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Proposing the capacity of bulk materials buffer in the simulation software

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Abstract: Storage is one of the primary activities of manufacturing enterprises. Mainly, enterprises deal with the storage of piece materials, but there are also production processes using bulk materials. For this material, enterprises need to create specific storage areas - buffers. The first activity before creating a buffer is determining the nature of its filling and emptying, which affect the main parameter of buffers, namely capacity. Specifically, it is necessary to know the hourly performance of the filling equipment, the method and speed of emptying, and the type and capacity of the means of transport into which the material is loaded. The simulation software brings a modern touch to the years-proven procedures for determining the capacity of bulk material buffers and speeds up the process. In the paper, simulation replaces the previous approaches to creating graphic outputs, which check the mathematical part of the algorithm and visualize the behaviour of the buffer in specific situations. The result of the use of simulation is the rapid creation of graphs of material supply and easy checking of several options through experimentation with the simulation model.

1 Introduction

In the primary industry, the dimensioning of bulk warehouses is an integral part of logistics activities in the production process. The task of storage is to create the necessary stock of material to eliminate the effects of uneven supply and removal of material, to further separate technological processes of other types from each other in time and to take into account the physicochemical properties of the processed materials [1].

Bulk materials are stored in landfills and storage buffers. Storage of bulk materials in buffers has its advantages and disadvantages. The main advantages include protecting the stored material from adverse weather effects and automation of filling and emptying the storage buffer. Buffers can be filled from the top by pouring. The discharge of the material is realized in the lower part of the buffer in the form of one or more discharge holes [2]. The main disadvantage appears to be various flow defects. These include defects in flow continuity, vaults, stick rings, and dead zones in the bulk material [3]. Storage buffers are divided according to several aspects. From the critical point of view of floor plan and height dimensions, we distinguish between low bunkers and high silos. Bunkers are intended for short-term storage because they have a smaller capacity due to their geometric shape. Bulk materials of all characteristics can be stored in them. Bunkers can be placed above or below ground and have different shapes. Silos create a more extensive stock. Therefore, they are mainly used for long-term storage and are only suitable for powdery or fine-grained, small loose materials [4]. When designing a Buffer for bulk materials, it is essential to determine the process of filling and emptying the buffer, which is closely related to the design of its capacity. The course of filling and emptying it depends on several factors [5]:

- The method and speed of filling are represented by the hourly performance parameter of the filling device, e.g. continuously using a belt conveyor.
- The method and speed of emptying could be continuous or at specific intervals.
- Type and capacity of means of transport, e.g. truck, railway wagon, a system of conveyor belts.

The article aims to show how to speed up the process of designing the buffer capacity using a simulation software.

Many authors defined simulation as a research method [6,7]. A computer simulation is the most common approach to solving tasks in various areas, not only in transport [8]. Simulation is a research method, the essence of which is that we replace the investigated dynamic system with its model - simulator and perform experiments with it to obtain information about the original investigated state. The simulation is carried out outside real objects without influencing the actual operation or without the existence of a real, investigated system. The simulation results in information about the investigated system and its elements according to the defined parameters [9]. Simulation is an established analysis method for manufacturing and logistic purposes. It is frequently used when decisions with high risks must be taken, and the consequences of such decisions are not directly visible, or no suitable analytical solutions are available [10]. A simulation is a suitable tool for evaluating the efficiency of the production process even in the case of non-invasive changes, such as production adjustment, planning and rationalization of logistics operations [11].

Today there is a significant number of analytical software products focused on simulation in the information technology market. The range and variety of such software continue to grow. As the dominant basic concepts in modern simulation modelling are used [12]:

- discrete-event simulation systems (description-based systems for process description);
- systems based on network paradigms (are used in structuring causal relationships and modelling;
- systems with parallel processes, serving for stratification and algorithmization dynamics of discrete and discrete-continuous systems);
- systems based on process models and organizational;
- structures;
- systems focused on continuous modelling;
- dynamic systems;
- other.

Currently, many simulation programs are used, such as TECNOMATIX, SIMUL8, WITNESS, ExtendSim or ARENA [13]. In this article, a simulation model created in ExtendSim is presented. ExtendSim is a block-oriented simulation program that offers both discrete and continuous simulation. Program blocks are divided into Value, Item, Chart, Rate, Utilities and Animation libraries. The number of blocks in the model is not limited. Pre-prepared blocks with a built-in programming language make it easier for creators to work logically with the model [14]. Several researchers have used this simulation software. For example, Ondov et al. [15] present a simulation model as a tool used in the redesign of the medium enterprise production process, Šaderová et al. [16] present a simulation model of selected activity in a warehouse operation, Kopytov et al. [17] present a simulation model for the supply chain "producer – wholesaler – 3 customers, and other authors [18].

Among the partial objectives, the use of simulation as an analytical tool to monitor the behaviour of the designed buffer and the proposal of various measures to rationalize the amount of raw material in the buffer can be pointed out.

2 Methodology

The volume and capacity of an already existing buffer are simply determined by calculation based on its dimensions. Another case occurs when it is necessary to design the capacity and volume of a new buffer for specific operating conditions. The volume and capacity must be designed effectively so that it is not over-dimensioned or under-dimensioned and could represent a bottleneck in the production or transport process. The design of buffer capacity and volume can be divided into two parts. The first part – computational, is the basis for the development of the second part, the basis of which is the graphic representation of the filling and emptying of the buffer and the subsequent determination of its volume and dimensions [19]. According to the buffer design algorithm, the following steps must be followed [19]:

1. Design of the shape and dimensions of the buffer outlet.
2. Calculation of the permeability of the hole.
3. Calculation of the buffer emptying time.
4. Calculate the time of filling the buffer with the amount of material for one means of transport.
5. Calculation of the minimum amount of material in the storage buffer before loading.
6. Construction of a graph of supply and removal of material from and to the storage buffer. At this point in the algorithm, the simulation software is used.
7. The maximum amount of material in the buffer is determined.
8. The amount of material is recalculated using the volumetric bulk weight of the raw material.
9. They determine the dimensions of the buffer.

The chosen simulation software is ExtendSim 10, which contains many blocks in its libraries. The following

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blocks [20] are key to creating a simulation model according to point 6 of the algorithm mentioned above:

- Create - This block provides items or values for models. Introducing items or values is controlled by five options offered in the block's dialogue.
- Activity - Holds one or more items and passes them out based on the processing time and arrival time for each item.
- Holding tank - Accumulates the total of the input values, allows to request an amount to be removed, and outputs that requested amount, if it is available.
- Constant - Generates a constant value at each step.
- Batch - Allows items from several sources to be joined as a single item. This is useful for synchronizing resources and combining various parts.
- Line chart - traces the history of values received overtime during the simulation. The Chart can trace up to 20 lines.

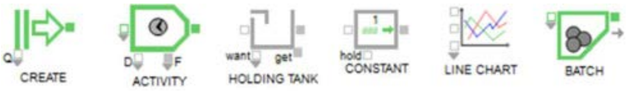

Figure 1 Important blocks for creating a simulation model [20]

Other blocks used to supplement the correct operation of the simulation model should be the Executive blocks to manage the simulation time. Queue as a place to store entities after their creation. Gate limits the flow of entities, and Exit allows entities to leave the model.

3 Results and discussion

Before the simulation model was created, it was necessary to perform calculations according to the algorithm. The authors of these publications give the relationships for the calculated values [21].

The simulation model for filling and emptying the buffer was created in the program ExtendSim 10 and is shown in Figure 2.

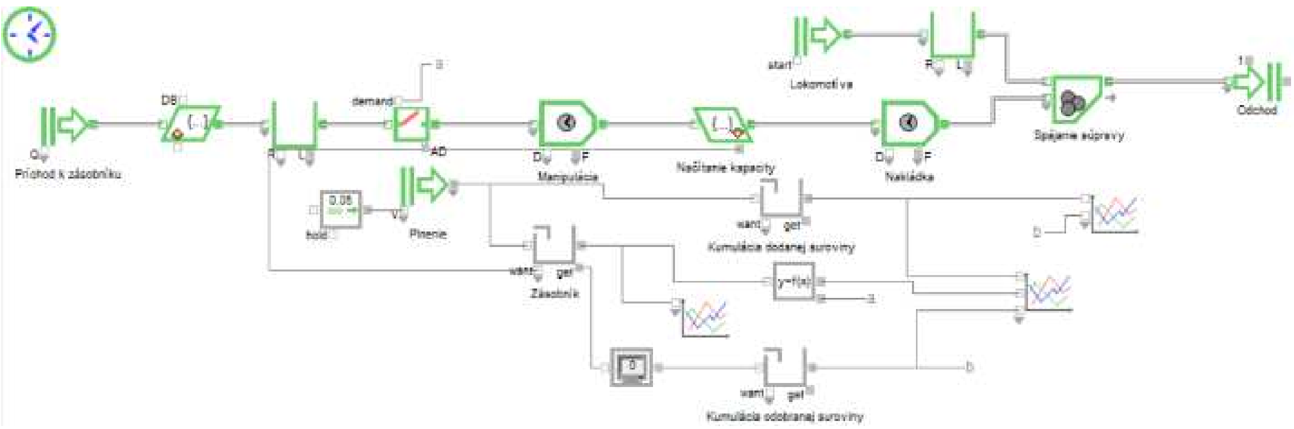

Figure 2 Simulation model of buffer filling and emptying

The simulation model in Figure 2 is a combined simulation model in which the green blocks represent the discrete part of the simulation, and the grey blocks the continuous part of the simulation. Time is recorded at certain moments. The "Príchod k zásobníku" block generates the wagons of the train set regularly so that after the wagon is loaded, the manipulation of the next wagon immediately begins. In the next block, the value of their capacity is assigned to the wagons. The following pair of blocks is fictitious and inserted only for the correct functioning of the simulation. The block gate from the mentioned pair will not let the next wagon for loading if the buffer does not have the required capacity from the wagon. This adjustment is necessary from the point of view of the chosen solution of the simulation model because the model could otherwise fill the wagons with a value different from the capacity. After the wagon is admitted for loading, manipulation is performed in the activity block, and the get block reads its capacity and sends the request to the buffer. Then another activity block simulates the delay during loading. The discrete part ends with the connection of ten wagons and the locomotive, generated in the highest positioned create block and the departure of the train set. In the continuous part of the model, the "Plnenie" block regularly fills the reservoir with the value generated in the block before it - a constant block. The buffer is represented by the holding tank block named "Zasobnik". Holding tank accumulation blocks also accumulate values for plotting curves in graphs created in line chart blocks. The block connected to the buffer is an equation. In this block, the condition of the amount of material in the buffer is checked, and the closing and opening of the gate before loading is controlled.

In the first experiment, the filling time of one train set, i.e. ten wagons, is monitored. The authors set the simulation duration to 300 minutes based on a subjective estimate. To set up the blocks, it is necessary to establish the parameters. These parameters are selected input values and calculated values according to formulas. These values are shown in Table 1.

Table 1 Input and calculated values needed to create a simulation model, source: author

	Parameter	**Value**
Input data	power, in hours, of continual filling equipment $\mathbf{Q}_{\mathbf{h}}^{\mathbf{FD}}$, t.h^{-1}	180
	volumetric bulk density of stored material ρ , t.m^{-3}	1,6
	maximum size of the discharged pieces in the buffer ***z***, m	0,05
	the capacity of a vehicle K_V, t	45
	Coefficient of filling the cross-section discharge outlet φ.	0,5
Calculated data	throughput - the performance of an outlet hole of the buffer, $\mathbf{Q}_{\mathbf{h}}^{\mathbf{T}}$ t.h^{-1}	560
	the buffer emptying time T_{ET}, min	7
	time of a wagon manipulation T_{VM}, min	3
	Time of the buffer filling by material for one wagon T_{FT}, min	23
	the minimum amount of material in the buffer before loading $\mathbf{K}_{\mathbf{T}}^{\min}$, t	48

The results of the first experiment are shown in Figure 3.

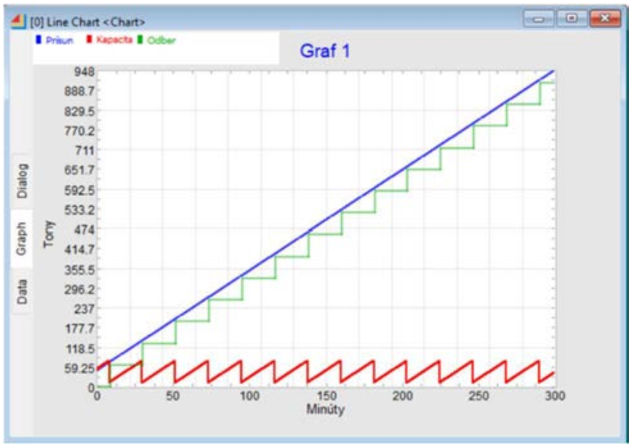

Figure 3 Graphic display of experiment outputs

The material in the buffer decreased slightly during the simulation but did not fall to zero. The blue feed curve does not go below the level of the displacement curve. During the simulation, 14 wagons were filled, which means that one train set was able to leave for 300 minutes. 948t was added to the value in the buffer. Figure 4 shows the detailed evolution of the storage capacity.

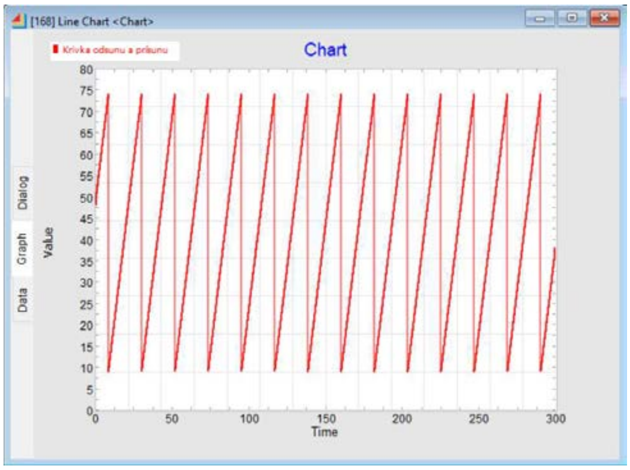

Figure 4 Graph of supply and removal of material from and to the buffer

The process set up in this way points to the correctness of the relationships stated in the available literature. The ideal situation would be if, at the end of the shift, there was again a minimum amount of material in the buffer. In our process, instead of the minimum 48t, only a little less remained - 38t.

The following experiments were also performed on the simulation model:

1. How many wagons can be filled in one shift (450 minutes), Experiment 2.
2. How long will it take to load ten train sets (100 wagons), Experiment 3.
3. How will the loading time change when the performance of the continual filling equipment is changed to $\mathbf{Q}_{\mathbf{h}}^{\mathbf{FD}}$ = 250 t/h, Experiment 4.

Experiment 2 shows the graph in Figure 5. During one shift, 450 minutes, two train sets left the simulation model, and one more wagon was filled. One thousand three hundred ninety-five tons flowed into the buffer, and 1,365 tons of material was removed.

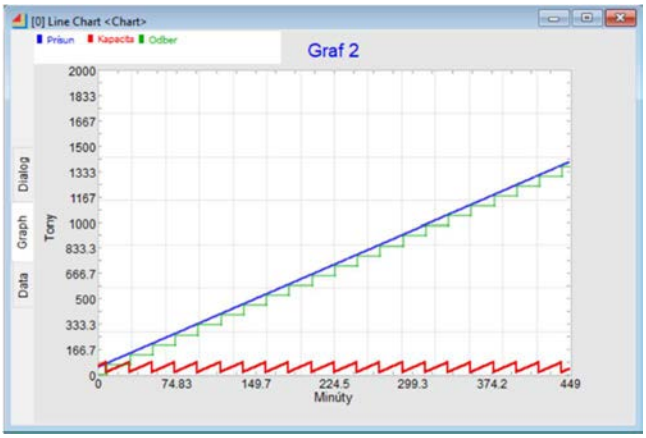

Figure 5 Results of Experiment 2

Experiment 3 is shown in Figure 6. In this experiment, the goal was to find the time needed to load ten train sets, i.e. 100 wagons. The resulting time is 2,164 minutes, which is less than five shifts. Out of the fifth shift, we need 365 minutes to complete the loading. As part of loading, 6,500t will be removed from the buffer, and 6,543t will be added.

Figure 6 Results of Experiment 3

The last experiment is Experiment 3. The performance of the continuous filling equipment is changed to 250 t/h. The time of the buffer filling by material for one wagon and the minimum amount of material in the buffer before loading depend on this value. Based on the calculation according to the formulas, the time of the buffer filling by material for one wagon was determined to be 15.6 minutes, and the minimum amount of material in the buffer before loading is 36t. The results of the experiment are shown in Figure 6.

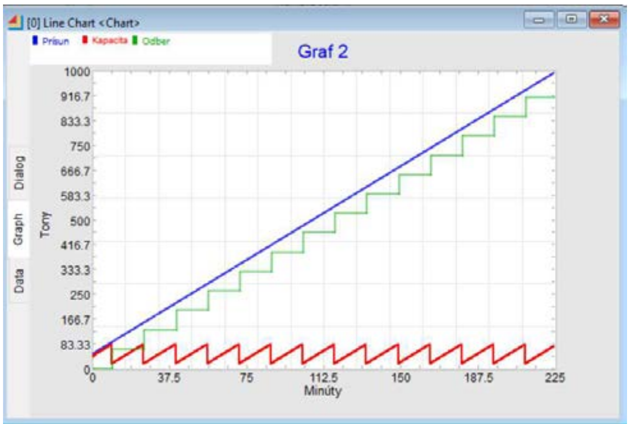

Figure 7 Results of Experiment 4

With such a change, 14 wagons from Experiment 1 can be filled in just 225 minutes.

4 Conclusions

By inserting the simulation into the algorithm for determining the capacity of bulk materials buffers, we can determine the capacity of the buffer by reading the values from the graph of supply and removal of material from and to the buffer relatively clearly. This graphic solution should be supplemented with a recalculation. When we subtract the maximum amount of material in the reservoir and convert it using the volumetric bulk density of the material into volume, the resulting value is the basis for determining the dimensions of the buffer.

The graphical results of the simulation show the correctness of the formulas used. Returning to the buffer's original value of the amount of material is considered an ideal state. In our experiments, we had deviations from the original value in the range of 10 to 20% after completion.

The application of simulation software in the process of determining the capacity of a bulk buffer eliminated the laborious drawing of graphs. Furthermore, it was possible to perform several experiments in a relatively quick time sequence, and the rapid change of parameters was immediately reflected in the graphs.

In addition to the mentioned experiments, buffers can be emptied into vehicles of different types and capacities. For example, different trucks with different capacities can be loaded. In this case, the arrival cycle of vehicles at the buffer must also be considered. In practice, there are also different approaches to filling or emptying the buffer. The simulation model can be easily adapted by correctly calculating the selected devices' data and inserting new parameters into the blocks.

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Meaning and functions of the specialized laboratory Testbed 4.0

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Keywords: Testbed, industry, technology.
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.

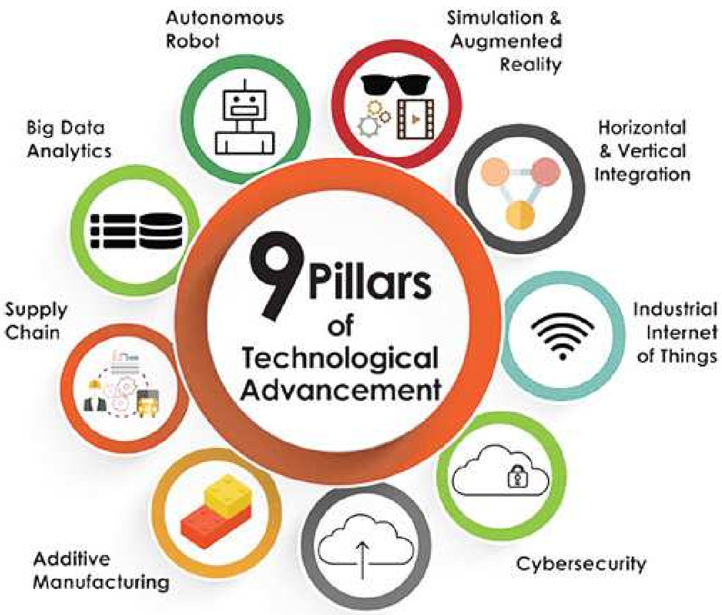

Figure 1 Pillars of industry 4.0

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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