EXTERNAL FINISHING OF TURNED SURFACES BY TECHNOLOGY OF BURNISHING

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Abstract

The paper is the scientific study of the burnishing technology which is finishing operation of turned surfaces. The topic of experiments is the comparison of surface qualitative parameters between turned only and burnished surfaces on cylindrical experimental samples. The burnishing of turned surface is a cold forming method with using of fulcrum cylindrical rollers. This method bring better surface quality, dimensional accuracy or surface hardness increase. Therefore the burnishing technology could replace surface finishing by grinding or polishing. First chapter describes the ways of turning. Second chapter deals with turned and then burnished surfaces and used burnish tools. Chapters three and four are core of the paper and they are targeted to experiment realization. Conclusion summarizes the advantages of burnishing process and its good influence on the utility parameters of industrial components.

Keywords: burnishing, turned surface, surface quality, microgeometry, cutting parameters.

1 Introduction

The finishing technologies of machined components consist of grinding, honing, super finishing, laping, polishing and also burnishing of the cylindrical as well as coplanar surfaces [1, 2, 13].

The purpose is to reach the increase of surface quality after turning or milling and drilling and reaming at holes machining. For example Arithmetic average of surface roughness R_a increases after application of burnishing technology. Also surface hardness, corrosion resistance and wear resistance could be achieved [8].

Conventional technologies of surface finishing (grinding, honing, super finishing, laping or polishing) typically request specialized, precise and single purpose machining tools with several disadvantages:

- they are expensive
- they have low productivity
- high qualification of operator is needed
- final mechanical properties and microstructure are influenced by heat transfers connected with those technologies [3, 11]

2 Description of the approach, work methodology, materials for research, experiments

All metal materials with plastic forge ability are also suitable for surface burnishing. Most important parameters are elongation (A), tensile strength (R_m) or hardness (HB). The materials with low elongation are hard forgeable and therefore they must have lower surface roughness. Good forge ability have following materials:

a) Constructional carbon steels of class 11 (11107 – 11700, classification according STN standards)
b) Untreated as well as quenched and tempered premium steels of class 12 ($R_m \leq$ 1350 MPa, A $\geq$8% to 15%)
c) Annealed low carbon steels for cementation (12020, 14220 , 16220)
d) Constructional alloyed steels with tensile strength $R_m \leq$ 1350 MPa
e) Some non ferrous metal with A $\geq$ 8%
f) Ductile iron with A $\geq$ 8% [12]

Tools and various additional devices on the machines for plastic forging of the external cylindrical surfaces are designed in several ways with purpose of static surface smoothing, hardening or dimensional calibrating.

The burnishing by fulcrum cylindrical rollers brings the decreasing of the surface roughness and the increasing of the fatigue strength [4, 10]. The device used for experiment is on the fig. 1.

How to meet high dimensional precision required by assembly drawing, effectiveness of production or saving of production time and other characteristics that are all given by nowadays trends? There are various design of tools for static (fixed, compact, adjustable) or dynamic smoothing of the surfaces as well as tools with axifugal influence on the surface [5, 7].

The principle of burnishing technology lies in plastic deformation of the surface irregularities where the irregularities are caused by application of previous machining technologies. Forging element of suitable shape (sphere, cylinder) influencing the burnished surface by specific static force whereby original micro irregularities are falling with creating of the compressive stresses. Increasing of these internal stresses leads to the hardening of the turning surface [6].

The surface before burnishing consists of the peaks and the cavities with irregular highs and steps. These steps are pushed to the cavities by the quenched rolling segments during burnishing process. The results of this process are mirrored bright surface with higher corrosion and fatigue resistance. The final roughness after burnishing decreases about 50% in comparison to the initial one. The final dimensions after burnishing are affected by initial roughness particularly. Changes in dimensions can be determined empirically [9].

Forging process applied on the surface layers and its application on the industrial components has following advantages:

- Surface roughness decreases form $R_a = 3,2 \div 1,6$ μm to $R_a = 0,4 \div 0,1$μm
- Mechanical properties of the surface are improved
- Corrosion and Fatigue resistance are increased
- Sliding properties are increased and therefore the surface can be loaded with higher forces
- Productivity is increased and the process can be realized on the conventional and universal turning machines or CNC turning machines

Several companies deal with production of special rolling burnishing tools (HEGENSCHEIDT, MADISON, ŠKODA, HYDRONIKA-DEE, HELLER, BURGSMŰLLER, IMEXIM TS etc.) nowadays. Effect of the surface burnishing lies in surface roughness improvement, surface load bearing increase about 80%÷90% and surface hardness increase about 50%.

3 Experimental tests of roller burnishing technology application

For roller burnishing tests of turned surfaces by the holder with rotating pulley (Fig.1) were prepared 6 pieces of samples „PUZDRO“ (Fig.2) with diameter Ø55mm /35 mm and length l = 53mm. The samples were mark by the „Center Punch“ on one face with number of holes 1 to 6. Material of samples is 11523. Chemical analysis was identified by spectral analysis of the device Spectrolab Jr^{CCD}. Chemical composition of this material is as follows: C 0.158; Mn 1.057; Si 0.439; P 0.028; S 0.017. Tests were carried out on a universal lathe SUI 32x750 and clamp the sample half ribbed follower into the hole in the spindle of the machine. Support by the tailstock with a nozzle can see on Fig. 2. Applied compressive force has been established by the front bench (see on Fig. 3).

Tools and equipment for molding plastic outer cylindrical surfaces are designed in different design variants, such as for the purpose of smoothing the surface, as well as for reinforcing and calibrating dimension [8].

If pressed cross slide on the appropriate distance value, then it is characterized by axial force dynamometer as follows:

Pressure: 0.12 mm / Ø = axial force 0,25 kN
0.25 mm / Ø = axial force 0,50 kN
0.37 mm / Ø = axial force 0,75 kN
0.43 mm / Ø = axial force 1,0 kN

To use the material for each sample was taken in the middle of recess. Then for each sample were carried out on two roller surfaces. For turning were used tool holder PN 25 x 25mm (PRAMET Šumperk) cutting insert: CNMG 120408-MM, and cutting material GC2015 (SANDVIK Coromant).

3.1 Smoothing parameters of test samples with roller burnishing

According to various authors - the burnishing with speeds range from $v_c = 60 \div 120\text{m.min}^{-1}$, depending on the strength and hardness of the material. Used for smoothing the shift is chosen depending on the starting roughness after turning radius and the forming tool in the range f = 0.1 to 0.5 mm.

When burnishing technology is recommended to cool and lubricate the best and sparse cutting oil (the machines) or oily emulsion. Contact force F = 100 to 1500 N according to the shape and size of reinforcement tool.

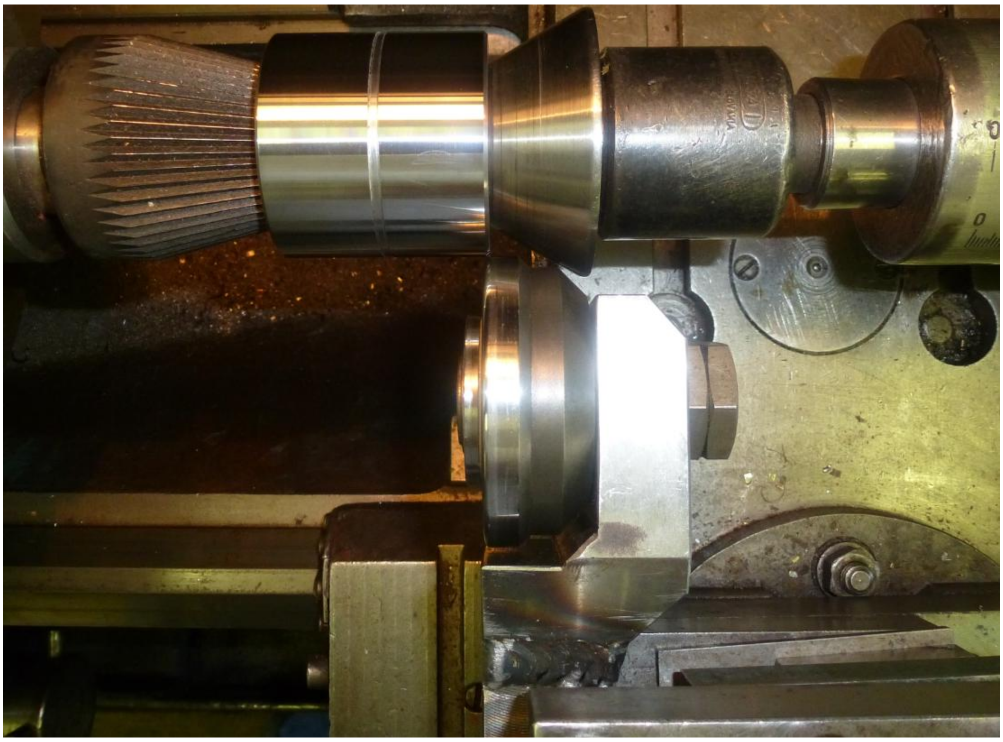

Fig. 1 *Burnishing tool with rotating hardened pulley and the sample " PUZDRO"*

Holder with hardened roller is designed to fortify the radius from the front surface with universal automotive parts mainly for increased seal life [11]. It is also useful for roller burnishing test samples using cooling E5%. The method of mounting the sample and the front dynamometer is shown in Fig. 2 and 3.

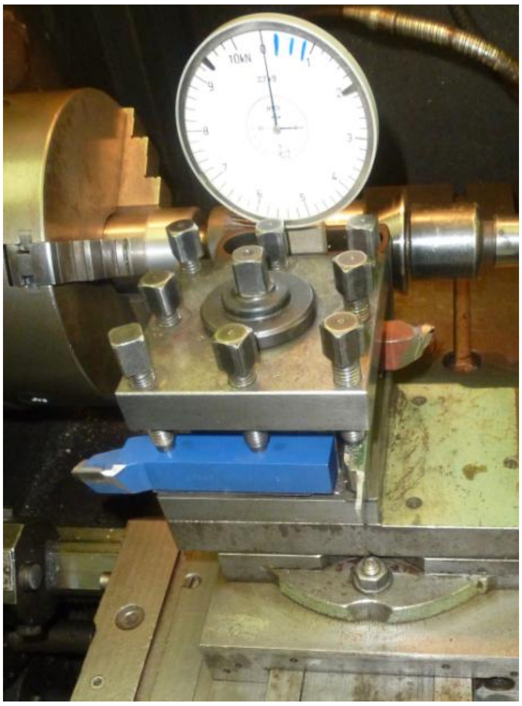

Fig. 2 *Calibrating method of front dynamometer*

Fig. 3 *Front dynamometer*

4 Description of achieved results

In the process of experiment I. was realized external longitudinal turning of samples „PUZDRO“ on lathe machine SUI 32 (see Fig. 5) by the cutting tool with carbide insert (SANDVIK Coromant) using the following cutting conditions:

Rotational frequency: $n = 630\ min^{-1}$
Cutting speed: $v_c = 108\ m.min^{-1}$
Feed motion: $f = 0.141$ mm
Depth of cut: $a_p = 0.25$ mm
The turning process was realized without coolant.
The reached roughness of turned surface (Fig. 4a) after measuring on apparatus MITUTOYO SURFTEST SJ301 has the value Ra = 1.20µm.

Fig. 4a *Measured profile of surface roughness Ra after turning technology*

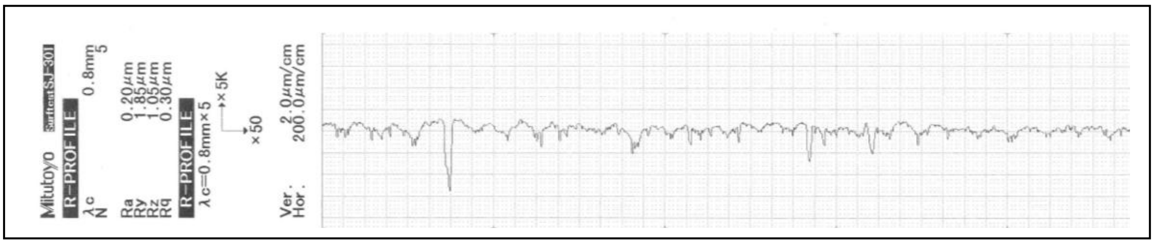

Fig. 4b *Measured profile of surface roughness Ra after burnishing technology*

Parameters of burnishing for experiment: (Fig.8)
Rotational frequency: $n = 630\ min^{-1}$
Cutting speed: $v_c = 106.8\ m.min^{-1}$
Feed motion: $f_1 = 0.141$ mm - the direction of feed motion from spindle to tailstock (see Fig.6)
$f_{\Gamma} = 0.202$ mm - the direction of feed motion from spindle to tailstock
$f_3 = 0.111$ mm - the direction of feed motion from spindle to tailstock
$f_4 = 0.081$ mm - the direction of feed motion from spindle to tailstock
$f_5 = 0.141$ mm - the direction of feed motion from spindle to tailstock
Coolant: drilling emulsion E5%
Contact pressure: P = 0.5 kN

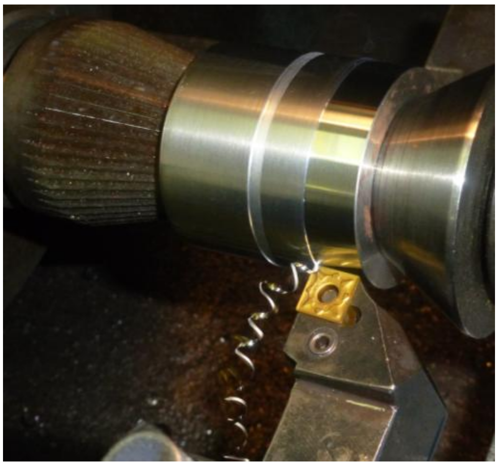

Fig. 5 *Longitudinal surface turning of the testing sample no.1*

Fig. 6 *Burnishing of rotational surface of the sample.1 with feed motion f_1 (experiment 1)*

The achieved results for experiment I can listed in Table 1 and on Fig. 8 (graphical dependence Ra = F(f).

***Table 1** Experimental results (experiment I)*

Sample with 3 sockets on rake	f_1 = 0,141 mm	average surface roughness after roller burnishing R_{a1} = 0.48μm
	f_2 = 0,202 mm	average surface roughness after roller burnishing R_{a2} = 0.49μm
Sample with 2 sockets on rake	f_3 = 0,121 mm	average surface roughness after roller burnishing R_{a3} = 0,51μm
	f_4 = 0, 111 mm	average surface roughness after roller burnishing R_{a4} = 0,46μm
Sample with 1 socket on rake	f_5 = 0, 081 mm	average surface roughness after roller burnishing R_{a5} = 0.39μm
	f_6 = 0, 141 mm	average surface roughness after turning R_{a6} = 1.19μm

Changing the diameter burnishing: - D = D_{turned} – 0.01 to 0.02 mm

In the process of experiment II was realized external longitudinal turning of samples „PUZDRO" on lathe machine SUI 32 (see Fig. 5) by the cutting tool with carbide insert (SANDVIK Coromant) using the following cutting conditions:

Rotational frequency: n = 630 min^{-1}
Cutting speed: v_c = 108 $m.min^{-1}$
Feed motion: f = 0.243 mm
Depth of cut: a_p = 0.25 mm
The turning process was realized without coolant.
The reached roughness of turned surface (Fig. 7a) after measuring on apparatus MITUTOYO SURFTEST SJ301 has the value Ra = 2.18μm.

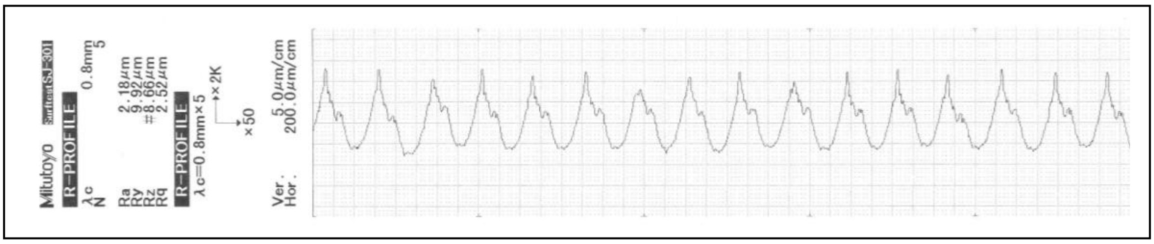

***Fig. 7a** Measured profile of surface roughness Ra after turning technology*

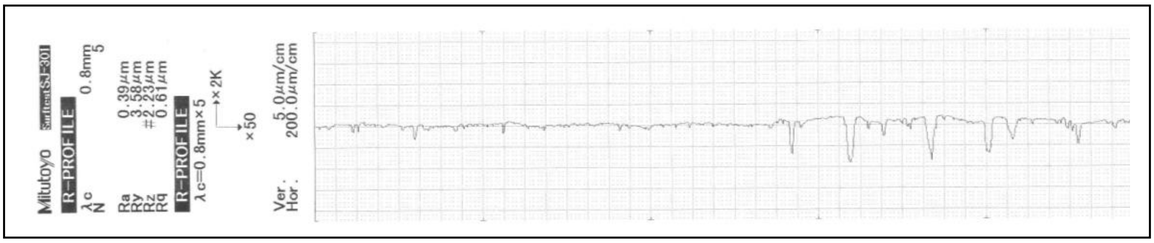

***Fig. 7b** Measured profile of surface roughness Ra after burnishing technology*

Parameters of burnishing for experiment II.: (Fig. 9)
Rotational frequency: n = 630 min^{-1}
Cutting speed: v_c = 106.8 $m.min^{-1}$
Feed motion: f_1 = 0.243 mm - the direction of feed motion from spindle to tailstock
f_2 = 0.202 mm - the direction of feed motion from spindle to tailstock
f_3 = 0.141 mm - the direction of feed motion from spindle to tailstock
f_4 = 0.111 mm - the direction of feed motion from spindle to tailstock
f_5 = 0.121 mm - the direction of feed motion from spindle to tailstock
Coolant: drilling emulsion E5%. Contact pressure: P=0.5kN

The achieved results for experiment II can listed in Table 2 and on Fig. 9 (graphical dependence Ra = F(f).

***Table 2** Experimental results (experiment II)*

Sample with 3 sockets on rake	f_1 = 0,243 mm	average surface roughness after roller burnishing R_{a1} = 0.36μm
	f_2 = 0,202 mm	average surface roughness after roller burnishing R_{a2} = 0.33μm
Sample with 2 sockets on rake	f_3 = 0,141 mm	average surface roughness after roller burnishing R_{a3} = 0.31μm
	f_4 = 0, 111 mm	average surface roughness after roller burnishing R_{a4} = 0.26μm
Sample with 1 socket on rake	f_5 = 0, 121 mm	average surface roughness after roller burnishing R_{a5} = 0.29μm
	f_6 = 0, 243 mm	average surface roughness after turning R_{a6} = 2.11μm

Changing the diameter burnishing: - D = D_{turned} – 0.01 to 0.02 mm

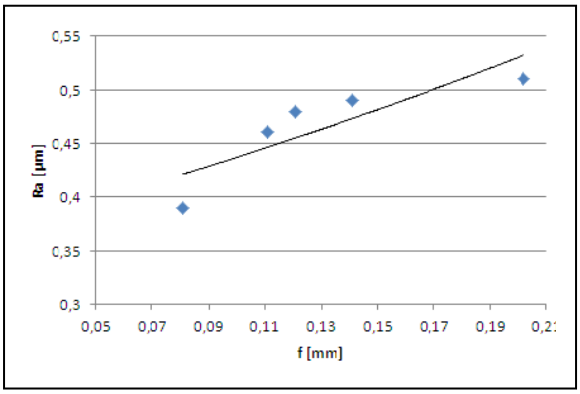

Fig. 8 *Graphical dependence Ra = F(f) after burnishing (experiment I.)*

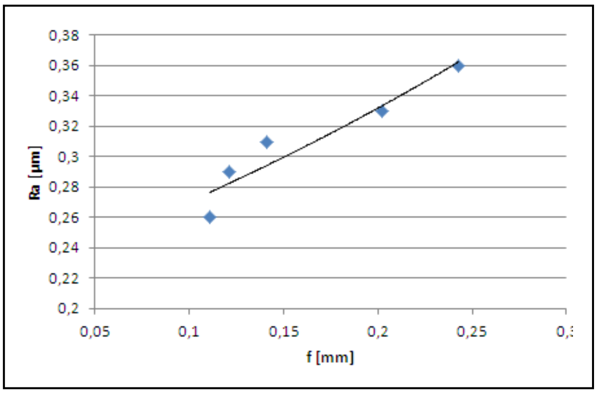

Fig. 9 *Graphical dependence Ra = F(f) after burnishing (experiment II.)*

5 Conclusion

In conclusion we can say that the fact that smoothing the surface with a roller (statically or dynamically) is the practice of paramount importance for a wide range of applications. It can be recommended as the unit production prototypes, repairs, but with modern advanced tools even in mass production. In this case, it is always necessary to perform an analysis of unit costs for the original and the proposed technology. The outcome of the roller has the greatest influence first crossing with burnishing tool. The following passages have been weaker effect and a larger number may even affect the surface quality. The reached values of surface roughness Ra are significantly much better after burnishing application then we can reach on turned or grinded surfaces. This is due to reduction of fatigue strength and peeling of the surface layer. In industrial practice, therefore, has attempted roll on surfaces of parts per shift. In the event that this is technically not possible (as parts of complex shape, thin-walled components, thin shaft) is a roller made several transits. The own justify of using roller under practical conditions of industrial production which is based on the operational reliability of products (e.g. torsion bars, axles, wagons, shafts, etc.). Benefits of burnishing technology lie in higher quality of surface finish of achieved components.

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