Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 53(12) (2022) 1411-1414
DOI: 10.22060/mej.2021.19853.7131

Experimental Study of the Effect of Initial Surface Roughness on Ball Burnishing Forces and Endurance Limit of AISI 4130 Hardened Steel

M. Arsalani, M. R. Razfar*, A. Abdullah, M. Khajehzadeh

Department of Mechanical Engineering, Amirkabir University of Technology

ABSTRACT: Machining of hardened steels, which their hardness is generally higher than 45 Rockwell C, is called hard turning. These components usually work under dynamic loading conditions and require a high level of surface finish (in the order of 0.15 µm Ra) which cannot be achieved by sequential hard turning and burnishing processes. However, there are serious concerns about this complement grinding operation; the grinding process, on one hand, increases tensile residual stresses and on the other hand, increases crack nucleation regions. Therefore, these two factors might decrease workpiece fatigue strength. So, in this paper, the effects of adding a grinding operation before the ball burnishing process, have been experimentally studied on final surface roughness and burnishing forces; at the same time, in order to consider the possible destructive effects of the grinding process, a set of experimental measurements including surface residual stresses and endurance limit measurement, have been done for AISI 4130 fatigue samples. Based on the achieved results, adding a grinding operation before the burnishing process has led to a 91.56% improvement in surface finish and a 39.52% reduction in burnishing forces. In addition, surface residual stress is compressive and there is a slight difference in the magnitude of compressive residual stresses in comparison to burnished hard turned samples. Due to these positive findings, the endurance limit of produced samples shows 10.95% improvement in comparison to burnished hard turned samples.

Review History:

Received: Nov. 11, 2021
Revised: Aug. 02, 2021
Accepted: Aug. 10, 2021
Available Online: Aug. 29, 2021

Keywords:

Ball burnishing process
Surface roughness
Burnishing forces
Grinding
Endurance limit

1. INTRODUCTION

Today, hardened steels are widely used in the automotive industry such as pinions, gears, axles, crankshafts, etc. These components typically operate under dynamic loading conditions and therefore require fully polished surfaces to extend fatigue life.

At the same time, the hard turning process alone cannot provide the required surface roughness of these parts [1, 2] and in addition, it increases the tensile residual stresses on the surface of machined parts; Therefore, the fatigue life of turned parts does not meet their functional requirements and it is necessary that such parts after hard turning undergo additional machining processes such as grinding, ball and roller burnishing, etc. to improve their surface roughness and reduce residual tension stresses on the surface Fig. 1. [3].

2. METHODOLOGY

In the present study, 68 solid rods samples of AISI 4130 with a diameter of 40 mm and a length of 150 mm. The specimens were then hammered using a forging process and formed into rods 19 mm in diameter and 600 mm long, Fig. 2(a). The samples were then annealed at 840°C for 3 hours according to ASTM A519 and cooled in a furnace. In the next step, as shown in Fig. 2 (b), the specimens were hard turned with a numerical control lathe.

Then half of the samples were ground using a cylindrical grinding machine, Fig. 2(c). Finally, the ball burnishing process was performed on a traditional lathe using a ball burnish tool Fig. 2 (d).

Samples were subjected to standard tests of tensile, roughness, micro hardness, residual stress, and fatigue according to Table 1.

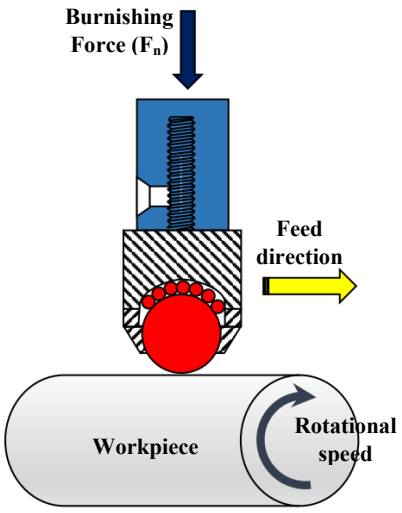
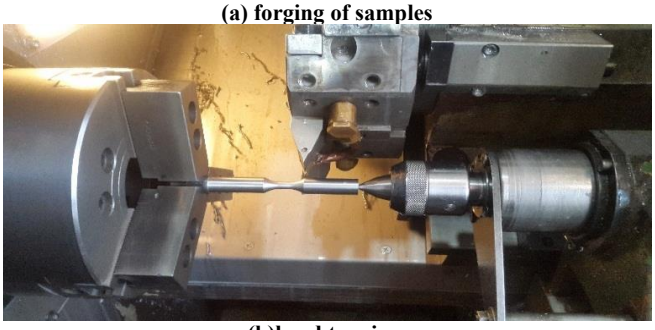


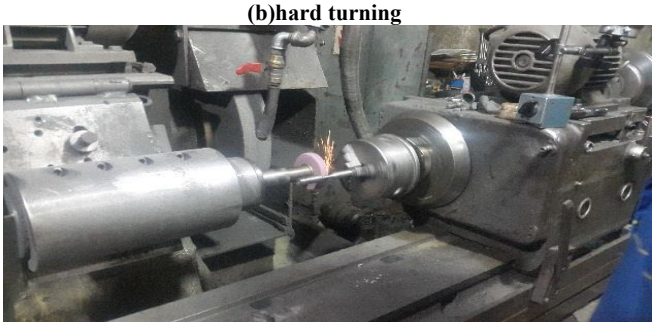
Fig. 1. Schematic of Ball Burnishing process.

*Corresponding author's email: razfar@aut.ac.ir

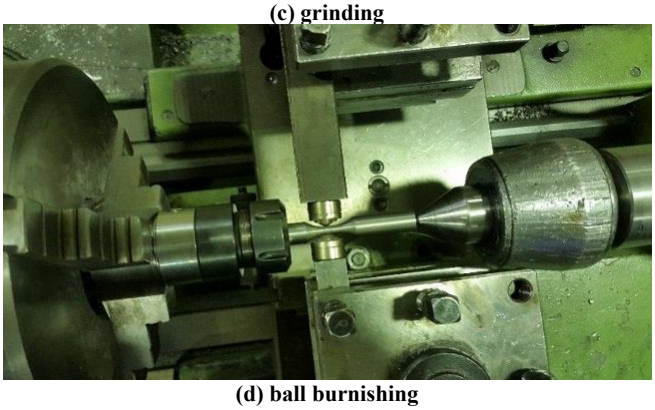
(a) forging of samples



(b)hard turning



(c) grinding



(d) ball burnishing

Fig. 2. Preparing of Experimental samples.

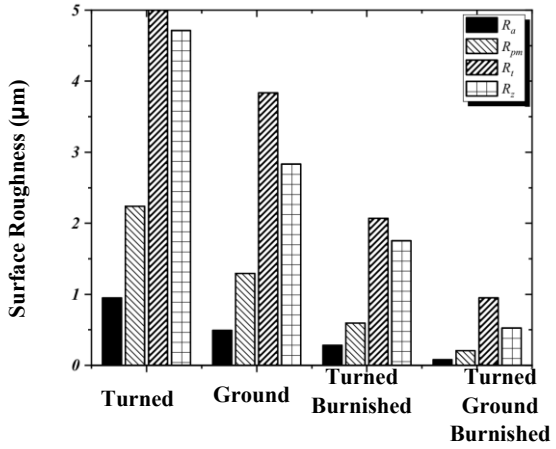


Fig. 3. Surface roughness of samples.

Table 1. Numbers of Experimental samples.

	Turned	Ground	Turned+ Ground	Turned+Ground+Burnished
Tensile Test	1	1	1	1
Surface Roughness	1	1	1	1
Residual Stress	3	3	3	3
Fatigue Test	12	12	12	12
Total Samples	17	17	17	17

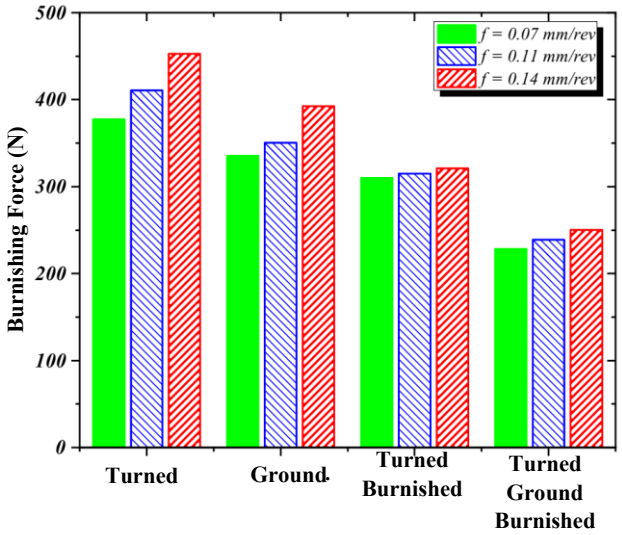


Fig. 4. Burnishing force of samples.

3. RESULTS AND DISCUSSION

3.1 Surface roughness

R_a value after grinding, burnishing, and grinding-burnishing operations decreased by 48.10, 70.36, and 91.56% compared to the hardened sample, respectively, Fig. 3; a similar trend was observed for the R_{pm}, $R_{t,}$ and R_z parameters.

3.2 Burnishing forces

The forces of the burnishing process, in addition to the mechanical and geometrical characteristics of the surfaces contact, depend to a considerable extent on the initial roughness. Burnished pre-ground samples show not only a significant reduction in the surface roughness, Fig. 3 but also resulted in a 39.52% reduction in burnishing forces, Fig. 4.

3.3 Residual stresses

The residual stresses measured at the surface of the turned-burnished and turned-ground-burnished specimens are of a

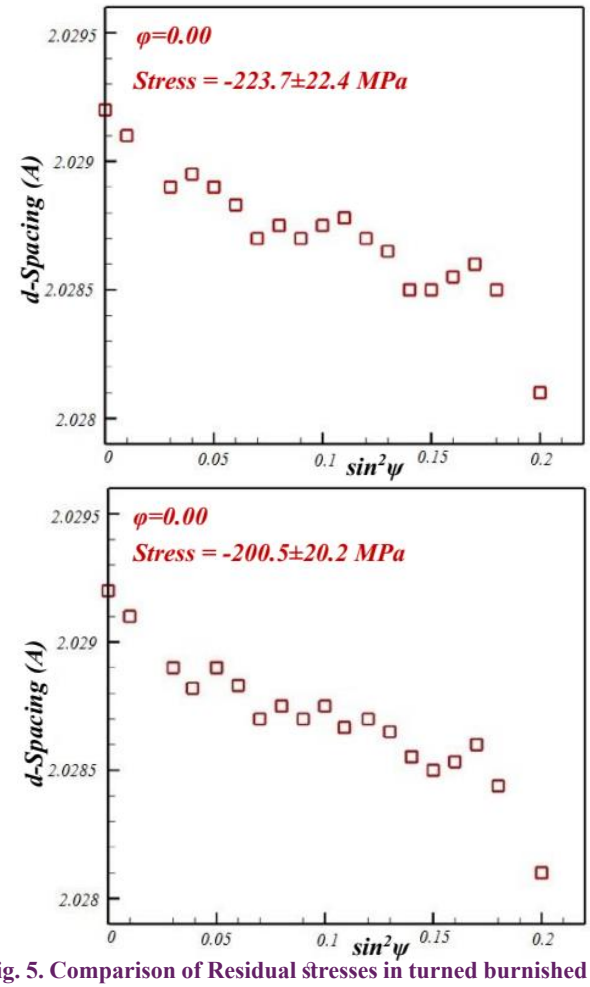


Fig. 5. Comparison of Residual stresses in turned burnished and turned ground burnished process.

compressive type and are slightly different from each other, and the residual stresses are more compressive in specimens that have not been grounded before burnishing. Therefore, it is concluded that the addition of a supplementary grinding operation will not significantly increase the tensile residual stresses after the hard turning process and before the ball burnishing, Fig. 5.

3.4 Endurance limit

The fatigue life of the ground specimens is much lower than the durability of the hard turned specimens (as a standard specimen), but the durability of the turned-ground-burnished specimens is significantly higher than the turned-burnished samples.

The endurance limit of hard turned and ground samples are respectively 283 and 272 MPa. Ground samples, despite having a better surface finish, Fig. 3, have a lower endurance limit due to higher residual stresses, Fig. 5. Meanwhile, the endurance limit of turned burnished and turned-ground-burnished respectively show 4.24 and 10.95% improvement in endurance limit in comparison to hard turned samples. Therefore, it can be concluded that adding a grinding process before the burnishing operation will increase the endurance limit considerably.

Generally, improvement in endurance limit of turned-ground-burnished samples is related to better surface finish, harder micro surface hardness, and lower residual stresses on the machined surface.

4. CONCLUSION

According to the achieved results, the following conclusions can be achieved:

1. Adding a supplementary grinding operation before the hammering process will significantly increase the fatigue strength.

2. The addition of a grinding operation prior to the burnish process, resulted in a 39.52% reduction in burnish forces.

3. The endurance limit of turned-burnished and turned-ground-burnished samples show a 4.24 and 10.95% increase compared to hard-turned samples, respectively.

REFERENCE

[1] W. Grzesik, J. Rech, T. Wanat, Surface finish on hardened bearing steel parts produced by superhard and abrasive tools, International Journal of Machine Tools and Manufacture, 47(2) (2007) 255-262.

[2] F. Hashimoto, Y. Guo, A. Warren, Surface integrity difference between hard turned and ground surfaces and its impact on fatigue life, CIRP annals, 55(1) (2006) 81-84..

[3] A. Saldaña-Robles, H. Plascencia-Mora, E. Aguilera-Gómez, A. Saldaña-Robles, A. Marquez-Herrera, J.A. Diosdado-De la Peña, Influence of ball-burnishing on roughness, hardness and corrosion resistance of AISI 1045 steel, Surface and Coatings Technology, 339 (2018) 191-198.

HOW TO CITE THIS ARTICLE

M. Arsalani, M. R. Razfar, A. Abdullah, M. Khajehzadeh, Experimental Study of the Effect of Initial Surface Roughness on Ball Burnishing Forces and Endurance Limit of AISI 4130 Hardened Steel, Amirkabir J. Mech Eng., 53(12) (2022) 1411-1414.

DOI: 10.22060/mej.2021.19853.7131