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# Multicriteria Optimisation of Machining Operations Using a Spreadsheet Model

Borut Buchmeister*, Iztok Palcic, Robert Ojstersek, Klemen Kovic, Aljaz Javernik

**Abstract:** The rapid development of new materials and tools demonstrates the need for efficient and feasible machining processes. Modern production systems must guarantee sustainable, flexible, productive and high-quality production at low cost. Therefore, the combination of technological data with advanced software solutions is very important, especially when using complex CNC machining systems, where the reliability of the technological information is crucial, as simple measures can make a very positive contribution to the productivity achieved. When optimising the machining parameters, costs and machining time must be taken into account. The article deals with the optimisation of the turning process with a large number of influencing variables (machine, workpiece material, tool, cutting parameters, costs, etc.) and two objectives: the fastest possible machining (minimisation of machining time) and the lowest possible machining costs. The model is designed in an Excel spreadsheet and the multi-criteria optimisation is carried out using the approximation method. Step by step, we can find the optimal processing regime for each selected case.

**Keywords:** cost; cutting parameters; machining; optimisation; time

## 1 INTRODUCTION

Technological progress is one of the most important development issues. The process that was called the "industrial revolution" in the 19th century because of the key role of industry was called the "scientific-technological revolution" in the 20th century because of the decisive role of science and the development of technology. In the 21st century, automation and computer programmes are gaining ground and replacing traditional machines. This is why we speak of an ongoing "information revolution" that has catalysed the evolution from Industry 4.0 to the emerging frontiers of Industry 5.0, reshaping the global economy.

Accelerated advances in computer, telecoms and information processing technology are enabling real economies of scale in service offerings and technology transfer. There are more and more new suppliers on the world market, the age of globalisation has virtually eliminated the importance of geographical distances, and response times are very short due to customer requirements.

Industrial processes are carried out in computer-integrated and flexible production systems that prioritise the quality of human resources and are designed to be sustainable and adaptable to new conditions at low cost. Rapid advances in the life sciences are also changing the demographic profile of the population and increasing human performance in all age groups.

The latest knowledge in the field of machining techniques opens up opportunities for the industry to successfully adapt to new conditions at a time when much knowledge is needed to reduce the gap with the most developed economies. Compliance with international standards is the key to the global market, so we must give this aspect our full attention. In order to be able to machine the increasingly complex workpieces economically, all process parameters must be adapted to the task at hand [1]. Those who master these challenges will remain competitive on the global market.

All processing companies face the same challenge: processing raw materials into an end product in the right quality, quantity and within the right time frame. Near net shape raw materials are crucial as they minimise waste and streamline production, optimising efficiency and reducing costs. Sustainability and environmental aspects must also be taken into account without compromising competitiveness and profitability. A perfect example of today's process improvement efforts is Industry 4.0, which includes cutting-edge technology for capturing, storing and sharing manufacturing process data [2]. For companies with smaller capacities compared to global giants, increasing productivity often seems out of reach. However, simple, low-cost analyses and measures can have a very positive impact on the productivity of SMEs.

Machining plays an important role in the manufacturing industry and the optimisation of cutting parameters is a key component in the planning of machining processes. This is also confirmed by the abundance of research publications [3]. The cutting tool is directly involved in the optimisation process and is the first element of renewal when the technology changes. The tool must be correctly selected according to the machine's limit capacities in order to achieve the required productivity, quality and low costs. Optimal solutions are only possible if all factors influencing the cutting process are taken into account, creating the most suitable cutting conditions. It is necessary to ensure the best possible combination of process parameters for stable operation of the process within the product requirements.

The profitability of cutting processes is based on the production costs per product [4]. There is a non-linear cost relationship between chip volume per unit of time and tool life. A higher chip volume per unit of time generally increases productivity more, as the machining costs increase. Optimisation begins with the choice of cutting speed, which can be determined according to the tool manufacturer's guidelines, with in-house tests (which are associated with high costs) or with the recalculation of the durability/cutting speed curves for the combinations of machined material – tool – cutting material. In our daily work, we often do not have the capacity to analyse production processes and optimise them for even greater efficiency. We also often do not have enough time to adapt new cutting materials, tool geometries or process technologies to individual machining tasks.

Manufacturers today face a number of new challenges in terms of ensuring sustainability and environmental protection, which are being solved with new technologies and processes [5, 6]. Dry processing, for example, helps to reduce the use of coolants, which has less impact on the environment and lowers costs. The increasing use of lead-free raw materials etc. also avoids the impact of hazardous metals on the environment. Optimised processing parameters also mean energy savings [7].

## 2 PROCESS OPTIMISATION

The general budgeting approach in manufacturing companies is to procure all necessary elements at the lowest possible price. However, low price alone is not the best basis for choosing a tool, as the end result (product quality, processing time) should also be taken into account. We are also bound by practical constraints, such as the strength and stability of the machine, dimensional tolerance requirements, surface roughness, etc. It should be emphasised that it is not necessary to exceed the requirements in the product specifications.

Depending on the number of tool geometries, their sizes and materials, the number of possible configurations of cutting tools is practically infinite. In the workshops, decisions are usually made on the basis of single operations, mainly one tool for each shape (detail) on the workpiece.

Manufacturers try to reduce processing times (with increased cutting parameters) but neglect other activities that increase product lead times (downtime due to tool failure, poor quality, inadequate chips, etc.). Factors affecting total processing costs include tools or tooling systems, workpiece materials, processes, personnel, organisation, maintenance, equipment; there are also many random influences.

### 2.1 Selection of Machining Parameters

After deciding on the working method and selecting the appropriate tool, the machining parameters must be determined: cutting speed, feed rate and depth of cut [6]. Higher values for these parameters mean higher productivity, higher tool wear and higher tool costs (and vice versa).

Economic aspects are decisive for the cutting speed. In principle, we want to work at the lowest possible cost when there is no rush. In rough machining, we are limited by the power and rigidity of the machine tool, the properties of the cutting tool and the strength of the workpiece. Of course we want to utilise the power, but not at the expense of permanent deformation of the machine, the tool or the workpiece. The aim of roughing is to remove as much material as possible in a unit of time at as little cost as possible, and the cutting parameters chosen are as high as the machine, cutting tool and workpiece will allow [8]. In fine machining, we want to achieve the appropriate dimensions and surface quality of the workpiece [9]; all the machining parameters mentioned above as well as the geometry of the cutting insert, the lubricant, etc. have a significant influence. The machining parameters must be selected so that the required machining accuracy is achieved, the capacity of the machine is utilised and thus the machining costs are reduced. In general, we only maintain relatively high cutting speeds.

Detailed calculations are required for larger batches, as this is economically justifiable. For small batches, detailed analyses are more expensive than the savings or benefits, so in this case the use of general guidelines and experience prevails.

### 2.2 Modelling of Turning Process

Turning is a continuous cutting process with a single cutting edge and a constant chip cross-section that is mainly used for the manufacture of round products. Turning is categorised as a conventional machining process, which means that we know the geometry of the workpiece and the tool [10]. Longitudinal turning, in which the direction of the feed motion is parallel to the axis of the workpiece, and transverse turning, in which the direction of the feed motion is perpendicular to the direction of the workpiece, are predominant (Fig. 1).

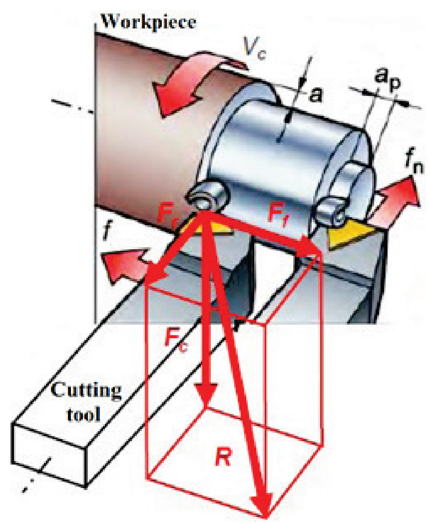


**Figure 1** Presentation of longitudinal and face turning process and cutting forces

Optimisation is about finding the optimum cutting parameters in terms of costs and processing time, as this is the only way to achieve the maximum technical and economic effect with the available manpower, machines and tools. If there is sufficient capacity and there is no rush, we look for the cheapest machining; if costs are less important and you are in a hurry or there are bottlenecks, we look for the fastest machining (highest productivity). Another goal of optimisation can be to maximise the profit margin on processing. The processing costs are extremely important as they must be lower than the added value in order to make a profit [11].

The existing optimisation models are based on the selection of the optimum cutting speed and its influence on the optimised variables as shown in Fig. 2.

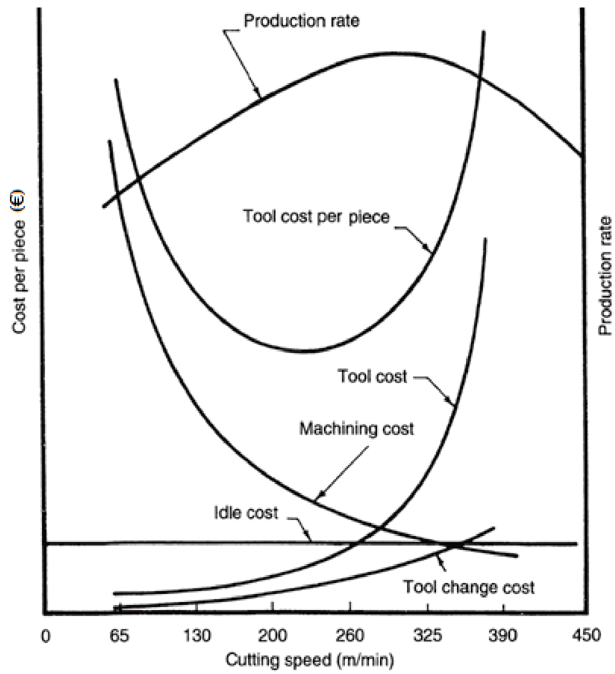


**Figure 2** Effect of cutting speed on machining costs and productivity [12]

In this article, we therefore aim to provide an extended model that comprehensively addresses the cutting process in terms of machining parameters and machining economics (the area of interest is circled in Fig. 3).

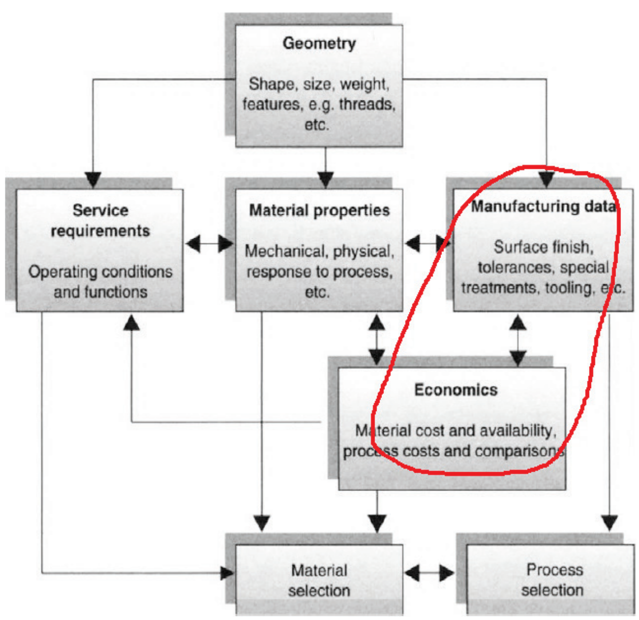


**Figure 3** Factors of material selection and technological processes [13]

After choosing the machining method and tool, we need to make an important decision regarding three process parameters: cutting speed, feed rate and depth of cut [14]. To calculate the cutting speed, we use the extended Taylor equation [12] for turning with uncoated turning tools:

$$v_c T_L^n a^q f^p = C_v V_B^m K_{mv} K_\tau , \qquad (1)$$

where: $v_c$ – cutting speed (m/min); $T_L$ – tool life (min); $n$ – exponent of tool life; $a$ – depth of cut (mm); $q$ – exponent of depth of cut effect; $f$ – feed rate (mm); $p$ – exponent of feed effect; $C_v$ – constant, the equivalent of cutting speed with one minute of tool life; $V_B$ – flank wear value (mm); $m$ – exponent of tool wear effect; $K_{mv}$ – coefficient of material hardness; $K_\tau$ – coefficient of tool cutting edge angle.

The basic assumptions and limitations of the model are:

- a stable lathe – the rigidity or robustness of the machine is adequate,
- good maintenance condition of the machine,
- the positioning accuracy is less than 0.01 mm,
- clamping of workpieces from one side is possible up to a maximum length : diameter ratio of 2 : 1,
- a steady rest and a tailstock are available for long or thin-walled workpieces,
- the clamping point for the tool is stable, with minimal overhang,
- the edges and radii of the workpiece are properly bevelled, ensuring smooth entry and exit of the tool,
- the durability of the tool corresponds to the manufacturer's specifications,
- the foundation of the machine is stable – to avoid vibrations from other machines,
- the system also has uncontrolled influencing variables (undesirable sources of variability), such as changes in the quality of the material of the workpiece and tools, variations in temperature and humidity in the room (environmental influences), etc.

The model was created in an MS Excel spreadsheet and contains the following variables and valid (generally known) relationships between them:

- Workpiece: rough (initial) diameter, finished diameter, length of step (cut), number of passes (cuts), depth of cut, feed, Taylor constant and exponents, batch size, yield, manipulation time.
- Machine tool: operating cost per hour, operator's salary, effective power, machine set-up time, unplanned downtime.
- Cutting tool: toolholder cost, insert cost, number of cutting edges, maximum allowed wear (VB), maximum tool life (carbide quality), tool set-up time, insert index time.

The **steps** of our simple optimisation process are:

1) Initial calculation of the parameters to check the suitability of the machine tool.
2) Multi-stage calculation of the possible number of passes, taking into account the insert constraints and the performance of the machine tool.
3) Selection of the best result and definition of the final cutting speed with approximation to the limit values.

The results of the model calculation include: maximum cutting speed due to power limits, optimal cutting speed, tool life, machining cost and total production time per batch.

The optimisation of the cutting parameters is carried out using the example of longitudinal turning of a cylindrical step. The aim of the optimisation is to find machining conditions in which minimum machining costs and minimum machining time (maximum productivity) are achieved at almost the same cutting speed. We tolerate up to 2.5 % deviation from the optimum.

## 3 APPLYING THE MODEL TO THE SELECTED CASES

### 3.1 Case 1 – Turning on Conventional Universal Lathe

The workpiece material is a special low-carbon structural steel EN 6CrMo15-5 (Ravne CT194), which is normally used for gears, crankshafts, etc. Other related data for the example: Taylor constant and exponents ($C_v$, $m$, $n$, $p$, $q$) are 331, 0.46, 0.20, 0.25 and 0.1; $K_{mv}$ is 1.13, $K_\tau$ is 0.80.

Toolholder cost is 130 €, ISO code: DCLNR3225P16; insert cost is 9 €, ISO code: CNMG160608, double sided, P25 grade, 4 cutting edges, maximum allowed wear ($V_B$) is 0.1 mm, maximum tool life ($T_L$) is 30 minutes.

Machining with longitudinal turning of a cylindrical step with a diameter of 150 mm to 80 mm and a length of 250 mm is required. The batch size is 100 parts. The yield is 95 %.

Machine tool hourly cost is 150 €/h. Operator salary cost is 16 €/h. Machine effective power is 18 kW. Conventional universal lathe is used.

The operator needs 4.2 minutes to manipulate the workpiece, the set-up time for the machine is 75 minutes. The set-up time for the tool is 16 minutes and insert index time is 2 minutes. The proportion of unplanned downtime is 15 %.

From the tool manufacturer we have the following guidelines for the use of the turning tool: the cutting depth should be in the range: 1.5 to 8 mm, the feed rate should be between 0.2 and 0.7 mm.

To test the model and the machine tool suitability, we start with the values from the centre of the intervals: the initial depth of cut ($a$) is 5 mm (7 passes) and the feed rate ($f$) is 0.45 mm. We obtain the following results of the model:

- The maximum cutting speed ($v_{max}$) due to machine power limits is 254 m/min.
- The minimum machining costs per part (74.6 €) is achieved at a cutting speed of 195 m/min and a total production time of 2150.0 minutes per batch (2.938 parts/h).
- The maximum productivity of 3.135 parts/h (2014.3 minutes per batch) is achieved at a cutting speed of 295 m/min with machining costs of 80.3 € per part. Due to limited cutting speed, this is not achievable.

The cost difference is 7.6 % and the productivity difference is 6.7 %, both more than the 2.5 % we had previously determined.

By running the model for different combinations of machining parameters, making appropriate use of the effective power of the machine (the average of the cutting speeds must be within the speed limit) and the tooling guidelines, we obtain a range of solutions (see the data in Tab. 1 and the graphic presentation in Fig. 4).

**Table 1** Cutting speeds for minimum machining costs and maximum productivity at different machining parameters (case 1)

| No. of passes | $a$ (mm) | $f$ (mm) | $v_{cost}$ (m/min) | Cost (€) | $v_{prod}$ (m/min) | Total prod. time (min) |
|---|---|---|---|---|---|---|
| 5 | 7 | 0.27 | 215 | 79.4 | 320 | 2131.4 |
| 6 | 5.83 | 0.37 | 205 | 75.0 | 305 | 2025.6 |
| 7 | 5 | 0.48 | 195 | 71.9 | 290 | 1948.1 |
| 8 | 4.38 | 0.58 | 190 | 70.7 | 280 | 1919.3 |
| **9** | **3.89** | **0.70** | **180** | **68.8** | **270** | **1874.4** |
| 10 | 3.50 | 0.70 | 185 | 74.0 | 270 | 1999.9 |
| 11 | 3.18 | 0.70 | 185 | 79.1 | 275 | 2124.0 |

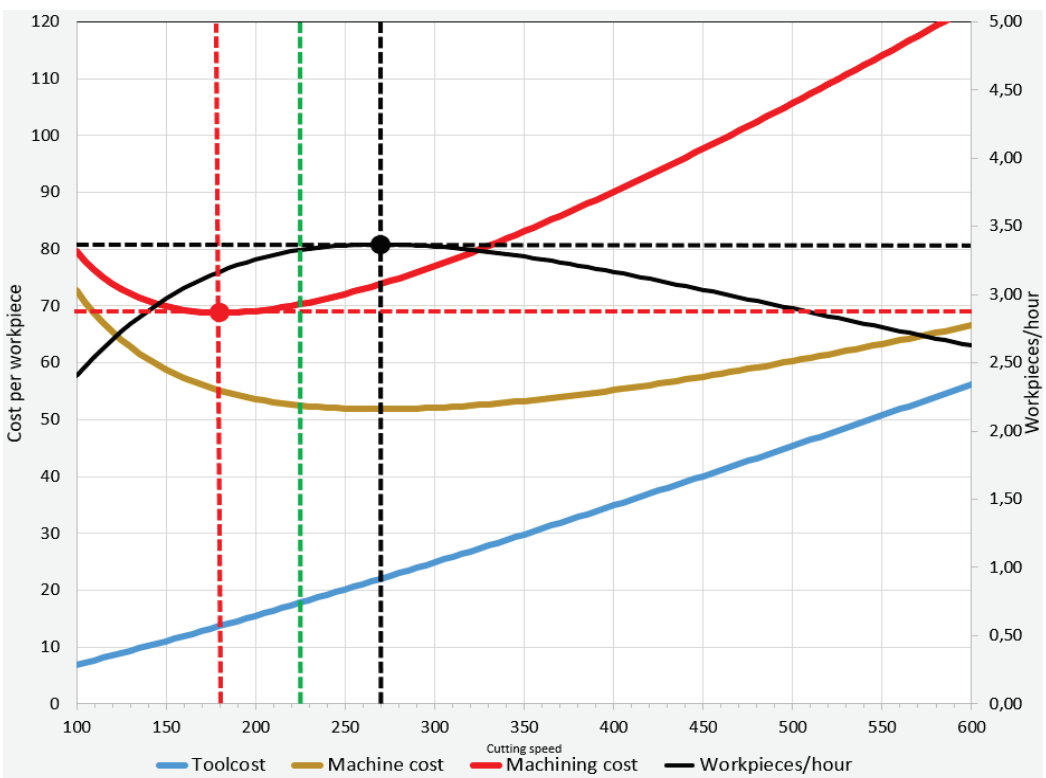


**Figure 4** Cost per workpiece and the number of products per hour versus cutting speed

The best results are achieved with 9 passes. The simulation of the costs per workpiece and the productivity achieved as a function of the cutting speed is shown in Fig. 4. Assuming that the two target variables have the same weight, we can consider the average cutting speed as optimal; thus we obtain the optimal feasible solution with the cutting parameters: cutting speed **225 m/min** (green line in Fig. 4), cutting depth 3.89 mm and feed 0.7 mm, which results in a total production time of 1898.0 min per batch (3.328 parts/h) at a cost per part of 70.3 €. The deviation from the ideal productivity is 1.2 % (lower) and from the minimum machining costs 2.2 % (higher). Both within 2.5 %. The maximum cutting speed is 230 m/min (due to the power limitation).

### 3.2 Case 2 – Turning on CNC Lathe

The workpiece material is a gray cast iron EN-GJL-250 (SL 25) with the following data: Taylor constant and exponents ($C_v$, $m$, $n$, $p$, $q$) are 533, 0.46, 0.25, 0.25 and 0.1; $K_{mv}$ is 0.66, $K_\tau$ is 0.80. Material hardness is 200 HB.

Toolholder cost is 240 €, ISO code: A20R-PCLNR09, min. internal diameter of 25 mm, max. cutting length is 200 mm; insert cost is 8.9 €, ISO code: CNMG090308-M3, TP2501, double sided, 4 cutting edges, maximum allowed wear ($V_B$) is 0.1 mm, maximum tool life ($T_L$) is 30 minutes.

Machining with longitudinal internal turning with a diameter of 32 mm to 84 mm and a length of cut of 170 mm is required. The batch size is 60 parts. The yield is 95 %.

Machine tool hourly cost is 170 €/h. Operator salary cost is 25 €/h. Machine effective power is 7.35 kW. CNC lathe has max. spindle speed of 3000 rpm and 8 turret tools.

The operator needs 1.1 minutes for all workpiece manipulations, the set-up time for the machine is 24 minutes. The set-up time for the tool is 12 minutes and insert index time is 0.8 minute. The proportion of unplanned downtime is 14 %.

From the tool manufacturer we have the following guidelines for the use of the internal turning tool: the cutting depth should be in the range: 0.5 to 3.5 mm, the feed rate should be between 0.12 and 0.36 mm.

We start with the values from the centre of the intervals: the initial depth of cut ($a$) is 2 mm (13 passes) and the feed rate ($f$) is 0.24 mm. We obtain the following results of the model:

- The maximum theoretical cutting speed ($v_{max}$) due to machine power limits is 426 m/min.
- The minimum machining costs per part (77.0 €) is achieved at a cutting speed of 250 m/min and a total production time of 1022.1 minutes per batch (3.707 parts/h).
- The maximum productivity of 4.173 parts/h (908.1 minutes per batch) is achieved at a cutting speed of 410 m/min with machining costs of 87.9 € per part.

The cost difference is 14.2 % and the productivity difference is 12.6 %.

Running the model for different combinations of machining parameters (the average of the cutting speeds must be within the speed limit) gives the results shown in Tab. 2.

**Table 2** Cutting speeds for minimum machining costs and maximum productivity at different machining parameters (case 2)

| No. of passes | $a$ (mm) | $f$ (mm) | $v_{cost}$ (m/min) | Cost (€) | $v_{prod}$ (m/min) | Total prod. time (min) |
|---|---|---|---|---|---|---|
| 8 | 3.25 | 0.17 | 260 | 65.5 | 425 | 779.4 |
| 9 | 2.89 | 0.20 | 250 | 64.6 | 415 | 769.0 |
| 10 | 2.60 | 0.25 | 240 | 60.5 | 395 | 723.6 |
| 11 | 2.36 | 0.29 | 235 | 59.2 | 385 | 708.4 |
| **12** | **2.17** | **0.33** | **230** | **58.2** | **375** | **697.6** |
| 13 | 2 | 0.36 | 225 | 58.5 | 370 | 701.5 |
| 14 | 1.86 | 0.36 | 225 | 62.1 | 375 | 741.6 |

The best results are achieved with 12 passes. Again we can consider the average cutting speed as optimal (for equal importance of both criteria); thus we obtain the optimal feasible solution with the cutting parameters: cutting speed **303 m/min**, cutting depth 2.17 mm and feed 0.33 mm, which results in a total production time of 713.6 min per batch (5.312 parts/h) at a cost per part of 60.7 €. The deviation from the ideal productivity is 2.3 % (lower) and from the minimum machining costs 4.3 % (higher). Achieved productivity is within the 2.5 % tolerance. The maximum cutting speed is 305 m/min (due to the power limitation).

By lowering the cutting speed, we can lower the machining costs (at the expense of productivity). With the balanced cutting speed of 290 m/min we can get a total production time of 720.6 min per batch (3.3 % lower productivity) and 60 € cost per part (2.6 % higher).

### 3.3 Discussion

In the optimisation model, we have taken into account the generally known equations for the turning process and for calculating the machining costs. Since the number of passes is an integer, we have a limited number of combinations of machining conditions. The model simulates all possible combinations of cutting parameters, taking into account the effective power of the machine and the limits of the tool (depth of cut, feed rate). Since the optimal values to achieve the lowest cost and the highest productivity are different, we suggest the middle value of the cutting speed as the optimal choice. We have chosen this because we only have two optimization variables of equal importance. If the importance differs, the value within the cutting speed interval could also be shifted towards a more important value. Based on the two examples shown, we can see that the deviations from the individual optima are less than 5 %.

The optimization idea used is universal and can be applied to other turning cases as well as other types of cutting operations. The method is simple, feasible, practically useful (spreadsheet model) and understandable, as we only have two optimization variables. It is supporting process planner's work.

Compared to other authors, there is little similarity in the methods and models used. Anand et al. [1] consider the machining process from the point of view of friction and heat generation in the cutting zone, which have a significant influence on tool life and the quality of the workpiece surface. Cesén et al. [4] start from the recommendations of the tool manufacturers, determine the Taylor constant experimentally and optimize the cutting speed in order to achieve minimum machining costs. Abbas et al. [6] present a very complex multi-criteria optimisation (minimum consumption of energy, tools, machining time and costs; maximum productivity and surface quality) with different algorithms: Gray Wolf Optimizer, Weighted Value Gray Wolf Optimizer, Multi-Objective Genetic Algorithm and Multi-Objective Pareto Search Algorithm. Agarwal and Khare [7] minimise energy consumption, processing time and costs with a mathematical multi-objective model. Pujiyanto et al. [8] emphasise sustainable production and minimise energy consumption, surface roughness, noise, cost and carbon emissions with a special multi-criteria algorithm in Matlab. Vukelic et al. [9] optimise the surface roughness of workpieces in the turning process using a regression model. Wakjira et al. [10] use a mathematical analysis to obtain optimal cutting parameters for minimum forces and power requirements. Pangestu et al. [11] develop a multi-objective optimisation model to minimise energy consumption, carbon emissions, production time and production cost. Verma and Pradhan [14] use finite element simulation of the turning process and predict temperature, forces and strains to select optimal cutting inserts. Jiang et al. [15] investigate how to minimise the environmental cost and maximise the economic benefits of turning. They use the concept of the multi-objective optimisation algorithm NSGA-II.

A comparison of the articles cited shows that our optimisation method is original, easy to apply in practise and effective.

The future digitalisation of the presented optimisation method for turning is very promising. With advances in computing power, the expansion of simple computational models to more sophisticated systems, machine learning algorithms and data analysis, it is increasingly possible to develop digital solutions for optimising cutting parameters in machining processes such as turning. The implementation steps should include:

*Data collection and analysis:* The first step is to collect data on various cutting parameters such as cutting speed, feed rate, depth of cut, tool material, workpiece material, etc. This data can be collected from machining operations within the company or from existing databases. Once collected, advanced analysis techniques can be used to analyse the data and identify patterns and correlations between different parameters and machining results (e.g. surface finish, tool wear, machining time).

*Machine learning models:* Machine learning algorithms can then be trained using the collected data to develop predictive models for optimising the cutting parameters. These models can learn from previous machining experience to recommend the most appropriate combination of parameters for a particular machining task. Techniques such as regression analysis, decision trees or neural networks can be used for this purpose.

*Integration into existing systems:* The digital optimisation tool can be integrated into existing business systems such as Manufacturing Execution Systems (MES), Computer-Aided Manufacturing (CAM) software or even directly into the control systems of CNC machines. Integration ensures seamless communication between the optimisation tool and the machining environment, enabling real-time adjustments to cutting parameters based on changing conditions or requirements.

*User interface:* An intuitive user interface should be developed that allows machine operators and engineers to easily interact with the optimisation tool. The interface can provide recommendations for optimal cutting parameters based on user input such as desired machining outcomes (e.g. minimising tool wear or cost, maximising productivity) and constraints (e.g. machine capabilities, material properties).

*Feedback loop:* Continuous improvements are essential to increase the effectiveness of the optimisation tool. Feedback mechanisms should be implemented to collect data on the actual performance of the recommended cutting parameters during machining operations. This data can then be used to refine the machine learning models to improve their accuracy and relevance over time.

Overall, digitising the optimisation of cutting parameters in machining offers considerable potential for improving the efficiency, quality and cost effectiveness of machining processes.

## 4 CONCLUSION

Companies are increasingly recognising that large investments, the introduction of high-tech solutions or additional employment are not necessary to solve productivity problems. In a fast, cost-effective and sustainable future, intelligent software paves the way for optimised production and better decision-making capabilities. Digital technology and smart software have already transformed the hardware industry, as actionable data for better results has never been more readily available [16]. The right approach and the right knowledge can solve key problems. Optimising cutting parameters during machining is crucial for low machining costs, high productivity and sustainable production. With properly set parameters, we can achieve exceptional results, which include reducing material waste, optimising machining time and extending tool life [15].

When planning the optimisation of cutting parameters, several factors must be taken into account, including the material of the workpiece, the type of cutting tool, the cutting speed, the cutting depth and the feed rate. The combination of precision machining and advanced cutting tools ensures incredible productivity in metalworking. With a focus on low machining costs, the key is to achieve an optimal balance between cutting speed and tool life, which enables a reduction in production costs without compromising on machining quality. With a suitable traditional model, we can capture the influencing factors and arrive at feasible multi-criteria optimisation solutions. In this article, this is demonstrated using the example of longitudinal turning of the workpiece.

At the same time, however, it is also important to consider the sustainable aspects of production. Lowering energy consumption, reducing waste and extending tool life are key elements of sustainable production that can be achieved through the correct optimisation of cutting parameters. This extension of optimisation will be the goal of our future research.

By constantly monitoring, adjusting and improving cutting parameters, manufacturing companies can achieve exceptional results that combine the above-mentioned low machining costs, high productivity and sustainable production. Careful planning and implementation of cutting parameter optimisation is therefore a key strategy for achieving a competitive advantage in modern production. In the near future, the use of artificial intelligence will most likely completely change the way we approach solving the above problem.

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**Authors' contacts:**

**Borut Buchmeister**, Full Prof. Dr. Sc.
(Corresponding author)
University of Maribor, Faculty of Mechanical Engineering
Smetanova 17, 2000 Maribor, Slovenia
Tel. +386-2-2207631, e-mail: borut.buchmeister@um.si

**Iztok Palčič**, Full Prof. Dr. Sc.
University of Maribor, Faculty of Mechanical Engineering
Smetanova 17, 2000 Maribor, Slovenia
Tel. +386-2-2207636, e-mail: iztok.palcic@um.si

**Robert Ojsteršek**, Asst. Prof. Dr. Sc.
University of Maribor, Faculty of Mechanical Engineering
Smetanova 17, 2000 Maribor, Slovenia
Tel. +386-2-2207585, e-mail: robert.ojstersek@um.si

**Klemen Kovič**, M.Sc., Assistant, PhD student
University of Maribor, Faculty of Mechanical Engineering
Smetanova 17, 2000 Maribor, Slovenia
Tel. +386-2-2207514, e-mail: klemen.kovic@um.si

**Aljaž Javernik**, M.Sc., Assistant, PhD student
University of Maribor, Faculty of Mechanical Engineering
Smetanova 17, 2000 Maribor, Slovenia
Tel. +386-2-2207585, e-mail: aljaz.javernik@um.si