VIBRATORY BURNISHING OF EXTERNAL CYLINDRICAL SURFACES

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ABSTRACT

The paper presents a prototype structural solution of a stand for vibratory burnishing of external cylindrical surface. It also discusses the influence of technological parameters of the treatment on surface roughness and dimensional accuracy of an object made of the constructional steel 45 /Polish Standard/. The experiment was carried out with an application of the rotatable design type two /2^2-type/ and the obtained result has a form of a second degree polynominal

$$R_a = f/F,v,p/ \quad \text{and} \quad \Delta d = f/F,v,p/$$

where:

R_a - surface roughness after the treatment
Δd - diameter change of the treated element
F - burnisher pressing force
v - object's speed
p - burnisher feed

Vibration frequency: /10; 20; 30Hz/
The results of the tests /tables, equations, diagrams/ and their analysis are shown in the summary.

KEYWORDS
Vibratory burnishing, cylindrical surface, surface roughness, test stand.

INTRODUCTION

Quality improvement of machine elements and various instruments can be achieved due to selection of the proper finishing. One of the methods of that kind is vibratory burnishing [1] . It is a simple and economical method of machining based on embossing micro-grooves on the machined surface by means of a metal ball or a diamond element. This kind of treatment can be performed on any machine tool. Vibratory burnishing as a surface treatment of machine elements submitted to an intensive wear, changes profitably their lubrication conditions [2]. In this connexion vibratory burnishing of slide bearings, cylinders, pistons and other machine elements seems to have considerable development prospects in the contemporary manufacturing technology. For several years now investigations on operating properties of the surface after vibratory burnishing have been carried out in the Institute of Technology in Opole, Poland [3].

TEST STAND

Principle of Operation of the Vibratory Burnishing Device

The test stand Fig.1 and the instrument's principle of operation are shown in Fig.2. The burnished element /1/ is fixed in the

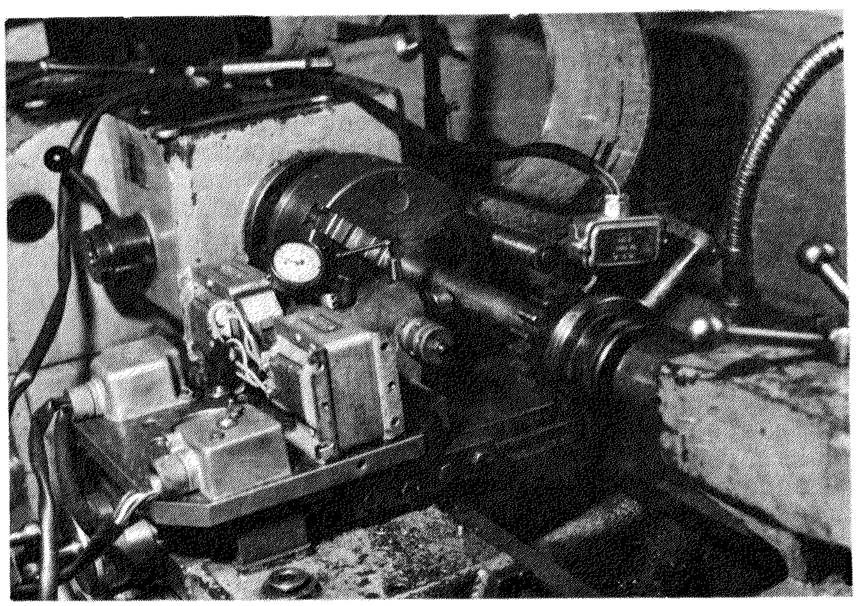

Fig.1 Test stand

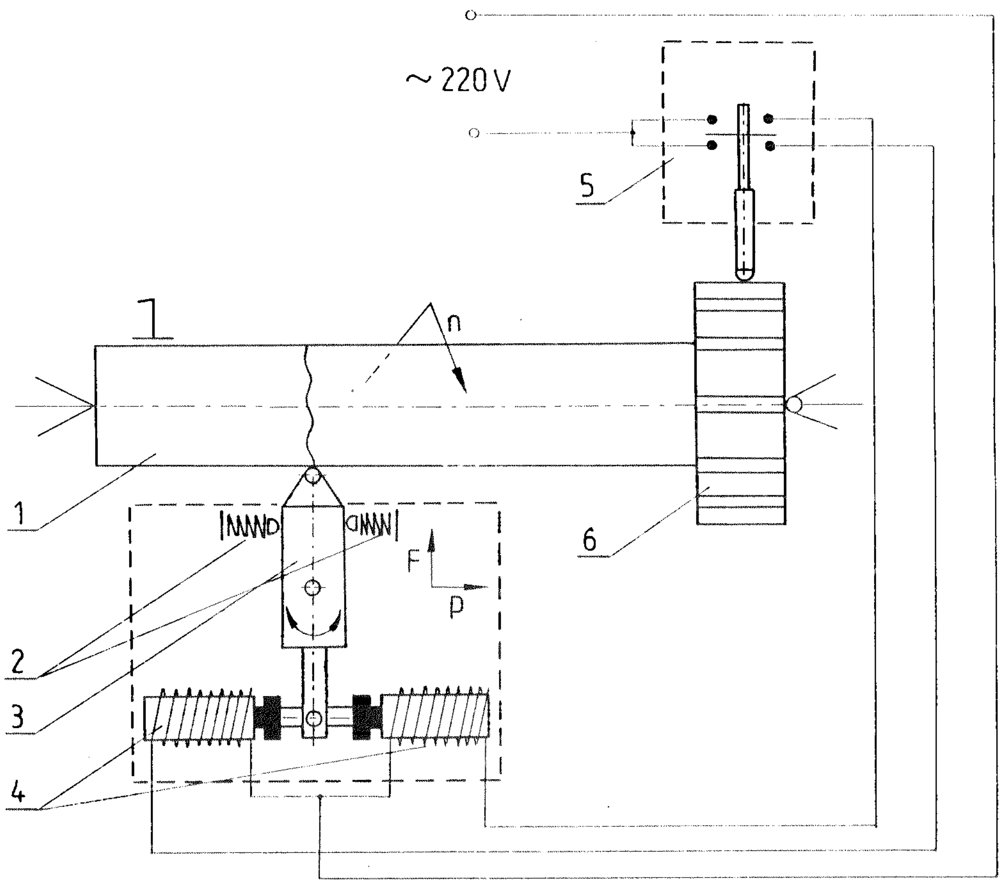

Fig.2 Kinematic scheme of the vibratory burnishing stand

1. burnished element /workpiece/
2. shock absorbers
3. burnishing element
4. electromagnets
5. electric switch
6. toothed wheel

lathe centres. Burnishing element /ball/ is seated in the head /3/ coupled with two electromagnets /4/ by means of their armatures. The head's vibrations are supressed by shock absorbes /2/ Mechanical vibration damping system lets an operator control the head's vibration amplitude and improves the surface profile.
The vibration amplitude is controlled by means of proper setting adjusting sleeves in brackets on both sides of the vibratory head. During the experiment the burnishing static force 'F' was determined empirically Fig.1. The vibratory head is mounted instead of lathe's TUD - 50 cutter holder.

Control System

The whole control system Fig.3 is placed on the revolving centre

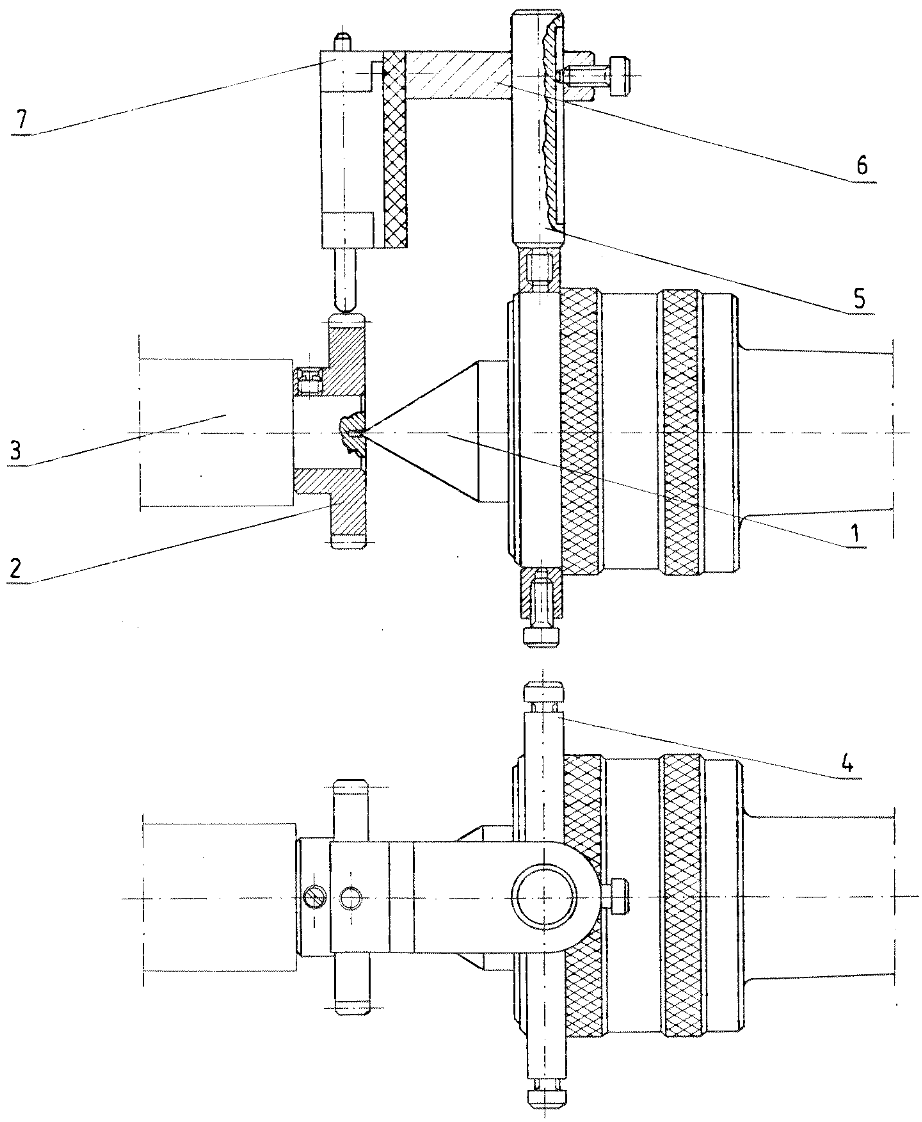

Fig.3 Control system

1.revolving centre
2.toothed wheel
3.test shaft
4.clamping ring
5.mandrel
6.arm
7.electric switch

/1/ in the lathe's tailstock spindle. It transmits electric impulses to the vibratory head through electromagnets that make the ball vibrate.Toothed wheel /2/ is mounted on the shaft neck /3/ whereas clamping ring /4/ together with mandrel /5/ are mounted on the revolving centre casing. On the clamping ring a sliding arm and a switch are mounted. The dependence of the burnisher ball vibration on the burnished object rotation is achieved by changing the switch position.

METHODOLOGY AND CONDITIONS OF THE TEST

The test was performed on samples made of toughened steel 45/Polish Standard/ of the hardness value 30 HRC $\pm$2. They were shaft -shaped Ø 40 in diameter and divided into three separate measurement fields each 50 mm long. Sample surfaces had been initially turned with a carbides S10 /Polish Standard/ cutter to obtain roughness R_a= 2,5 - 5 µm. And then they were burnished on the same lathe TUD-50. Range of changes of the burnishing parameters values amounted to:

- burnisher pressing force F = 300 - 500 kN
- object's speed v = 0,04 - 0,10 m/s
- burnisher feed /head and saddle/ p = 0,08 - 0,024 mm/rev
- vibration freqency n_o = 20, 30 and 40 Hz

Diameter of the burnishing ball was Ø 12 mm.
The experiment was carried out with no use of any fluid. The machining was performed in one round only since the next ones have little influence on surface and also impair the quality of the obtained surface layer. Surface roughness parameters were determined with the use of a profile measurement gauge 'Kalibr 201' while the change within the sample's diameter - with an Abbe horizontal metroscope as preliminary experiments showed, big initial surface roughness constitutes a shield for inner layers and considerably impedes their deformation which, in consequence, results in non-homogenuous roughness and hardness of the burnished surface.

Tab.1 Burnishing parameters values

Coded burnishing parameters values		Not coded burnishing parameters values		
Variables denotation		F kN	v m/sec	p mm/2Πrd
		X_1	X_2	X_3
Central point	0	400	0,07	0,16
Variation interval	X	459,45	0,0178	0,0475
Lower level	-1	340,54	0,0521	0,112
Upper level	+1	459,45	0,0878	0,207
Level /-α/	-1,682	300,00	0,04	0,08
Level /+α/	+1,682	500,00	0,1	0,24

RESULTS OF THE TESTS

On the base of statistic method of experimental design the influence of the treatment parameters /F, v, p, n_o/ on the final surface roughness R_a was determined and diameter change of the treated element Δd. The treatment parameters corresponding to individual tests and the range of their changes are shown in table 1. After a statistic analysis of the test results a general form regression equation, adequately describing the research object at 5% significance level, was obtained.

$$Y = x_0 + x_1X_1 + x_2X_2 + x_3X_3 + x_{11}X_1^2 + x_{22}X_2^2 + x_{33}X_3^2 + x_{12}X_1X_2 + x_{13}X_1X_3 + x_{23}X_2X_3 \qquad (1)$$

Table 2 shows coefficient values of regression equations for different test conditions.

Tab.2 Coefficient values of regression equations

Coefficients of regresion equation	Impulse frequensy n_o					
	n_o = 20 Hz		n_o = 30 Hz		n_o = 40 Hz	
	Tested factor "Y"					
	R_a	Δd	R_a	Δd	R_a	Δd
x_0	0,33075853	0,42106995	0,49816104	5,5123854	12,8250966	14,705039
x_1	-0,00093110	-0,0045237	0,00269815	-0,0199104	1,0845240	0,006734
x_2	0,00332621	0,0001317	0,00375809	-0,4125552	0,8483881	2,265821
x_3	0,00688519	-0,037361	-0,0463854	-0,4425672	-1,3574208	0,053289
x_{12}	0	-0,01125	0,01375	0,125	1,25	-0,25
x_{13}	0	0,00125	-0,00875	0,125	-2,25	0,5
x_{23}	0,0025	-0,00375	-0,04625	-0,625	0,5	0,25
x_{11}	-0,02516	-0,045472	-0,0247689	-0,1944116	-1,0622378	0,795543
x_{22}	-0,011023	-0,034863	-0,0389145	-0,5480521	-2,299979	-1,149478
x_{33}	-0,012791	0,0022685	-0,0123915	-0,3712319	7,7787748	-2,740861

CONCLUSIONS

a) Vibratory burnisher designed for working external cylindrical surfaces testified to its operating usability.

b) Realizing the research project the following response function formulated as a regression equation was obtained. Minimal roughness of a vibratory burnished surface/R_a = 0,12 µm /within the tested working parameters was obtained for the bur - nish force F = 300 kN, tangential velocity of the burnished element v = 0,475 m/sec, burnish feed p = 0,0878 mm/2πrd and vibration frequency n_o= 20 Hz.

c) An additional effect of vibratory burnishing is a regular recurrence of micro-unevennesses that differ from ridges after turning or grinding. The micro-unevennesses improve superficial oil absorptivity and thus they improve the working conditions of those machine elements that are exposed to an intensive wear.

d) This kind of treatment can be applied to make various patterns /reliefs/ on surfaces to improve their decorative quality.

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