DIGITAL FACTORY

Milan Gregor, Štefan Medvecký, Józef Matuszek, Andrej Štefánik

Abstract:

The paper presents the results of research and development of the Digital Factory solutions in industry. The implementation of this technology in industry is described and discussed. The results of research and development cover design of assembly system, its processes, simulations model, ergonomic analysis etc. In the paper are presented the solutions developed in the framework of co-operation with industrial partners like Volkswagen Slovakia, Thyssen Krupp – PSL, Whirlpool. The paper contains results of research realized in 3D laser scanning and digitization of large size objects of the current production systems. The developed and validated methodology shows the procedure of 3D laser scanning application by the digitization of production halls, machine tools, equipment, etc. This procedure was tested and validated in chosen industrial companies. The paper presents achieved benefits and future research goals as well.

Keywords: *digital factory, reverse engineering, simulation, 3D laser scanning.*

1. Introduction

The economic significance of intense and sustainable production basis in Europe is well supported by the fact that production employed 27 million people in Europe during 2001 and it produced added value of more than 1 300 billion EUR in 230 000 enterprises with 20 (or more) employees. More than 70% of this value was produced by six main spheres: automobiles, electric and optic devices, food, chemistry, materials, semi-finished goods and mechanical engineering [6].

The underdeveloped technology is one of the most significant barriers impeding the rapid expansion of research and development in Central European Region (CER). Technological approaches used daily by High-Tech automotive and electronics factories are, due to being financially demanding, difficultly available to the CER researchers. Research and development in automotive and electronics industries use completely new approaches to designing and testing of new products and production processes. Progressive approaches utilizing the most progressive technologies of Rapid Prototyping, digitalization, Virtual Reality and simulation, are what CER design teams require. The Virtual Reality can be used as by the product development as by the design of production processes, workplaces, production systems, etc. The utilization of Virtual Reality and simulation by the design and optimisation of production processes and systems is often entitled as Digital Factory [4].

This progressive technology, which has already been accepted in the most developed European countries, provides the ways to reduce the amount of necessary time and thus, as well, to reduce the development costs to the level of 10 to 20% of costs required by conventional technologies. Digital Factory currently represents the most progressive paradigm change in both research and industry covering the complex, integrated design of products, production processes and systems [5].

The results of recent year´s research conducted in the framework of international Intelligent Manufacturing Systems (IMS) research program showed that the future for manufacturing lies with new forms of manufacturing strategies. The global networks of self-organizing and autonomous units will create basis for new production concepts. Modelling and simulation have became the decisive analytical tool of the 21st century. Global markets require short time to market, high quality products with the lowest possible price. Digital Factory seems to be a solution for above introduced demanding requirements.

Different types of software are linked in PLM solutions, which control different parts of the manufacturing cycle. Computer Aided Design (CAD) systems define what will be produced. Manufacturing Process Management (MPM) defines how it is to be built. Enterprise Resources Planning (ERP) answers when and where it is built. Manufacturing Execution System (MES) provides shop floor control and simultaneously manufacturing feedback. The storing of information digitally aids communication, but also removes human error from the design and manufacture process.

The European Union has launched new project called ManuFuture – the future development of technologies and production systems. Its main goal is to foster the growth of EU's competitiveness in production sphere. ManuFuture has published its Strategic Research Agenda (SRA) and a strategic document ManuFuture – a Vision for 2020, which presents a vision of the future development of production in Europe. Vision 2020 covers the following spheres [12]: new products and services with new added value, new enterprise models, advanced industrial engineering, new production technologies, infrastructure and education, research and development system. Its practical steps are oriented on swiftly finishing the construction of the newest progressive technologies, such as [13]: virtual design, virtual enterprise, adaptable enterprise, digital factory, net production, knowledge-based production, rapid prototyping, new materials, intelligent systems, security, reliability, etc. In the sphere of technologies the future development will mainly focus on so-called converging technologies (nano, bio, cognitive) and miniaturisation, such as multi-material micro engineering, which enables to combine sensors, process signals and to react to them in micro scale.

The new generation production systems are supposed to generate the high Value Added. New designed, sophisticated and complex production systems, are understood among current European scientists as the final products, which can be sold similarly as the other products. This new concepts are built on the principles of Advanced Industrial Engineering, which uses the Digital Factory concept and digitization as a main tool [11].

2. The main productivity drivers in 21st century

The further development and prosperity of any country depends on quality of its engineers responsible for innovations. Investment into education brings almost 8 times higher increase of productivity than investment in capital assets.

The productivity and competitiveness improvement in the world was achieved, in years of 1900 till 1990, mainly through the mechanization and automation. The growth during 1990 till 2000 was achieved through IT applications. According to the world leaders in technology development, the digital technologies will be the main driver of productivity and competitiveness improvement in 21st Century.

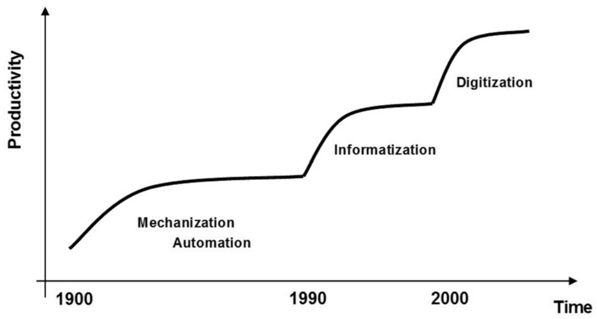

Fig. 1. Technological progress from the productivity point of view.

The digitization brought new phenomena, principal fastening of time to market. This was possible thanks the fact that digitization enables to create and test virtual prototypes through which it reduces or totally eliminates the need to create physical prototypes.

3. Production systems innovations

The future cannot exist without innovation of production processes and production systems as it cannot exist without the innovation of products. Competitive production systems require redesign as well, new machines and devices, transport systems, control systems, work organisation, etc. Such changes are introduced by teams of specialists, designers and planners.

The production systems innovations are realised by principal, revolutionary changes of production, organizational or control principles, which are conducted in long term, time periods. Small, continuous changes are conducted in between stepped changes, sometimes signed as evolution changes. They are realised in a short term time periods, practically by any change of production systems or even production line or mix. These changes are comparable to known Kaizen, continuous process improvement.

Any change, even the smallest one, bring risk of success. The change has to be realised by real people who do mistakes as well. The quality and fastness of changes can be supported by 3D digital models of production systems. The dynamic development currently undergoes in the companies running business in the HighTech sphere application of Digital Factory systems. Some years ago the University of Žilina and the University of Bielsko Biala have started to build such complex Digital Factory system [4]. The Digital Factory system utilises 3D digital models of real objects (DMU – Digital Mock Up). DMUs have firstly begun to be used in the sphere of products designing and analyzing. They are starting to be used in the sphere of complex production systems as well, or even of whole factories (for instance in automotive industry). Such digital models are called FMUs – Factory Mock Ups, i.e. digital models of factories.

To design whole factories is an extremely complex and difficult problem. Quality of the project determines the future long-term effectiveness of the factory. FMU make it possible to greatly enhance the communication among the design teams, to lower the risks evoked by making wrong decisions and to speed up innovation and increase the efficiency of the innovation process by improving the performance.

Mainly classical approaches are being used for digitalisation and geometric analyses of the existing production systems. Information about the real state of the production system is, in case of complex production systems, obtained using the measuring tape, or laser measurers. Using such approach makes digitalisation of the whole enterprise extremely time demanding and expensive. It is also a potential source of waste, inaccuracies and errors.

It is much faster, much more effective and qualitatively better to create the 3D models of the existing production systems using the newest 3D laser scanners. These make transforming the existing, real 3D word into its exact 3D digital copy, which correctly reproduces the exact geometry of the recorded space and can simply be used for any computer analyses, a matter of a few moments.

Thus obtained 3D digital model (so-called master model) can be used in all designer professions; it can be used by analysts as well as by the factory's management. Using the Internet it is possible to share such model from anywhere worldwide. Its accessibility makes it easier to eliminate errors. Designers from all over the world can simultaneously work on new projects without any need to travel on to the spot and manually do all the measurements required before they start to design.

Extensive research is currently underway, all over the world, in the sphere of utilising the digital methods for digitization, modelling, analysing, simulation, recording and presenting of real objects [1], [6], [7], [14].

4. Digital Factory

Digital Factory entitles virtual picture of a real production [11]. It represents the environment integrated by computer and information technologies, in which the reality is replaced by virtual computer models [15]. Such virtual solutions enable to verify all conflict situations before real implementation and to design optimised solutions.

Digital Factory supports planning, analysis, simulation and optimisation of complex products production and simultaneously creates conditions and requires team work [5]. Such solution enables quick feedback among designers, technologists, production systems designers and planners. Digital Factory represents integration chain between CAD systems and ERP solutions.

One of very important property of Digital Factory is the vision to realize process planning and product development with parallel utilisation of common data.

Digital Factory principle is based on three parts [2]:

- digital product, with its static and dynamic properties,
- digital production planning and
- digital production, with the possibility of utilisation of planning data for enterprise processes effectiveness growth.

It is very important to gain all required data only one time and then to manage them with the uniform data control, so that all software systems will be able to utilize it. The integration is one of the main conditions for the implementation of Digital Factory.

4.1. The application area of Digital Factory

Digital Factory is appropriate mainly as a support for the batch manufacturing of high sophisticated products, their planning, simulation and optimisation. Its main current application area is automotive industry, Mechanical Engineering industry, aerospace and ship building industries as well as electronics and consumer goods industries [2].

3D digital model of products (DMU – Digital Mock Up) creates currently basic object for the work in digital manufacturing environment [5]. There exists possibility to optimise products, processes and production systems even by the development phase with the utilisation of 3D visualisation and modelling techniques. Such solution brings time to market reduction and significant cost reduction [4].

The system for the design of shop floor 3D layouts and generation of 3D models of production halls is missing in current Digital Factory solutions [7]. It is possible to create the 3D model of production hall directly in CAD systems. Such solution is advantageous by new layouts or by new production systems designs. But, production halls do exists, in majority of real cases. By such conditions, it is often more effective to create 3D model of production hall with the utilisation of Reverse Engineering technologies and 3D laser scanners [8].

The material flow simulation enables to optimise the movement of material, to reduce inventories and to support value added activities in internal logistics chain [9], [10].

The subsystems for effective ergonomics analysis utilise international standards as The National Institute for Occupational Safety and Health (NIOSH), Rapid Upper Limb Assessment (RULA), etc., which enable right planning and verification of man-machine interactions on the single workplaces [3].

The highest level of analysis is represented by a computer simulation of production and robotics systems, which enables optimisation of material, information, value and financial flows in the factory [5].

4.2. The advantages of Digital Factory solutions

Digital Factory implementation results directly in economic as well as production indicators improvement. Any slight saving realised in a design and planning phase can bring huge cost reduction in a production operation phase. Thanks to this is payback period by investment in Digital Factory very short.

Digital Factory main advantages [5]:

- reduction of entrepreneurship risk by the introduction of a new production,
- processes verification before start of production,
- possibility of virtual “visit“ of production halls,
- validation of designed production concept,
- optimisation of production equipment allocation,
- reduction in required area,
- bottlenecks and collisions analysis
- fast changes,
- better utilization of existing resources,
- machines and equipment off line programming saving time resources,
- reduction or full elimination of prototypes,
- ergonomics analyses, etc.

Digital Factory enables to test and reveal all possible production problems and shortages before start of production.

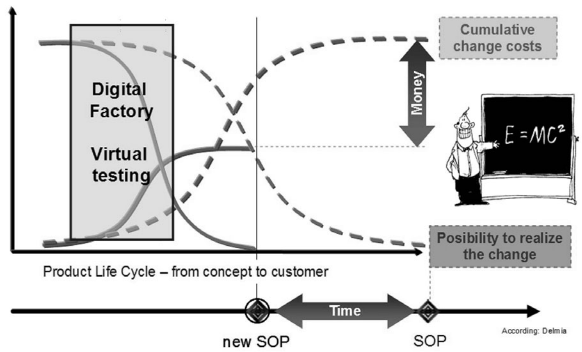

Fig. 2. The Digital Factory advantages.

The highest potentials for high quality and low costs of products are in product development and production planning phases. The statistics show that product design and production planning influence about 80 % of production costs [5].

Digital Factory enables product launching time reduction up to 25 - 50%. Estimated cost savings are supposed from 15 to 25%. According to some studies done in industry, using digital manufacturing techniques, twice the amount of design iterations can be processed in 25 percent of the time.

The current production equipment is often inflexible by quick changes. That is why the designers of such equipment are looking for new solutions (automatic reconfiguration of production machines) with fully automated control systems, which will be able to find optimized production process and parameters after production task definition.

According to CIMdata report (March 2003), Digital Factory enables to achieve following financial savings:

- cost savings by assets reduction about 10%,
- area savings by layout optimisation about 25%,
- cost savings by better utilisation of resources about 30%,
- cost savings by material flows optimisation about 35%,
- reduction in number of machines, tools, workplaces about 40%,

- total cost reduction about 13 %,
- production volumes growth about 15 %,
- time to market reduction about 30 %.

4.3. Digital Factory implementation methodology

Rough procedure of Digital Factory implementation is as follows [5]:

(I) definition of total standards and production principles for entire planning operations, creation of primitives and customer databases, (II) first data collection and organisation with the utilisation of data management system. All responsible persons have direct access to the date, their addition, inspection and changes,

(III) in the third phase, Digital Factory system improves co-ordination and synchronisation of individual processes throughout their networking supported by workflow management system,

(IV) in the fourth phase, Digital Factory system takes automatically some routine and checking activities, which are very time consuming in common systems. Implemented system insures high quality of all outputs.

5. Digital Factory in a Research

The University of Žilina and the University of Bielsko Biala belong among the universities using software solutions for Digital Factory in education and research [4]. These Universities in co-operation with the Central European Institute of Technology started to build their own Digital Factory concept, structure of which is shown in Fig. 3.

The above-introduced concept increases the borders of current Digital Factory solutions. It endeavours to integrate activities conducted by designers, technologists, and designers of manufacturing systems, planners. It simultaneously tries to increase the offer of individual existing modules. The concept design goes from theoretical studies as well as practical experience gained in industry (VW Slovakia, Whirlpool Slovakia, Thyssen Krupp - PSL, Power Train, Farmet, etc.).

6. Digital Factory in the industry

The above-mentioned partners have conducted several research studies in industry focused in Digital Factory solutions.

The DMU model of a real gearbox was developed using Reverse Engineering technology (3D laser scanning), in the framework of co-operation with VW Slovakia.

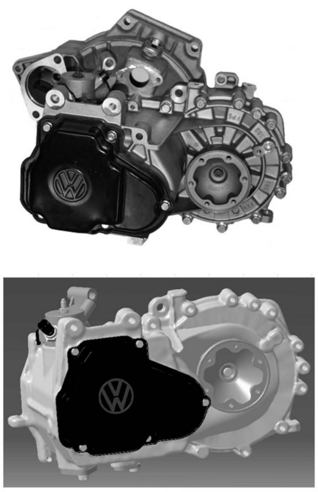

Fig. 4. Real versus virtual VW Gearbox [6].

Following the Gearbox DMU a set of DMUs of VW production workplaces and transportation equipments was developed.

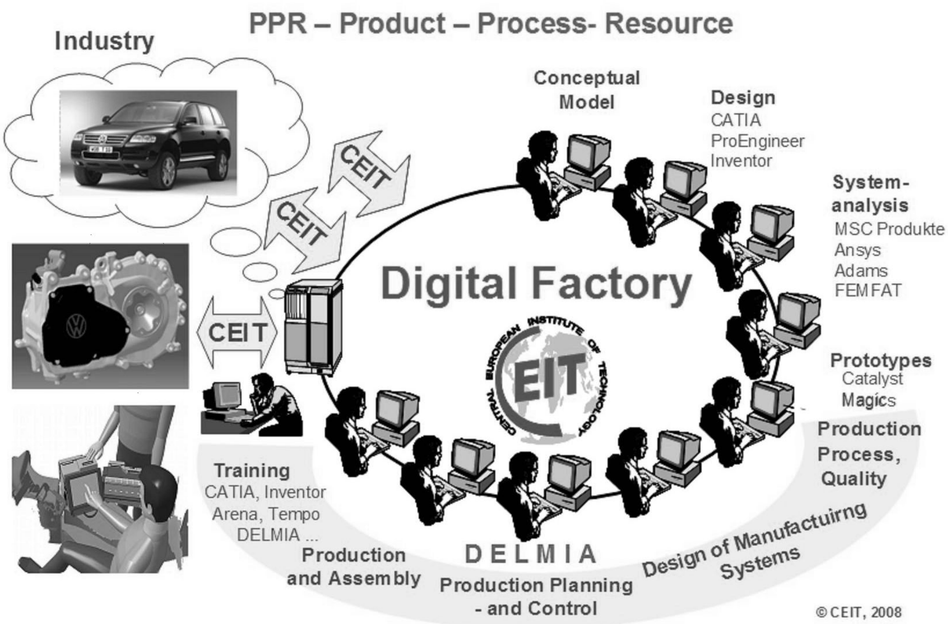

Fig. 3. Digital Factory concept [5].

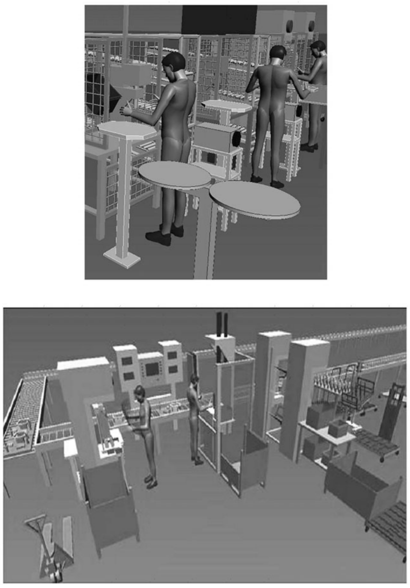

Fig. 5. DMUs of assembly workplaces [6].

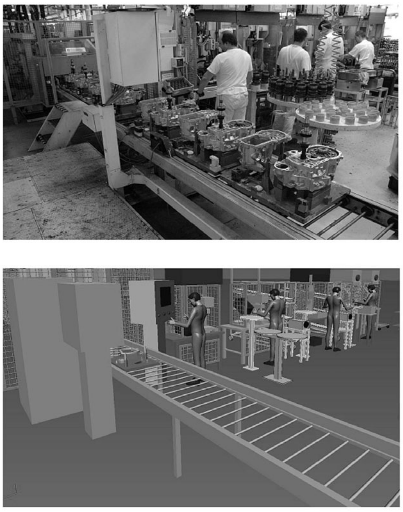

Fig. 6. VW Slovakia – Real Versus - 3D Digital Model [6].

The design of workplaces was especially checked by an ergonomics analysis whereas manikin concept of Delmia V5 Human was used (see Fig. 7).

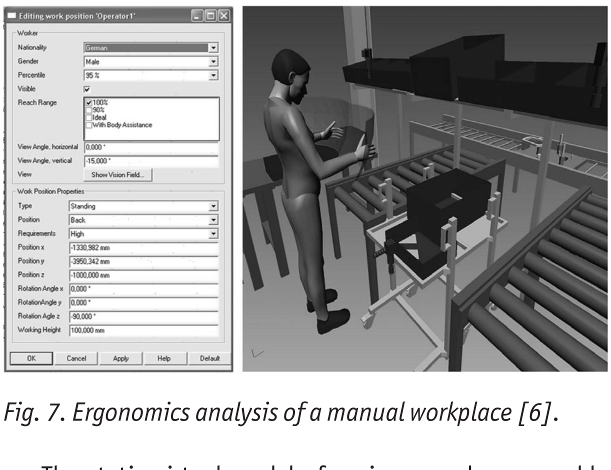

Fig. 7. Ergonomics analysis of a manual workplace [6].

The static virtual model of a given gearbox assembly line was developed through integration of individual DMUs into manufacturing system scene as it is shown in Fig.8.

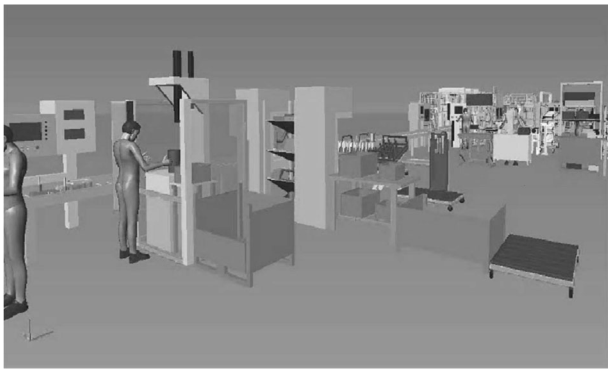

Fig. 8. Static Digital Model of Assembly Line [6].

The dynamics of production system was added in the 3D simulation environment Quest (see Fig. 9). The set of simulation experiments was conducted with the developed simulation model, which showed bottlenecks stations and the possibilities for performance growth of gearbox assembly line.

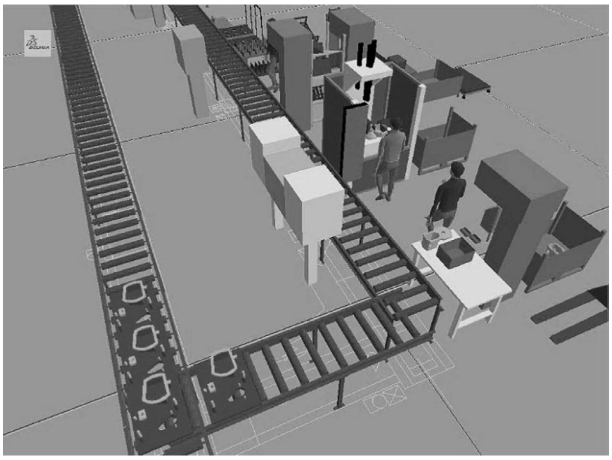

Fig. 9. 3D Simulation Model of Gearbox Assembly Line [6].

Afterwards an FMU of the whole assembly line for gearboxes assembly in VW Slovakia was developed. This FMU represents the complex digital model of the entire assembly line. The final solution is shown in Fig. 10.

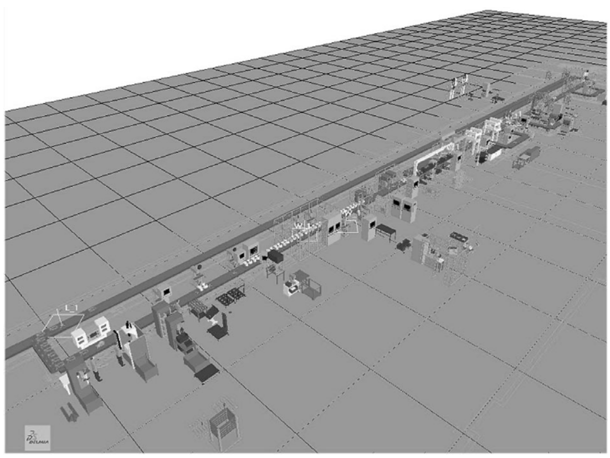

Fig. 10. VW Slovakia – FMU of Gearbox Assembly Line [6].

7. How to become Digital?

The sphere of creating, modelling and storing 3D digitalised virtual models of real objects is one of the most significant spheres, which are able to radically influence the effectiveness of producers. Research and development in this High-Tech sphere is technically and financially demanding.

The most significant automotive and electronics companies are well aware of the constant need to innovate their products, which is why they release a new model every 2-3 months [5]. Innovation can only be successful if it is swiftly put on the market. To fulfil the requirement to shorten the whole production cycle of a product from its design to delivering it to the customer keeping the costs as low as possible is the most important prerequisite of success of every enterprise. The launch of a new product is always connected with the initial chaos, which increases the realisation costs behindhand.

The system for the creation of 3D production layouts and the generation of DMUs of production halls or FMUs is what Digital Factory solutions miss today. It is principally possible to design the DMU of production halls and production layouts using the direct CAD system approach. Such solution is convenient when designing new production systems. However, the more frequent case is, that the production halls do already exist. That is the reason why it is often more efficient to create production hall DMU using the Reverse Engineering technologies (e.g. 3D laser scanning). The following Figure 11 shows the basic principle of 3D laser scanning.

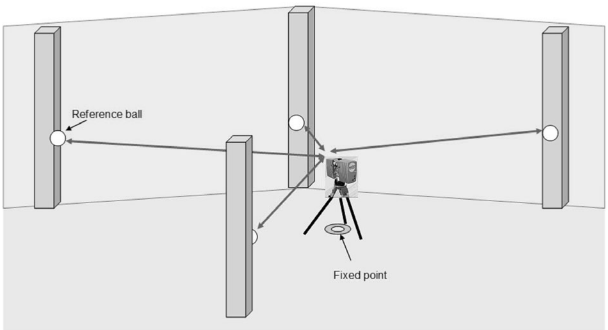

Fig. 11. The principle of 3D Laser Scanning of Production Halls [7].

Reverse Engineering is the step we need to take to achieve high efficiency and accuracy of digitization, not only considering the existing equipment, but also when the production layout themselves come into question. It opens up new opportunities to realize virtual designing. Creation of 3D-DMU of large objects using the 3D scanning is, at the moment, the joining link between virtual reality and real virtuality.

7.1. The main problems by the digitization of large objects

Based on experience of authors as well as conducted analysis, they can be summarized as follows [7]:

(I) current approaches prioritize 3D digital models of halls; they are not focused into creation of machines or equipment DMUs,

(II) DMU machines and equipment obtained from their designers (e.g. from Catia) have to be simplified, being possible to use them in DMU of production halls,

(III) many DMU of existing large objects were created by increase of 2D models (pulling of 2D model in CAD system). These solutions do not assure required precision (deviation higher than 10 centimetres) on the contrary to laser scanning where the deviation is in millimetres,

(IV) there does not exist any methodology and no approaches were described to the integration of DMU machines with DMU of production halls and following creation of FMU (Factory Mock Up),

(V) up till now, no procedure has been developed for cyclical actualisation of existing DMU (cyclical scanning and automatic identification and comparison of changes), there exist no standards for FMU creation,

(VI) there exist no obligatory regulations, which can instruct the designers of new objects to create simultaneously DMU with the real construction and after realization of project to compare the level of unity of real objects with its DMU, through the scanning, (VII) up till now was not developed any approach for integration of production halls DMUs, obtained through laser scanning with the production systems DMUs obtained from digital factory solutions (Delmia).

7.2. Practical procedure for large objects digitization

The practical and simultaneously effective procedure for scanning, digitization, modelling, analysis and storing of digital models of large objects do not currently exist. Any workplace which works with 3D laser scanning uses its own approach.

These approaches are characterised mainly by following [7]:

- procedure of an efficient way of realising 3D laser scanning of large objects,
- procedure of creating 3D digital models using the obtained 3D scanned data,
- fulfilling the standards (e.g. technical standards of buildings, construction drawing, etc.),
- the way of storing, handling and change management of created 3D digital models using a structured database system,
- procedure of integrating DMUs of real objects with DMUs of production systems created in Digital Factory environment (Delmia),
- system of digital models presentation,
- the way of Internet support for using the 3D models.

The procedure developed at the CEIT Žilina [7]:

Obtaining of data about digitized object through Reverse Engineering. It is based on computer model of the object (DMU – Digital Mock Up), which is obtained through 3D scanning (digitization) of real, existing objects. It will be used for obtaining of the computer model of the real object, to which no drawings do exist. The Computer Tomography could be used for purpose of Reverse Engineering, it means 2D cuts, which are integrated into complex 3D model of the object, during next phase.

3D laser scanning is used for the building of 3D digital model of existing layout or by the analysis of static constructions (production halls), etc. The basis of scanning is creation of reference raster, with the support of reference points; software (e.g. Faro Clouds) is used for this step. It enables the integration of 3D scans for the specification of the future virtual model. The 3D objects digital model is obtained from 3D scans through modelling in CAD systems environment (e.g. Autocad, Microstation, Catia, etc.). The software systems (e.g. Faro Scene), supplied by laser scanner producers, are used for data export from gained scans. Created 3D digital model of production hall is saved into DMU models database. Complex, digital model of production system (PPR – Product, Process, Resource) is created in Digital Factory (DF) environment (Delmia). This 3D digital model of production system is integrated into created 3D digital model of production hall.

After integration 3D digital model is used for the detailed analysis of the complex production system (e.g. production processes analysis, ergonomics analysis, etc.).

The computer simulation, supported by virtual reality (Quest simulation system), is used for the dynamic analyses.

Obtained 3D digital model of a real object is further used for the identification of potential collisions, for example in system environment of Navis Works, or Walk Inside.

The developed procedure is shown in the Figure 12.

7.3. The means for 3D laser scanning and digitization.

Reverse Engineering laboratories in Žilina and Bielsko Biala, which already runs workplaces for acquiring 3D scanned data, utilise different equipment and software systems for scanning of real objects.

The mobile measuring arm FARO with laser head is used for measurement and scanning of shape complicated objects. It provides contact or contact-less digitization, supported by PolyWorks software for 3D scanned data processing. The accuracy of scanning when doing contact measurement is 0,05 mm, in contact-less laser measurement 0,03 mm.

3D measuring device MORA MS 10 is used for CNC digitization, providing contact measurement or contact-less scanning, supported by the software INCA 3D for 3D scanned data processing. The accuracy is 1,8 μm.

Minolta Vivid 900 is used to scan small objects of, say, 1 metre at distance of about 1,5 metre. Processing of the 3D scanned data is carried out in Geomagic Studio 8.

The new 3D laser scanner FARO LS880, with a reach of about 100 meters and with the accuracy of 1 mm on 30 meters is used to scan large objects (e.g. buildings, large machines and equipment, etc.).

The Reverse Engineering laboratories have purchased licenses to various innovative, modelling, simulative and optimization programs. Program bundles from Invention Machine (Goldfire Innovator), MSC (Nastran, Patran, Marc, ADAMS,...), PTC (PRO/Engineer, PRO/Mechanica, ...), Dassault Inc. (Catia, Delmia, Quest,...), Ansys, Witness, Mantra 4D, Virtual Reality, AutoCad and other, are available.

A special software systems are used for processing of 3D scanned data, like FARO Clouds for the collection of data from 3D laser scanning, FARO Scene for the design of virtual sceneries, Polyworks for polygonization of 3D digital models obtained by laser scanning, Delmia – the comprehensive system for Digital Factory, Quest – the simulation system with the support of virtual reality, with the direct integration to Delmia system, etc.

Current digitization technologies enable 3D scanning of large objects with precision of some millimetres (creation of clouds of points, their identification and working out of 3D digital model). These technologies enable, as well, very precise measurement of object dimensions, snap shot the colours, spatial shapes, scanning type and its transformation into digital form, etc. The digitization technologies enable to create digital documentation of complex digital models, which can be later, used for objects analysis, study, design, protection, maintenance, etc. These technologies enable integrated working out of data and using of existing data (e.g. 2D scans, photos, paintings, machines passports, construction projects, etc.).

It will be needed to save and archived all obtained

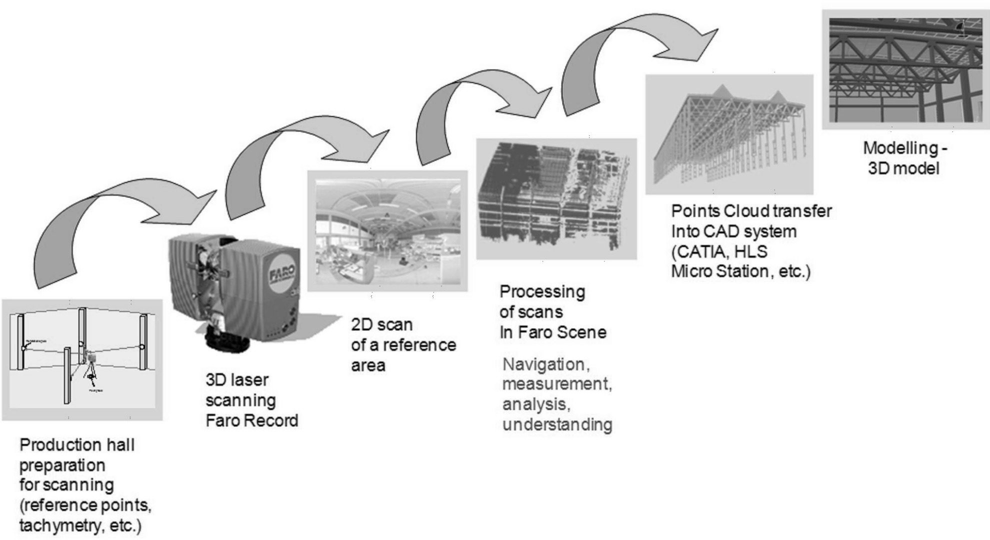

Fig. 12. Methodology of 3D Laser Scanning of Production Halls [7].

information in databases of digital objects. Such databases have to be able to save alphanumerical as well as graphical information (2D, 3D, pixel and vector).

The created digital models of objects enable utilisation of modelling and simulation methods for testing of objects properties, level of their damage, firmness and fatigue characteristics, important for objects safety (e.g. large buildings, halls, machines, equipment, etc.).

Below introduced examples show the 3D laser scanning technologies used in research and industrial applications by partners. The special, high powerful 3D scanners are used for digitization of large objects and creation of virtual scenes. 3D scanner Faro LS 880 (IQVOLUTION) equipped with software FARO Clouds and FARO Scene is used for scanning of production halls. It enables spatial scanning into distance of 100 meters.

Fig. 13. 3D Laser Scanner FARO LS 880.

Figures 14 and 15 show results from research and cooperation with industry.

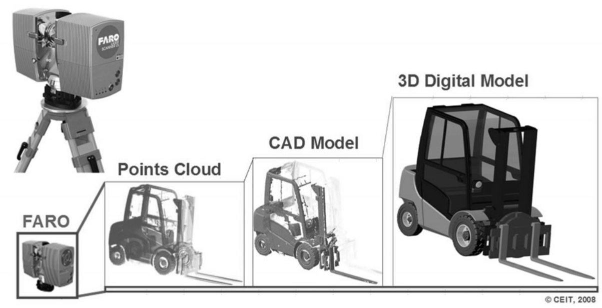

Fig. 14. The building up of a transporter DMU – Thyssen Krupp, PSL [7].

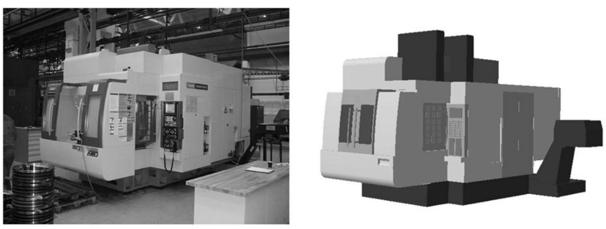

Fig. 15. Machine tool and its DMU - Thyssen Krupp, PSL [8].

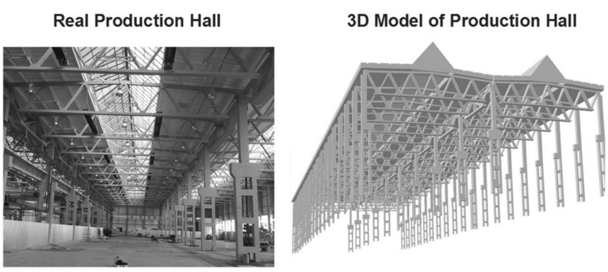

Fig. 16. Production Hall and Its 3D Model - Thyssen Krupp,

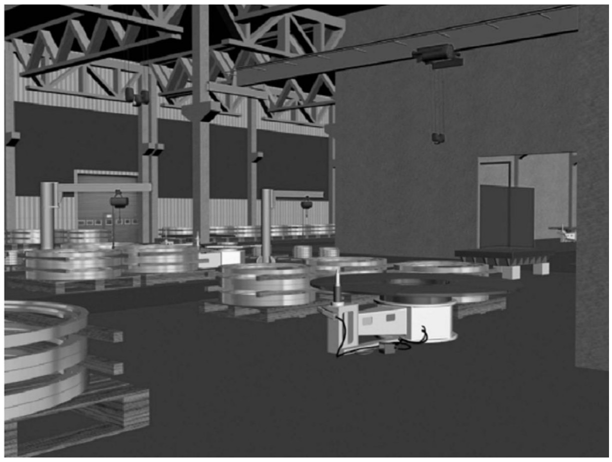

Fig. 17. 3D digital model of shop floor - Thyssen Krupp, PSL [8].

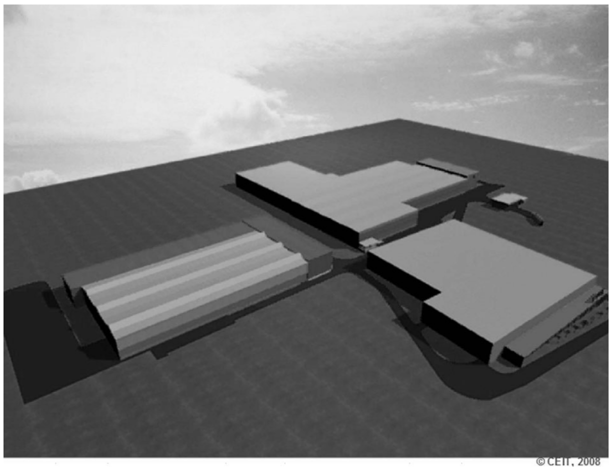

Fig. 18. Factory mock-up - Thyssen Krupp, PSL [8].

7.4. Economic benefits from digital technologies

3D laser scanning is basis for application of Digital Factory solutions [7], [8]. The authors of this paper estimate, that only during the first phase of transition to the digital solutions (HighTech companies undertaking in the CER) will be required to scan about 150 million m^2 of industrial area. The direct costs of the scanning of surfaces written above will, according the nowadays price relations, create the sum of minimum about € 450 million. The economic benefit can be documented on the next example. According to the analyses of Asea Brown Boveri (ABB) company orders it resulted, that about 20 data from customer in a simple order leads in average to:

- 200 data till optimization,
- 2000 data in structure and documentation of product, includes results, calculations,
- 20000 data in geometrical description,
- 200000 data in documentation for production, material, planning, NC-control, scheduling, etc.

If it is considered, that in the company is in the course of year executed for example 100 orders, we receive data capacity about $2*10^7$. Let next consider, that in a car industry is every car an individual order, so than for example in case of VW Slovakia, which produces about 300 000 cars per year, it represents data capacity of about $6*10^{12}$.

Following statistics are known in a project practice of big project companies:

- € 100 mill investment requested
- € 10 mill increased costs because of lower transparency and about
- € 1 mill additional costs and time because of lower transparency, clashes, organization problems and mistakes in suggestions.

3D laser scanners users achieved following costs savings [7]:

- € 3-4 millions trough the virtual reality. According to the research, consistent application of 3D factory can save 30-40 % additional costs and time in projects.
- Complex 3D data are basis for detection and elimination of clash causes. It can be saved up to 2 % of investment costs by investment into factories by using detection and elimination clash causes.
- Created and complex 3D DMUs allow accurate, quick, easy and effective change management. Time, in this case is featured. These planning and management systems are also marked as 3D-CAD-Planning tools (also marked 4D). The automated scanning, based on ahead set plan, allows fast obtaining of 3D DMU. The planning system on the other side allows with one click to realize changes in integrated form, which were in past solved by groups of specialists for months.

Among the other benefits of digitization of large objects belong [7]:

- direct access of researchers and industrialist in digital models of large objects, the growth of quality and availability of information about preserved objects,
- cost reduction of documentation, analysis, precision of working out and preserving of information about objects,
- simplification of documents and saving of information about objects,
- the growth of degree of objects protection,
- precise monitoring of objects movement (e.g. machines, equipment, etc.),
- the development of new scientific methods for the maintenance of objects,
- the growth of productivity and precision of digital models of spatial objects,
- cost reduction and effectiveness growth by creation of databases of digital models of different objects,
- support of development of knowledge about 3D laser scanning, digitization, modelling and simulation supported by virtual reality means and through comprehensive databases of digital models.

8. Further research

The further research on the area of digital technologies moves the whole scientific and technological basis and opens the possibilities for co-operation in the framework of the European Research Area and international research.

The further research on the area of Digital Factory will be focused mainly into following:

- the simplification of the introductory phase of implementation (e.g. digital product definition),
- the integration of production hall DMU with product and process DMUs,
- the simulation of such complex systems.

3D laser scanning is powerful but expensive technology. It needs in depth research not only in development of new equipment for 3D laser scanning but especially the development of new highly productive approaches, supported by user friendly software systems for processing of scanned data and creating of 3D models from it.

The research team will focus its further effort in Laser scanning into following:

- productivity improvement of 3D laser scanning of big real objects,
- productivity improvement of 3D modelling,
- development of new algorithm for gathered data squeezing, saving, storage and transfer,
- establishment and increase of 3D digital models libraries with the possibility of Internet presentations.

9. Conclusion

The future outlook shows that next generation products can benefit from digital manufacturing. Any type of process elements are stored so that as modifications are made at any stage of product development, they are made to the entire design and manufacturing process.

The University of Žilina, in co-operation with the University of Bielsko-Biala, have long been investing their human and financial resources into obtaining and developing progressive technologies. They have gained extensive experience in application of such technologies as: digitalization, Reverse Engineering, 3D laser scanning, visual data processing, creation of 3D digital models of objects, modelling and simulation of real objects' properties, creating copies of real object using additive technologies, Rapid Prototyping and Vacuum Casting.

ACKNOWLEDGMENTS

This paper was supported by the Agency for Support of Research and Development, based on agreement No. APVV-0597-07.

AUTHORS

Milan Gregor - Professor at the Central European Institute of Technology (CEIT), University of Žilina, Slovakia.

Štefan Medvecký - Professor at the Faculty of Mechanical Engineering, University of Žilina, Slovakia.

Jozef Matuszek - Professor at the Faculty of Mechanical Engineering and Computer Science, University of Bielsko-Biała, Poland.

Andrej Štefánik* - Central European Institute of Technology (CEIT), University of Žilina, Univerzitná 6, 010 08 Žilina, Tel.: +421 415 139 258, Fax: +421 415 139 201 Slovakia. E-mail: andrej.stefanik@ceit.eu.sk.

* Corresponding author

References

[1] Ďurajová M., Mačúš P., Gregor M., Medvecký Š., *Objects Digitization Using 3D Laser Scanning*, Study No. 008-

UKaI-06. University of Žilina, August 2006, (in Slovak).
[2] DELMIA – DPE. DELMIA, Paris, 2008.
[3] DELMIA – Human. DELMIA, Paris, 2008.
[4] Gregor M., Medvecký Š., Matuszek J., "Digital Factory", *Productivity and Innovation*, vol.2, no. 1, 2006, ISSN 1734-9834, pp.38-42.
[5] Gregor M., Medvecký Š., Mičieta B., Matuszek J., Hrčeková A., *Digital Factory*, SLCP Žilina, KRUPA print 2007, ISBN 80-969391-5-7. 148, pp. (In Slovak).
[6] Gregor M., *et al.*, *Factory Mock Up, VW Assembly System, Research Study*. CEIT- S002-12-2007, 2007, pp. 27.
[7] Gregor M., *et al.*, *3D Laser Scanning. The methodology of large production halls scanning*, Research project CEIT-V001-11-2007, CEIT, Žilina, 2007, 82, pp. (In Slovak).
[8] Gregor M., Budzel F., Štefánik A., Plinta D., "3D Laser scanning in Digitization of current production systems". In: *9th IFAC Workshop on Intelligent Manufacturing Systems*, Szczecin, 2008, p. 137 – 144.
[9] Gregor M., Štefánik A., Furmann R., Škorík P., "Virtual manufacturing in research and industry". In: *9th IFAC Workshop on Intelligent Manufacturing Systems*, Szczecin, 2008, p. 131 – 135.
[10] Haas W., *AK-Digitale Fabrik, Bericht Roadmap*, June 2004, Audi Ingolstadt.
[11] Jovane F., Westkämper E., Williams D., *The ManuFuture Road, Towards Competitive and Sustainable High-Adding-Value Manufacturing*, Springer Verlag: Berlin, ISBN: 978-3-540-77011-4, 2009, p. 262.
[12] MANUFUTURE – a vision for 2020, *Assuring the Future of Manufacturing in Europe*, Report of the High Level Group, DG Research, European Commission, Brussels, November 2004.
[13] Taisch M., Thoben K.D., Montorio M.E., *Advanced Manufacturing, An ICT and Systems Perspective*, Taylor & Francis: London, 2007, pp. 319.
[14] Westkaemper E., Bischoff J., von Briel R., Duerr M., "*Factory Digitalizing – An adapted approach to a digital factory planning in existing factories and buildings*", Werkstattstechnik, no. 91, 2001.
[15] Zimmermann P., Virtual reality – *Forschung und Anwendung Bei Volkswagen*, VR-Labor der Konzern-Forschung, Wolfsburg, 2005, (in German).