ISSN 2078-7405. Cutting & Tools in Technological System, 2020, Edition 93

UDK 621.923.7 **doi: 10.20998/2078-7405.2020.93.01**

V. Ferencsik, V. Gal, Miscolc, Hungary

FE INVESTIGATION OF SURFACE BURNISHING TECHNOLOGY ABSTRACT

Abstract. *This paper investigates the finite element analysis of cold forming diamond burnishing process on aluminium alloy, where the input parameters are force, feed rate and speed, as an output parameter the changing of surface roughness is analysed. This lifetime increasing process effectively reduces roughness, improves shape correctness, and increases the hardness of the sub-surface area. Machining simulation of the turned surface before burnishing is based on the real model, corresponding to the measured values, by using DEFORM-2D software in order to validate the improvement of surface quality with numerical values too.*

Keywords*: lifetime-increasing surface hardening technologies; burnishing process; surface roughness; polycrystalline diamond; finite element (FEM) model.*

1. INTRODUCTION

During operation, the individual components and their surfaces of a machine are subjected to several forms of damage caused by stress (mechanical, thermal, chemical, etc.), so lifetime-increasing surface hardening technologies have an important role in industrial practice [1-2]. Furthermore, there is a growing demand for material- and energy-saving processes that can be implemented environmentally friendly without special conditions [3-4] even to be applied to non-iron-based material quality such as the subject of the present study.

A preferred and efficient solution is burnishing, which use sliding relative displacement, decreases surface roughness, increases the micro-hardness of the sub-surface area and corrosion resistance by rearranging the dislocations. It also improves shape correctness and does not require large amounts of coolant lubrication [3-6]. Industries apply, for example, to finishing hydraulic cylinders, pistons, bearing bushes and rings, crankshafts [6].

The aim of our study is to model the effects of the different burnishing parameters (burnishing force, speed, feed rate) on the surface quality. In the past many researchers have placed great emphasis on the theoretical study of technology [7-11] and there is still a special need for a reliable finite element (FEM) model that provides a basic understanding of the mechanics of the process.

In this paper 2D FEM model for surface burnishing technique is established and results show that the developed model is useful for predicting the surface roughness. The usage of this method allows to reducing partial or totally the high cost of experimental testing.

2. BURNISHING PROCESS AND THE IMPLEMENTATION OF IT

Burnishing is used as a finishing treatment. If the surface integrity of the previously machined surfaces need to be improved, it is also suitable as a substitute for conventional machining such as grinding and lapping.

The surface quality of the manufactured parts is a constant priority in the development of mechanical engineering technology and machining. It is determined by the condition of the surface layer and the created topography. As it has a decisive influence on the functional properties and lifetime of components, investigations to pre-determine (estimate) surface roughness parameters are important. In these publications, researchers use different approaches, one of the important directions is the analysis by determining the roughness of the theoretical surface created by modelling. This approach has been successfully applied to machined surfaces, so the change of roughness values for rotating tools could be analysed for special tools [12] and different inserts [13, 14].

During burnishing the reduction of surface roughness is caused by the interaction between the tool and the specimen with surface sliding friction between them. The kinematic relations in the burnishing process can be seen in Fig. 1.

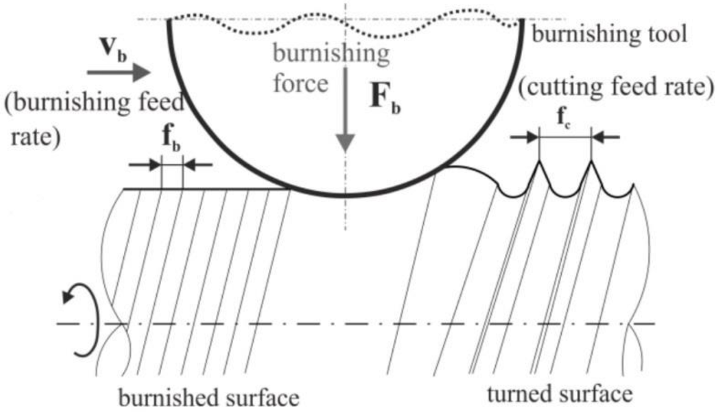

Figure 1 – Schematic illustration of burnishing [15]

Burnishing of outer cylindrical surfaces can be realized on conventional lathes and CNC lathes as well. In this experiment the operation was executed on OPTIMUM (OPTIturn L-Series 440) flatbed CNC lathe using PCD (polycrystalline diamond) tool with 3.5 mm radius with 12 N burnishing force, 0.001 mm/rev burnishing feed and 15 m/min burnishing speed.

3. FINITE ELEMENT ANALYSIS OF BURNISHING PROCESS

The finite element simulation of burnishing process was made by the DEFORM FE code. The simulation was created as a 2D problem to achieve the best comparability between the physical and modelled surface roughness reduction.

For the simulation of the technology, a hemispherical tool with 3.5 mm radius was needed. The burnishing force was 12 N and the relative movement on the surface was constant 0.001 mm/s, while the moving direction was parallel to the axis of the workpiece and perpendicular to the surface. The modelled specimen's surface is based on the physical surface. Before burnishing, the physical workpiece was measured on a 4 mm long distance with Altisurf 520 free dimensional topography measuring device. The surface points - determined with the physical measurement - were imported to the DEFORM FE code to define the surface of the simulated workpiece. To create the accurate axisymmetric problem, the thickness of the 2D workpiece has to be equal to the radius of the specimen used for physical measurement. The results of the preliminary conducted simulations with the above-mentioned parameters show that the process has an effect up to 0.15-0.17 mm in the subsurface area. Accordingly, the thickness of the workpiece was set to 0.2 mm. The tool was rigid, and the workpiece was assumed as an elastoplastic body. In FE modelling, the application of the appropriate mesh is a critical issue in the point of view of results. In the present case, careful attention had to be paid to ensure, the surface roughness is not changing as a result of the meshing. Thus, square elements with a side length of 0.01 mm was used at the surface. After meshing, the surface roughness changed from the physically measured from 1.478 µm to 1.457 µm. With an even smaller side length of the mesh, the surface roughness can be more accurately following, but in this case the calculation time would increase significantly. Fig. 2 shows a section of the tool and the meshed workpiece.

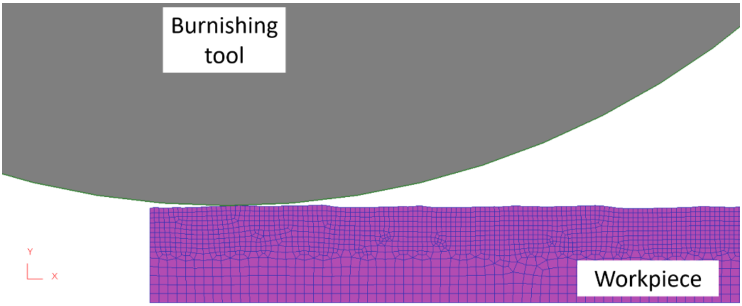

Figure 2 – Section of the 2D burnishing model with the workpiece and tool in DEFORM FE code

For describe the formability of the workpiece made of 6065 high strength aluminium in T0 condition, the mechanical properties of it need to be specified. The elastic behaviour of the material was specified with the Young modulus (68900 MPa) and a Poisson’s ration (0.33). At elastoplastic materials beyond the Yield stress, elastic and plastic deformations occur simultaneously. The stress value required for further plastic deformation (so the flow stress) changes with the deformation of the material. The DEFORM FE code provides different methods to defining the flow stress changing along deformation. In this paper we have used the Power law which can be described by the following equation:

$$\bar{\sigma} = c\bar{\varepsilon}^{n}\dot{\bar{\varepsilon}}^{m} + y \tag{1}$$

where $\bar{\sigma}$ is the flow stress, $\bar{\varepsilon}$ is the effective plastic strain, $\dot{\bar{\varepsilon}}$ is the effective strain rate, c is a material constant, n is a strain exponent, m is a strain rate exponent, and y is an initial value [16].

After determining the geometries and behaviour of the material, the contact between the tool and the workpiece and boundary conditions had to be specified. The simulation was carried out as an isothermal problem, so the change in the temperature was not considered. Since lubrication was used during the physical measurement the friction between the tool and the specimen was considered zero. To achieve an accurate result the separation criteria (which defines how the nodes of the workpiece on the surface of the tool will behave when tensile force appears) was also considered as zero.

4. RESULTS

After running the FE model made from the physical measurement, the comparison was performed based on the change in the surface geometries. Diagram 1 clearly shows the difference between the turned meshed workpiece surface (before burnishing) and the surface profile obtained after running the simulation.

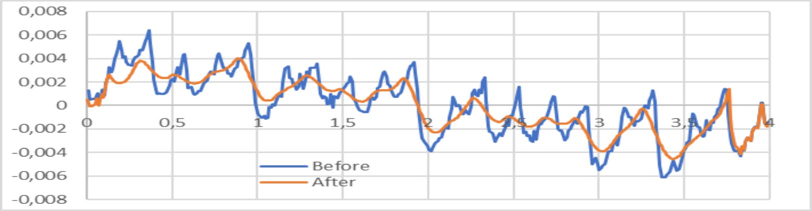

Diagram 1 – Change in the surface profile after the burnishing simulation

The numerical results of the realized experiment and the simulation are summarized in Table 1.

Table 1 – Numerical results of arithmetical mean roughness (R_a)

R_a [μm]		
	Experiment	FE model
Turned	1,478	1,457
Burnished	0,0965	0,0916

5. SUMMARY AND DISCUSSIONS

In this paper 2D finite element model of ball burnishing process was developed with the same parameters as the empirical experiment by DEFORM-2D software. After running the simulation and evaluating the results, the following conclusions can be stated:

- Burnishing can be used effectively with these parameters (F_b = 12 N; f = 0.001 mm/rev; v_b = 15 m/min) according to the experiment and the modelling results as well.
- During simulation, choosing the right mesh size has a great importance for the credibility of the model.
- Numerical roughness Ra presented a good approximation with the experimental result considering that minimal simplifications of the model, the extent of the deviation is 5.35 %, so applying the simulation, the optimum ball burnishing conditions can be obtained to control the surface response.

The undertaken numerical studies will be continued, in the future we would like to examine and simulate the changing of stress conditions and surface micro-hardness caused by burnishing process.

ACKNOWLEDGEMENTS

“The described study was carried out as part of the EFOP-3.6.1-16-00011 “Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation” project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.”

“Project no. NKFI-125117 has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the K_17 funding scheme.”

References: **1.** *L. Balint, L. Gribovszki:* A gépgyártástechnológia alapjai, Miskolci Eyetem, (1975) 418-442. **2.** *G. Bagyinszki, E. Bitay:* Felületkezelés, Erdélyi Múzeum-Egyesület, Műszaki tudományos füzetek 5. (2009) 9-85. **3.** *A.A., El-Nasr:* Thermomechanical fatigue behavior of burnished 7075-T6 aluminium alloy, Proceedings of the 15th Int. AMME Conference (2012) 40-50. **4.** *Z.D., Kadhim, M.A., Abdulrazzaq, W.S., Hussain:* Mechanical properties of burnished steel AISI 1008, Al-Khwarizmi Engineering Journal, 14: 4 (2018) 133-142. **5.** *L., Gribovszki:* Gépipari megmunkálások, Miskolc, Egyetemi Tankönyvkiadó (1977) 421. **6.** *A., Abodena:* Optimization of surface roughness of brass by burnishing, The International Journal of Engineering and

Information Technology, 5: 2 (2019) 90-96. **7.** *A., Bougharriou, K., Sai, W., Bouzid:* Finite element modeling of burnishing process, Materials Technology: Advanced Performance, Materials 25:, (2010) 56-67. **8.** *A., Rodriguez, L. N., Lopez De Lacalle, A., Celaya, A., Lamikiz, J., Albizuru:* Surface improvement of shafts by the deep ball-burnishing technique, Surface and Coatings Technology, 206:1, (2012) 2817-2824. **9.** Y.C., Yen, P., Sartkulvanich, T., Altan: Finite element modeling of roller burnishing process, CIRP Annals-Manufacturing Technology, 54:1, (2005) 237-240. **10.** *F., Klocke, V., Backer, H., Wegner, M., Zimmermann:* Finite element analysis of the roller burnishing process for fatigue resistance increase of engine components, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 225:1, (2011) 2-11. **11.** *M., Sayahi, S., Sghaier, H., Belhadjsalah:* Finite element analysis of ball burnishing process: comparisons between numerical results and experiments, The International Journal of Advanced Manufacturing Technology 67:5-8, (2013) 1665-1673. **12.** *J., Kundrák, C., Felhő:* 3D Roughness Parameters of Surfaces Face Milled by is Special Tools, MANUFACTURING TECHNOLOGY, 16:3 (2016) 532-538. **13.** *C., Felho, A., Nagy, J., Kundrak:* Effect of Shape of Cutting Edge on Face Milled Surface Topography, LECTURE NOTES IN MECHANICAL ENGINEERING, 46:10, (2020) 525-534. **14.** *J., Kundrak, C., Felho:* Comparison of theoretical and real surface roughness in face milling with octagonal and circular inserts, KEY ENGINEERING MATERIALS 581, (2014) 360-365. **15.** *M., Posdzich, R., Stöckmann, F., Morczinek, M.,Putz:* Investigation of a plain ball burnishing process on differently machined Aluminium EN AW 2007 surfaces, MATEC Web of Conferences 190:11005 (2018) 1-7. **16.** DEFORM v12sp2 System Documentation July 2, 2020; Scientific Forming Technologies Corporation.

Вікторія Ференчик, Віктор Гал, Мішкольц, Угорщина

КІНЦЕВО-ЕЛЕМЕНТНЕ ДОСЛІДЖЕННЯ ТЕХНОЛОГІЇ ВИГЛАДЖУВАННЯ ПОВЕРХОНЬ

Анотація. *Технології поверхневого зміцнення, що збільшують термін служби деталей машин, грають важливу роль в промисловій практиці. Кращим і ефективним рішенням є вигладжування, при якому використовується відносне переміщення з ковзанням, зменшується шорсткість поверхні, збільшується мікротвердість підповерхневої області і корозійна стійкість за рахунок перестановки дислокацій. Метою цього дослідження є моделювання впливу різних параметрів процесу вигладжування (сила притиску, швидкість вигладжування, швидкість подачі) на якість поверхні. Існує особлива потреба в надійній кінцево-елементної моделі (МСЕ), яка дає базове розуміння механіки процесу. У цій статті представлена 2D-модель FEM для методу вигладжування поверхні. Використання цього методу дозволяє значно знизити вартість експериментальних випробувань. Під час вигладжування зменшення шорсткості поверхні викликано взаємодією інструменту і зразка з поверхневим тертям ковзання між ними. В цьому експерименті операція була виконана на токарному верстаті з ЧПУ OPTIMUM (OPTIturn L-Series 440) з використанням інструменту PCD (полікристалічний алмаз) з радіусом 3,5 мм із зусиллям притиску 12 Н, подачею 0,001 мм / об і швидкістю вигладжування 15 м / хв. У даній роботі 2D звичайно-елементна модель процесу вигладжування кулькою була розроблена з тими ж параметрами, що і емпіричний експеримент за допомогою програми DEFORM-2D. Після моделювання і оцінки результатів можна зробити наступні висновки: вигладжування може бути ефективно використано з параметрами (F_b = 12 Н; f = 0,001 мм / об; V_b = 15 м / хв) відповідно до експериментом і результатами моделювання. Під час моделювання вибір правильного розміру сітки має велике значення для достовірності моделі. Величина шорсткості R_a являє собою добре наближення до експериментального результату, враховуючи, що при мінімальних спрощення моделі ступінь відхилення становить 5,35%, тому, застосовуючи моделювання, можна отримати оптимальні умови вигладжування.*

Ключові слова: *поверхневе зміцнення; вигладжування; шорсткість поверхні; полікристалічний алмаз; кінцево-елементна модель.*