Advances in Science and Technology
Research Journal

Advances in Science and Technology Research Journal, 2025, 19(6), 17–31
https://doi.org/10.12913/22998624/202552
ISSN 2299-8624, License CC-BY 4.0

Received: 2025.01.29
Accepted: 2025.04.15
Published: 2025.05.01

Optimization of production processes and tool utilization in industrial grinding operations

Peter Malega[1], Naqib Daneshjo[2*]

[1] Faculty of Mechanical Engineering, Technical University of Kosice, Slovak Republic
[2] Faculty of Commerce, University of Economics in Bratislava, Dolnozemska cesta 1, 852 35 Bratislava 5, Slovak Republic
* Corresponding author's e-mail: daneshjo47@gmail.com

ABSTRACT

This paper focused on an optimization of production processes in a tool-room with a specific emphasis on grinding operations. A main objective was to identify and implement approaches that enhance production efficiency, minimize downtime, and reduce manufacturing costs. Through an analysis of a current state of production processes, the key factors negatively affecting productivity were identified, including underutilization of tools and inefficient planning. The paper presents a methodology for evaluating a performance of production systems, which includes an use of a overall equipment effectiveness (OEE) tool and workflow analysis. On the basis of the collected data, specific improvements were proposed, such as the introduction of modern tools, optimization of workflows, and the implementation of sensor-based predictive maintenance. These measures resulted in a significant reduction in production downtime and an increase in workplace productivity. The results demonstrate that the proper combination of technical innovations, effective planning, and monitoring of production processes can lead to significant improvements in the performance of production systems. The contribution of this study lies in providing practical solutions that can be applied across various industrial sectors while highlighting the importance of integrating modern technological tools into production processes. This article is valuable for professionals in industrial production, quality management, and operations engineering who seek effective strategies for optimizing production operations and increasing the competitive advantage of their enterprises.

Keywords: production process, layout, optimization, simulation, grinding, diamond dresser.

INTRODUCTION

The aim of this article was to optimize the use of production equipment and the layout of the production hall in the production of flat thread jaws in the company. Another goal was to optimize the current state, increase productivity, optimize costs and the production process, as well as streamline production for the benefit of the company.

Every company tries to use their resources, machines, workers, technologies, procedures and methods the best possible. The ability of production companies to be successful and competitive under today's conditions requires the simultaneous improvement of three key factors: a flexibility growth, a quality improvement and the reduction of costs [1]. The processes and activities in the company that show signs of inefficiency need to be thoroughly analyzed and subsequently found as well as an appropriate optimization method has to be applied. Optimization of production processes is therefore currently one of the most common optimization tasks in production.

The complexity and intensity of a market environment forces companies to pay particular attention to improving operating conditions [2, 3]. The company has to work in such a way that transformation from input to output proceeds with optimal consumption of production inputs, optimal choice of production processes, instruments and optimal utilization of production capacity [4, 6]. At the same time, it must enable the company to compete, achieve economic goals and increase efficiency [7, 8, 9].

Literature review

The complexity and demands of the market environment compel companies to focus primarily on improving operational conditions. A company must operate in such a way that the transformation of inputs into outputs occurs with optimal consumption of production inputs, optimal selection of manufacturing processes, tools, and the optimal use of production capacity. At the same time, it must enable the company's competitiveness, the achievement of economic goals, and the improvement of efficiency.

The optimization of manufacturing processes is a key aspect of modern industry, which is continuously evolving to enhance efficiency, reduce costs, and improve product quality. Various authors have focused on different approaches and methods in this area. Jaydeep Karandikar [10] focused on the use of artificial intelligence and machine learning in the optimization of manufacturing processes. He addressed tool life prediction in milling using neural networks. Maleki and Amiri [11] discussed the simultaneous monitoring of process mean and variability using artificial intelligence. Prapatsorn Borisut [12] focused on process optimization using simulation and machine learning. He compared different sampling techniques for process modeling.

In the field of process optimization in the oil and gas industry, IT Okorocha et al. [13] addressed the challenges and optimization strategies in this area. Mourad Nouioua et al. [14] explored the optimization of machining process parameters for polymers using various methods. In addition, methods such as simulation, machine learning, data analysis, and advanced engineering techniques are often used in the optimization of manufacturing processes to enhance efficiency and quality. These approaches enable companies to better respond to dynamic market conditions and technological challenges. All these studies and approaches contribute to a better understanding and implementation of effective methods for optimizing manufacturing processes across various industries.

The focus was on production planning for weaving processes and optimization to help make decisions about batch sizing and production scheduling activities [15].

RESEARCH METHODOLOGY

Current production process in selected company

The production in a selected company is carried out in this way (Figure 1). On the expedition (Fig. 1i) comes an order from a customer at a certain quantity, dimensions, material, according to the customer's requirements and then is processed the technological method.

A material is delivered from the material stock (Fig. 1a), where it is also cut to dimensions that are larger about the allowance for the milling and grinding and the required number of pieces is cut. From this place, it goes to the milling machines (Fig. 1c), where it is milled to size and leaves the allowance for grinding. The worker on a department of technological control (Fig. 1b) checks the dimensional accuracy. The material is subsequently hardened in the hardening room (Fig. 1j) to the necessary hardness, which is there checked immediately whether it is within tolerance limits.

Then, the material goes to a flat grinding machine (Fig. 1d), where better surface roughness, parallelism of sides, perpendicularity and dimensional accuracy are achieved. After grinding, the grinder checks on the department of technological control (Fig. 1b), if it produces or does not produce scraps. The material is then transferred to the ELB 08 or ELB 10 (ELB covers the requirements for flat and profile grinding, Fig. 1e), where the desired thread with the necessary pitch is cut through the deep profile grinding. A worker then checks the dimensions of the first pair of threaded jaws on the department of technological control (Fig. 1b), specifically teeth height, teeth angles, radius, thread drop, chamfer, pitch, etc. Subsequently, a material is moved to the corner-rounding mill (Fig. 1f), where one or both sides are rounded on the jaws. The material continues into the tempering furnace (Fig. 1g), where it is tempered to remove the internal stresses and to achieve the necessary material toughness and the hardness that is achieved after the milling in the hardening furnace. After sufficient cooling, the material is sanded in the sandbox (Fig. 1h), the surface of the thread is roughened so that the produced screw does not slide during cold rolling.

After sanding, the jaws are demagnetized, then are described and preserved with the preservative oil and continue on the department of technological control (Fig. 1b) for the final inspection, where the thread dimensions, rounding, shrinkages, roughness, description according to the drawing are checked again if they are within the required tolerances.

After acceptance, the threaded roller jets continue to expedition (Fig. 1i) where they are packed, weighed and shipped to the customer. Flowchart of the current production process in the company is displayed in Figure 2. Current layout of production facilities in the selected company is shown in Figure 3.

The main production program of the company is focused on the production of threaded rolling dies (Figure 4, Dimension: M 18x1.0, Use: Steels up to 800 N/mm^2, Standard: DIN22568 round). They are produced by deep profile grinding with overall surface treatment, material treatment (hardening, rounding, chamfering, sandblasting and PVD and CVD surface treatments). They are used for the production of threaded connecting components in the automotive industry.

RESULTS

Proposals for optimization solutions will be specified in three basic areas.

Proposal 1

Financial analysis, the full version of which is not the part of this paper, shows that it is economic effective to replace ELB 08 and ELB

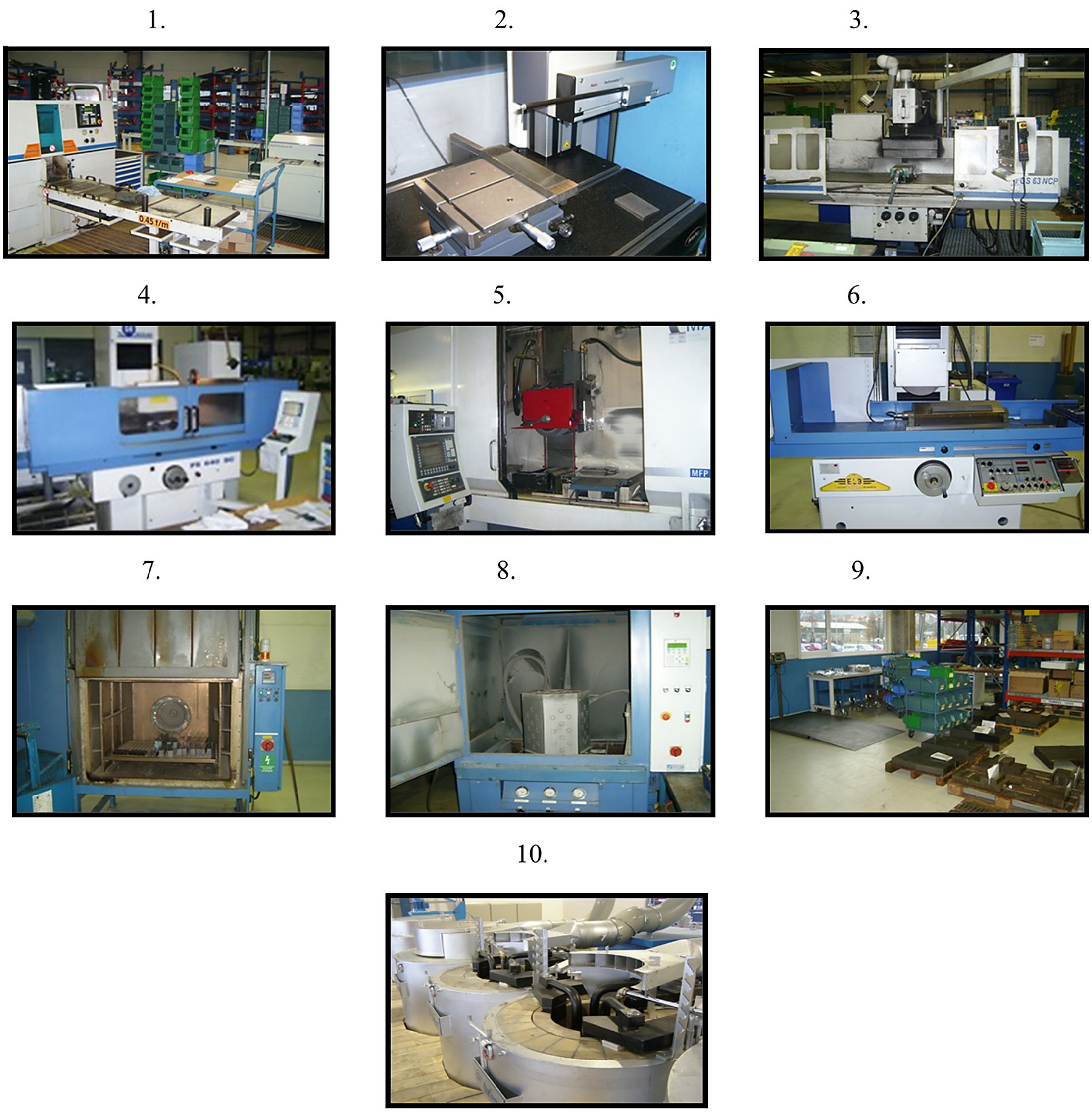

Figure 1. Individual workplaces in the production process

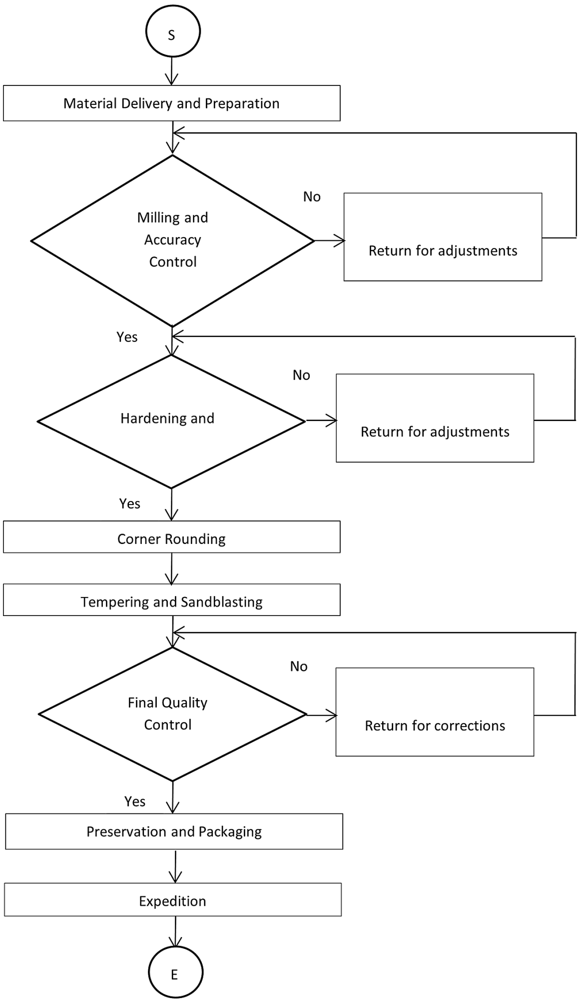

Figure 2. Flowchart of the current production process in the company

10 machines for Mägerle 125 machines (3 machines), because it increases efficiency and is also more cost-effective than the current situation. New layout with a Mägerle 125 is shown in Figure 5. Table 1 shows a number of pieces produced on individual machines, while on the 3rd Mägerle 125, only half of the pieces is machined, because this machine produces workpieces with dimensions that are necessary to machine twice. Expected operating costs related with the investment are summarized in Table 2. Expected revenue from sales related with the investment is summarized in Table 3. According to proposal 1, it is possible to say that the increasing of effectiveness will approximate 5.5%.

Proposal 2

The company uses circular saw blades of diameter 130 mm (Fig. 6a) and 160 mm (Fig. 6b) and diamond dressers to cut almost all jaw dimensions without z-axis displacement. Figure 6 is only the demonstration of diamond dressers.

By grinding a workpiece leans out by an angle (Table 4), which is given for the given pitch and the thread dimensions (Table 5).

To ensure lean out and angle underlay scales at the end of the workpiece that causes that a workpiece 405 × 160 mm on which the M10 × 2 thread will be ground, will need to be

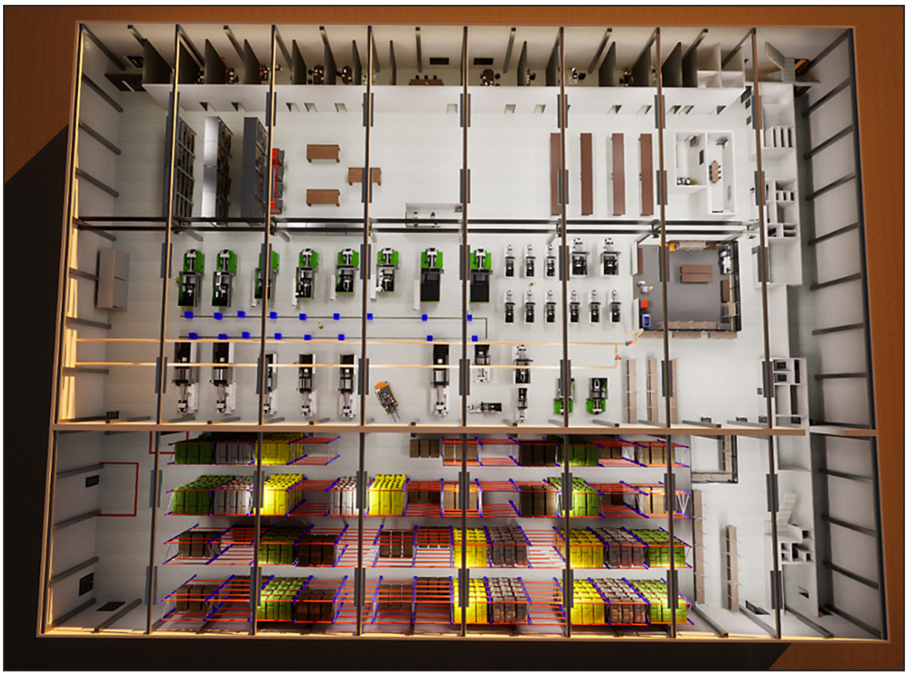

Figure 3. Current layout of production facilities

ground twice, because this dimension of the flat threaded jaws, after lean out for a given thread size and pitch, is wider than the width of the disc and dresser used by selected company. For example, at this dimension – at the beginning of the grinding – the workpiece has width of 160 mm, but at the end of the grinding, the side is lean out about an angle of 4 ° 14’22.3 “, i.e. the scale is 18.2876 mm long, then the side has a dimension of 178.2876 mm, so this size is cut twice. By grinding, the disc moves in the “z” axis, while the thread connection is important, the displacement in the tolerance is ± 0.005 mm. A power supply may be shifted in the “y” axis and the “z” axis, which is the most common power failure (Figure 7). The MarTalk measuring device is used for measuring dimensions and geometry, checking surface roughness, analyzing shape and position, checking threads and automated inspection. It uses precise sensors (e.g. optical, laser or mechanical) for measurement. The device includes specialized software for analyzing and evaluating the measured data. The measurement results can be displayed on the screen, stored in a database or exported to production systems.

Figure 4. Example of threaded rolling dies

Due to the power supply movement, there were a number of repairs that prolonged the production and delivery times. For the parts that are ground twice and are to be ground only once, a 180 mm wide disc is required, which is suitable for the Mägerle 180 and a 180 mm diamond dresser.

Figure 5. New layout according to proposal 1The following tables (Table 1–3) show an increase in productivity and efficiency resulting from a proposal 1

Table 1. Utilization of production capacity

Year	1st year	2nd year	3th year	4th year	5th year	6th year
Production capacity	65%	85%	85%	85%	85%	85%
1. Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
2. Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
3. Mägerle 125 (pcs)	5 952	7 784	7 784	7 784	7 784	7 784

Table 2. Expected operating costs

Year	1st year	2nd year	3rd year	4th year	5th year	6th year
Production capacity	65%	85%	85%	85%	85%	85%
1. Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
1. Mägerle 125 (€)	2 976 188	3 891 938	3 891 938	3 891 938	3 891 938	3 891 938
Grinding sets (€)	25 000	30 000	30 000	30 000	30 000	30 000
2. Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
2. Mägerle 125 (€)	2 976 188	3 891 938	3 891 938	3 891 938	3 891 938	3 891 938
Grinding sets (€)	25 000	30 000	30 000	30 000	30 000	30 000
3. Mägerle 125 (pcs)	5 953	7 784	7 784	7 784	7 784	7 784
3. Mägerle 125 (€)	1 488 094	1 945 969	1 945 969	1 945 969	1 945 969	1 945 969
Grinding sets (€)	25 000	30 000	30 000	30 000	30 000	30 000

Table 3. Expected revenue from sales

Year	1st year	2nd year	3rd year	4st year	5st year	6st year
Production capacity	65%	85%	85%	85%	85%	85%
1. Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
1. Mägerle 125 (€)	3 928 568	5 137 358	5 137 358	5 137 358	5 137 358	5 137 358
2. Mägerle 125(pcs)	11 905	15 568	15 568	15 568	15 568	15 568
2. Mägerle 125(€)	3 928 568	5 137 358	5 137 358	5 137 358	5 137 358	5 137 358
3. Mägerle 125(pcs)	5 952	7 784	7 784	7 784	7 784	7 784
3. Mägerle 125(€)	1 964 284	2 568 679	2 568 679	2 568 679	2 568 679	2 568 679

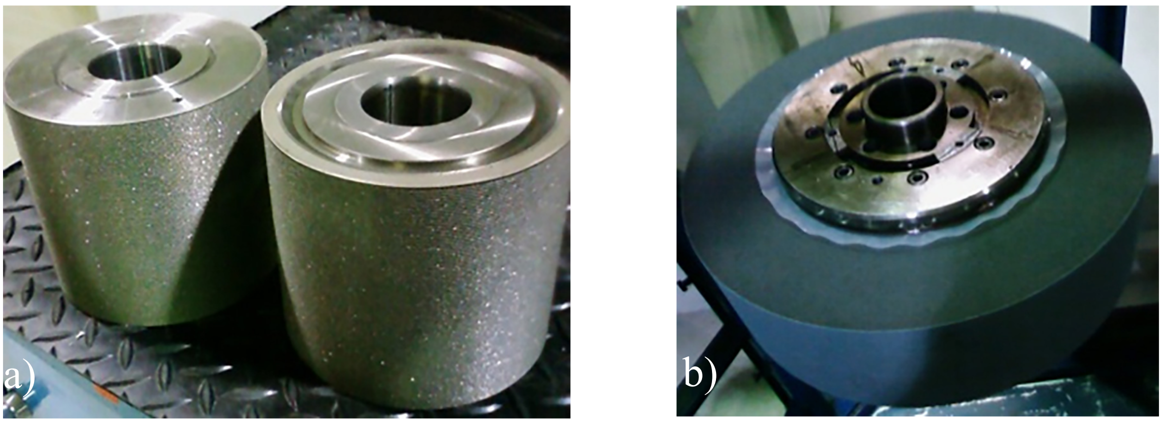

Figure 6. Diamond dressers a, 130 and b, 160, grinding wheel

Second optimization proposal

The second optimization proposal is the usage of a diamond dresser and a 180 mm wide disc. From Tables 4 and 5, it is concluded that when grinding these pieces once, a minimum width of the diamond dresser and the disc is required at 180 mm. The Mägerle company is able to produce a machine with the same technical parameters as the Mägerle 125, to which a diamond dresser and a 180 mm wide disc can be clamped. Exchanging the Mägerle 125 for the Mägerle 180 will require a new layout of the hall (Figure 8). Price category of this machine would be comparable to the price of the machine owned by the selected company. There was a problem with the production of diamond dressers with a length of 180 mm. A supply company that delivers diamond discs and dressers with their technological processes does not currently produce such diamond dressers in a required plane geometric dimensional tolerances needed by the selected company (Figure 9).

Table 4. Used scales for leans out of workpiece

Thread	Pitch	A	B	C	α*	Degrees	Hours	Minutes
		Mean	Setting the scale of the jig	Setting the location jig	Angle			
M3	0.5	12.172	7.828	15.364	3.48			
M3.5	0.6	12.549	7.451	15.775	3.59			
M4	0.7	12.824	7.176	16.069	3.67			
M5	0.8	11.562	8.438	14.717	3.31			
M6	0.75	8.782	11.218	11.735	2.52			
M7	0.75	7.419	12.581	10.27	2.13			
M8	0.75	6.421	13.579	9.198	1.84			
M6	1	12.094	7.906	15.288	3.46			
M7	1	10.165	9.835	13.219	2.91			
M8	1	8.766	11.234	11.717	2.51			
M8.5	1	8.202	11.798	11.111	2.35			
M9	1	7.706	12.294	10.578	2.21			
M10	1	6.874	13.126	9.684	1.97			
M11	1	6.205	13.795	8.964	1.78	a=tgα*200		
M12	1	5.655	14.345	8.374	1.62	b=20-α		
M14	1	4.803	15.197	7.456	1.38	c=tgα*215+2.35		
M17	1	3.917	16.083	6.503	1.12			
M7	1.25	13.054	6.946	16.315	3.74			
M8	1.25	11.215	8.785	14.345	3.21			
M9	1.25	9.831	10.169	12.86	2.82			
M10	1.25	8.92	11.08	11.883	2.55			
M11	1.25	8.021	11.979	10.917	2.3			
M12	1.25	7.178	12.822	10.011	2.06			
M14	1.25	6.082	13.918	8.832	1.74			
M24	3	8.726	11.274	11.674	2.5			
M27	3	7.675	12.325	10.545	2.2			
M30	3.5	8.088	11.912	10.989	2.32			
M10	1.5	10.704	9.296	13.797	3.07	3°	3´	45´´
M11	1.5	9.626	10.374	12.64	2.76			
M12	1.5	8.748	11.252	11.698	2.51	2°	30´	15´´
M13	1.5	8.014	11.986	10.91	2.3			
M14	1.5	7.394	12.606	10.243	2.12	2°	7´	3´´
M15	1.5	6.8576	13.1423	9.7377	1.9638	1°	57´	50´´
M16	1.5	6.403	13.597	9.178	1.83			
M18	1.5	5.647	14.353	8.364	1.62			
M19	1.5	5.331	14.669	8.025	1.53			
M20	1.5	5.05	14.95	7.722	1.45			
M22	1.5	4.567	15.433	7.203	1.31			
M24	1.5	4.17	15.83	6.775	1.19			
M26	1.5	3.834	16.166	6.414	1.1			
M27	1.5	3.686	16.314	6.255	1.06			
M12	1.75	10.367	9.633	13.47	2.97			
M14	1.75	8.742	11.258	11.691	2.5			
M10	2	14.8246	5.1754	18.2876	4.23952	4°	14´	22.3´´
M12	2	12.045	7.955	15.299	3.44669	3°	26´	48.1´´

M14	2	10.126	9.874	13.177	2.9			
M15	2	9.3859	10.614	12.4398	2.68694	2°	41´	13´´
M16	2	8.737	11.263	11.687	2.5			
M18	2	7.684	12.316	10.554	2.2			
M20	2	7.266	12.734	10.106	2.08			
M22	2	6.19	13.81	8.949	1.77			
M24	2	5.643	14.357	8.361	1.62			
M18	2.5	9.802	10.198	12.829	2.81			
M19	2.5	9.225	10.774	12.267	2.641	2°	38´	29´´
M20	2.5	8.728	11.272	11.676	2.5			
M22	2.5	7.866	12.134	10.75	2.25			

Table 5. Dimensions of threaded jaws (length × width)

Long threaded jaw	Short threaded jaw	Long threaded jaw	Short threaded jaw	Long threaded jaw	Short threaded jaw
255 × 105	230 × 105	258 × 130	235 × 130	313 × 85	283 × 85
220 × 38	194 × 38	220 × 50.8	194 × 50.8	260 × 85	235 × 85
210 × 55	190 × 55	260 × 105	235 × 105	258 × 90	238 × 90
130 × 55	115 × 55	258 × 50	233 × 50	258 × 105	230 × 105
250 × 153	230 × 153	210 × 105	190 × 105	220 × 63.5	194 × 63.5
258 × 100	233 × 100	174 × 66	150 × 66	260 × 108	235 × 108
149 × 38.1	130 × 38.1	315 × 127	285 × 127	220 × 40.5	190 × 40.5
315 × 105	285 × 105	210 × 63	190 × 63	255 × 52	235 × 52
240 × 105	230 × 105	220 × 16	194 × 16	220 × 63	194 × 63
220 × 76.2	194 × 76.2	255 × 153	230 × 153	258 × 125	235 × 125
220 × 50	190 × 50	405 × 160	380 × 160	175 × 80	155 × 80
220 × 100	194 × 100	255 × 105	230 × 105	220 × 105	200 × 105
174 × 45	155 × 45	255 × 52.5	230 × 52.5	174 × 38	155 × 38
255 × 50	230 × 50	315 × 140	285 × 140	260 × 80	235 × 80
179 × 50.8	155 × 50.8	258 × 90	233 × 90	250 × 105	230 × 105
200 × 20	180 × 20	210 × 83	190 × 83	200 × 30	180 × 30
220 × 44.5	194 × 44.5	405 × 115	380 × 115	130 × 40	115 × 40
313 × 85	283 × 85	255 × 52.5	230 × 52.5	175 × 80	155 × 80
210 × 50	190 × 50				

As a result of this problem, the considered supply company is not in a position to determine the exact production costs as well as the total amount of this dresser. Following tables (Tables 6–9) show the values according to proposal 2.

In Table 6 is utilization of production capacity according to proposal 2. The expected operating costs (Table 7) have increased due to the increase in material consumption and a higher price of a 180 mm grinding wheel and a 180 mm diamond dresser.

Expected revenue from sales (Table 8) increased automatically as a result of increased production.

Proposal 3

Further optimization of the proposal 2 is related to the synchronization of machine work for flat sectional grinding. Work synchronization on these three machines requires, the production times of individual jaws. To calculate the individual times, the mathematical-regression method of dependence was used to obtain the formulas for a simple time calculation for individual lengths, dimensions, pitch threads and materials. Furthermore, it is necessary to know the time of complete setting, where the thread size and pitch change, e.g. from M12×1 to M16×1.5. The

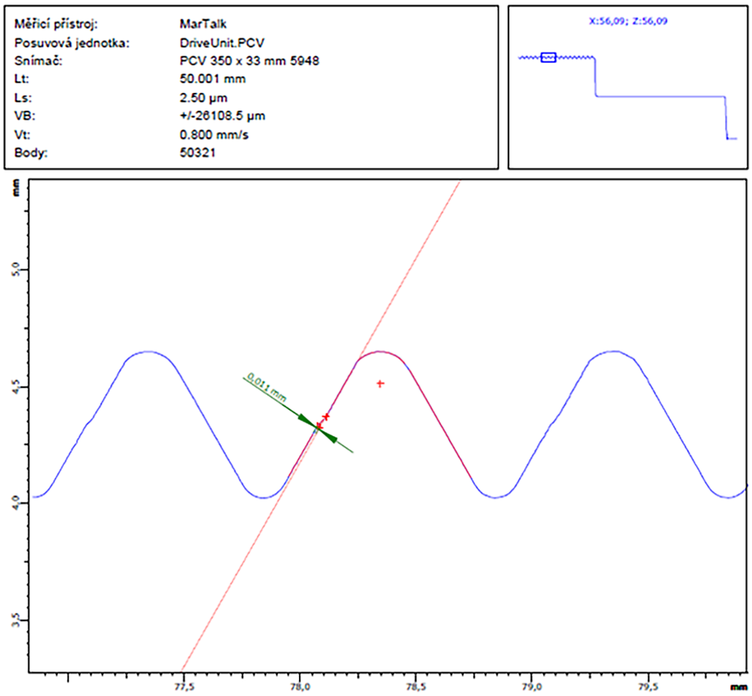

Figure 7. Power failure effect in the “z” axis”

Figure 8. New layout according to proposal 2

length of this setting depends mainly on the skill of the operator and takes about 100 minutes in average. The next setting time is the time when the size changes, but the pitch is the same, e.g. M12×1.5 to M16×1.5, where only the deflection angle is changed, i.e., the scale changes and the first tooth is set, which takes about 15 minutes. The necessary information is the workpiece replacement time, which ranges 1 to 2 minutes, depending on the size of the workpiece. Finally, the number of orders, the size of the orders and the delivery date of the orders are solved by applying Kanban cards. Kanban cards determine the order of importance.

The most advantageous situation will be: Mägerle 180 will produce threaded jaws, which at that time will be ground twice, i.e. 450 × 160 mm with a pitch of 1.75 and 2 mm. The most commonly ground pitch is a 1.5 mm pitch, which will be ground on one Mägerle 125 eventually also 1.75 mm pitch. On the third machine, will be ground 1.0 and 1.25 mm pitch, eventually 1.5 mm.

Empirical design method was used on the example flat threaded jaws production on two Mägerle 125 machines and one Mägerle 180

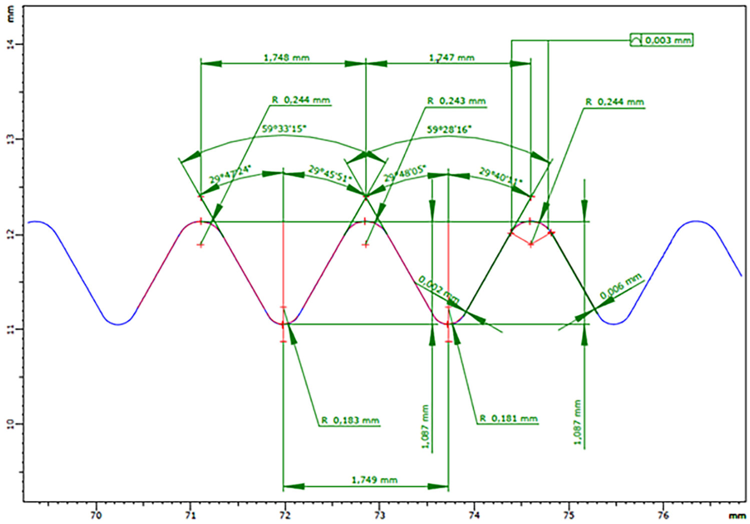

Figure 9. Geometric profile and shape of the tooth for the required diamond dresser

Table 6. Utilization of production capacity

Year	1st year	2nd year	3rd year	4st year	5st year	6st year
Production capacity	65%	85%	85%	85%	85%	85%
Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
Mägerle 180 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568

Table 7. Expected operating costs

Year	1st year	2nd year	3rd year	4th year	5th year	6th year
Production capacity	65%	85%	85%	85%	85%	85%
1. Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
1. Mägerle 125 (price of the material in €)	2 976 188	3 891 938	3 891 938	3 891 938	3 891 938	3 891 938
Grinding sets (€)	25 000	30 000	30 000	30 000	30 000	30 000
2.Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
2.Mägerle 125 (price of the material in €)	2 976 188	3 891 938	3 891 938	3 891 938	3 891 938	3 891 938
Grinding sets (€)	25 000	30 000	30 000	30 000	30 000	30 000
Mägerle 180 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
Mägerle 180 (price of the material in €)	2 976 188	3 891 938	3 891 938	3 891 938	3 891 938	3 891 938
Grinding sets (€)	35 000	42 000	42 000	42 000	42 000	42 000

machine (Figures 10 and 11). Fig. 8 presents an empirical simulation of machine start-up from the proposal 2, i.e. Mägerle 125, Mägerle 125 and Mägerle 180. Mägerle 125 is set at 100 minutes, which is the time for the complete machine setting, second Mägerle 125 and Mägerle 180 are stopped following these 100 minutes. After first Mägerle 125 is started, it is set second Mägerle 125, which also takes 100 minutes, and 12 minutes is the time for changing the workpieces on the first Mägerle, it takes 112 minutes totally, while the third Mägerle is stopped another 112 minutes. After the second Mägerle setting it is started and the third Mägerle is set, which takes 100 min. Changing the workpieces on first Mägerle (12 min) and second Mägerle (6 min) takes 18 minutes. After setting all three machines, the workpiece

Table 8. Expected revenue from sales

Year	1st year	2nd year	3rd year	4th year	5th year	6th year
Production capacity	65%	85%	85%	85%	85%	85%
1.Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
1.Mägerle 125 (price of products in €)	3 928 568	5 137 358	5 137 358	5 137 358	5 137 358	5 137 358
2.Mägerle 125 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
2.Mägerle 125 (price of products in €)	3 928 568	5 137 358	5 137 358	5 137 358	5 137 358	5 137 358
Mägerle 180 (pcs)	11 905	15 568	15 568	15 568	15 568	15 568
Mägerle 180 (price of products in €)	3 928 568	5 137 358	5 137 358	5 137 358	5 137 358	5 137 358

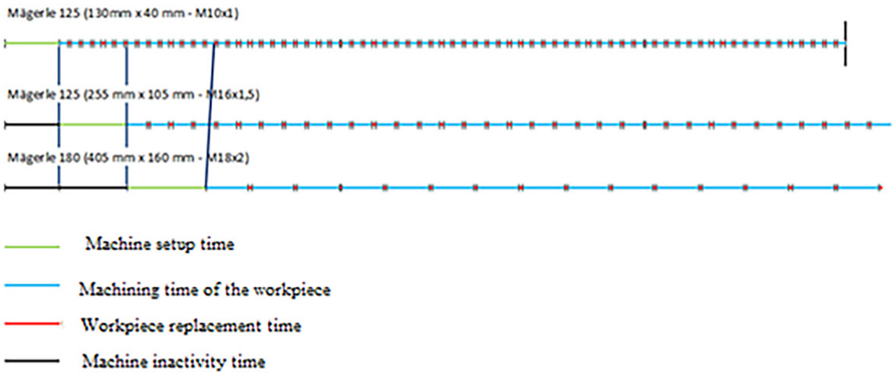

Figure 10. Empirical simulation of machine start-up 1

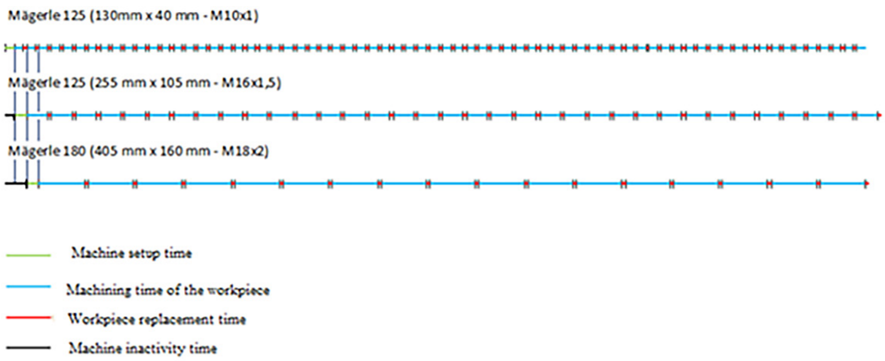

Figure 11. Empirical simulation of machine start-up 2

cycle is repeated until orders or new machine re-alignments are completed.

Figure 9 shows a similar situation as Figure 8, except that at the beginning there is only a partial adjustment of the machines, which takes only 15 minutes. For a size of monthly orders, it would be time consumption to find optimum order layout for the three machines using the empirical method to avoid long stoppages. Nowadays, there a lot of software is used for modeling simulations of production system, such as Witness software. With this simulation system in full version, it is possible to optimize the production process after setting a necessary parameters, such as machine setting times, adjustment times and single-time production times, workpiece replacement time, order number, order size, etc. The above-mentioned simulation was solved through empirical method. This problem can be also solved with the Witness software, which is shown in Figure 12. The full version of this software also includes optimization software, which, after placing orders for the entire month and defining a particular queue, e.g. delivery time in orders, determination of pitch on individual machines, then generates optimal order distribution on machines with minimal stoppages. This simulation system is mainly used to remove bottlenecks on production lines, production optimization, and workers movement, by conducting the investigation of devices and workers utilization [5]. The statistics generated by the Witness software for this case are in Table 9 (operator statistics), Table 10 (machine stats) and Table 11 (component stats).

Benefits of proposals

The first proposal deals with an efficiency increasing and cost-effectiveness comparison to the current state, i.e. replacing ELB 08 and ELB 10 with Mägerle 125 machines. Despite the increased operating costs, when comparing the net profit of the current state and the net profit of the proposed situation, it was found that proposal 1 will increase net profit by 45% per year, which is an acceptable percentage for this proposal. Proposal 2 solves the issue of grinding workpieces

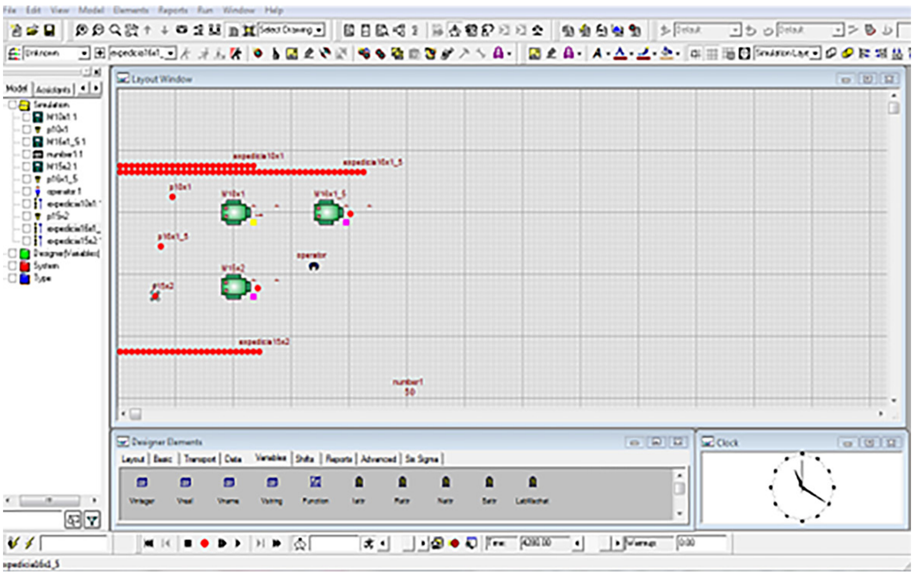

Figure 12. Simulation created using Witness software

Table 9. Operator stats

Title	Activity, %	Inactivity, %	Amount	Number of started operations	Number of completed operations	Number of operations actually conducted	Number of preferred operations	Average number of operations
Operator	100.00	0.00	1	155	155	0	0	27.61

Table 10. Machine stats

Type of component	M10×1	M16×1.5	M18×2
Activity, %	0	0	0
Inactivity, %	17.52	16.12	12.62
Compliance	0	0	0
Emptying	0	0	0
% blocked	0	3.74	20.09
Cycle/Stroke waiting for the operator	56.89	40.65	25.23
Machine setup, %	21.03	18.69	14.02
Machine setup waiting for the operator, %	4.56	20.79	28.04
Waiting for repair, %	0	0	0
Number of operations/actions	50	46	36

Table 11. Component stats

Title	M10×1	M16×1.5	M18×2
Number of entered items	50	46	36
Number of shipped items	0	0	0
Number of deleted items	0	0	0
Number of assembled items	0	0	0
Number of rejected items	0	0	0
In-process items	50	46	36
Average number of in-process items	22.49	22.22	20.96
Average time	1925.2	2067.83	2492.5
Sigma classification	0	0	0

with dimensions that have to be ground on the Mägerle 125 twice, already counting with the established proposal 1. The solution to this problem is aimed at replacement of the Mägerle 125 machine with Mägerle 180. Table 12 and Figure 13 show the comparison of net profits in the current state, proposal 1 and proposal 2.

Despite the increased operating costs, when comparing the net profit from proposal 1 and the net profit from proposal 2, it was found that proposal 2 will increase net profit by 30% per year. Compared to the current state, net profit through proposal 1 and proposal 2 will increase by 85% per year as it is shown in Table 12 and Figure 13. The third proposal is related with the synchronization of work on machines for plane sectional grinding. The proposal recommends modernization of selected company by purchasing optimization software, such as Lanner's Witness Software.

DISCUSSION

The paper focused on the optimization of manufacturing processes, a crucial aspect for

Table 12. Comparison of net profits

Status	Machines	Net profit in 1. year in €	Net profit in 2. year in €	Net profit in 3. year in €	Net profit in 4. year in €	Net profit in 5. year in €	Net profit in 6. year in €
Current state	M125 + ELB08 + ELB 10	1 012 376	1 500 924	1 498 882	1 496 741	1 494 494	1 492 137
Proposal 1	M125 + M125 + M125	1 512 723	2 163 859	2 163 307	2 162 734	2 162 137	2 161 516
Proposal 2	M125 + M125 + M180	1 978 915	2 774 570	2 774 018	2 773 445	2 772 848	2 772 228

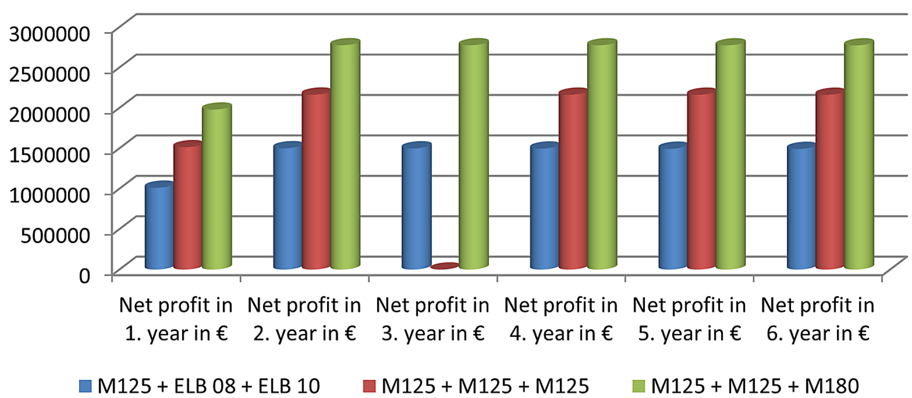

Figure 13. Graphical comparison of net profits

ensuring efficiency, cost reduction, and product quality in modern production environments. However, future research in this area could extend to exploring the integration of emerging technologies such as predictive maintenance powered by artificial intelligence (AI). Predictive maintenance, which uses machine learning algorithms to predict when equipment will fail, has the potential to significantly reduce downtime and maintenance costs. As AI continues to evolve, its application in predictive maintenance could play a key role in enhancing the reliability and efficiency of manufacturing systems. Future studies could investigate the impact of advanced automation on production efficiency, flexibility, and cost-effectiveness. Automation technologies will likely continue to evolve and integrate with AI, further enhancing the ability of manufacturing companies to respond to dynamic market conditions and improve overall productivity.

The ongoing evolution of manufacturing processes and technologies suggests that the future will bring significant changes in how optimization is approached. Researchers and practitioners alike will need to closely monitor the development of these new technologies and their integration into existing production systems. This will require a deeper understanding of the synergies between AI-driven predictive maintenance, advanced automation, and traditional optimization techniques. The continuous advancement in these areas will shape the future of manufacturing and offer new opportunities for improving operational efficiency and competitiveness in the global market.

CONCLUSIONS

Findings of this study underscore the critical importance of optimizing production processes to achieve higher efficiency, reduce downtime, and minimize costs in industrial tool-room operations. By employing advanced methodologies, such as Overall Equipment Effectiveness (OEE) and workflow analysis, this research has identified key inefficiencies and provided actionable solutions tailored to modern manufacturing needs. The introduction of modern tools, predictive maintenance, and optimized workflows has demonstrated measurable improvements in productivity and operational performance. This research emphasized the necessity of integrating modern technologies, such as sensor-based monitoring and data-driven decision-making, into production systems. These innovations not only enhance operational reliability but also provide a flexibility needed to respond to dynamic market demands. The adoption of predictive maintenance strategies further highlights the value of proactive approaches in mitigating unexpected breakdowns and ensuring uninterrupted production. Additionally, this study highlighted the broader implications of production system optimization. Beyond cost savings and increased productivity, these measures contribute to sustainable manufacturing practices by reducing waste and improving resource efficiency. This aligns with global trends in manufacturing, where sustainability and innovation are becoming key drivers of competitiveness.

In conclusion, the results of this study provide a valuable framework for professionals and industry leaders seeking to improve production performance in a competitive environment. The strategies presented here are not only practical but also scalable, making them applicable across diverse manufacturing sectors. Future research could explore further integration of advanced technologies, such as artificial intelligence and machine learning, to push the boundaries of production efficiency and innovation. A significant contribution of this research is the identification of key inefficiencies in current manufacturing processes and the design of concrete solutions based on modern tools such as sensor technology and data-driven decision-making. The results show that the implementation of these innovations significantly increases the performance of manufacturing systems, not only in terms of productivity, but also sustainability. This research provides a framework for professionals and industry leaders to improve manufacturing performance, while opening up new possibilities for the further development of technologies such as artificial intelligence and machine learning in the field of manufacturing optimization.

Acknowledgements

This work has been supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic (project VEGA 1/0064/23, KEGA 003EU-4/2025, KEGA 003TUKE-4/2024 and VEGA 1/0383/25).

REFERENCES

1. Sabadka, D., Molnar, V., Fedorko, G. The use of lean manufacturing techniques–SMED analysis to optimization of the production process. Advances in Science and Technology. Research Journal. 2017; 11(3): 187–195. https://doi.org/10.12913/22998624/76067
2. Weichert, D., Link, P., Stoll, A., Rüping, S., Ihlenfeldt, S., & Wrobel, S. A review of machine learning for the optimization of production processes. The International Journal of Advanced Manufacturing Technology. 2019; 104(5): 1889–1902. https://doi.org/10.1007/s00170-019-03988-5
3. Nektegyaev, G. G., Borisov, A. I. Ways of automation and optimization of measuring instruments. In IOP Conference Series. Materials Science and Engineering. 2020; 862(4): 042052. https://doi.org/10.1088/1757-899X/862/4/042052
4. Song, Y. Design and optimization of thermal instruments: Comparing traditional and modern technologies. Journal of Electrotechnology. Electrical Engineering and Management. 2023; 6(5): 45–50. https://doi.org/ 10.23977/jeeem.2023.060506
5. Yasir, A. S. H. M., Mohamed, N. M. Z. N. Assembly line efficiency improvement by using WITNESS simulation software. In IOP Conference Series: Materials Science and Engineering. 2018; 319(1): 012004. https://doi.org/10.1088/1757-899X/319/1/012004
6. Vysocký, T., Marcinčinová, NĽ., Marcinčinová, NE. Simulation as a designed tool for material flow analysis by means of Witness Horizon. In MATEC - EDP Sciences - Web of Conferences. 2023; 137: 01020. https://doi.org/10.1051/matecconf/201713701020
7. Wells, S., Tamir, O., Gray, J., Naidoo, D., Bekhit, M., Goldmann, D. Are quality improvement collaboratives effective? A systematic review. BMJ quality and safety. 2018; 27(3): 226–240. https://doi.org/10.1136/bmjqs-2017-006926
8. Dohale, V. D., Akarte, M. M., Verma, P. Determining the process choice criteria for selecting a production system in a manufacturing firm using a Delphi technique. In 2019 IEEE international conference on industrial engineering and engineering management. 2019; 1265–1269. https://doi.org/10.1109/IEEM44572.2019.8978820
9. Röder, A., Tibken, B. A Methodology for modeling inter-company supply chains and for evaluating a method of integrated product and process documentation. European Journal of Operational Research. 2006; 169(3): 1010–1029. https://doi.org/10.1016/j.ejor.2005.02.006
10. Drouillet, C., Karandikar, J., Nath, C., Journeaux, A. C., El Mansori, M., Kurfess, T. Tool life predictions in milling using spindle power with the neural network technique. Journal of Manufacturing Processes, 2016; 22, 161–168. https://doi.org/10.1016/j.jmapro.2016.06.003
11. Maleki, M. R., Amiri, A. Simultaneous monitoring of multivariate-attribute process mean and variability using artificial neural networks. Journal of Quality Engineering and Production Optimization. 2015; 1(1), 43–54. https://doi.org/10.1080/25728406.2015.1112673
12. Borisut, P., Nuchitprasittichai, A. Optimization of methanol production via CO_2 hydrogenation: comparison of sampling techniques for process modeling. In IOP Conference Series: Materials Science and Engineering. 2020; 778(1), 012088. IOP Publishing. https://doi.org/10.1088/1757-899X/778/1/012088
13. Okorocha, I. T., Chinwuko, C. E., Mgbemena, C. E., Mgbemena, C. O. Gas lift optimization in the oil and gas production process: a review of production challenges and optimization strategies. International Journal of Industrial Optimization, 2020; 1(2), 61. https://doi.org/10.1007/s11595-020-0237-x
14. Chabbi, A., Yallese, M. A., Nouioua, M., Meddour, I., Mabrouki, T., Girardin, F. Modeling and optimization of turning process parameters during the cutting of polymer (POM C) based on RSM, ANN, and DF methods. The International Journal of Advanced Manufacturing Technology, 2017; 91, 2267–2290. https://doi.org/10.1007/s00170-016-9316-7
15. Ferro, R., Cordeiro, G. A., Ordóñez, R. E., Beydoun, G., Shukla, N. An optimization tool for production planning: A case study in a textile industry. Applied Sciences. 2021; 11(18), 8312 https://doi.org/10.3390/app11188312