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Study of Shot Peening Process and Their Effect on Surface Properties: A Review

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***Abstract*:** *The objective of this study is to review and evaluate the effect of shot peening process that can significantly contribute to surface property enhancement and obviate surface-induced failures. Shot peening causes plastic deformation in the surface of the peened part. This mitigates surface tensile stresses that may have been introduced in machining the component, and more importantly it introduces a salutary compressive residual stress that accommodates to invigorate the surface of the component. The paper presents an effect of shot peening process parameters on surface properties of target material; role of target material properties in shot peening treatment and overview of advanced shot peening processes such as laser peening, nano-peening etc.*

Keywords: *Shot peening, micro hardness, fatigue strength, residual stress, peenability.*

I. Introduction

The process of shot peening involves the bombardment of the treated surface with a stream of minute hard spherical media called shots. As a result, elastic and plastic deformation is induced in near surface layer of the treated sample, since the plastically stretched surface layer wants to expand and the adjacent elastically responding material around and below the impact restrains the expansion; therefore, a compressive residual stress field is engendered in near surface layer which amend the performance and elongate the life of critical components viz. connecting rods, gears.

Fatigue is the main reason for failure of the rotating components and which mainly depend on surface residual stresses. Residual stress is crucial in ascertaining the integrity of engineering component and shot peening can be acclimated to introduce the propitious compressive residual stress levels [1]. Residual stresses are those internal stresses left after perpetual deformation. Residual stress can be either tensile or compressive. Failures are often cognate to residual tensile stress induced during manufacturing procedures like grinding, milling and bending. On contrary compressive residual stress induced over the surface of connecting rod leads to ameliorating the fatigue resistance. It can reduce the efficacious applied stresses of the component during application, which results in delayed crack initiation and retarded crack propagation from the surface. Benign manufacturing processes include surface hardening, burnishing and surface rolling as it induces residual compressive stress into the surface. These processes primarily inhibited to cylindrical geometries. Shot peening has no geometry circumscriptions and engenders results that is conventionally the most economical. Compared with the other advanced mechanical treatment technology like laser shot peening (LSP) and low plasticity burnishing (LPB), which are more expensive and time consuming [2],[3],4].

II. Shot peening process parameters

Shot peening process has to be controlled for optimum benefits, in order to accomplish this all its process variables must be identified and controlled. Shot peening is a process which involves immensely colossal number of parameters such as, shot density, hardness and size of the shots, exposure time, impact angle, no of passes, distance from nozzle to work piece , linear and rotational speed of work piece relative to nozzle [5] . Some other parameters which depend on type of shot peening machine such parameters are nozzle characteristics, air pressure, number of nozzles etc.

To control the shot peening process, it is monotonous task to control all above peening process parameters in Industry. The most of the peening parameters are automatically incorporated in to one single process parameter called the “Almen Peening Intensity”. Peening intensity is related to the amount of kinetic energy transferred from the shot stream to a work piece during the process. Almen and Ebony (1963) introduced Almen test method to measure peening intensity. In this test standardized SAE1070 spring steel test strip of given dimensions and material that is clamped to a mounting fixture by means of roundhead bolts. This Almen strips having dimensions 76mm×19mm for three commercially available thicknesses: 2.39mm, 1.29 and 0.79 respectively kenned as type C, type A and type N. After the peening, once the bolts are abstracted, the Almen strip will curve towards the peening direction. The resulting arc heights under different shot peening times can be quantified by dedicated quantifying equipment called Almen gauge. Hence, Almen intensity, shot size peening coverage is desire to entirely define the peening process [6]. The perfect Almen intensity indicates that the work piece attains appropriate characteristics such as hardness, compressive residual stress, fatigue strength etc. Measurement of Almen peening intensity is a fastest method to control peening process hence used in Industries.

III. Effect of shot peening on target material

Fatigue resistance is the main beneficial effect induced by shot peening and which mainly depend on magnitude of compressive residual stress. Residual stresses are those internal stresses left after permanent deformation. Residual stress can be either tensile or compressive. Failures are often related to residual tensile stress induced during manufacturing procedures like grinding, milling and bending. On contrary compressive residual stress induced over the surface of components by shot peening and leads to improving the fatigue resistance. It can reduce the effective applied stresses of the component during application, which results in delayed crack initiation and retarded crack propagation from the surface. By shot peening process the magnitude of compressive residual stress is induced as high as 50-60% of the material's ultimate tensile strength [7].

Shot size is an important parameter which will affect on compressive residual stress and surface finish of a component. As shot diameter increases then it will increase the magnitude of maximum compressive residual stress as well as push its location inside away from surface. As hardness of shot increases there will be increase in the value of surface compressive residual stress [1].

Surface finish plays an important role to improve fatigue resistance of component. Surface finish developed after the shot peening depends on various parameters such as nozzle angle, shot size peening intensity etc. As nozzle angle decreases below 90^0 there will be increase in surface roughness. Also as shot size and peening intensity increases then there will be increase in surface roughness at all nozzle angles [8].

Microhardness is another beneficial effect and its magnitude varies along surface to depth of component. A magnitude of the microhardness depends on residual stress and domain size. At surface both domain size and residual stress will affect where as at depth domain size won't affect. Therefore at the surface of component have larger microhardness than at its depth [9].

IV. Role of target material properties in shot peening

Component designers can assess whether or not their components have the capability for service improvement by shot peening. The extent of such improvement can be termed component 'peenability'. More than 90% of moving engineering component is made of steel. Peenability of steel component depends mainly on its composition. The material of low nickel has less peenability and the material of high manganese has high peenability. According to David Krick peenability is directly proportional to yield strength of material. If two materials 'A' and 'B' having peenability 'X' and '2X' respectively then compressive residual stress produced in material 'B' will be double than material 'A' [David Krick].

Hardness of work material or component also affect on compressive residual stress. As hardness of target material increases then the value of compressive residual stress will increases. For soft target material (230-300HV) it is feasible to produce a compressive layer of depth 800-1000 µm deep. For hard work material (700HV) it is difficult to produce a compressive layer more than 250 µm deep [6].

V. Shot Peening Machines

There are two types of shot peening machine for accelerating the shots, one is shot peening machine powered by compressed air and another is powered by centrifugal force.

By compressed air: In compressed air type system shown in fig.1the peening media is stored in pressurized vessel, which is mixed with compressed air. This system is suitable for lower production applications where maximum flexibility is needed. These systems are very flexible in that the shot can be delivered horizontally through a rubber hose and nozzle assembly.

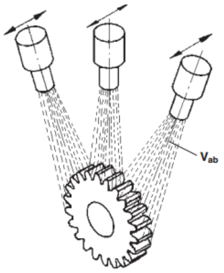

Fig.1: Machine powered by **compressed-air**

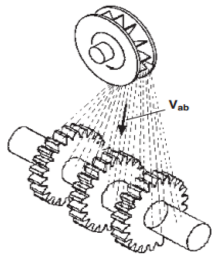

Fig. 2: machine powered by **centrifugal force**

By Centrifugal force: In this system shot media is fed to the centre of impeller shown in fig. 2, which is rotating at high speed. The media is rapidly accelerated by centrifugal force and is directed on the surface to be peened.

The shape and size of the parts determine the number of impeller used in a machine. This system is suitable for mass production application e.g. peening of connecting rods, pistons etc.

VI. Effect of multistep shot peening

Compressive residual stresses are developed after the shot peening treatment. Uniformity of such developed compressive residual stress is also an important criterion. Uneven residual stress distribution on the surface can deteriorate the surface properties of the treated component. Single step shot peening results uneven residual stress distribution. Therefore as steps of shot peening increases there will be more in uniformity of residual stress distribution. Hence, dual and triple shot peening will produce more beneficial effect than single step shot peening [10].

VII. Advanced Shot peening Techniques

A. Nano-Peening: It is a patented mechanical surface enhancement technology developed by Winoa. It enables to transform the surface of metals by reducing grain size down to a "nanometric" scale, without heat/chemicals or additional matter input, only by a mechanical operation as shown in Fig. 3. A nano-peening enhance surface properties in terms of better fatigue resistance, less wear, enhanced chemical properties. The main applications of nano-peening in peening of forging dies, casting dies, gears, shafts, pistons etc. Due to nano-peening the surface hardness increase by 200% and it will develop up to 200µm transformed thickness.

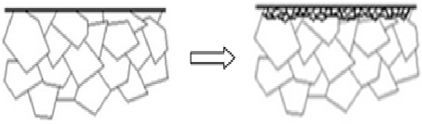

Fig. 3: Nanometric grain size after Nano-peening

B. Laser Peening: It is a mechanical surface enhancement process and not a thermal one. Using a high energy pulsed laser beam, shock waves are generated and propagate through the material. These shockwave mechanics are responsible for inducing cold-work into the microstructure and contributing to the increased performance of the material. The laser peening process requires 3 key parameters to operate efficiently: laser beam, target, confining media. Different combinations of these parameters can be used and are dependent upon the equipment and technology available (*LSP Technologies*).

C. Flapper Peening: It is also called Flap-peening or Roto-peening. It is a shot peening process that's ideal for peening in small and hard-to-reach areas. It is used extensively in the aerospace industry where weight and fatigue are key issues. During the manufacturing and service life of a component, a peened surface might get scratched or slightly damaged. In this case, re-peening is necessary to restore the compressive residual stress layer after removal of the damage area. When repeening is necessary, flapper peening, is often used because it is quick, clean and cost effective [11].

VIII. Conclusion

From the critical analysis given above, the following conclusions can be drawn:

1. Peenability is directly proportional to yield strength of material.
2. Surface roughness is depending on shot size, peening intensity and nozzle angle. Increase in shot size and peening intensity lead to increase a surface roughness value of the component.
3. Magnitude of compressive residual stress induced on the surface of the component by shot peening is as high as 50-60% of its ultimate tensile strength.
4. Depth of compressive residual stress depends on the hardness of target material. For soft target material (230-300HV) and hard target material (700HV) it's feasible to produce a compressive layer up to 0.8-1 mm and 0.2-0.25mm deep respectively.
5. Increase in shot velocity, shot hardness and peening time will increase the value of maximum residual compressive stress and push its location inside away from a surface.
6. Uniformity in compressive residual stress is achieved by multistep shot peening.

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