Kinect could recognize movements from 1.2 m. In the year 2012, Microsoft introduced Kinect for Windows. This device is designed for operation system Windows and its versions Windows 7 or Windows 8 and can recognize movements from 0.5 m. Microsoft also released Kinect´s SDK (Software development Kit). It allows developers to write their own applications in Visual Basic or C++ programming languages.

Kinect for Windows consists of a VGA camera that captures three basic colour scenes (it enables human recognition

Figure 3. Motion Capture Animazoo IGS 180

ability), depth sensor that enables 3D space recording, microphone that enables also voice commanding in applications and from tilt motor in the sensor that enables the field of view tilt.

- Colour VGA video camera – this video camera aids in facial recognition and other detection features by detecting three colour components: red, green and blue. Microsoft calls this an „RGB camera" referring to the colour components it detects,
- Depth sensor – an infrared projector and a monochrome CMOS (complimentary metal-oxide semiconductor) sensor work together to „see" the room in 3-D regardless of the lighting conditions,
- Multi-array microphone – this is an array of four microphones that can isolate the voices of the users from the noise in the room. This allows the user to be away from the microphone and still use voice commands,
- A further look at the technical specifications for Kinect reveal that both the video and depth sensor cameras have a 640 x 480-pixel resolution and run at 30 FPS (frames per second).

The specifications also suggest that sensor allows about 1.8 meters of visible space between user and the Kinect sensor, but its variation depends on where the sensor is put. If the height above the floor is not in the optimal range (0.6 – 1.8 metres), nothing appears.

To use Kinect with Tecnomatix Jack a special plugin is needed. Kinect plugin has two different modes. An exploration mode is focused on the developing of surrounding. User selects one human figure and flies through a created scene. For orientation user uses hands. The right hand enables movements to the sides and to the front. The left hand enables up and down movements. A posture mode is focused on a quick posture creation. Kinect records user movements and they are carried to the virtual figure in Jack.

The current version can recognize well only a movement when human is oriented directly on Kinect and for posture creation not all sixty nine joints are used, but only twenty of them. At present with this device user cannot track fingers. It is also impossible to record movements created via this device; user can just save static postures. [15]

The use of these tracking technologies in Tecnomatix Jack can significantly shorten time of animation creation and of dynamic loading appraisal. They can save hours of time when evaluating longer movements, because user does not have to create movement manually, as they can be created thanks to tracking and saving his own movements. These technologies do not work always properly yet, but they are rapidly developing. It is believed that in the future this type of the operator loading appraisal will be common and often used.

Assembly is a collection of activities aimed at creating a functional unit (machine, equipment, etc.) by means of joining various components. Usually it is the last stage of production, followed by functional testing and running in. It has decisive impact not only on quality and reliability of products, but also on productivity and efficiency of the whole assembly and production system. The assembly of difficult products is still manual work even in automotive or mechanical industry. Therefore, it is necessary to ensure suitable working conditions during designing assembly workstations. When the operator manipulates a hand tool or some other object (e.g. drilling machine) in an incorrect way many times per day, it can cause serious health problems. That is the reason why the know how to measure loading should be known. [13, 14]

3. Measurement of loading using ErgoPAK

When solving a real project there are no problems to detect real weight of components or work pieces, but there is problem how to detect real loading while pushing or pulling something. [5]

There are several possibilities how to measure this loading. One of them is ErgoPAK. It is a tool kit for collecting and analysing data under real job conditions. It can measure force, velocity and also angle. It has few sensors that can measure push or pull activities. Each sensor is calibrated independently. Its wireless hub has eight ports so more sensors can be used at the same time. For collecting and processing data a special ErgoPAK data acquisition software must be installed, however it is very user friendly. [6]

ErgoPAK toolkit includes following sensors:

- Handle sensor for measuring push or pull of both hands.
- Handle sensor for measuring push or pull of one hand.
- One finger sensor for push measuring.
- Two fingers sensor for push measuring.
- "Mushroom" sensor for push measuring of the whole hand.
- Gyroscopes for angle measuring.
- Accelerometers for acceleration measuring.
- Special glove with four push sensors measuring each finger independently.

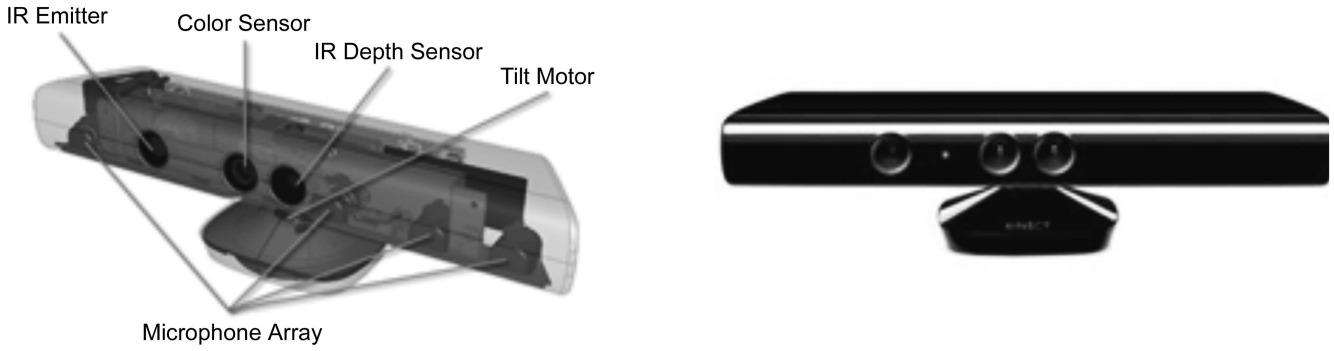

Figure 4. Kinect for Windows

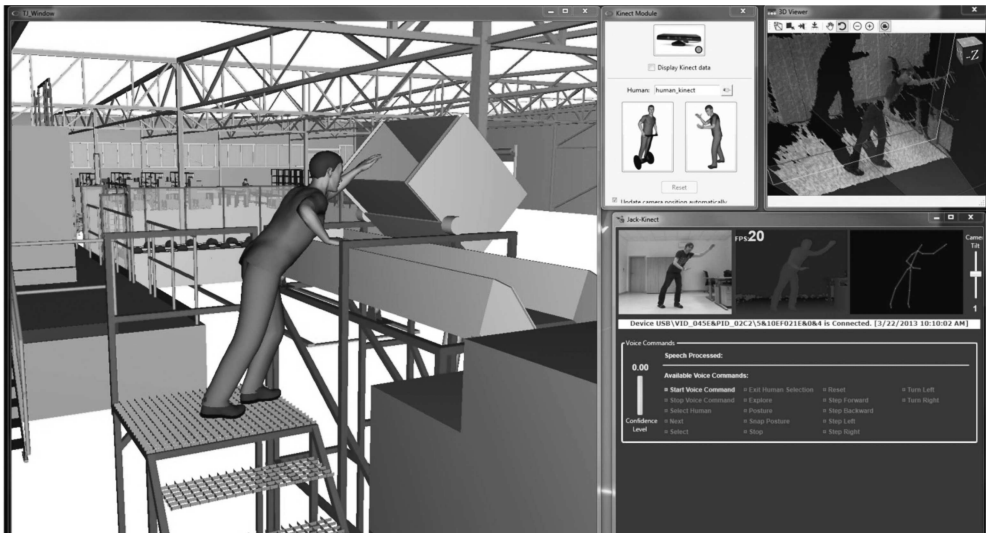

Figure 5. Posture creation using MS Kinect

This device is able to capture one hundred elevations per second. It means that about one thousand values in ten seconds are acquisited. Push values are captured in positive numbers and pull values are captured in negative numbers. In Figure 7 a sample of the pushcart handles pulled with two hands. In the graph push forces at four fingers and pull force needed for movement of the pushcart can be observed.
It is very important to know the right loading values especially in assembly processes where the same movements are repeated very often. Because when they have some harmful influences they can cause serious health problems. This part describes possibility how to measure push and pull forces in working and assembly processes using ErgoPAK tool kit and how to use these values in loading appraisal. Loading appraisal can be also done in many other ways. Loading appraisal using ergonomics analyses in Tecnomatix Jack software is presented as an example of many possibilities. [7, 12]

4. Conclusion

In the time of rapid changes in demand it is necessary to flexibly react to customer requirements. Because of that it is necessary to rebuilt and change existing working and assembly workstations. Modern information technologies and software solutions give a range of possibilities to try new ways how to design or evaluate a workstation. In the article one possible software solution, Tecnomatix Jack and its features have been introduced. These technologies are not without defects or disadvantages, but they are constantly developing. The assumption is that these technologies will become more and more common and widely used. They will be very helpful because already the current versions shorten time of designing and significantly reduce costs.

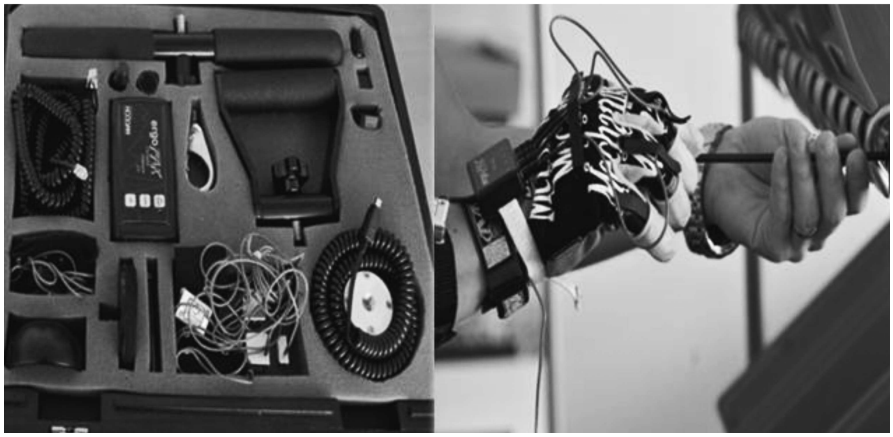

Figure 6. ErgoPAK toolkit

References:

[1] Kurkin O., Polášek P., Görner T., Hořejší P., *Virtual reality using in industry*. Ai Magazine, No. 1/2013, (2013), p. 58-61.

[2] Mičieta B., Dulina Ľ., Smutna M., *New Approach of Ergonomics Workplace Design*, In: The 22nd International DAAAM Symposium. DAAAM International Vienna. Vienna 2011, p. 303.

[3] Dulina Ľ., Smutná M., *Methods and software support in industrial ergonomics*, 1st edition. Slovenská ergonomická spoločnosť (SES), Žilina 2010.

[4] Krajčovič M., Furmann R., *Modern approach of 3D layout design*, In: Transcom 2011: 9-th European conference of young research and scientific workers, EDIS. Žilina 2011, p. 43-46.

[5] Kupka M., Hulín M., *Progressive approach to analyses of assembly process*, In: Produktivita No. 4, (2005), p. 18-19.

[6] Smutná M., Dulina Ľ., *Selecting software product as a support tool ergonomics*, In: InvEnt '12, EDIS. Žilina 2012, p. 148-151.

[7] Smutná M., Dulina Ľ., *Advanced access to detailed workplaces design using the principles of ergonomics*,

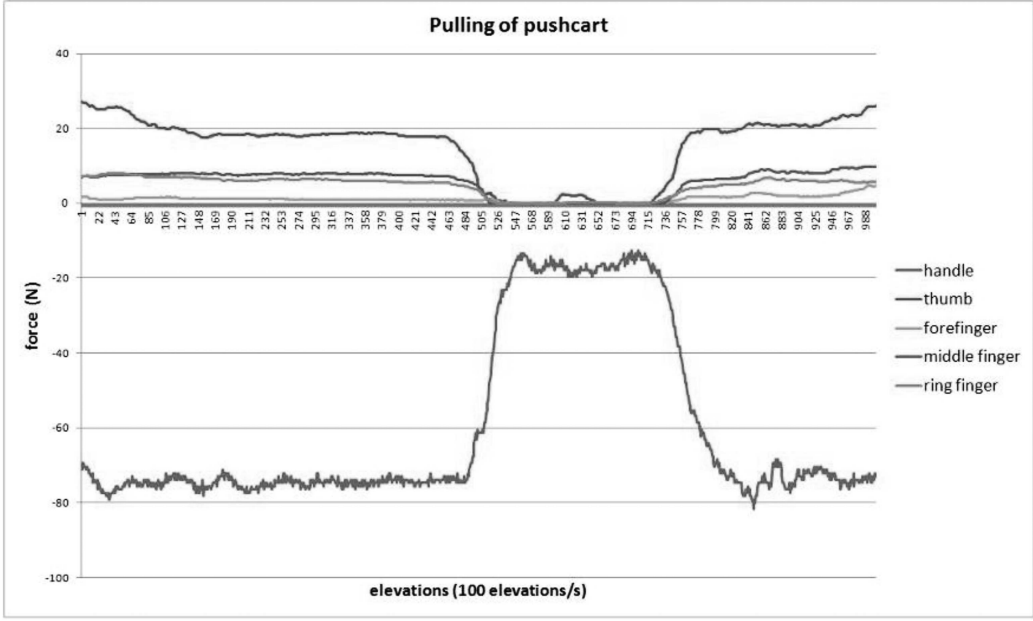

Figure 7. Pulling of pushcart – measured values

Ergonomics 2013, Croatian Ergonomics Society. Zagreb 2013, p. 81-86.

[8] Kall F., *Appraisal of workplaces using modern ergonomics solutions*, In: Advanced Industrial Engineering, Wydawnictwo Fundacji Centrum Nowych Technologii, Bielsko-Biała 2013, p. 81-92.

[9] Kall F., Krajčovič M., Hnát J., *Tracking systems in ergonomics*, In: InvEnt 2014 – Industrial engineering navigating the future, Žilina 2014.

[10] Kall F., Bartánusová M., *Using Tracking Systems for Ergonomic Analysis*, In: Transcom 2013, Section 6: Machines and Equipment Applied Mechanics, p. 157-160.

[11] Mičieta B., Biňasová V., Haluška M., *Reconfigurable manufacturing system and sustainable production*, Reconfigurable manufacturing system as the right way to achieving sustainable and energy efficient production 1st edition. LAP LAMBERT Academic Publishing. Saarbrücken 2014, p. 86.

[12] Mičieta B., Kuric T., *Augmented assembly*, In: Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM Symposium, Book Series: Annals of DAAAM and Proceedings, Volume: 20, (2009), p. 499-500.

[13] Hovanec M., Sinay J., Pačaiová H., *Application of Proactive Ergonomics Utilizing Digital Plant Methods Based on Augmented Reality as a Tool Improving Prevention for Employees*, In: International Symposium on Occupational Safety and Hygiene: 13-14.02.2014: Portugal, Guimares: SPOSHO, Guimares 2014, p. 182-185.

[14] Plinta D., *Production management with the use of digital tools*. PAR: Pomiary, Automatyka, Robotyka, 2013, nr 2, s. 213-217.

[15] Plinta D., Więcek D., Mielcarek D., *Analysis of working conditions on the example of assembly workplaces.* MOPP 2011: 13. Ročník mezinárodního semináře: Modelování a optimalizace podnikových procesů, Česka republika, Plzno 24-25.11.2011, p. 1-7.

Key words:
Tecnomatix Jack, Microsoft Kinect, Tracking system, ErgoPAK

Abstract:
The article deals with the possibility of implementing ergonomics analysis in digital factory with focus on the load analysis of the human musculoskeletal system. The emphasis is on research results in the area of connection of simulation software on the inertial and optical MoCap systems. The importance of these analyses is to estimate as accurately as possible the effects on human health due to the design of work systems at the design stage. This article deals with the theoretical basis, the results of laboratory verification and the results of implementation outputs.

WYKORZYSTANIE SYSTEMÓW ŚLEDZENIA RUCHU W ANALIZACH ERGONOMICZNYCH

Słowa kluczowe:
Tecnomatix Jack, Microsoft Kinect, system śledzenia, ErgoPAK

Streszczenie:
Artykuł przedstawia możliwości wykonania analizy ergonomicznej w oparciu o narzędzia cyfrowej fabryki, zwłaszcza w zakresie analizy obciążenia ludzkiego układu mięśniowo-szkieletowego. Szczególną uwagę zwrócono na wyniki badań związanych z połączeniem oprogramowania symulacyjnego oraz inercyjnych i optycznych systemów MoCap. Istotą wymienionych analiz jest możliwość dokładnego oszacowania wpływu wykonywanej pracy na zdrowie ludzkie już na etapie projektowania systemów pracy. W artykule przedstawiono podstawy teoretyczne, wyniki badań laboratoryjnych oraz rezultaty stosowania zaproponowanych rozwiązań.

Doc. Ing. Ľuboslav DULINA, PhD.
Žilinská univerzita v Žiline
Strojnícka Fakulta
Katedra priemyselného inžinierstva