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Study of the Influence of the Honing Process by Plastic Deformation on the Turning of AISI 1045Steel

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Abstract

Burnishing is a machining process without chip removal that seeks to improve the surface roughness of a component by means of plastic deformation of the surface layers. Due to the process mechanics, during its execution, a compressive residual stress is introduced into the surface of the workpiece during its execution, which improves various physical-mechanical properties of the component. This process has been used industrially since the 1950s, mainly in pieces made of soft materials (hardnesses up to 45 HRC), in operations subsequent to processes such as turning. The development of tools with harder materials, has opened up the possibility of burnishing on harder materials (hardnesses up to 62 HRC). Burnishing of hard materials has opened up an alternative to traditional finishing processes such as grinding, its main comparative advantage is its low-cost operation, which reduces grinding costs by 8 to 15 times. The plastic deformation burnishing is a metal working process with material removal whose advantages are that it does not generate waste, which is a competitive advantage over other surface finishing processes such as grinding, where waste is generated which also needs to be collected

and subsequently treated. The use of e.g. coolants is not necessary either, in recent years, attempts have been made to eliminate them from material working processes, because their presence not only causes a significant cost that impacts the manufacturing process, also represents an environmental problem due to its polluting effect, with the associated management costs involved. This article presents the results of an AISI 1045 test specimen experiment, to which a turning process has previously been carried out.

Keywords: honing process, plastic deformation, turning, AISI 1045 steel

1. Introduction

Burnishing is a plastic deformation machining process that consists of applying by means of an indenter (spherical or cylindrical), a pressure that changes the surface roughness profile on the work surface, at the same time as a feed rate is applied to the tool, flattening the profile ridges in such a way that the excess material present in the ridges occupies the empty part present in the valleys of the roughness profile.

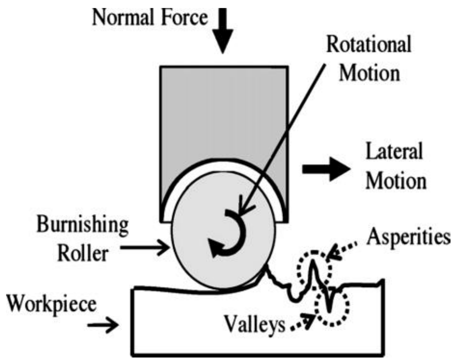


Figure 1. General scheme of the honing process [1]

The process can be classified into two categories, depending on the type of element that causes the deformation, in Ball honing, Rigid or Flexible, Roller honing, or depending on the movement of the tool on the surface, normal or ordinary, impact-based and vibrating.

Some of the most common applications are all those parts that are assembled and require a high level of finish on the contact surfaces and easy disassembly, such as areas where it is mounted, for example bearings, sliding bearings, rotor blades and stators of electric motors, pump parts, turbines and compressors, hydraulic and pneumatic equipment parts (with precise sealing surfaces), shafts, valve seats, household utensils or parts for the military industries (conventional and reactive artillery parts), aeronautics and aerospace (engine and turbine parts), automotive (pistons, cylinder liners, crankshafts, camshafts), chemical, electronic, textile, etc

[1]. During the plastic deformation honing process a residual compressive stress is induced on the surface of the workpiece, it has been found to be beneficial for fatigue strength, wear resistance and even corrosion resistance due to hardening of the surface layers. Ball honing hardens the surface layer, as it softens the surface topography, obtaining surfaces with low surface roughness, creating a fine finish that will also last longer than one achieved with traditional finishing processes such as grinding. In this article will be specifically addressed the process of roller burnishing on parts machined by turning previously [2].

From literature review, it has been found that roller burnishing can be used as a surface finishing process in the industry. The following items should be taken into consideration. Compressive residual surface stress has been found to be beneficial for the control of average fatigue stress as well as for creep [3-4]. This in turn affects and is detrimental to the average compressive stress. However, in most engineering applications, machine elements such as shafts experience tension load conditions, and residual compressive tensions effectively improve resistance to fatigue [5]. Therefore, honing is highly beneficial for most elements of rotating machines such as shafts as they improve their service life. More studies are needed to evaluate the effectiveness of residual compressive tensions resulting from an industrial burnishing process by plastic deformation burnishing, by extending the current studies for cyclic/fatigue loading - high cycle (HCF; Basquin's empirical power fatigue law) and low cycle (LCF; Coffin-Manson's fatigue power law) [6-9]. Such studies should also address progressive relief in net residual compressive stresses with the degree of fatigue damage as progressively occurs with the number of fatigue cycles. Burnishing has shown to be an important technological process [10]. The resulting surface finish has low surface friction, good wear resistance and high contact capacity [11-13].

2. Methodology

A conventional lathe from the general steel company was used for this test, for this purpose, an AISI 1045 steel specimen with a diameter of 2.25 inches was machined. Then the assembly is carried out on the turret of the lathe, to perform the burnishing, a roller with a 3 mm wide face is used. For a better visualization of the change between machining and honing, it was left 30 mm at the tip of the specimen with machining, an additional 1 inch of specimen was honed with a spindle speed of 750 rev/min, spring displacement was 8 mm and a tool feed rate of 0,09 mm/seg, and for a second test the spindle speed was reduced to 550 rev/min, with a spring displacement of 16 mm and a tool feed rate of 0,09 mm/seg, Figure 2.

Figure 2. Honing process in test tube 1.

To carry out the test, a specimen was prepared from a 57.15 mm diameter cold-rolled AISI 1045 steel bar. Figure 3.

Figure 3. Machining of specimens for honing tool testing.

The outer diameter of the specimens, Dp, is 53 mm. This value is accepted by the relationship between this diameter and the diameter of the roller, Drod (32 mm) that according to Odintsov [14] is governed by the following condition:

$$1,5 < \frac{Dp}{Drod} < 2,5 \tag{1}$$

In order to guarantee the surface finish prior to honing, the specimen was machined with the data shown in Table 1.

Table 1. Specimen machining data.

Specimen machining			
RPM	**Feed (mm/Rev.)**	**Penetration**	**Specimen diameter**
900	0,085	1mm	53mm

3. Results and Discussion

The entire surface was machined with the same finish in such a way that the same roughness was achieved for the sections to be used for the burnishing test, in this way the results are as truthful as possible. To check that the tool performs the honing process correctly, are taken as independent variables in the experimental model a: the compressive force (N) and the tool feed rate (mm/rev). These parameters have a range of variation according to the following Table 2.

Table 2. Range of variation of test parameters.

Variable	**Minimum**	**Maximum**
Strength (KgF)	40	110
Tool feed rate (mm/Rev)	0,055	0,22

In addition to the parameters mentioned above, the following variables remained constant:

- The number of runs will remain constant at one (1) for all the tests since our objective is to verify the improvement of the surface in the process, it is worth noting that the literature indicates that even more passes, the improvement with respect to the first one is not significant [10].
- The spindle speed during the execution of the honing process will be 140 rpm.
- For all tests, lubricating oil is used to reduce friction between the tool and the workpiece, as well as to prevent overheating because of the process.

This in order to find the dependent variable, which in this case will be the surface roughness, Ra, and thus measure and test the effectiveness of the process. Eight (8) 10 mm strips were taken to carry out the test as shown in Figure 4, width on the surface of the specimen to perform the honing process and the rest of the specimen was left with the machined grinding finish as a reference to qualify the efficiency of the process as shown in Figure 5.

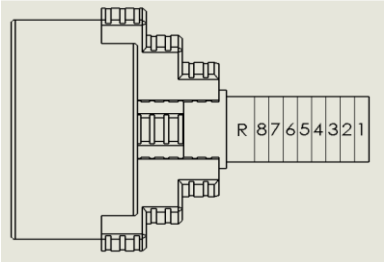


Figure 4. Sample distribution for the honing process.

Figure 5. Honing process.

Once the specimen is ready and the tool is properly attached to the tool holder turret, the honing process can be carried out. As can be seen in Figure 4, the tool approaches the part until it makes contact with it, then the application of force is performed, which is achieved through the compression of the roller that is transmitted to the spring by means of the piston, with the dial of the cross slide it can be observed how much is the displacement of the cross slide and therefore the compression of the spring, with this data the spring force can be obtained. To make measurements of the surface roughness of each area of the specimen, a roughness tester was used: Mitutoyo, model: SJ-210 as shown in Figure 6.

Figure 6. Measuring with the rugosimeter.

Once the test is completed, the data is organized in such a way that the roller honing parameters used in this study, such as: specimen material, specimen diameter, RPM (revolutions per minute) of the lathe spindle, the penetration of the blade for machining, N (number of experiments), Ra (Average final surface roughness (μm) measured in the direction parallel to the direction of tool movement), the feed rate of the tool and the force applied by the burnisher are summarized in the Tables 3 to 5.

Table 3. Specimen and tool data.

Initial data	
Specimen material:	**Honing roller face**
AISI 1045	3mm

Table 4. Machining data of the specimen

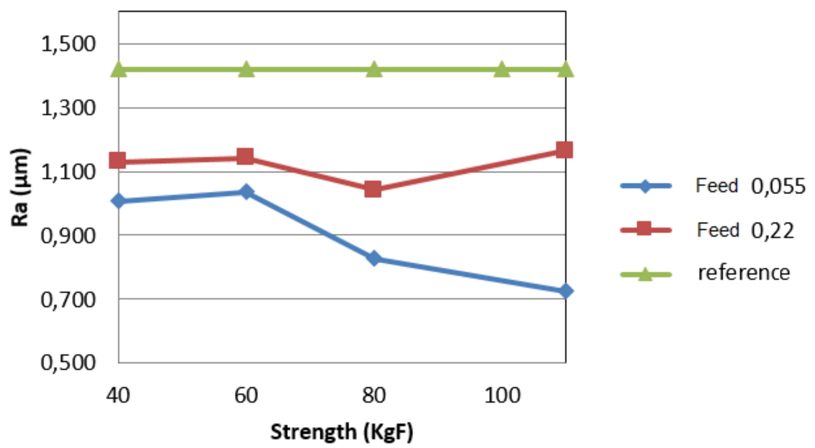
SPECIMEN MACHINING			
RPM	**FEED (mm/rev)**	**PENETRATION**	**SPECIMEN DIAMETER**
900	0,085	1mm	53mm

Table 5. Data from the test

Data of the test							
N	**FEED (mm/rev)**	**STRENGTH (KgF)**	**Ra (µm)**				**% Improvement of surface quality**
			TEST 1	**TEST 2**	**TEST 3**	**AVERAGE**	
1	0,055	40	0,992	1,07	0,96	1,007	28,9
2	0,055	60	1,017	1,067	1,024	1,036	26,9
3	0,055	80	0,787	0,883	0,811	0,827	41,6
4	0,055	110	0,72	0,65	0,806	0,725	48,8
5	0,22	40	1,1	1,092	1,197	1,130	20,3
6	0,22	60	1,18	1,107	1,139	1,142	19,4
7	0,22	80	1,007	1,047	1,072	1,042	26,5
8	0,22	110	1,113	1,201	1,177	1,164	17,9
brushed	0,085	NA	1,43	1,446	1,378	1,42	NA

Figure 7 shows the results of the variation in roughness against different types of tool feed rates, and the difference with the initial reference roughness of the part area without burnishing.

Figure 7. Roughness vs. honing strength.



Conclusions

Based on the data obtained from the tests carried out, the following conclusions can be drawn. Each test had an improvement in surface quality over the turned specimen, as showed in the Figure 7, looking at the test results, for an advance of 0,22 mm/rev percentages of improvement in surface quality between 17,9% a 26,5% were reached, where the lowest percentage of improvement occurs when the largest workforce is applied, it can be deduced that surface improvement is not proportional to the work force alone, as if this were the case in the feed of 0,055 mm/rev, as it has a percentage improvement in surface quality of between 26,9% a 48,8% where the highest percentage of improvement if it occurs when the largest workforce is applied. According to the data obtained in the tests, a feed rate of 0.055 rev/mm or as similar as possible is recommended to obtain a significant improvement in the honing process.

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