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Investigation on Surface Integrity on STAVAX ESR AISI 420 Martensitic Stainless Steel by Cryogenically Treated Steel Balls with Low Plastic Burnishing Tool

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Abstract. Low plasticity burnishing (LPB) is a new method of surface improvement, which raises the burnishing to the next level of sophistication. LPB can provide deep compression for improved surface characteristics. The study focuses on the surface roughness, micro-hardness and surface integrity aspects on soft AISI 420 STAVAX ESR martensitic stainless steel. This material is pronounced as difficult to cut materials like titanium, Inconel 718 etc. The investigation of surface integrity was done on this materials in terms of operating parameters like sliding speed, feed rate and depth of penetration (DOP) identifying the predominant factors among the selected parameters. The steel balls used were cryogenically treated at sub zero temperature of -176 degrees. The process can be applied to critical components effectively as the LPB process has cycle time advantages and also low investment cost. This can also be realized by introducing on high speed machines. This process was studied by using cryogenically treated 15.80mm ball diameter at various operating parameters. This also improved on concentricity of work material. The DOP also helps to improve on surface and sub-surface hardness and close roundness. There are limitations on DOP beyond which the surface deteriorated. It was obtained that high spindle rotation with low feed rate produced low surface roughness and high surface hardness. This is best suited for materials which can't be heat treated to obtain surface hardness.

Introduction

Burnishing is considered as cold working process which can be used to improve surface characteristics. Most of the work on burnishing that has been published was related to the effect of the burnishing process on the surface roughness and surface hardness [1]. Rajesekariah and Vaidyanathan [2] studied the influence of several parameters of ball burnishing such as the ball diameter, feed rate, ball forces and with the initial surface finish on the surface finish, surface hardness and wear resistance of steel components. They concluded that the burnishing force was the major factor affecting the wear resistance of the surface layer of the burnished components and that there was an optimum burnishing forces, which gave the best results. Neema and Pandey [3] studied the effect of burnishing speed, feed, ball diameter, burnishing force and number of tool passes on the quality of the work produced and its wearing characteristics. Burnishing offers certain specific advantages most notably, the high improvements in surface smoothness and hardness [4-8], which in turn can improve corrosion resistance [2, 9], wear resistance [2-3, 10] and tensile strength [3].

would take up to 20-25 hours. It is the methodology of ultra low temperature processing of materials to enhance their metallurgical properties to the desired level. The materials are treated in the cryogenic chamber. The process involves raising and reducing the temperature. Thermal control is achieved by continuously monitoring input and regulating the flow of liquid nitrogen into the chamber and alternating the heat. Precise program control takes the cycle through its three phases of descend, soak and ascend. The entire cycle takes 48 to 72 hours depending on the weight and type of material. It is imperative that a slow descend is followed by a soak period of at least 24 hours at minus 31° C and raised to room temperature with a slow ascend. The cooling potential is obtained from a bypass of a continuous nitrogen gas use. It also includes two solenoid valves tied in with a thermocouple and temperature controller allowing easy control of soak temperatures. Either way, the system is relatively simple and does not require large capital outlay. By controlling the flow of liquid nitrogen into the cold box the temperature and cooling rate can be controlled.

Table 1. Chemical composition

Grade	Carbon %	Chromium %	Manganese %	Nickel %	Sulphur %	Phosphorus %
AISI 420	0.15 max.	12-14	1 max.	1max.	0.03 max.	0.04 max.

Table 2. Mechanical properties

Properties	Values
Tensile strength	950,00 to 250, 000 PSI
Modulus of elasticity	290,000 PSI
Elongation	8 to 25 % per two inches

Table 3. Operating parameters

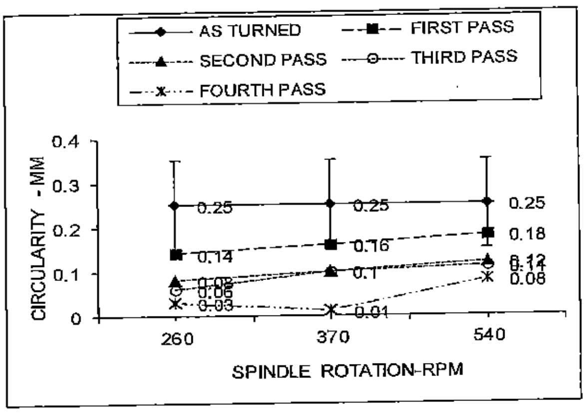
Spindle rotation	260, 370 and 540 RPM
Feed rate	0.30 mm/rev. - constant
Depth of penetration (DOP)	0.50 mm constant

Experimental Works. The work material was turned from 50 mm diameter to remove the oxide formation and grooved to 40 mm depth with 10 mm wide. Table 1 and 2 shows the chemical composition and mechanical properties respectively and Table 3 shows the operating parameters used. The experiment was repeated for four times and each time the surface roughness, weight loss by steel balls, surface hardness and roundness measured. The steel balls were used with springs in order to adjust during the burnishing process. The surface roughness were measured using Mitutoyo surface tester model SJ 301, surface hardness by portable hardness tester and circularity by dial gauge with work centre. Before starting the process each ball weight measured using 1 milligram weighing balance. The weight of the ball used varied from 28.10 grams to 28.71 grams.

Discussions

The rate at which the surface wears out depend on the characteristics of the materials in relative motion with each other. Surface roughness and surface hardness are two examples of the characteristics that affect the wear rate. Ball burnishing is a cold working process that can be used to improve surface finish and surface hardness. Both first and last author have established in previous researches both materials and number of burnishing tool passes are the most important

This was due to number of burnishing tool passes and the increase in the surface roughness and surface hardness leaving thus increasing the wear of the ball. The wear of the ball is not uniform for every tool passes, but increased drastically as number of tool passes was increased. As the number of time tool passes, this will increase in energy dissipated in overcoming friction which in turn converted to heat. This was also due to less area of contact, in fact, the area of contact is a small arc and unable to withstand the heat. This increased in temperature at interface between the work surface and area of contact which is cause the weight loss. Figure 5 shows the surface hardness obtained. The hardness was obtained by the work hardening of the work material. The number of time the burnishing tool passes, the surface is subjected to hardness. The hardness cannot be increased beyond certain limit owing to flaking effect on the surface. It can also be observed from the figure 5 that increase in the number of tool passes, increased the surface roughness. At high spindle rotation, plastic deformation occurred at faster rate which increased the surface hardness. Figure 7 shows hardness obtained on the surface like white band and may be viewed as case depth in hardening low carbon materials.



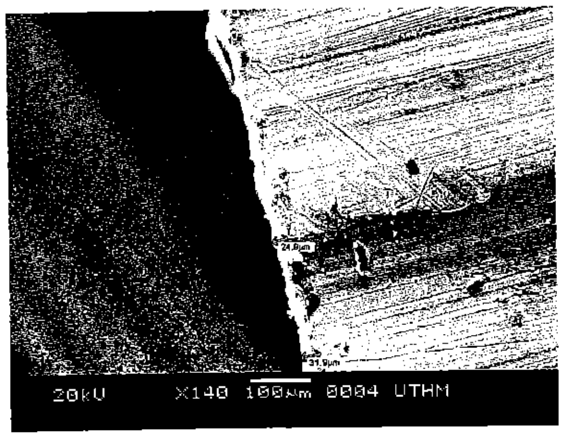


Fig.6. Spindle rotation vs roundness

Fig.7. SEM view of burnished band

The circularity of the work material increased at low spindle rotation for a given feed rate. This was due to more concentrated contact of the ball for a longer time than high rotational speed. As number of tool passed many time, the circularity increased at low spindle rotation than at high rotational speed. This is shown in the figure 6. It is nearly circular.

Summary

Based on the test results, the following conclusions were drawn:

i). It is possible to carry out the burnishing process by cryogenically treated steel balls to get smooth surface on difficult to cut materials. The surface is smooth at high spindle rotation than at low spindle rotation.

ii). The weight loss by steel balls was high at low spindle rotation due longer contact of the curved surface with the work material. However, the loss of weight was circular and not produced flat a surface.

iii) The surface hardness was improved at high rotation speed than at low speed. This was due to number of time tool passed.

iv). The circularity of work material was increased at low rotational speed than at high. As the tool passes many times, the circularity improved and it is near to a full circle.

v). Burnishing process can be used for non heat treated materials to obtain surface hardness to certain limit.