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Design and Fabrication of Multi Ball Burnishing for Post Machining Finishing Process

KEYWORDS: Burnishing, Multi Ball Bearing, Washer.

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ABSTRACT *Burnishing is a post machining finishing process to achieve smoother, accurate and hard surfaces. It is primarily a cold working process involving plastic deformation of thin layer of micro irregularities on the surface being treated. The present work was undertaken to fabricate a multiple ball burnishing tool using a spring to apply a known force and study the improvement resulting from burnishing in surface roughness of a mild steel specimen under various conditions of a burnishing feed rates where a single pass multi ball burnishing was done. The parameters that contribute to output of a burnishing processes has been identified as burnishing speed, feed rate, lubricant condition number of passes undertaken and force is impressed on the burnishing tool through preloading. Washers of specific loads are manufactured for preloading by calibrating the tool under varying loading conditions.*

1. INTRODUCTION

Engineers who want to improve the life of a component will eventually have to take into consideration the surface of the component. Virtually all fatigue and corrosion related failures originate from a surface produced by a manufacturing process. The "integrity" of the surface in resisting failure depends upon several characteristics including finish, residual stress, and cold working. Surface finish has long been known to have an impact on the life of a component that undergoes cyclic loading in service. This is why so much time and effort is spent on finish machining; finish grinding, honing, lapping, and polishing. The purpose of these processes is to produce a surface that is free of defects, such as gouges and scratches. A surface free of such defects has fewer flaws from which cracks can originate. A component that is free from surface defects will generally survive longer. Surface residual stresses are known to have a major affect upon the fatigue and stress corrosion performance of components in service. Tensile residual stresses, which can be developed during manufacturing processes such as grinding, turning, or welding, are well known to reduce both fatigue life and increase sensitivity to corrosion-fatigue and stress corrosion cracking in a wide variety of materials. It is well known that compressive residual stresses induced in the surface of a workpiece can increase fatigue life and reduce susceptibility to corrosion-fatigue and stress corrosion cracking. However, the benefit of a layer of surface compression in reducing susceptibility to stress corrosion, cracking, fatigue, and corrosion-fatigue is lost if the layer of compression relaxes with time in service. Surface enhancement, the creation of a layer of residual compression at the surface of a component, is widely used to improve the fatigue life in the automotive and aerospace industries. There are many methods currently used for inducing compressive stress in the surface of a metal part and the particular method selected depends on several factors including the dimensions and shape of the workpiece, its strength and stiffness, the desired quality of the finished surface, the desired physical properties of the finished part, and the expense of performing the operation. In industries generally two methods are commonly used; shot peening and burnishing. Shot peening is a costlier method than burnishing, hence there is a wide area of research on burnishing.

1.1 BURNISHING

Burnishing is a plastic deformation process in which the force is applied on a metal surface through hard balls. In burnishing, initial asperities are compressed and modified. The deformation caused is a function of load applied. If the load is small, burnishing will be insufficient. However, as load is increased a stage will be reached when the burnishing loss may be considered excessive, bulk deformation and metal displacement are

likely to arise. So, there is an optimum value of force where burnishing have a best effect. Burnishing has been used to improve surface finish, fatigue life, and corrosion resistance. The accepted practice for burnishing utilizes repeated deformation of the surface of the component; in order to deliberately cold work the surface of the material, to increase the yield strength. Compressive stresses are developed by yielding the surface of the material in tension so that it returns in a state of compression following deformation

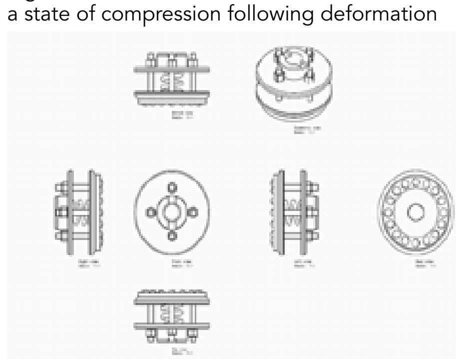

fig.2: 2-D and isometric view of tool assembly

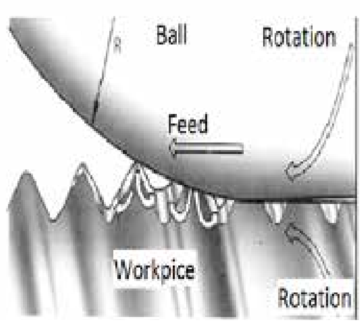

Fig.1: Schematic diagram of burnishing operation

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Fig.3: ball burnishing tool engaged with Milling machine

2. LITERATURE REVIEW

An extensive literature survey[1-6] revealed that burnishing operation is quite economical than other finishing operations. The cost associated with burnishing is equivalent to turning operation, while the finish is similar to grinding operation. Hence, burnishing has a wide area of research. Esme et al. focussed mainly on use of artificial neural networks in ball burnishing process for the prediction of surface roughness of AA 7075 aluminum alloy. In this study, high strength precipitation hardening7XXX series wrought aluminum alloy AA 7075 was used. The strength and good mechanical properties make the AA 7075 aluminum alloy appropriate for use in aerospace industry [1].

Shirsat et al. had done study of lubrication on surface finish and surface hardness of brass specimen using the combined turning and two-ball burnishing process. For this analysis, three burnishing parameters were considered, namely, burnishing force, speed and feed while other parameters were kept constant. Surface finish has significant effect on properties of the component like fatigue strength, corrosive resistance, wear resistance and surface hardness. They found that pre-machined surface roughness of 0.78 mm – 0.95 mm could be finished to about 0.121 mm and increase in surface hardness was also obtained [2]

L.Laouar et al. studied that work hardening resulted by plasticization increases superficial hardness. The beneficial effect depends upon initial state and burnishing parameter. The better result occurring at low roughness is characterized by moderate burnishing force, the low feed associated to large tool radius values [3].Low et al. demonstrated that ball burnishing is capable of enhancing the scratch hardness and indentation hardness of poly oxymethylene surfaces with a good correlation between these two properties. SEM investigations suggest that ball burnishing will alter the mode of scratch damage from severe ductile ploughing and brittle cutting deformation to a mild brittle fracture. A simple model has been proposed that separates the scratching action into two parts, the elastic behavior establish the effects of ball burnishing parameters on the surface hardness of high-strength low alloy steels (HSLA) dual-phase (DP) steel specimens. Statistical analysis of the results shows that the speed feed, lubricant and ball diameter have significant effect on surface hardness. Initial indentation,resulting in less ploughing depth during scratching [4]. Tayeb et al. studied the potential for using the roller burnishing process to improve surface roughness and hardness of thermoplastics (acetal homopolymer, POM-H) and thermo sets (polyurethane, PU). The results showed that all burnishing parameters had a controlling effect on surface roughness and hardness of POM-H and PU, but with different degrees. The effect of the roller burnishing process was more pronounced on

POM-H compared with PU. Depending on the burnishing parameters, the surface roughness of POM-H and PU was decreased by (32–37) and (28–32) percent, respectively. Meanwhile, the hardness was marginally increased, i.e. by 0.8 and 1 per cent for POM-H and PU, respectively [4]. S. Thamizhmnaii et al. identified that reduction in the surface roughness and the increase in hardness with increase in the initial hardness of the burnished work pieces by using multi roller burnishing tool [5]. C Y Seemikeri et al. studied various parameters of low plasticity burnishing process, which affect considerably the fatigue life of AISI 1045. Surface roughness up to 0.53 μ and corresponding fatigue life up to 1701280 cycles could be achieved by this process, which can be applied to critical components effectively, as the LPB process today has significant process cycle time advantages. Fatigue life improvement was evident in all the specimens, though the magnitude varied in each case depending upon the level of factors and their interaction. [6]. The present work was undertaken to fabricate a multiple ball burnishing tool using a spring to apply a known force and study the improvement resulting from burnishing in surface roughness of a mild steel specimen under various conditions of a burnishing feed rates where a single pass multi ball burnishing was done.

3. Experimentation

DESIGN AND FABRICATION OF BALL BURNISHING TOOL

3.1 Ball Burnishing tools: A burnishing tool develops a finished surface on machined metal surface by performing continuous planetary rotation of hardened steel balls. The rotation of the balls increases the yield point of the soft portion of the metal surface at the point of contact. This point of contact results in the plastic deformation of the metal surface to generate a finished metal surface. There are several ways in which ball burnishing tool can operate. A work piece is made to hold tightly on the bed of milling machine and tool mandrel applies pressure on the work piece to finish its surface. Specifications of a burnishing tool can vary, depending on the different types of burnishing tools. The outer diameter of a burnishing tool can vary depending upon the number of balls used in the tool. The adjustment range of burnishing tools depends on outer diameter. The shank size for a ball burnishing is made as according to the size of stub arbor of the respective milling machine. Burnishing tools are designed and manufactured to meet most industry specifications. After heat treatment and annealing, burnishing is employed to make the surface of the coin blanks brighter and remove any surface scaling or discoloration.

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Fig. 4: Burnishing Tool Parts and Work piece

The burnishing apparatus for implementing the method utilizes a multi point ball burnishing process to provide deep compression with a minimal amount of cold working and surface hardening. However, the area to be burnished on the surface of a work piece is defined and freely rotating burnishing balls are forced against the surface of the work piece to produce a localized area of deformation having a deep layer of compression within the surface. The burnishing balls are then rolled over the surface in a substantially no overlapping pattern. A preferred embodiment of the burnishing apparatus for implementing the burnishing method comprises a cylindrical plate having a casing incorporating a ball seat, having thrust ball bearing fitted within the lower casing, four studs, an upper casing having through hole for the stub arbor mandrel and a central spring for axial thrust.

4. RESULTS AND DISCUSSION

The burnishing method of the present study utilizes the process of multi-point burnishing to provide deep compression with a minimal amount of cold working and surface hardening. The surface roughness of burnished surface is the function of feed rate provided and the nose radius of the burnishing balls. The theoretical calculation can be done to calculate the surface roughness (µm) by using the following formula.

$Ra = f^2 / (31.2 \times r)$

Where,
f= feed rate of work (mm per ball per rev.)
r= radius of the ball (mm)
Now

$f = fz / (n \times N)$

4.1 Calculations:

The area to be burnished on the surface of the work piece is machined and a burnishing tool having a multi- point contact balls, is forced against the surface of the work piece to produce a zone of deformation producing a deep layer of compression within the surface. Then the tool is rotated and automatic feed is provided for the burnishing process across the area to be burnished such that the zones of deformation formed by each pass of the burnishing tool do not overlap. It has been unexpectedly found that the multi-point burnishing method, applied in a single-pass, or multiple passes of reduced compressive force, is effective for producing compressive residual stresses following tensile deformation on the surface to produce deep compression with minimum cold working. The theoretical values of surface roughness (CLA values), have been calculated below that are a function of the feed rate (fz) and the ball radius.

The feed (fz) of milling table is 38 mm/min

Number (n) of balls in the burnishing tool are 16;

Radius(r) of each ball is 5.5 mm;

Speed of the spindle (N) is 80 r.p.m
Therefore,

$$Ra = [(0.02968)^2 / (31.2 \times 5.5)] \times 1000$$

$$= \mathbf{0.005136\ \mu m}$$

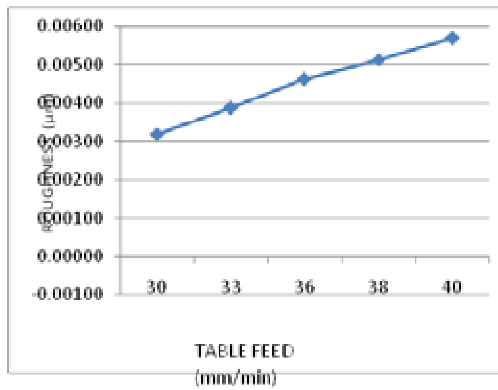

Fig 5.Roughness v/s Table Feed

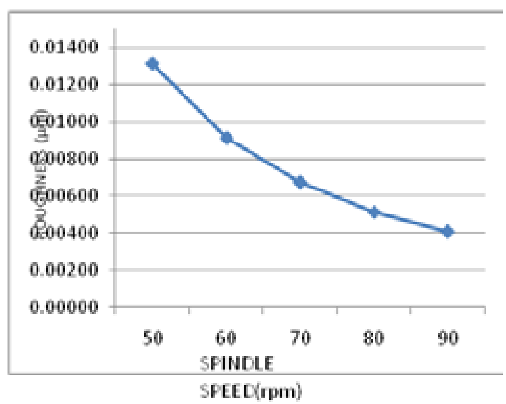

Fig 6.Roughness v/s Spindle Speed

5. CONCLUSION:

Washers of specific loads were manufactured for preloading by calibrating the tool under varying loading conditions. A multiple ball burnishing tool was fabricated using a spring to apply a known force and study was carried out on surface roughness of a mild steel specimen under various conditions of a burnishing feed rates where a single pass multi ball burnishing is done. The surface roughness with fabricated burnishing tool was found 0.005136 µm.

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