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Meaning and functions of the specialized laboratory Testbed 4.0

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Abstract: The highly specialized Testbed 4.0 laboratory is located on the premises of the Technical University in Košice at the Faculty of Mechanical Engineering, specifically in the building of the Department of Industrial and Digital Engineering. The idea of creating the Testbed concept arose as a response to the needs arising from the currently ongoing digital transformation of companies and at the same time as a support tool for companies in the competitive struggle, whether on the market of Slovak companies or on a European scale. The article will describe its individual focuses as well as its other forms abroad. It is necessary to point out that the Testbed located in Košice is the first and only specialized laboratory of its kind in Slovakia.

1 Introduction

In today's modern era, the development of technology, the IT sector and process engineering is driving the industry into a new industrial revolution with the number four. This aforementioned fourth industrial revolution has built foundations from the previous three. In the first phase of the evolution of industry, the main mission was to replace the manual work of a person with a machine, dominantly represented by a steam or mechanical principle of operation. This phase is followed by the second phase, which is primarily devoted to the organization and streamlining of work, where Ford's work lines and belt conveyors implemented in production are a good example. This shift in production inspired the third phase, the main purpose of which was to liberate people from strenuous physical work [1]. The essential innovative fuel of this evolutionary phase was automation and robotization, which continues to the present day and, with the continuation of industrial development and the opening of the world market, brings the industry into a new evolutionary phase of industry, namely Industry 4.0 or Industry 4.0. It is this fourth phase that measures its focus on human replacement in management and is built on digitization. A good question is certainly why the targeting of these innovation processes is aimed at the management and management of the company in which the goal is to replace the human factor? After a not very long consideration, we can come to the conclusion that the success of business nowadays is built on the quality of management and the person in this position reaches the limit of his abilities. Paradoxically, by the term human we mean a creature that is imperfect, has the nature to make mistakes, forget and often solve the given problems emotionally. Therefore, the vision of Industry 4.0 is to eliminate these negative impacts.

1.1 The importance of Industry 4.0 for industry

An important factor that is the key to the development of companies and the streamlining or optimization of their processes is information and data [2]. Even a person can, with a sufficient amount of information, decide or to take an opinion based on experience and intuition, but it is up to you to consider whether the opinion he issued is the most optimal and the best, thus it is possible to claim that by increasing the amount of data and collecting correct information, it is possible to refine the judgment and subsequently choose a better solution. After collecting a sufficient amount of data about the processes, it is possible to automate the process and thus completely exclude the human, or it is possible to provide the manager with tools for making effective and high-quality decisions. We can state that the breakthrough mindset of Industry 4.0 digitally connects all machines, processes, workers, suppliers and, last but not least, customers, collects data from them and processes them into control processes that produce outputs

in real time that make processes more efficient and modify optimality.

Thus, a person at any position in the company's hierarchy is freed from solving micro-management problems and other minor problems caused by blind spots created by an insufficient data image of the process.

So we can say that data must contain these 3 basic properties in order to become full-fledged and useful, and these are:

- Meaningfully usable,
- Quickly accessible,
- Protected against damage and loss.

Data processing and evaluation

As already said, the priority of companies should be the collection of information or process data. The next question is: What data should we collect? In the company, a lot of processes take place in real time, which represents a quantum of data, but so far it is possible to collect a very small fraction of this information, and other unmonitored processes and their information remain forgotten over time and potentially unused. Of course, every piece of information can be used in some way, but priority processes must be determined, and thus we can say what information leads us to a better understanding of processes and thus shows inefficient places, spaces or times that we should focus on.

The final stage after data collection and processing should be data evaluation. The approach to data processing can be divided into two approaches:

1. The first approach to data is use for direct control of processes, machines and products

2. The second approach uses data to support decision-making and process management with the help of data analytics

Industry 4.0 technologies

Another support point on which the industrial evolution of Industry 4.0 will be based will clearly be new technology. The generally held opinion and model calculates and redistributes Industry 4.0 into 9 main pillars (Figure 1) and here they are:

- Big data and data analytics – Efficient processing of data in large volumes of received data.
- Simulations – Verification and testing of the functionality and properties of digital processes and products and subsequent optimization, the benefit of which is a reduction in costs and an increase in the quality and efficiency of the process. It can be carried out even before the investment itself.
- Horizontal and vertical integration – Creation of a flexible environment that can react in real time to emerging stimuli
- Industrial Internet of Things - Connecting systems and physical devices using the Internet for the purpose of data collection, data exchange and data processing.
- Advanced robotics – The use of collaborative robots by a robot that can work together in one workplace with a person without endangering a person.
- Cloud computing and cyber security – Leasing or renting servers as data and software storage, thereby increasing computing power, reducing costs and keeping data protected and backed up.
- Augmented reality – Display of real space with the addition of digital information.
- Additive technology - Wide application in prototypes and designs of complex shapes.

Figure 1 Pillars of industry 4.0

Testbed

We can consider Testbed as an experimental workplace that is designed as a trial test line or as a complex set of equipment that is equipped with the most modern technology. Thanks to these conditions, it is possible to design, verify and evaluate digitalization products, processes and technologies. Testbed's applications extend to development, research and innovation in industry, and due to its location within universities or educational institutions, it is also used as an educational tool, thus helping the creation of new fields of study focused on the digitization of industrial requirements.

Industry 4.0 opens up unique solutions for the most diverse requirements and demands of companies, and thus it is absolutely important that Testbedy can respond flexibly to newly emerging problems associated with the introduction of new industry requirements. It follows that Testbed cannot be taken as a tool, but also as a workplace, or rather a platform, for the support of the above-mentioned areas such as research and innovation. Thus, we can consider Testbed as a support for Industry 4.0 concept solutions.

Since in medium and smaller companies there is no space and often no financial capital for testing new technologies, Testbed offers a platform for testing and searching for optimal ways and proposals without companies having sufficient know-how to implement projects. In testbeds, companies can test Industry 4.0 applications without competitive pressure, with low risk, acceptable costs and high value in the form of cutting-edge technology and expert assistance.

A very important strategic advantage is the use of Testbed even before the actual investment in technology. This approach is called testing before investment or in English "test before invest" when the company submits its requirements and proposals and Testbed offers them a comprehensive strategic and technological view of the process.

The extent of the scope of Testbeds is very wide, and with the addition of new ones, they can specify the requirements of the industry more precisely. The field ranges from cyber security, robotics, automation, data processing, offers solutions for serial and mass production, and extends to artificial intelligence or virtual and augmented reality [3]. The Testbed and its parts can fully communicate with other Testbeds and thus multi-industry connection is becoming a trend, so it is common that the engineering industry is possible in development and research with other industries such as the medical, civil or military sectors.

Testbed abroad

Slovakia and its industry is able to draw information about the Testbed issue, for example, from the Western countries of the European Union, and Germany is clearly the leader in this regard. According to the findings, in the current period of 2021, Germany has 89 test workplaces, which is clearly the most among other EU countries. The construction of testbeds can also be noted in the Czech Republic, and the first two were built strategically in Brno and Prague.

RICAIP ZeMA Testbed Saarbrücken

Testbed Saarbrücken is located in the German city of Saarbrücken, where its test area of 4,000 square meters includes two industrial halls and various areas for experimental demonstrations and prototypes for the production of the future. The main intention is the use of digitization for the needs of Industry 4.0 as well as the use of artificial intelligence for application purposes in the production area as well as the use of robots. The focus of this tesbed is manifested mainly in the following areas:

- Sensors and actuators – deploying intelligent materials for the development and innovation of new products and their application possibilities
- Automotive – Development of production and testing technologies for upcoming generations of cars
- Robotization – Development of robot-human cooperation and production applications associated with the use of artificial intelligence in production
- Handling technique – Digitization in the field of logistics with the help of digitization and AI.

RICAIP Testbed Prague CIIRC CTU

The testbed is located at the Czech Institute of Informatics, Robotics and Cybernetics at the Czech Technical University in Prague. This Testbed is spread over two floors with a total area of 1640 square meters. It is used for research, development, education and collaborations with partners. It enables the testing of solutions for advanced and integrated industrial production and processes for smart factories. It also enables optimization of the energy efficiency of the production system, diagnoses and proposes predictive maintenance or can manage data within the area of the product life cycle. The focus of this Testbed is dedicated in the following parts of the industry:

- System for production planning – production planning at different levels of the hierarchy, such as the level of one device up to the level of the entire production line and logistics systems
- Digital twin and digital shadow – Processing and analyzing production data such as production processes, scenarios, metrology solutions and statistical process control
- Enterprise ecosystem – links between production lines, logistics and customer services with support for autonomous decision-making and production planning
- Development of technologies – development of laser, additive and robotic technology

RICAIP Testbed Brno CEITEC BUT

Brno Testbed is located in the industrial hall on the campus of BUT in Brno, it is managed by the Central

European Institute of Technology (CEITEC). The workplace infrastructure is focused on research, development, education and experimental production. During the start-up phase, it was used in international large-scale projects in the field of Industry 4.0, and its use in automotive technology plays a major role. Brno Tetsbed is connected to the regional innovation ecosystem oriented towards machine and production technologies. The testbed hall is equipped with a precise optical localization system and provides enterprise software solutions for the design, modeling, simulation and operation of production lines, as well as a state-of-the-art automation network. In addition to these production technologies, there are also unique facilities for the development and testing of high-performance rotary drives up to 250 kW for industrial and automotive applications and linear motor drives up to 100 kW. The orientation of the testbed is therefore directed to the following areas:

• Flexible production systems – a combination of additive and machining technology as well as the development of transport technologies such as mobile manipulators.

• Human – machine – robot cooperation – 3D localization of robots and devices as well as the introduction of virtual and augmented reality.

• Machine diagnostics – predictions and estimates in the field of maintenance and machine conditions.

• Acoustic and vibration diagnostics – vibrodiagnostics, analyzes of acoustic emissions and development of sensors for diagnostics.

• Development of stepper motors – development of high-performance rotary and sliding motors and predictive maintenance.

Engine Testbeds Graz, Austria

The Testbed group, located in Graz, Austria, provides testbed services for the world's most prestigious automotive brands. During the year, the laboratories can test over 150 different engines according to TÜV Süd accreditation standards. The targeting of testbeds can be divided into:

• 24 engine testbeds – testing engines from 1kW to 1900kW.

• Alternative fuels.

• Assembly and testing equipment.

TestBed 4.0

If the contribution of TestBed 4.0 could be generalized, it can be said that it provides services for the industry, which enables companies to design, test, and search for optimal and effective solutions for processes arising from the introduction of Industry 4.0 principles. This enables companies to have a detailed overview of the processes that their investment will bring and provides several other options that should help in choosing a suitable solution.

Testbed's workplace highlights and emphasizes work with data from product development to method introductions and logistical operations to production itself. It is these potential sources providing data that encourage thorough collection and building of own data information flows. Testbed 4.0 provides the opportunity, the background and the advice of experts with which companies can better capture these overlooked places in production in terms of data, and quantify them sufficiently in the next steps. The design and conception of TestBed 4.0 was intended to be subject to equipment aging as little as possible. Hardware that could be considered obsolete in the course of months and years was represented by devices that are created in virtual space [4,5].

The main mission of TestBed 4.0 for each specific company is, in the broadest sense, a solution tailored to the given company. The solution includes the methodology, concept and procedures for Industry 4.0 applications, which represents a partial or complex integration of business processes and a broad focus on the collection, exchange, gathering of data and, after their evaluation, transformation into relevant information. The correct application of the digital twin concept is an integral part of the implementation of the design, optimization and verification. The support and presence of a digital twin helps in creating and controlling the digital ecosystem of an industrial enterprise. The entire ecosystem can include:

• EPR - solutions covering the needs of SMEs.
• PLM – a system for managing the development and pre-production phases.
• CAD/CAM systems.
• RTLS – tracking the flow of material, workers and logistics:
  • Production machines – devices, machines and robots connected in an ecosystem.
  • Monitoring of energy costs during operation.

According to the predetermined principles of Industry 4.0 and the options offered by TestBed 4.0 for companies in industry, the solutions could be divided into the following services in practice:

1. Verification of investments – The inclusion of Testbed in the preparation and design phase enables the creation of a virtual module of a work line or otherwise complex workplace that serves as an ideal model of this workplace. When solving and optimizing this model, it is possible to make changes without investment, and with the use of virtual reality, it also offers a view of the workplace. With this verification, it is possible to prevent errors that could arise during the implementation of investments.

2. Creating a parametric model – Many complications arise in the process of reorganizing or modifying the workplace with the aim of increasing performance and saving space. The parametric model can simulate process variants under different conditions/parameters and thus offers more solutions for process

optimizations with the aim of making the process more efficient.

3. Virtual commissioning – TestBed 4.0 enables the execution of simulations and tests before starting the production line or production process. This step can test the entire software equipment and therefore prevents the possibility of problems arising in the event of poor connection to operation, which could result in damage to a part of the line or human injuries [3].

4. Design of data collection from production - Enables the design of device interconnection structures under the IoT principle. These connections of machines and processes enable the collection of data that is essential for dependent operation and autonomous problem solving.

5. Monitoring of CNC machines - Automatic collection of data from the PLC control units of the CNC machine. With the help of accurate monitoring, i.e. data collection, it is possible to increase the utilization of the machine thereby reducing the time that the machine is not working, which is reflected in the profit from the given machine. Also, the collection of data on the operation of the machine informs about the needs of service and predictive maintenance, which results in improved production quality and the financial burden of possible machine repairs.

6. RTLS system for order flow and logistics - TestBed 4.0 helps in solving the localization of products in the production hall as well as suggests obtaining information about the supply of workplaces. With RTLS technology, it is possible to monitor the status and location of the order in real time, which gives an overview of the actions that have already been performed, which are being performed and which will be performed, and at which workplace or workstation it is performed.

Figure 2 Tesbed 4.0

2 Conclusions

The specialized scientific-research workplace Testbed 4.0 is nowadays a leader in its field and, so far, the only such laboratory in Slovakia (Figure 2). Its biggest advantage is helping manufacturing companies grow and transform. As part of his measures, he can offer the design and verification of the concept of, for example, workplaces, operations or warehouse spaces. As part of its orientation, it also deals with logistics and its optimization or digital verification of the operation of the constructed product or workplace. Nowadays, many companies draw on his ideas and he inspires other companies to cooperate with students and the academic community as well.

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