Effect of roller burnishing tool pass on surface roughness of austenitic stainless steel AISI 316L

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ABSTRACT

Burnishing is a cold working process improves surface roughness, wear resistance, corrosion resistance… etc. by introducing residual compressive stress into the surface of the work piece. In this study five pass of burnishing process was applied to machined 15 mm diameter AISI 316L austenitic stainless steel in five different depth of burnishing (0.1, 0.2, 0.3, 0.4 and 0.5 mm), burnishing time was one minute and spindle speed were 1050 rpm and 1800 rpm. Surface roughness of burnishing surface was detected. At low spindle speed 1050 rpm the lower surface roughness of burnished surface can be obtained during burnishing austenitic stainless steel AISI 316L in fifth pass and depth of burnishing equal to 0.5 mm. While at higher spindle speed the best surface finish can be obtained during burnishing AISI 316L austenitic stainless steel in fourth pass and depth of burnishing equal to 0.4 mm.

Figure (1): Roller burnishing process (E. Rafati et al. 2013).
Burnishing Parameters consists of burnishing force, feed, burnishing tool material, work piece material, number of tool pass, and lubrication. In recent years, burnishing becomes one of the most topics of research. The effect of process parameters on surface finish, corrosion resistance, fatigue strength, dimensional accuracy, surface hardness… etc. has been studied by many researchers. (K. Palka et al. 2006) carried out an experimental study on corrosion resistance of burnished X5CrNi 18-9 stainless steel and they concluded that burnishing causes increasing of yield strength from 230 MPa to 450 MPa and break down potential and the re-passivation potential were decreased with the burnishing load.

J. Labanowski and A. Ossowska (J. Labanowski et al. 2006) studied the effect of burnishing on stress corrosion cracking susceptibility of UR52N duplex stainless steel in boiling MgCl2 solution at 1250C. They discovered that increasing the burnishing force increases the crack initiation time. (Wojciecen Labuda, et al. 2011) undertaken an experimental analysis on influence of burnishing on corrosion resistance of AISI 304L stainless steel applied to sea water pump shafts and concluded that burnishing process caused 44% increase of electro chemical corrosion resistance in sea water when compared with turning.

(S. Thamizhmani et al. 2012) have presented their work on effect of burnishing on surface hardness and circularity of AISI 420 Martensitic stainless steel and observed that the surface hardness improved at high rotation speed than at low speed, but the circularity of work material is increased at low rotational speed than at high. (C.S. Jawalkar and R.S. Walia 2009) studied the roller burnishing process on En-8 steel using design of experiment and they found that the average surface roughness value observed is 0.21μm and the finest is 0.13 μm in addition number of tool passes and speed contributes maximum improvement in the surface hardness. (Qawabeha et al. 2009) presented a work on influence of burnishing force on corrosion resistance of steel; it was observed that corrosion potential and corrosion current decrease with increasing burnishing force and reached to its minimum value at about 80 N.

(Hryniewicz and Rokosz 2005) studied the influence of roller burnishing on corrosion resistance of C34 carbon steel in 3 % NaCl water solution and they reported that may be decreased many times after roller burnishing process. (Khalid S. Rababa et al. 2011) investigated the effect of roller burnishing on mechanical properties and surface quality of O1 alloy, it was observed that there was 76.6 %, 103.3 %, 113.3 % increasing ductility at 140, 175, 210 burnishing force respectively.

A work on the effect of lubrication on the surface roughness during burnishing aluminum alloy was presented by J. Naga (Malleswara Raw et al. 2010) and concluded that the lubrication has considerable effect on the reduction in the surface roughness and a light oil such as kerosene oil produce better surface finish values than heavy oil such as SAE 40 engine oil. (P. Ravidra Babu et al. 2009) worked on effect of burnishing speed on surface roughness and surface hardness of mild steel, it is observed that surface hardness and surface roughness increases with increasing speed up to 62m/min. and beyond that they will decrease.

A work on the effect of burnishing parameters i.e. burnishing speed, burnishing

Figure (2): Surface profile during burnishing (E. Rafati et al. 2013)
feed, burnishing force, and number of tool pass on surface roughness and surface hardness was presented by (El-Taweel and El-Axir 2009) using Taquchi technique and concluded that the burnishing force has dominated influence followed by burnishing speed, and the number of pass. A work was published by (A. A. Ibrahim 2013), in this work author investigated the effect of depth of burnishing, number of tool pass, and burnishing speed on surface roughness of Al2O3 / As56 composite and observed that, the better surface roughness was obtained with double pass burnishing, 0.12 mm depth of burnishing, and 72 mm/min burnishing speed. The originality of this paper is, although large numbers of burnishing paper have been reported up to date the information about burnishing of stainless steels is very scare. The aim of this study is to examine the effect of burnishing parameters on surface roughness and reduction in diameter of AISI 316L austenitic stainless steel rode.

2. EXPERIMENTAL PROCEDURE

Material: The work piece material used in this study is austenitic stainless steel AISI 316L, round bar with 15mm diameter. The chemical composition of workpiece material is given in table (1). Chemical composition detected using spectrometer metal analyzer model Spectromaxx Spectro Company. Germany 2010. Explain clearly but concisely your technical and experimental procedures. For metallographic examination, the specimens were mechanically finished with the aid of 600, 1000, and 2000 grid abrasive paper subsequently with using water to avoid overheating. Polishing has been done using diamond starry. The specimen etched chemically according to ASTM standard. The solution consists of a saturated solution of FeCl3 in HCl to which a little HNO3 is added and etching time equal to three minutes. (ASTM 1978). Figure (3) showed the microstructure of austenitic stainless steel AISI 316L in as received condition.

| Table 1. Chemical composition of austenitic stainless steel AISI 316L. |
|------------------|---|---|---|---|---|---|---|---|
| Material        | Cr% | Ni% | C% | Mo% | P% | Mg% | Si% | Fe% |
| AISI 316L        | 17.5 | 12  | 0.03 | 2.25 | 0.045 | 2  | 1  | Bal |

Figure (3): Microstructure of as received austenitic stainless steel AISI 316L.

The 15mm diameter AISI 316L austenitic stainless steel rode is machined using turning without the application of cutting fluid (dry turning) the cutting tool used were Tic inserted, the cutting speeds were 1500 rpm and 1800 rpm, 0.11 mm/rev. feed rate and 0.2 mm depth of cut. The AISI 316L specimen is turned to have five steps and grooves in between them for applying five different burnishing depth on steps. The geometry of the specimen showed in figure (4). After turning the surface roughness was performed, the measurements were made at three different locations and the average value was taken which is 1.3 µm.
2.1 Burnishing

Roller burnishing tool consists of roller, bolt, washer as shown in figure (5). The burnishing operation is conducted on turning machine, the workpiece is fixed between the centers of the lathe. The burnishing tool is fixed in the tool post of the lathe as shown in figure (6). Burnishing operation was conducted without the application of lubricant (dry burnishing), two spindle speed 1050 rpm and 1800 rpm, five different burnishing depths (0.1, 0.2, 0.3, 0.4 and 0.5 mm), and 1min burnishing time were selected for all the case, and burnishing operation were repeated for five different passes.

2.2 Surface Roughness

After burnishing surface roughness measurement was performed on Tyler – Hobson surface roughness tester [Talysur-10] figure (7). The measurements were made on the burnished surface at three different locations and the average value was taken.

3. Results and Discussions

Figure (8) shows the variation of surface roughness in the first pass of burnished AISI 316L austenitic stainless steel for five different depth of burnishing 0.1, 0.2, 0.3, 0.4 and 0.5 mm. with two different spindle speed 1050 rpm and 1800 rpm. At a low depth of burnishing 0.1 mm, the surface roughness obtained at 1050 rpm and 1080 rpm spindle speeds was 0.323 µm and 0.204 µm respectively. When the depth of burnishing increased to 0.2 mm the surface roughness at both spindle speed decreased to 0.283 µm and 0.188 µm respectively. By increasing the depth of burnishing at high spindle speed 1800 rpm the surface roughness decreased gradually and reached to its minimum value 0.139 µm at a higher depth of burnishing 0.5mm. Related to low spindle speed 1050 rpm minimum roughness 0.196 µm can be obtained when the depth of burnishing is 0.4 mm and beyond that increased to 0.2 µm when the depth of burnishing is 0.5 mm.
Figure (8): Surface roughness of burnished AISI 316L austenitic stainless steel (1st pass)

Figure (9) shows the relationship between surface roughness and five different depths of burnishing 0.1, 0.2, 0.3, 0.4 and 0.5 mm at two different spindle speed 1050 rpm and 1800 rpm in the second pass of burnished AISI 316L austenitic stainless steel. The surface roughness value at a low depth of burnishing 0.1 mm was 0.2 µm and 0.236 µm at both 1050 rpm and 1800 rpm spindle speed respectively. As the depth of burnishing increases from 0.2 mm to 0.4 mm at low spindle speed 1050 rpm the surface roughness remains unchanged 0.186 µm and beyond that it's decreased to 0.163 µm when the depth of burnishing is 0.5 mm, but related to high spindle speed 1800 rpm the surface roughness decreased gradually and reached to 0.156 µm at a higher depth of burnishing 0.4 mm and beyond that remains unchanged. Compared to the first pass the surface roughness values in the second pass decreased for all depth of burnishing at low spindle speed 1050 rpm but related to high spindle speed 1800 rpm the surface roughness is fluctuated.

Figure (9): Surface roughness of burnished AISI 316L austenitic stainless steel (2nd pass).

Figure (10) illustrate the variation of surface roughness in the third pass of burnished AISI 316L austenitic stainless steel for five different depth of burnishing 0.1, 0.2, 0.3, 0.4 and 0.5 mm. At low spindle speed, 1050 rpm and low depth of burning 0.1 mm the surface roughness value is 0.246 µm increasing the depth of burnishing the surface roughness reduced gradually and reached to 0.156 µm at a higher depth of burnishing 0.5 mm. Compared to the second pass the surface roughness at the third pass is higher at low depths of burnishing 0.1 and 0.2 mm but this result inverted at a higher depth of burnishing 0.3, 0.4, and 0.5 mm, nearly the same behavior can be seen related to high spindle speed 1800 rpm.

Figure (10): Surface roughness of burnished AISI 316L austenitic stainless steel (3rd pass).
Figure (11) shows the variation of surface roughness in the fourth pass of burnished AISI 316L austenitic stainless steel for five different depths of burnishing 0.1, 0.2, 0.3, 0.4 and 0.5 mm. At low spindle speed 1050 rpm and low depth of burnishing the surface roughness value is 0.263 µm higher than that of third pass for the same depth of burnishing and increasing the depth of burnishing to 0.2 mm small reduction in surface roughness can be seen which is 0.24 µm, increasing depth of burnishing further great reduction in surface roughness can be seen in which reaches to its minimum value 0.143 µm at 4 mm depth of burnishing and beyond that it increased to 0.146 µm at 5 mm depth of burnishing. In connection with high spindle speed 1800 rpm in the fourth pass, as the depth of burnishing increased the surface roughness decreased and reached to its minimum value 0.13 µm at 0.4 mm depth of burnishing and beyond that which is increased. Excessive roller burnishing force and a number of passes may produce flaking of surfaces which leads to the formation of lapping and hence deterioration of burnished surface. 

Low spindle speed 1050 rpm and low depth of burnishing 0.1 mm is 0.236 µm and increasing the depth of burnishing the surface roughness decreased gradually and reached to its minimum value among all pass and depth of burnishing detected in this research 0.1 µm at a higher depth of burnishing. Related to high spindle speed 1800 rpm in fifth pass the AISI 316 L austenitic stainless steel behave in the same manner and the surface roughness at higher spindle speed 1800 rpm is lower compared to lower spindle speed 1050 rpm from the depth of burnishing 0.1 mm to 0.4 mm and beyond that this approach is inverted.

Figure (12): Surface roughness of burnished AISI 316L austenitic stainless steel (5th pass).

4. CONCLUSIONS

This paper presents the effect of five roller burnishing tool pass on the surface roughness of AISI 316L austenitic stainless steel in five different depth of burnishing, and two different spindle speed. Burnishing time was constant and the following conclusions can be drawn:

1. the depth of burnishing and burnishing pass have a significant role on the surface roughness of burnished AISI 316L austenitic stainless steel.
2. Increasing the spindle speed from 1050 rpm to 1800 rpm nearly decreases the surface roughness in all passes.
3. At low spindle speed 1050 rpm, the best surface finish in burnished AISI 316L can be obtained during burnishing with 0.5 mm depth of burnishing and the fifth number of pass.

4. At high spindle speed 1800 rpm, the best surface finish in burnished AISI 316L can be obtained during burnishing with 0.4 mm depth of burnishing and the fifth number of pass.

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