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INVESTIGATION OF SHAPE CORRECTNESS OF DIAMOND BURNISHED LOW ALLOYED ALUMINIUM COMPONENTS

Abstract. *Conventional machining methods such as turning or milling can cause surface irregularities, defects such as tool traces and scratches, resulting in energy dissipation (friction) and surface damage (wear). In contrast, the environmentally friendly chipless burnishing process clearly improves the integrity of the machined surface and largely considered in industrial cases in order to restructure surface characteristics. In this paper influence of different burnishing parameters, such as burnishing speed (v), feed rate (f) and burnishing force (F) are examined. Based on theoretical considerations, we use full factorial experimental design method to determine the optimal combination level of the different parameters in the given interval. The measurement of the shape correctness was executed with Taylor Hobson Talyrond 365 measuring equipment at the Institute of Manufacturing Science.*

Keywords: *plastic deformation; burnishing; aluminum alloys; factorial experimental design method.*

1. INTRODUCTION

More and more intensive and/or varied [1-2] technologies are emerging in the machining of components. At the same time, the productivity of the manufactured parts can only be increased if the accuracy (shape, size, position) and surface roughness of the parts can be ensured even under the conditions of the applied processes [2-3]. So finishing processes have always been important in manufacturing of all kinds of parts and in engineering it is obligate to improve the surface quality of different machine parts to ensure their durability and reliability. As a post finishing operation, the aim of applying burnishing can be increasing surface smoothness and dimensional accuracy of the elements [4-6] such resistance against fatigue strain [7-8]. This is particularly important when machining aluminum alloys because it allows the production of lightweight and high-strength components which are made mass production in the automotive (and aerospace) industry [3]. As a result, research is under way in both machining and cold plastic forming to achieve better results.

In this work a comparing analysis of cylindricity deviations of low alloyed aluminium components is presented focusing on the determination of chosen burnishing parameters such as burnishing speed (v), feed rate (f) and burnishing force (F) using the full factorial experimental design method [9-10], which is valid between the applied maximum and the minimum of the above mentioned parameters.

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2. EXECUTING BURNISHING PROCEDURE ON EXTERNAL CYLINDRICAL SURFACES

Burnishing process is one of the micro plastic manufacturing methods, when a special tool compresses the surface and causes plastic deformation in the subsurface layer, while the pressure must exceed the yield point of the material of the workpiece and flattens asperities from previous machining processes [6, 11].

Experimental work was carried out to determine the effect of the burnishing process parameters on the shape correctness of the external cylindrical surfaces. Before burnishing the components were fine turned on a universal lathe with $f_1 = 0.2$ mm/rev, than $f_2 = 0.15$ mm/rev. The schematic illustration of the component with its dimensions can be seen on Fig. 1.

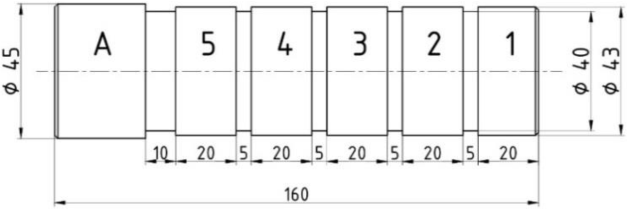


Figure 1 – Schematic illustration of component to be burnished

Burnishing of outer cylindrical surfaces can be executed on conventional universal lath or up-to-date CNC lathe. In our experiments the latter one was used as can be seen on Fig. 2, when the burnishing tool is pressed against pre-machined surfaces to plastically deform peaks into valleys. The deformation is different depending on a lot of things, e.g. among them the magnitude of the force pressing against [12].

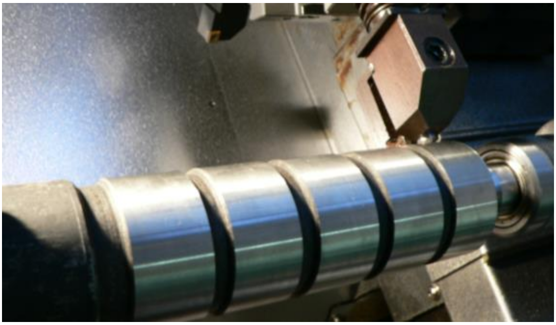


Figure 2 – Executing of burnishing process

3. IMPLEMENTATION OF THE EXPERIMENT

3.1. The applied experimental design method

In order to achieve the optimum set of burnishing parameters for a given specific workpiece requires a large number of experiments. For reducing the total number of the experiments the use of factorial experimental design method is advantageous, which experimental design method is effective and active. The aim of this method is to determine the function relationship between the dependent variable (shape correctness) and the independent variables (burnishing parameters). Each independent variable, called factor can take more values, which are called levels.

3.2. The applied burnishing parameters

During planning of technological process of manufacturing machine components, the method of burnishing, the machining conditions, etc. should be selected [5].

So, in accordance with the full factorial experimental design method the values of the selected factors were set to two (minimum and maximum) levels, which are summarized in Table 1.

Table 1 – The applied burnishing parameters

No.	Adjusted parameters			Transformed parameters		
	v [m/min]	f [mm/rev]	F [N]	x_1	x_2	x_3
1	15	0.001	10	-1	-1	-1
2	30	0.001	10	+1	-1	-1
3	15	0.005	10	-1	+1	-1
4	30	0.005	10	+1	+1	-1
5	15	0.001	20	-1	-1	+1
6	30	0.001	20	+1	-1	+1
7	15	0.005	20	-1	+1	+1
8	30	0.005	20	+1	+1	+1

In determination of the numerical values, we have taken into consideration the results of previous theoretical and practical research works.

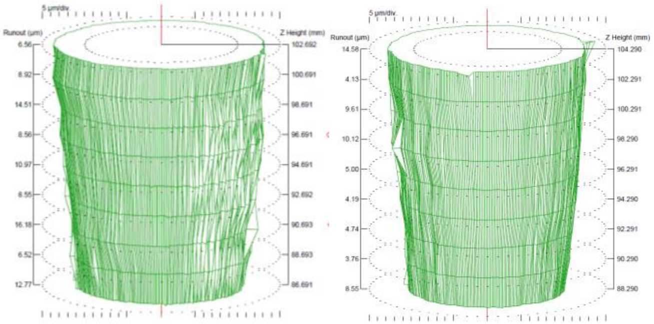
3.3. Measuring of cylindricity deviations

Measuring process of the shape correctness was done with a circular and position error measuring equipment type Talyrond 365. Basic functions of this device include a profile scan with a measuring element fixed in the desired vertical position on the rotating workpiece. This function is suitable for detecting and evaluating circular errors and cylindricity deviations.

In this investigation inductive sensor made from artificial ruby was applied for measuring before and after burnishing in 2 mm distances on 18 mm length of the external cylindrical surface of the component.

In all 16 cylindricity indices was analysed and 3 of them was chosen and examined which mostly determine operating properties. These are so called CYLp and CYLv that write down maximal difference from cylindricity as peaks and valleys, CYLt shows the total distance between peaks and valleys.

For the complete characterization of the cylindricity deviation, a 3D representation of the measured values of the specimen is also required. An example can be seen in Fig. 3 which shows the changing of shape correctness of the component marked 5.



a) b)

Figure 3 – Cylindricity deviation a) before, and b) after burnishing

4. EVALUATION OF RESULTS

In our investigation we have created dimensionless ratios to make the changing of shape correctness more obvious, which are shown in formula (1) and (2):

$$\rho_{CYL} = \frac{CYL_{burnished}}{CYL_{turned}} \tag{1}$$

$$\rho\% = (\rho_{CYL} - 1) \cdot 100 \tag{2}$$

where:

ρ_{CYL}	Improvement ratios of cylindricity parameters (ρ_{CYLp}, ρ_{CYLv}, ρ_{CYLt}). These are dimensionless ratios, that texture the changes occurring because of burnishing,
$CYL_{burnished}$	Cylindricity remain after burnishing,
CYL_{turned}	Cylindricity remain after turning,
$\rho\%$	The percentage value of the improvement ratios.

The lowest the values of ρ%, the greater the improvements due to burnishing. Measured calculated data are summarized in Table 2.

Table 2 – Results

No.	CYLp [µm]		ρ_{CYLp} [%]
	Turned	Bursnihed	
1	9.92	13.28	**33.87**
2	4.09	8.97	**119.32**
3	4.93	10.29	**108.72**
4	4.42	5.77	**30.54**
5	17.25	14.29	**-17.16**
6	7.49	11.05	**47.53**
7	7.61	6.63	**-12.88**
8	5.51	7.53	**36.66**
No.	CYLv [µm]		ρ_{CYLv} [%]
	Turned	Bursnihed	
1	4.98	4.91	**-1.41**
2	5.70	8.06	**41.40**
3	4.79	5.66	**18.16**
4	3.97	7.24	**82.37**
5	9.08	10.61	**16.85**
6	6.58	6.85	**4.10**
7	5.06	5.83	**15.22**
8	5.15	9.65	**87.37**
No.	CYLt [µm]		ρ_{CYLt} [%]
	Turned	Bursnihed	
1	14.90	18.18	**22.01**
2	9.79	17.03	**73.95**
3	9.72	15.95	**64.09**
4	8.39	13.01	**55.07**
5	26.34	24.90	**-5.47**
6	14.06	17.90	**27.31**
7	12.67	12.45	**-1.74**
8	10.66	17.18	**61.16**

Application of Factorial Experiment Design method empirical formulas (3-5) were created from the calculated values. Calculations and axonometric figures (Fig. 4-6) were prepared by using „MathCAD 15.0" software.

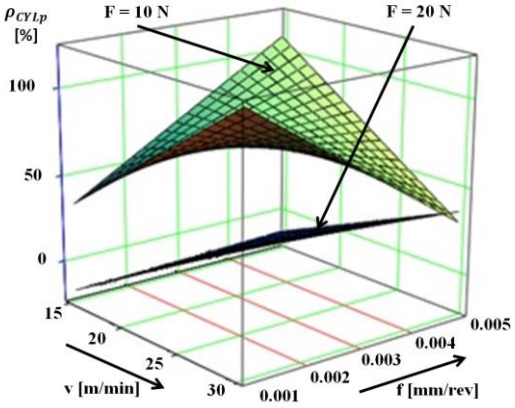


Figure 4 – Changings of cylindricity error in the point of view of peaks

$$\rho_{CYL_p} = -135.69 + 12.28 \cdot v + 1.14 \cdot 10^5 \cdot f + 2.45 \cdot F - 5.20 \cdot v \cdot f - 0.39 \cdot v \cdot F - 5.48 \cdot 10^3 \cdot f \cdot F - 247.47 \cdot v \cdot f \cdot F \tag{3}$$

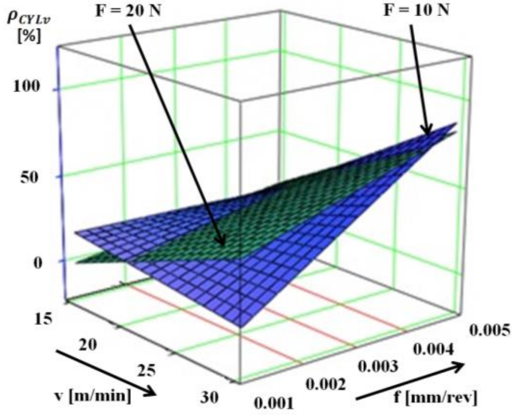


Figure 5 – Changings of cylindricity error in the point of view of valleys

$$\rho_{CYL_v} = -138.76 + 7.26 \cdot v + 2.07 \cdot 10^4 \cdot f + 9.49 \cdot F - 701.67 \cdot v \cdot f - 0.476 \cdot v \cdot F - 2.12 \cdot 10^3 \cdot f \cdot F + 105.83 \cdot v \cdot f \cdot F \quad (4)$$

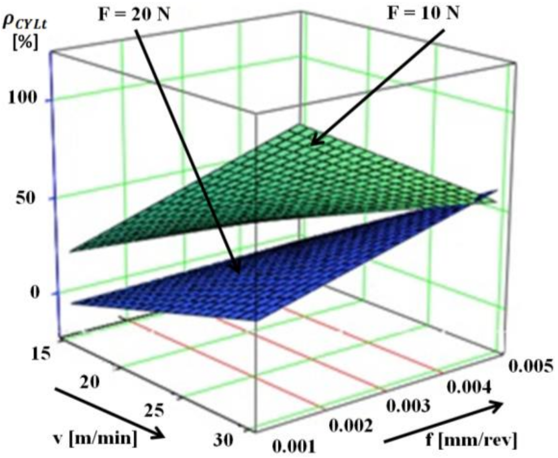


Figure 6 – Changings of cylindricity error in the point of view of total cylindricity deviations

$$\rho_{CYL_t} = -79.72 + 7.27 \cdot v + 5.81 \cdot 10^4 \cdot f + 2.40 \cdot F - 5.53 \cdot 10^3 \cdot v \cdot f - 0.28 \cdot v \cdot F - 3.24 \cdot 10^3 \cdot f \cdot F + 151.80 \cdot v \cdot f \cdot F \quad (5)$$

5. SUMMARY AND DISCUSSIONS

The paper deals with the experimental analysis of sliding burnishing when the material of the workpiece was low-alloyed aluminium. Experimental parameters were the burnishing speed, feed rate and burnishing force. The aim of the experiments was to determine how these parameters have effect to characterising values of shape correctness.

On the base of the present research work it can be stated:

- Contrary to theoretical research and expectations, the diamond burnishing process has not brought such an improvement as it should have. This phenomenon may be due to improper pairing of material quality and burnishing parameters, of course, a more detailed examination of this belongs to our future research plans.

- Examining the evaluated results it can be stated that applying the smaller burnishing parameters is more positive in these ranges and the most appropriate improvement ratio was resulted when the burnishing parameters were as follows:

$$v = 15 \text{ m/min}$$
$$f = 0.001 \text{ mm/rev}$$
$$F = 20 \text{ N}$$

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ДОСЛІДЖЕННЯ ПРАВИЛЬНОСТІ ФОРМИ ДЕТАЛЕЙ З НИЗЬКОЛЕГОВАНИХ АЛЮМІНІЄВИХ СПЛАВІВ ПІСЛЯ ОБРОБКИ АЛМАЗНИМ ВИГЛАДЖУВАННЯМ

Анотація. *Звичайні методи обробки різанням, такі як токарна обробка або фрезерування, можуть викликати дефекти поверхні, такі, як сліди інструменту і подряпини, що призводить в результаті до розсіювання енергії (тертя) і пошкодження поверхні (знос). Навпаки, екологічно чистий процес вигладжування без стружки явно покращує цілісність оброблюваної поверхні і в значній мірі розглядається в промислових випадках для реструктуризації характеристик поверхні. У цій статті розглядається вплив різних параметрів вигладжування, таких як швидкість вигладжування (v), величина подачі (f) і сила притиску вигладжувача (F). Виходячи з теоретичних міркувань, ми використовуємо метод повного факторного планування експерименту, щоб визначити оптимальний рівень комбінації різних параметрів в даному інтервалі. Вимірювання правильності форми було виконано за допомогою вимірювального обладнання Taylor Hobson Talyrond 365 в Інституті виробничих наук. Вигладжування зовнішніх циліндричних поверхонь може бути виконано на звичайному універсальному верстаті або на сучасному токарному верстаті з ЧПУ. У наших експериментах останній використовувався, коли інструмент для вигладжування притискається до попередньо обробленої поверхні для її пластичної деформації. На підставі даної дослідницької роботи можна констатувати: всупереч теоретичним дослідженням і очікуванням, процес вигладжування алмазним інструментом не приніс такого поліпшення, як слід було б. Це явище може бути пов'язане з неправильним поєднанням якості матеріалу і параметрів процесу вигладжування, звичайно, більш докладне вивчення цього питання відноситься до наших планів майбутніх досліджень. Вивчивши отримані результати, можна констатувати, що застосування менших параметрів вигладжування є більш позитивним в цих діапазонах, і найбільш підходящий коефіцієнт поліпшення був отриманий*, коли параметри вигладжування були наступними: v = 15 м / хв, f = 0,001 мм / об, F = 20 Н.

Ключові слова: *пластична деформація; алмазне вигладжування; алюмінієвий сплав; повне факторне планування експерименту.*