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ANALYSIS OF SURFACE MICROHARDNESS ON DIAMOND BURNISHED CYLINDRICAL COMPONENTS

Abstract. *Cold-plastic forming technologies are one of the most dynamically developing technological processes in these days The main purpose of modern plastic forming is to achieve the shape and size of the designed component by providing minimum environmental loads, while ensuring the proper values of strength and deformation characteristics.These methods include surface strengthening processes, characterized by the introduction of cold forming hardening and residual compressive stress [1]. In this paper, we study the main types of surface consolidation in detail to burnishingof outer cylindrical surfaces.The application of burnishing results in cost reduction in several aspects: cheaper, lower alloyed, lower rigid structural materials can be used as raw materials, abandoned grinding and other fine surface machining, can be replaced by heat treatment operations. In our investigation we used polycrystalline diamond tool with spherical machining surface on C60 hardened steel examining the changing of surface micro-hardness caused by different burnishing parameters.*
Keywords: *burnishing; Factorial Experimental Design; microhardness of burnished layer; number of burnishing passes.*

1. INTRODUCTION

In the course of the analysis of the structure of the material and its properties, several strengthening mechanisms are known, one of which is forming hardeningoccurred by cold forming. As a consequence of the cold forming is limited to the surface layer, this strengthening mechanism can be exploited to increase the load capacity and, above all, to increase the lifetime by increasing resistance to fatigue strain.Moreover, in the industrial practice the quality requirements of the parts, exposed to fatigue strain, include the value and distribution of residual stressin the subsurface area [2].

To design and execute the experiments, Taguchi type full factorial experimental design method [3-4] was used to create empirical formulas and evaluate the results by a special relationship ratio to determine the parameter setting values that provide the best results within the given technological parameter ranges.

In the present experiments the examined parameters were: burnishing speed (v_b), feed rate (f), burnishing force (F_b) and the number of passes (i). The latter means how many times the tool passes along linearly on the rotating workpiece surface.

Measuring of the surface micro-hardness of the specimens were executed with Wilson Instruments Tukon 2100B measuring equipment in Vickers hardness.

2. SURFACE BURNISHING

Finishing operations of high precision and low roughness working surfaces of shafts are grinding or polishing, lapping. These operations significantly reduce the surface roughness, but essentially only slightly modify the properties of the surface layer. For occasional substitution of these relatively low productivity and costly chip removal processes, burnishing is used on outer cylindrical surface. The practical implementation of it can be seen in Fig 1.

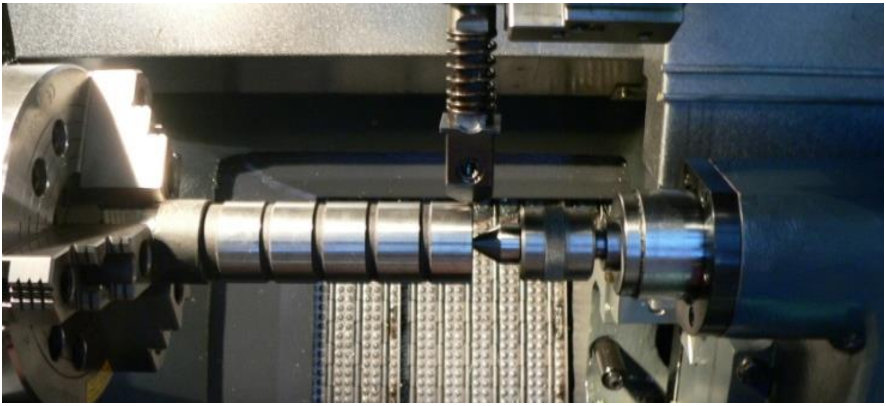

Figure 1 – Burnishing in CNC lathe

During the experiments, a CNC lathe with flatbed by firm OPTIMUM type OPTIturn S600 was used which is located in the workshop of Institute of Manufacturing Science at University of Miskolc. The tool tip was PCD (polycrystalline diamond) with 3.5 mm radius and the kinematic viscosity of the manual dosed oil was 70 mm^2/s.

3. EXPERIMENTAL CONDITIONS

3.1. Burnishing parameters

A number of test results are available in the literature for the burnishing of certain heat-treated (hardness) workpieces with different technological parameters [5-9]. Summarized the factors determining the micro-hardness of the surface layer, according to the above mentioned studies, the following pie chart can be drawn:

From these parameters the burnishing force, feed rate, and speed were choosen setting with two values of number of passes. The latter does not belong to the factors because the experimental design, such as the representation of the results will be too difficult and less obvious with four factors.

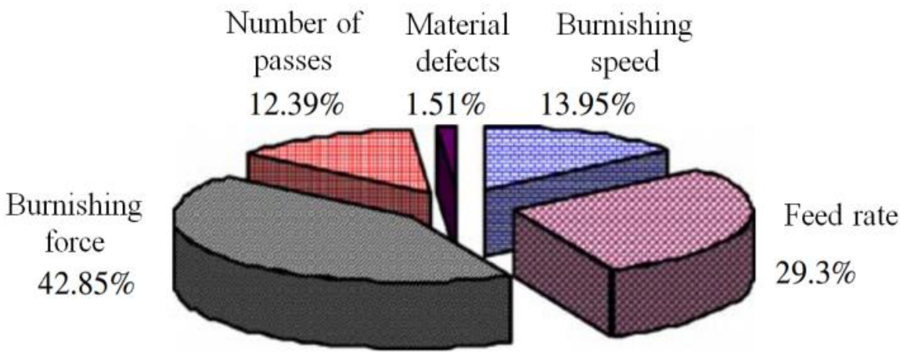

Figure 2 – Parameters affecting surface micro-hardness [8]

In the matrix of the Taguchi type full factorial experimental design (Table 1) we can see these parametersin natural dimensions and their transformed values

Table 1 – Applied burnishing parameters

Sign of specimen	Parameters of burnishing			Transformed parameters		
	F_b[N]	f [mm/rev]	v_b [m/min]	X_1	X_2	X_3
1	50	0.05	40	-1	-1	-1
2	100	0.05	40	+1	-1	-1
3	50	0.1	40	-1	+1	-1
4	100	0.1	40	+1	+1	-1
5	50	0.05	80	-1	-1	+1
6	100	0.05	80	+1	-1	+1
7	50	0.1	80	-1	+1	+1
8	100	0.1	80	+1	+1	+1

3.2. Measuring of surface micro-hardness

The apparatus (Wilson Instruments Tukon 2100B) also measures Vickers hardness, which has the same principle as all hardness measurements, is to examine how a material is subject to plastic deformation by using a standard force. During the measurement, a 136 ° diamond pulley is pressed with a specific force, 10 N in our experiments for 10 seconds on the surface to be measured. In the course of the evaluation, using a CCD camera, weigh the traces of the imprint and the average of the two is calculated by the device own software calculating the impression surface [10]. Fig 3 illustrates the measurement and a Vickers test imprint on the workpiece surface.

Figure 3 – Measurement process

In order to capture the most accurate values, we carried out control measurements both on the workpiece surface and on a control block calibrating the device.

4. RESULTS AND EVALUATIONS

For evaluation of measured data an improvement ratio was introduced, which is shown in formula (1):

$$\rho_{HV} = \frac{HV_b - HV_g}{HV_g} \cdot 100\% \quad (1)$$

where: ρ_{HV} Dimensionless improvement ratio of the surface micro-hardness,

HV_b Hardness of the burnished surface,

HV_g Hardness of the grinded surface.

The larger the value of ρ_{HV}, the greater is the improvement due to burnishing.

In some cases decrease in hardness was experienced, the reason of it will be investigated

Measured data and the improvement ratios of surfacesmicro-hardness, calculated by formula (1), in the case of setting 1 and 3number of passes, summarized in Table 2.

Table 2 – Measured and calculated results

Sign of specimen	HV i = 1		ρ_{HV1}[%]	HV i = 3		ρ_{HV3}[%]
	after grinding	after burnishing		after grinding	after burnishing	
1	882.4	985.5	11.68	883	1018.5	15.35
2		914	3.58		961.5	8.89
3		977	10.72	874.6	986	12.74
4		1059	20.01		909	3.93
5		1024	16.05		906.5	3.65
6	883	860	-2.60		865.5	-1.04
7		832	-5.78		1042.5	19.19
8		854.5	-3.33	846	991.5	17.19

We created empirical formulas (2-3) from the calculated values,further calculations and demonstrations (Fig. 7-8) were created by „MathCAD 16.0" software.

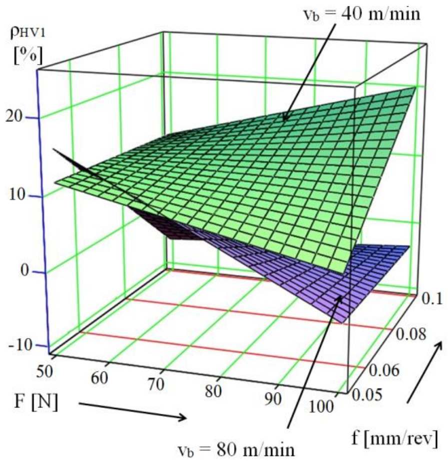

Figure 4 – Changing of surface micro-hardness in the case of i =1

$$\rho_{HV_1} = -1.37 - 0.225 \cdot F_b + 124.6 \cdot f + 0.998 \cdot v_b + 5.472 \cdot F_b \cdot f - 7.13 \cdot 10^{-3} \cdot F_b \cdot v_b - 12.29 \cdot f \cdot v_b + 0.037 \cdot F_b \cdot f \cdot v_b \quad (2)$$

$$\rho_{HV_3} = 48.65 - 0.017 \cdot F_b - 267.4 \cdot f - 0.665 \cdot v_b - 2.956 \cdot F_b \cdot f - 1.635 \cdot 10^{-3} \cdot F_b \cdot v_b + 6.555 \cdot f \cdot v_b + 0.05 \cdot F_b \cdot f \cdot v_b \quad (3)$$

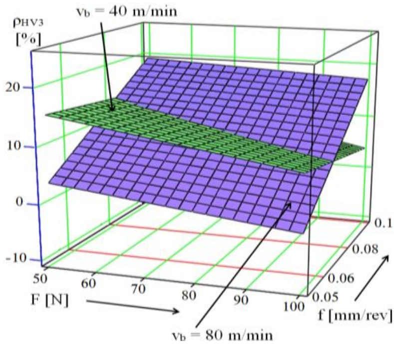

Figure 5 – Changing of surface micro-hardness in the case of i =3

5. SUMMARY

The paper contains diamond burnishing experiments on hardened steel with its measurement and evaluation results. The purpose of this study was to determine how the choosen burnishing parameters affect the change of micro-hardness. The experiments and the evaluation of the measurement results were performed by using the Taguchi type full factorial experimental design method. According to the measured, calculated and illustrated results the following conclusions have been drawn:

- Among the examined parameters, the effect of feed rate is the most dominant and it has a strong interaction with the burnishing speed
- Parameters that resulted the largest and thus the most favorable surface micro-hardness were follows:

F = 50 N; v_c = 80 m/min; f = 0.10 mm/rev; i = 3

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АНАЛІЗ ПОВЕРХНЕВОЇ МІКРОТВЕРДОСТІ НА ЦИЛІНДРИЧНИХ ДЕТАЛЯХ ПІСЛЯ АЛМАЗНОГО ВИГЛАДЖУВАННЯ

Анотація: *Технології холодного пластичного формування є одними з тих, які найбільш динамічно розвиваються у наші дні Основною метою сучасного пластичного формування є досягнення форми і розмірів проектованого компонента шляхом забезпечення мінімальних екологічних навантажень, при забезпеченні належних значень міцності та деформаційної стійкості. Ці методи включають в себе процеси поверхневого зміцнення, що характеризуються введенням холодного поверхневого зміцнення і залишковими напругами стиснення. В даній роботі ми вивчаємо основні типи ущільнення поверхні детально до ущільнення зовнішніх циліндричних поверхонь. Застосування спалювання призводить до зниження вартості в декількох аспектах: дешевші, низьколеговані, нижчі тверді конструкційні матеріали можуть бути використані як сировина, відмова від шліфування та іншої тонкої обробки поверхні, може бути замінена термічною обробкою. З аналізу структури матеріалу і його властивостей відомо кілька зміцнюючих механізмів, одним з яких є зміцнення, що виникає при холодній деформації. Внаслідок того, що холодне деформування обмежене поверхневим шаром, цей підсилюючий механізм може бути використаний для збільшення опору зовнішнім навантаженням і, перш за все, для збільшення терміну служби за рахунок збільшення опору втомної деформації. Крім того, в промисловій практиці, вимоги до якості деталей, схильних до втомних напружень, відносяться величина і розподіл залишкових напружень в приповерхневій зоні. Мета цього дослідження полягала в тому, щоб визначити, як вибрані параметри зміцнення впливають на зміну мікротвердості. Експерименти і оцінка результатів вимірювань проводились з використанням методу планування повного факторного експерименту типу Тагучі. На підставі виміряних, розрахованих і проілюстрованих результатів були зроблені наступні висновки: серед розглянутих параметрів вплив швидкості подачі є найбільш домінуючим, і воно тісно пов'язане зі швидкістю ущільнення. Параметри, які привели до найбільшої і, отже, найбільш сприятливою мікротвердості поверхні, були наступними: сила притиску 50Н, швидкість 80 м / хв, подача 0,1 мм / об.*

Ключові слова: *вигладжування; планування факторного експерименту; мікротвердість полірованого шару; кількість вигладжувальних проходів.*