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# INVESTIGATION OF THE DIAMOND BURNISHING PROCESS ON EXTERNAL CYLINDRICAL SURFACES

BOOKLET OF PHD THESES

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## NOTATIONS USED IN THE THESIS BOOKLET

$c$	– strain hardening coefficient [-]
$F$	– applied/burnishing force [N]
$f$	– burnishing feed [mm/rev]
HV	– Vickers hardness
$i$	– number of passes [-]
$m$	– strain rate sensitivity exponent [-]
$n$	– strain hardening exponent [-]
$n_{wp}$	– workpiece rotational speed [1/min]
PCD	– polycrystalline diamond
$R_a$	– average surface roughness [ $\mu\text{m}$ ]
$R_p$	– maximum profile peak height [ $\mu\text{m}$ ]
$R_t$	– total height profile [ $\mu\text{m}$ ]
$R_z$	– maximum height profile [ $\mu\text{m}$ ]
$R_1$	– radius of the burnishing tool [mm]
$v$	– burnishing speed [m/min]
$y$	– initial yield stress [MPa]
$\delta$	– theoretical indentation depth of the burnishing tool [mm]
$\lambda$	– wavelength of the X-ray radiation [m]
$\nu$	– kinematic viscosity [ $\text{mm}^2/\text{s}$ ]

# 1 INTRODUCTION

In the first chapter, I present the position of diamond burnishing among cold plastic deformation processes aimed at improving lifetime. Based on a comprehensive preliminary literature review, I define the subject of my scientific dissertation and outline the objectives to be achieved.

## 1.1. Scientific background

In ensuring the intended lifetime of individual components, the manufacturing method and the appropriate selection of its technological parameters play a crucial role alongside design and operation. This is due to the fact that the properties and integrity of surface elements significantly influence the functional behaviour of the system. Consequently, the quality of surfaces subjected to operational loads has cardinal importance in terms of lifetime [1, 2]. Cold plastic deformation processes allow for favourable modification of the geometry of machined surfaces by reducing surface irregularities and increasing service life [1, 3, 4]; surface burnishing is one of these technologies.

In engineering practice, it has been effectively applied for decades. Originally developed for the machining of railway axles and automotive crankshafts, its range of applications has gradually expanded. It is widely used as a finishing process for hydraulic and other cylinders, pistons, bearing housings, bushings and shafts. [3, 5, 6]. Its general fields of application include the automotive, aerospace, and space industries [7-9], but numerous examples also exist of its use in the medical sector [10, 11].

During the burnishing of external cylindrical surfaces, plastic deformation occurs as a result of the interaction taking place due to sliding friction generated by the static contact between the tool and the workpiece. The process does not produce chips, sparks, or dust and the use of coolant and lubricant is minimal - sometimes even entirely unnecessary - making this a cost-effective and environmentally friendly machining method [12-14].

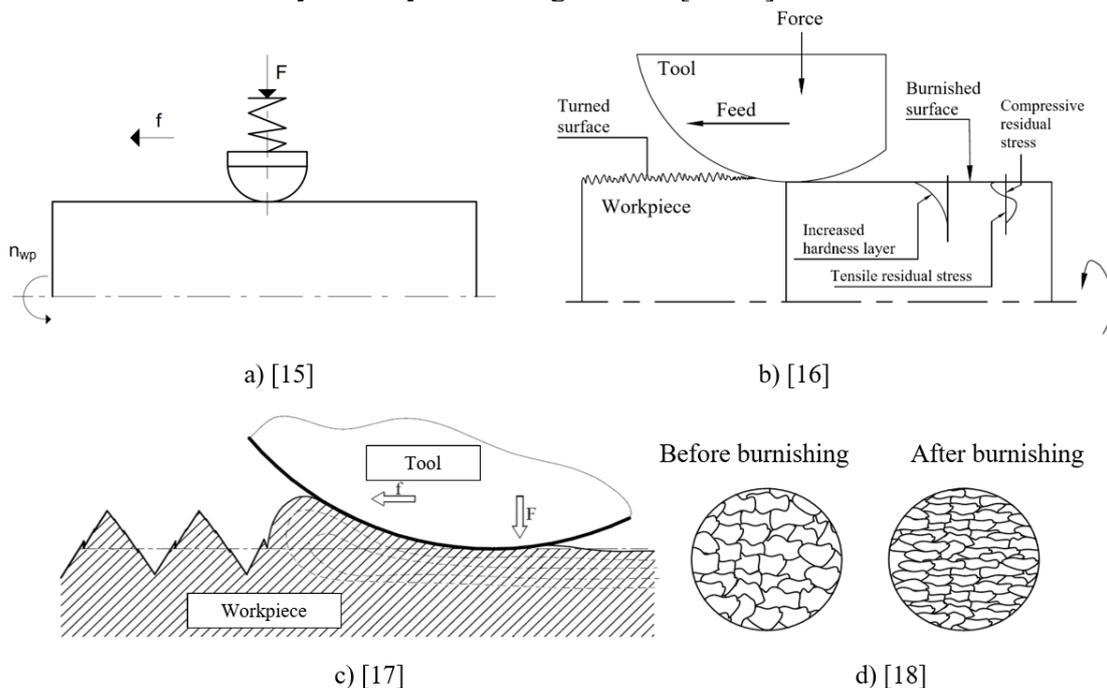


Figure 1. Phenomena occurring during surface burnishing

Figure 1.a) illustrates how the built-in spring in the tool generates the required burnishing force that exceeds the yield strength of the workpiece material. Subsequently, the tool moves linearly with a feed rate  $f$  in a direction parallel to the rotational axis of the workpiece, which is rotating during the process. As described by Dzionk et al. [17, 19] the processes occurring during the surface burnishing operation can be divided into several stages. In the initial stage, the tool exerts pressure on the peaks of the surface irregularities, inducing plastic deformation, which alters the structure of the asperities, reducing their height and changing their shape (Figure 1.b). In the second phase, due to the increased pressure, the deformed material moves toward the free spaces at the tool-workpiece contact point (Figure 1.c), meaning the surface peaks are flattened into the valleys. In the final stage, the material grains undergo plastic deformation in such a way that they become elongated (Figure 1.d). It is evident that before deformation, the grains have approximately equal volume, but along the direction of the forming process, they become increasingly stretched, resulting in anisotropy due to the development of a deformation texture.

The range of materials that can be effectively processed by burnishing is fundamentally broad, starting from aluminium and its alloys [2, 7], through bronze [6, 20], steel and its alloys [5, 9, 12, 13, 17, 19] and extending to special materials such as biodegradable MgCa alloy [10], forged titanium alloy [11], Inconel 718 [21] or even ultra-high molecular weight polyethylene [22].

Despite the fact that the surface burnishing technology was originally developed by General Electric in the United States [23], its industrial-scale application became widespread in the former Soviet Union, thereby necessitating a scientific-level approach to the topic. Hundreds of publications have been produced regarding both the integrity of burnished surfaces and the physical mechanisms of the process (as well as the synthesis of polycrystalline diamonds). The reviewed national and international literature has significantly contributed to defining the direction of my own research, with particular emphasis on exploring the relationships between surface roughness, residual stress state and machining parameters.

Several research groups have conducted detailed investigations into the mechanism of surface burnishing applied to various aluminium alloys, using both experimental and numerical methods. Posdich et al. [24] examined the effects of burnishing force, feed rate and speed on surface roughness and also analysed changes in the residual stress state using finite element methods. Based on the numerical and experimental results, they concluded that the initial surface integrity characteristics prior to burnishing - such as surface roughness and residual stress - do not significantly influence the effectiveness of the burnishing process.

Basak and his research team [25] investigated the Al-Mg 5083 alloy - commonly used in vehicle manufacturing - in terms of surface roughness, hardness and tensile strength. Based on their measurements, they clearly concluded that increasing the feed rate has a detrimental effect on the investigated properties, while the impact of spindle speed was found to be negligible.

Rodriguez and his colleagues [26] conducted investigations on friction stir welded 2050 aluminium alloy in T3 and T4 heat-treated conditions, focusing on the weld zone and its surroundings. The unfavourable mechanical properties (hardness, tensile strength) caused by friction stir welding were favourably altered through the application of the burnishing process. They also confirmed the beneficial effect of burnishing on two surface topography parameters. Sanchez Egea and his team [27] also carried out burnishing experiments on the same alloy, supplementing their study with simulation analyses. Based on their results, they consistently concluded that the burnishing force has the most significant influence on the development of compressive residual stresses. However, at higher force values, it adversely affects surface roughness due to the low hardness of the alloy.

Kluz and his co-authors [28] also applied the burnishing process to friction stir welded specimens, but on the EN AW-2024-T3 alloy, which has higher hardness. By using various

parameter settings, they achieved significant improvements in microhardness, surface roughness, and compressive residual stress. On the same alloy grade, Amini and his colleagues [29] extended their experimental investigations with simulation analysis using ANSYS software. In addition to hardness and surface roughness, they uniquely examined the changes in elongation at break. Regarding the latter, burnishing induced a positive but minor improvement. Furthermore, they also made observations concerning residual stress, despite employing an isotropic hardening model in the simulation.

Schubnell and Farajian [30] likewise representing a unique case, analysed - among other factors - the effect of surface enhancement on fatigue strength in friction stir welded EN AW-5083 material, comparing the impact of deep rolling and surface burnishing. In terms of surface roughness and fatigue strength, only minor differences were observed between the two plastic deformation processes. However, regarding hardness, burnishing proved more beneficial, while in terms of residual stress, rolling yielded more favourable results. For the latter, the authors formulated opposing conclusions, highlighting contrasting effects between the two methods.

Huuki and colleagues [31] likewise representing an unconventional case, investigated not only surface roughness and hardness, but also the effect of the burnishing process on roundness deviation in EN AW-6082-T6 aluminium alloy. However, during the experiment, only a single set of process parameters was applied, which, particularly in the case of aluminium, resulted in an inexplicably high degree of scatter.

The study by Randjelovic and his research team [32] is distinctive in that, in order to demonstrate that the surface quality prior to burnishing does not influence the resulting surface roughness, they based their finite element simulations on the kinematic model of milling. Both experimental and simulation results confirmed that the optimal condition is achieved when the penetration depth of the burnishing tool corresponds to the value of  $R_p$  (maximum profile peak height), which characterizes the roughness of the surface to be burnished.

Sharma and Kapoor [33] designed and supplemented their experimental burnishing study on Al7075 aluminium alloy using the Taguchi method and analysis of variance (ANOVA). In their investigation, they applied an unconventional combination of parameters to assess the effects of speed, feed rate, and number of passes on surface roughness and hardness. Based on the analysis of the results, they reached an equally atypical conclusion: the feed rate has no significant impact on the change in surface quality and increasing it may even reduce the overall machining time.

Travieso-Rodriguez et al. [34] also applied a design of experiments approach to investigate the changes in hardness and residual stress state induced by burnishing on convex A92017 aluminium alloy workpieces. Their research builds on the studies conducted by Travieso-Rodriguez, Dessein, and Gonzales-Rajas [35] in which the same material grade was processed on concave surfaces to analyse surface roughness changes. For both geometrical configurations, the radius of curvature had the most significant influence on the resulting surface quality, and a higher feed rate proved to be more beneficial.

Amdouni and collaborators [36] focused on investigating the burnishing direction and determining the optimal tool movement strategy for the burnishing of flat surfaces made of 2017A-T451 aluminium alloy. Their study centred on surface roughness and hardness. For their experiments, they used a tool made of chromium-plated 100Cr6 bearing steel, while all other burnishing parameters were kept constant; among these, the penetration depth was treated as a discrete variable.

Stöckmann and Putz [37] analysed the effects of burnishing on aluminium alloys using finite element simulations on flat surfaces, which they validated through experimental investigations. Their research was based on the fundamental assumption that the initial surface quality does not influence the effectiveness of the burnishing process. The model they developed exhibited

an average deviation of 0.53-3.8  $\mu\text{m}$  (corresponding to a 2-23% relative error) in terms of average surface roughness compared to the experimental results.

Just like the numerous reviewed publications included in the dissertation, the findings of the highlighted studies not only contributed to defining the research topic but also revealed certain contradictions and gaps in the literature. My research aims to explore, clarify and scientifically complement these areas.

## *1.2. Aims of the dissertation*

The primary objective of this dissertation is to investigate and enhance the effectiveness of diamond burnishing, with a particular focus on its influence on theoretical surface roughness, based on existing mechanical models. The analyses are conducted in light of the increasingly stringent requirements imposed on finishing operations.

The process is also studied using the finite element method, which is supplemented by several experimental series designed according to factorial experimental designs, carried out on low-alloyed aluminium. One of the aims of the dissertation is to uncover empirical correlations between various surface quality indicators and the technological parameters applied during the process implementation.

Another objective is to develop an improved theoretical and finite element model capable of predicting the surface roughness generated during burnishing with a spherical-tipped tool, thereby supporting the optimization of the process for the given material grade.

In my PhD dissertation, I present the research work from its initial activities to the achieved results, while formulating the new scientific conclusions in the form of theses, in accordance with the implementation of the following steps:

- Theoretical investigation of the burnishing process performed with a spherical-tipped tool, using existing mechanical models, with the aim of developing a more relevant model applicable to the machining of external cylindrical surfaces.
- Finite element analysis of the relationship between the technological parameters characteristic of burnishing and the resulting surface roughness and residual stresses.
- Experimental investigation of the process's impact on surface roughness and residual stress state.
- Analysis and optimization of the technological parameters of diamond burnishing on external cylindrical surfaces with respect to the examined surface quality characteristics. Identification of the most influential parameters, uncovering correlations, and providing explanations for any deviations.
- Development of an analytical model – applicable in engineering practice – based on the results, simulation studies, and insights gained during the research work.

The developed model may contribute to enhancing the efficiency of the burnishing process and thereby support the environmentally friendly extension of the application range of the investigated material.

The steps, methodology and main determining components of the investigation of diamond burnishing are illustrated in Figure 2.

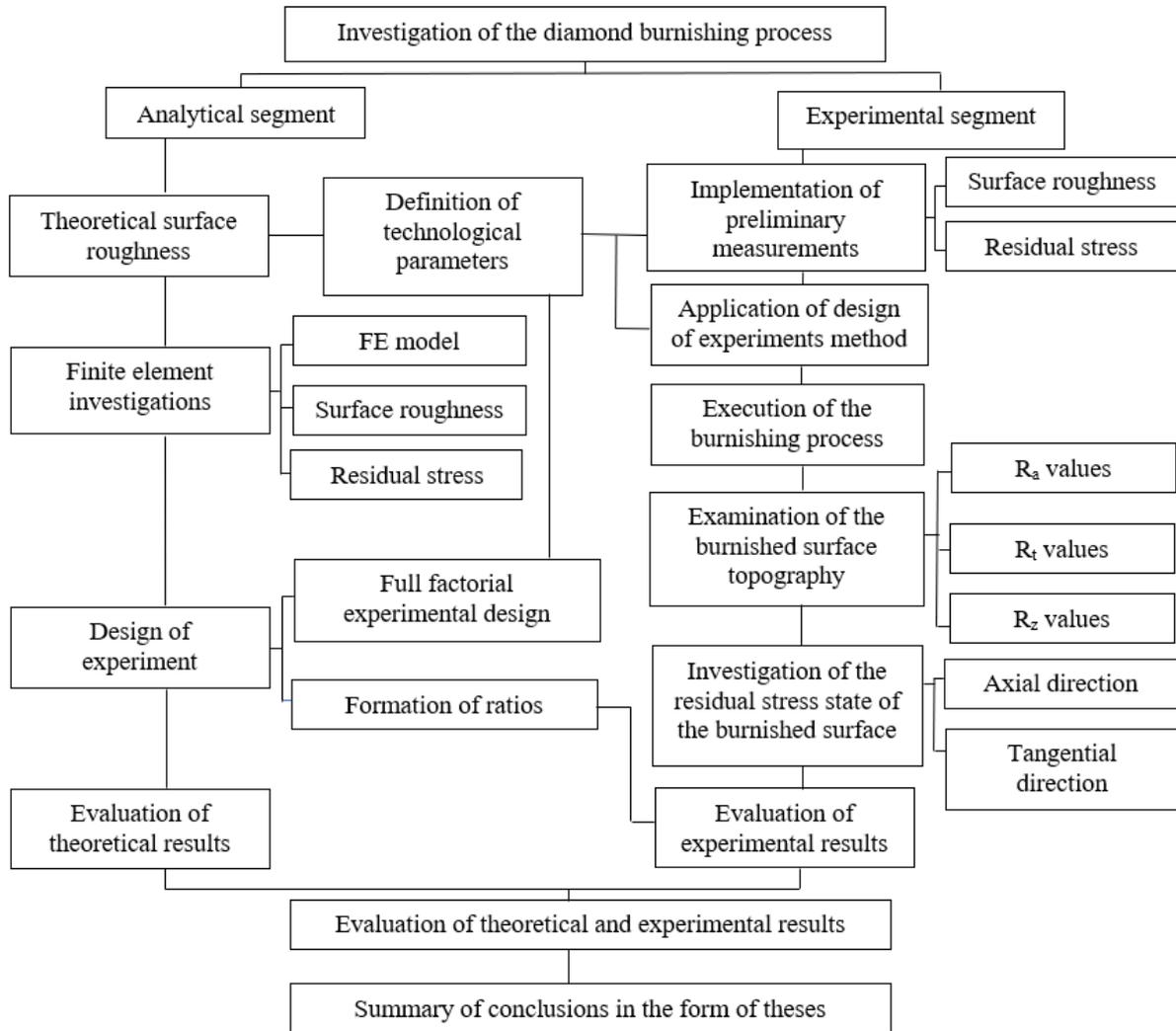


Figure 2. Presentation of the investigation procedure

## 2 RESEARCH METHODS AND CONDITIONS

Based on the theoretical foundations of surface burnishing and the literature review concerning the efficiency of the process and the quality of the burnished surface, I have defined the subject of my scientific dissertation and outlined the objectives to be achieved. In the following, I establish the methodology of the theoretical research, identify the characteristics to be examined, detail the procedure for conducting these investigations, and define the conditions for the practical experimental work.

### *2.1. Implementation of the analytical investigations*

Considering the specific characteristics of surface burnishing and the trends observed during the literature review, the process is examined through analytical models, complemented by finite element simulations and practical experiments. In the course of the theoretical investigations, I briefly analyse and compare the existing mechanical models that characterize surface burnishing, which serve as a basis for both the direction of further analytical studies and the implementation of the experimental research segment.

Building on existing models and my own analytical deductions, I developed a formula for calculating one of the key parameters of the theoretical maximum roughness height ( $R_t$ ), namely the indentation depth ( $\delta$ ), which I expressed as a function of mechanical parameters. In order to ensure a more accurate prediction that better reflects real technological conditions, I incorporated the burnishing speed ( $v$ ) as an additional predictor into the correction model using multivariable linear regression.

The research is based on the method of full factorial experimental design, which allows for the statistical analysis of the effects of key parameters. Following the selection of the primary influencing factors of the process (burnishing parameters), the determination of their levels and the size of the investigation domain, as well as the definition of the applicable mathematical model, the experiment is carried out according to the generated experimental matrix. This is followed by data processing and evaluation, which can be performed using various methods such as simple effect analysis, analysis of variance, or the development of approximation functions. Furthermore, since both experimental precedent and literature references confirm that in surface burnishing the effect of a given factor on a response variable depends on the setting level of other factors and considering that the examined factors are of quantitative nature, their effects can also be interpreted graphically. This is made possible by response surface methodology based on the least squares method, i.e., the spatial representation of the regression function. This approach not only allows for the identification of the optimum within the investigated domain, but also the designation of optimal directions beyond it [38, 39].

As part of the theoretical investigation segment, I developed a finite element model that incorporates realistic geometric conditions and material properties, which I used to numerically examine the deformation processes and the resulting surface quality. In the dissertation, the surface burnishing process was simulated using the DEFORM software in a two-dimensional investigation domain, as this approach is significantly more cost- and time-efficient than its three-dimensional counterpart and it also allows for easier modification of the model's geometric characteristics. Through the simulations, virtual prototypes support the rational design of material selection, machining parameters, tool characteristics, and other relevant factors.

## 2.2. Conditions of the burnishing experiments

To examine and analyse surface roughness and residual stress, I conducted a series of burnishing experiments. The machining and measurement processes were carried out partly using the machine and equipment resources of the Institute of Manufacturing Science at the University of Miskolc and partly in collaboration with the Institute of Physical Metallurgy, Metal Forming and Nanotechnology.

The burnishing experiments were performed on an Optimum OptiTurn L440 CNC lathe, which features high-precision Siemens control and adequate rigidity. Its tool holder is suitable for clamping the selected burnishing tool. During the process, I applied Cogsdill polycrystalline diamond (PCD) tool with spherical surface and diameter of 7 mm. The required burnishing force is generated by a spring integrated into the tool body, the preload and spring characteristics of which were determined based on preliminary measurements conducted with Kistler 9257A piezoelectric dynamometer.

The process does not require a significant amount of coolant or lubricant; in all cases, I applied minimal lubrication using Ciks slideway oil with kinematic viscosity of  $\nu = 70 \text{ mm}^2/\text{s}$ . When designing the geometry of the shaft-like workpieces, it was important to take into consider the nature of the full factorial experimental design described later. As illustrated in Figure 3, the workpieces consist of multiple segmented sections and were machined uniformly using finishing turning with feed rates of  $f_{1e} = 0.2 \text{ mm/rev}$  followed by  $f_{2e} = 0.15 \text{ mm/rev}$ .

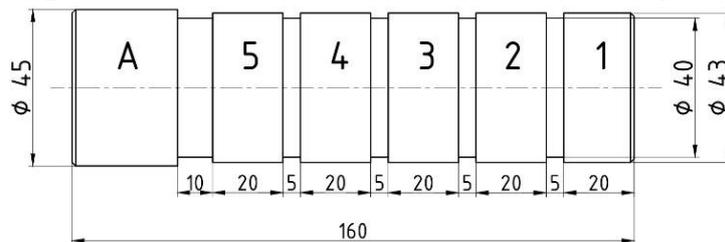


Figure 3. Schematic representation of the workpiece geometry

For the purposes of the investigations, I selected low-alloyed EN AW-2011 aluminium grade with an approximate hardness of 160 HV, as the mechanical properties of this material type - due to its low alloying element content - can primarily be influenced through the method of machining. This offers the opportunity to enhance the material's surface quality and service life through surface burnishing, without the need for additional alloying elements or heat treatment processes. Such an approach not only contributes to simplifying the manufacturing process and reducing environmental impact, but also sustainably broadens the applicability of low-alloyed aluminium. Moreover, the accurate understanding of aluminium machinability has become increasingly important, given the widespread industrial use of this material and its various alloys. This is particularly critical in the aerospace, automotive, electronics and construction industries, where its favourable strength-to-weight ratio, good corrosion resistance and recyclability are key attributes. At the same time, technological expectations regarding surface quality are becoming increasingly stringent, which makes it essential to conduct a detailed, parameter-specific investigation of the behaviour of aluminium alloys in the context of finishing operations. My assertions are supported by a substantial body of literature I have reviewed and processed, as detailed in section 1.2.3.3 of the dissertation.

Taking into account the findings presented in related research works, the experiments focus on examining the effects of burnishing force, feed rate, speed, and number of passes. The numerical values of these parameters were determined based on the results of the reviewed literature and the conclusions drawn from preliminary tests, in accordance with the mechanical properties of the investigated material grade and the applied full factorial experimental design.

### 2.3. Measurement of surface roughness and residual stress

To perform the comparative analysis, I conducted measurement investigations at multiple points on both the pre-turned and the burnished workpieces, examining both surface roughness and residual stress.

The surface roughness measurements and their evaluation were carried out using an AltiSurf<sup>®</sup>520 roughness measurement device. For each sectional area, measurements were taken along three generatrices rotated 120° relative to each other, using a CL2 confocal chromatic sensor equipped with an MG140 magnifier, featuring a sensitivity of 0.012 μm and a sampling frequency of 1000 Hz. In accordance with the relevant standard [40] based on the feed rate applied in the preceding turning operation, an evaluation length of 4 mm was set. Since the form deviation must be removed according to the nominal shape of the surface, a cut-off length of  $\lambda = 0.8$  mm and a Gaussian filter were used for evaluation. Considering industrial applicability and comparability with theoretical and simulated values, the examined roughness parameters include the average roughness ( $R_a$ ), the average peak-to-valley height ( $R_z$ ), and the maximum roughness height ( $R_t$ ). For the evaluation, the arithmetic mean of the three measurements taken along each sectional segment was used in the analysis. Additionally, these values were utilized for determining the theoretical surface roughness and in the development of the finite element model.

The non-destructive evaluation of the stress state was carried out using the X-ray diffraction (XRD) method, which utilizes the wave nature of X-ray radiation to map the internal stress state of the material [41]. Measurements were performed using a Stresstech Xstress 3000 G3R type X-ray diffraction device at four points with 90° rotations, in both tangential and axial directions, in accordance with the MSZ EN 21432:2019 standard [42]. Data acquisition and processing were conducted using the XTronic software developed by the manufacturer, thereby providing quantitative results regarding the residual stress of the examined surfaces.

Figure 4 illustrates the logical structure of the experimental system, highlighting the relationships between variable parameters, constant factors, and output information. The effects of burnishing force, feed rate, speed, and number of passes were examined through the evolution of surface roughness characteristics and residual stress state. The measured results serve not only to evaluate surface quality but also provide a foundation for finite element simulations and support the development and refinement of a predictive model for surface roughness. The combination of theoretical and practical investigations contributes to the optimization of processing parameters and thus enhances the industrial applicability of the material properties.

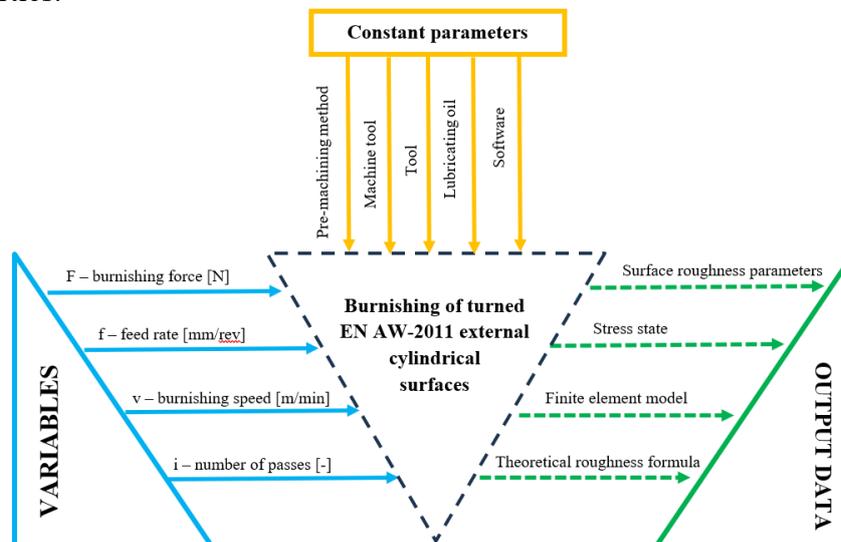


Figure 4. Schematic representation of the experimental design

### 3 NEW SCIENTIFIC RESULTS, THESES AND POTENTIAL APPLICATIONS

Diamond burnishing is a highly effective technology for the sustainable manufacturing of high-precision components with extended service life. My research, focusing on the processing of non-ferrous metals, addresses questions that have not been previously discussed or examined in sufficient depth, in line with the objectives defined in the dissertation.

#### 3.1. Theses

- T1. I defined empirical correlations specific to the investigated material grade between the technological parameters and the efficiency of the machining process, applying the full factorial experimental design method. It was established that, in terms of surface roughness, the burnishing force, feed rate, and speed exert a primary influence, while increasing the number of tool passes does not result in proportional improvement. In certain parameter combinations, it may even cause unstable behaviour, leading to surface damage on the workpiece. Based on the measurement results, it can be stated that increasing the number of passes is not justified from either a technological or an economic perspective with regard to improving surface roughness [S1, S8]. (*Experimental conditions: EN AW-2011 material,  $R_1 = 3.5$  mm PCD tool,  $F = 10-20$  N,  $f = 0.001-0.005$  mm/rev,  $v = 15-30$  m/min,  $i = 1-3$ ; examined roughness parameters:  $R_a$ ,  $R_z$ ,  $R_t$ .)*
- T2. I developed a material-specific finite element model based on real surface roughness data, suitable for the numerical investigation of the plastic deformation processes and resulting roughness characteristics occurring during diamond burnishing. The reliability of the model is supported by its predictive accuracy, which proves sufficiently sensitive to changes in technological parameters; under stable technological conditions, the deviation between the measured and simulated average surface roughness values typically remains below 5%. Based on its trend-conform predictions and parameter sensitivity, it was concluded that the model is suitable for industrial-level surface quality prediction, process optimization, and can serve as a solid foundation for further high-precision material and process research [S5, S7, S10, S11]. (*Material model coefficients:  $c = 191.454$ ,  $n = 0.10571$ ,  $m = 1.02487$ ,  $y = 87.194$ ; examination range:  $F = 10-20$  N,  $f = 0.001-0.005$  mm/rev,  $v = 15-30$  m/min,  $i = 1-3$ ; examined roughness parameters:  $R_a$ ,  $R_t$ .)*
- T3. A contact mechanics analysis of the burnishing process - considering the interaction between the spherical-tipped tool and the external cylindrical surface - enabled the development of a novel model variant for the theoretical prediction of maximum surface roughness height ( $R_t$ ). The core analytical expression of the model incorporates a geometrically accurate description of the contact area. In addition to the traditional input parameters such as burnishing force and feed, the model also integrates burnishing speed, whose influence was characterized via multiple linear

regression. This correction enhanced the predictive capacity of the model, leading to an analytical formulation that more accurately reflects real processing conditions and supports the selection of optimized parameters [S12]. (*Experimental conditions: contact between spherical tool and external cylindrical surface; parameter range:  $F = 10-20\text{ N}$ ,  $f = 0.001-0.005\text{ mm/rev}$ ,  $v = 15-30\text{ m/min}$ ,  $i = 1-3$ ; examined roughness parameter:  $R_t$ .)*

- T4. Based on experimental investigations, I verified that sliding-friction-based surface burnishing on external cylindrical surfaces induces significant compressive residual stresses in both the tangential and axial directions. The magnitude of these stresses is influenced not only by individual technological parameters but also by their interaction effects. In the tangential direction, the combined increase of feed rate and number of passes plays a decisive role in mitigating residual stress inversion. In the axial direction, burnishing speed exerts a direct influence as well; its increase also contributes to reducing the inversion effect [S2-S4, S6, S9]. (*Experimental conditions: EN AW-2011 material,  $R_1 = 3.5\text{ mm}$  PCD tool,  $F = 10-20\text{ N}$ ,  $f = 0.001-0.005\text{ mm/ford}$ ,  $v = 15-30\text{ m/min}$ ,  $i = 1-3$ ; evaluated directions: tangential, axial.)*
- T5. Through experimental investigations and response surface analysis, I confirmed that nonlinear interactions are observable during the transfer of deformation energy and the development of residual stresses, particularly in the combined effects of feed rate and number of passes, as well as speed and burnishing force. As a result, the optimization of compressive residual stress is only feasible through multiparametric modelling. By comparing parameter combinations affecting residual stress and surface roughness, I established that the complex improvement of surface integrity requires a compromise in the selection of technological parameters [S8, S9]. (*Experimental conditions: EN AW-2011 material,  $R_1 = 3.5\text{ mm}$  PCD tool,  $F = 10-20\text{ N}$ ,  $f = 0.001-0.005\text{ mm/rev}$ ,  $v = 15-30\text{ m/min}$ ,  $i = 1-3$ ; evaluated directions: tangential, axial; examined roughness parameters:  $R_a$ ,  $R_t$ .)*
- T6. I verified that the depth distribution of axial residual stress generated during diamond burnishing can be predicted numerically using a finite element model based on actual material properties and simplified geometric conditions. By comparing the results of numerical simulations and X-ray diffraction measurements, I demonstrated that the simulation model systematically predicts lower compressive stress values; however, it provides valuable information on the magnitude and trend of the stress-depth profile. I concluded that the finite element model is suitable for evaluating the depth distribution and homogeneity of residual stresses and thus applicable for predicting the integrity of fatigue-critical surface layers [S11]. (*Material model coefficients:  $c = 191.454$ ,  $n = 0.10571$ ,  $m = 1.02487$ ,  $y = 87.194$ ; examination range:  $F = 10-20\text{ N}$ ,  $f = 0.001-0.005\text{ mm/ford}$ ,  $v = 15-30\text{ m/min}$ ,  $i = 1-3$ ; evaluated direction: axial.)*

### *3.2. Possibilities of the application and further development*

The research findings related to the application of diamond burnishing are beneficial in several respects for industrial fields requiring high dimensional accuracy and favourable surface condition. I confirmed that the investigated process is suitable for the fine finishing of non-ferrous alloy surfaces, where the aim is to increase fatigue resistance and reduce surface roughness. The modelling and experimental results presented in this dissertation enable the predictive application of burnishing in the production of automotive, aerospace, medical, and precision engineering components, particularly in cases where the desired surface quality cannot be achieved, or only at high cost, using conventional machining methods. Furthermore, in case of shafts, the improved residual stress profile and reduced roughness contribute to vibration and noise reduction.

Using the theoretical model and finite element simulations, the desired surface characteristics can be predicted in advance, which enables process parameter optimization to reduce both production costs and the scrap rate. The ability to predict the distribution of residual stresses allows for the reliable design of fatigue-critical components such as shafts, mechanical arms, pressure-retaining elements or thin-walled profiles.

The predictive capabilities offered by the finite element model and the analytical formula can be readily adapted to other material grades by modifying the relevant elastic properties and material model coefficients. As a result, the developed theoretical and numerical toolset is suitable for more general application and its industrial integration does not require profound modifications to the model.

One promising direction for future research is to deepen the theoretical description of the residual stress state by developing a formula capable of estimating the maximum or characteristic compressive stresses based on machining parameters and the mechanical properties of the material. This would establish a third, analytical pillar alongside simulation and experimental investigations.

In conclusion, I assert that diamond burnishing, when executed with appropriate technological parameters and supported by the models presented in this dissertation, is suitable for application in both conventional and advanced manufacturing environments. The methodological and modelling approaches developed during the research contribute to the formulation of surface-quality-driven machining strategies.

## MAJOR PUBLICATIONS RELATED TO THE TOPIC OF THE DISSERTATION

- [S1] G. Varga and V. Ferencsik, "Analysis of Surface Topography of Diamond Burnished Aluminium Alloy Components," *Lecture Notes in Mechanical Engineering*, vol. 12, pp. 143-154, 2017.
- [S2] G. Varga and V. Ferencsik, "Examination of Residual Stresses on Diamond Burnished Cylindrical Surfaces," *Rezanie I Instrument V Tekhnologiceskikh Sistemakh*, vol. 87, no. 1, pp. 18-27, 2017.
- [S3] G. Varga and V. Ferencsik, "Investigation of the Influence of Different Burnishing Parameters on Shape Correctness and Residual Stresses," *IOP Conference Series: Materials Science and Engineering*, vol. 448, pp. 1-8, 2018.
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