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# Effect of Shot Peening On Fatigue Life

Shreyas S. Kulkarni*, Prof. Sachin Jain**
*(Department of Mechanical Engineering, NRI Institute of Technology/ Rajeev Gandhi Technical University Bhopal, India)
** (Department of Mechanical Engineering, NRI Institute of Technology/ Rajeev Gandhi Technical University Bhopal, India)

***ABSTRACT :*** *The cold work process, including compressive residual stresses in near surface layers, improving the fatigue strength of components is known as "shot peening". It produces a phase transformation like nano ferrite phase and metal flow layer under intensified peening condition of high peening velocity. It is mainly used for increasing the strength. In this paper, the study of shot peening, its mechanism and its effect on fatigue strength is studied. The thickness of layer with compressive residual stress is strongly influenced by shot peening intensity. The estimation of residual stresses by using hole drilling strain gauge method is studied to find the fatigue life using three point bending test is determined.*
**Keywords** *: Shot peening, compression, residual stress, fatigue.*

## I. INTRODUCTION

Shot peening which is one of the cold working processes. In this method the metal part is hit by stram of small hard spheres (shot). It involves the complex stress histories with stress reversals and cyclic loading conditions. It produces a comprehensive residual stress on surface of material under normal condition without inducing a phase transformation. It is mainly used to increase the fatigue strength of the material. To determine the effect of shot peening on fatigue enhancement, the relaxation of residual stress under cyclic loading must be considered [1]. The favorable compressive residual stress can relax or even fade when peened component is subject to cyclic mechanical loading or temperature exposure [1]. In order to have remarkable long fatigue life of metal shot peening is most important operation.

## II. LITERATURE REVIEW

Shot peening is an old process which was used in forging processes to increase the strength of amour's, swords and tools. Evolution of peening took place in early twenty first centuries. The material was shot peened with many tiny balls of high velocity.

1. "Fine Particles Shot Peening" was described by "Oguri" in 2011. This method enhances the fatigue properties of aluminum parts for aerospace and refers it with traditional shot peening. The special characteristics of Fine Particles Shot Peening are high velocity of media flow and small ceramic media. It generates fine dimples with small surface roughness and high compressive residual stress at very near surface. The fatigue crack initiation at the subsurface is the reason of superior fatigue life by Fine Particles Shot Peening.
2. Using twelve different combinations of shot size, peening intensity and peening coverage percentage Lundberg described various surface conditions in 2012. High surface compressive residual stresses vary between 245 to 565 MPa and depth reaches up to 280 µm and 770 µm. An increase in peening coverage percentage, shot size or peening intensity lowers the surface compressive stresses.
3. The influence of shot peening on fatigue durability of normalized carbon steels are subjected to variable amplitude loading. This was observed by "Dalaei" in 2012. The relaxation was measured during fatigue life time. Shot peening increases life time especially for smaller amplitudes.

Most of the researchers work to increase the service life of material by various methods.

## III. METHODS AND MATERIALS

### A] What is Shot Peening?

It is a cold working process inducing compressive residual stresses in near surface layers and improves fatigue strength of components. It involves complex stress records with stress reversals and cyclic loading conditions [8]. It improves the fatigue strength of materials.

Shot peening under normal condition produces a compressive residual stress on surface without inducing a phase transformation [9]. It introduces phase transformation on carbon steel surface under intensified peening conditions.

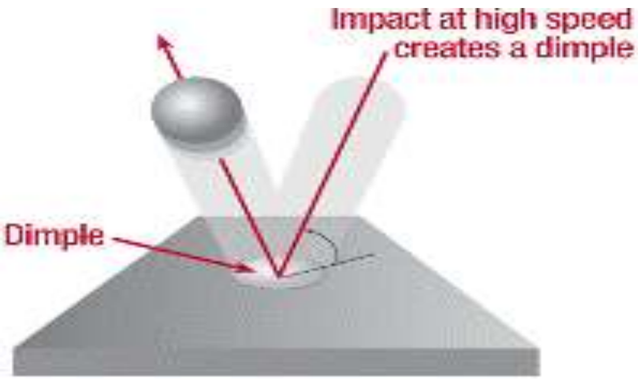



**Fig 1: Shot Peening**

In shot peening, the surface of work piece is hit repeatedly with the large number of cast-steel, glass or ceramic shot (small balls) making overlapping indentations on the surface, this action causes plastic deformations of the surface to depth up to 1.25mm using shot sizes ranging from 0.125mm to 5mm in diameter. Because plastic deformation is not uniform throughout a parts thickness, hot peening imparts compressive residual stresses on the surface, thus improving the fatigue life of components. This process is used extensively on shafts, gears, springs, oil well drilling equipment's, jet engines parts etc.

**B] Working of Shot Peening:**

Shot peening is performed by accelerating shots towards the surface of a part to be treated. During this process compressive stresses are generated as shown in figure below.

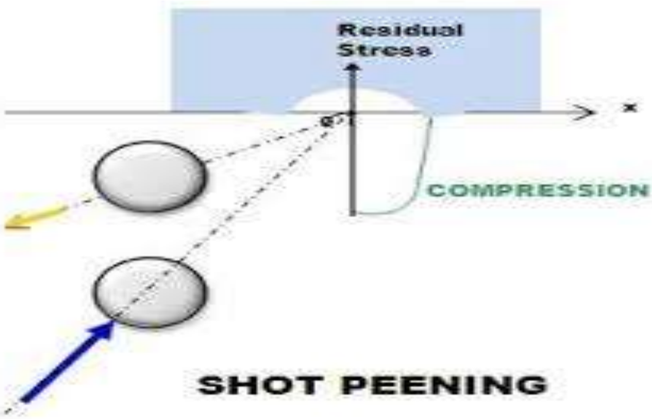



**Fig 2:** Working of Shot Peening

The impact of each particle of shot on the component produces small dimples. It is a process as shown in figure which is used to produce a beneficial compressive residual stress layer and modify mechanical properties of metal. It requires impacting a surface with high velocity shot (round metallic, glass or ceramic beads) with force enough to make plastic deformations, each bead functions as minute peening hammer.

Shot peening surface extents its plasticity, causing changes in mechanical properties of the surface. It is often called for unresponsive parts repairs to dismiss tensile stresses built up in grinding process and substitute them with useful compressive stresses.

Depending on part geometry, part material, shot material, shot quality, shot intensity, shot coverage, shot peening can increase fatigue life from 0% to 100%. Surface compressive stresses confer resistances to metal fatigue and to some forms of stress corrosion.

**C] Methods of Shot Peening:**

There are various methods by which shot peening can be done.

*1) Conventional Shot Peening:*

It can be done using two different methods.

*a) First method includes accelerating shot material with compressed air. Shot is introduces into a high velocity air stream that accelerates the shot to speed up to 250 ft/s.*

*b) Second method involves accelerating the shot with a wheel. The shot lands on the middle of the wheel and accelerates to outer edge where it follows the tangential path.*

**2) Dual Shot Peening:**

It enhances the fatigue life from a single shot peening operation by re-peening the surface a second time with smaller shot and lower intensity. Lower shot leaves small peaks and valleys. Peening the surface a second time drives the peak into valleys. It increases the compressive stress at the surface.

**3) Strain Peening:**

The effect of strain peening on fatigue strength of leaf spring. Stress peened in compression in order to introduce adverse tensile residual stresses in the surface.

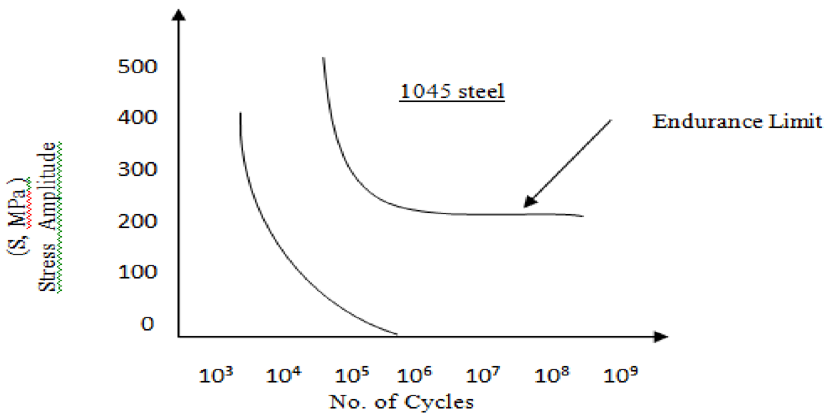
**D] What is Fatigue?**

Machine parts are frequently subjected to varying stresses and it is important to know the strength of materials under such conditions. It is well known that the materials fail under repeated loading and unloading, or under reversal of stress, at stresses smaller than the ultimate strength of the material under static loads. The magnitude of the stress required to produce to produce failure decrease as the number of cycles of stress increases. "This phenomenon of the decreased resistance of a material to repeated stresses is called "fatigue".

Testing of a material by the application of such stresses is called "endurance test" [1]. The fatigue behavior is characterized by,

i) Loss of strength
ii) Loss of ductility
iii) Increased uncertainty in strength and service life.

The inhomogeneity of the material is responsible for all these three features of fatigue behavior [2]. Fatigue occurs at stresses well within the ordinary elastic range as measured in a static tensile test on the material. It occurs under all kinds of loading and at high and low stresses.




A typical plot, known as an S-N curve is as shown in the figure. S-N curve are based on complete reversal of the stress i.e. maximum tension, maximum compression. The maximum stress to which the material can be subjected without fatigue failure, regardless of the number of cycles, is known as the "endurance limit" or "fatigue limit". The limit is related to their ultimate tensile strength [2].

**E] Fatigue Mechanism:**

The fatigue [2] of the material is primarily an effect of repetitions of loads and not simply a time effect. The rate of application of the load is not an important factor in fatigue. The progress of simple fatigue can be traced in three stages:

1) Nucleation
2) Crack Propagation

3) Fracture as shown in figure below,

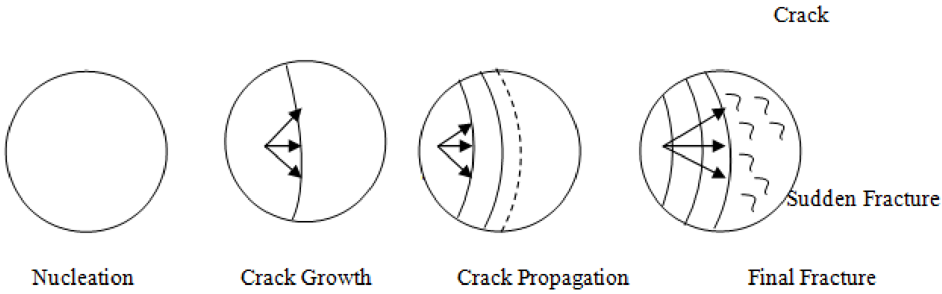



**Fig 4:** Fatigue Process

Fatigue metal begins with highly localized yielding. In polycrystalline metals in simple tension, there always exist a few crystals which are so oriented that slip can easily start in these crystals. As the load is increased, these weak crystals yield first, but since they are surrounded by elastic material, they do not affect the static stress- strain diagram. If the material is loaded only for once, the effect of the localized yielding is insignificant. If the load is repeated, each repetition produces additional localized yielding which eventually results in formation of submicroscopic cracks in the yielded region, due to strain hardening effect produced by repeated loading cycles.

**F] Fatigue Properties and Factors affecting it(som jindal):**

The total number of cycles required to bring about the final fractures under the given conditions (of stress amplitude maximum stress and rate of cycling) is the basic fatigue property.

1) Fatigue strength (σN):

The fatigue strength is well-defined as the stress which a material can resist repetitively for N cycles, and is gained by interpolation from graph of stress versus fatigue life.

2) Surface effect(som jindal) :

The most fatigue cracks are nucleated near the surface of members. The condition of the surface is very important. A rough surface can lower the fatigue strength by 15-20 per unit. The surface scratches must be removed by slow grinding and polishing operation. The most common surface treatment for improving the resistance of fatigue and increase in service life are those which produce residual compressive stress in the surface such as “Peening”.

3) Under stressing :

The process of repeated cycling at sequentially higher level, by which the fatigue properties of materials are enhanced, is called as “under stressing”.

In some material having well defined fatigue limit has been observed that applications of stress cycles at stresses below “σe” can strengthen the material, if these cycles are applied to material in a series of increasing stress cycles starting from just below “σe”.

4) Fatigue is not a linear function, it varies according to direction ranges of stresses.

**G] Residual Stress: [mpem book]**

It can develop in sheet- metal parts because of the non-uniform deformation that the sheet undergoes during forming. When disturbed by removing a portion of it, the part may change. Tensile residual stress on surfaces can also lead to stress-corrosion cracking of the part unless it is properly stress dismissed.

After the beam has been bent into the plastic range, removal of the load leaves the beam with the internal residual stresses, because the stress-strain for unloading is different than the loading [ som jindal]. When the load is completely removed, the moment of stress distribution must be zero, so as to maintain equilibrium. Consequently the stress all across the cross section is reduced further such that the stress in the outer fibers changes sign and produces an opposite moment to balance that of the remaining stress in the inner fibers. The result is that in most of the part the unloaded beam, the residual stress is not zero. On the tension side there are residual compressive stresses in the outer fibers and tensile residual stresses in interior. On the compression side,

there are residual tensile stresses in the outer fibers and compressive residual stress in the interior, the net moment of the stress distribution is zero.
The following conditions must be satisfied while testing the residual stresses: [Jindal book]
1) Loading has to be in the plane of symmetry so as to avoid unsymmetrical bending
2) Freedom from longitudinal restraint
3) Constant bending moment with zero shears in the portion of the beam under consideration.

***Effect of Residual Stress [som Timoshenko}***

Residual stresses are usually produced during heat treatment of machine parts and during welding of structures and the question arise as to the effect of these stresses on the endurance limit. Experiments with reduced steel specimens tested in a rotating-beam fatigue testing machine showed that the residual stresses are concentrated to less than one-quarter of their initial value by the application of cycles of reversed stress. The effect of residual stresses on the endurance limit was insignificant.

**H] Laser Shot Peening Process:**

LSP is a mechanical cold working process where pulses hit the surface with high power intensity and shock waves are produced [5, 6, 7, 8]. These waves plastically distort the surface and compressive stresses are stretched into the subsurface [6, 8]. These dynamic compressive stresses are highest on the surface and decrease with depth into the material [9].
The basic steps for laser shock wave generation can be termed as the following sequence;

*a) The target surface is covered with an absorbent (sacrificial) coating. This layer vaporizes, forming plasma on the surface with short duration pulse pressure. Absorbent layer prevents melting and laser ablation while maintaining high surface quality and without this layer, the energy conversion from pressure to shock cannot be made effectively. This layer can be aluminum, copper, lead, vinyl tape, zinc or black paint.*

*b) Transparent overlay (tamping layer) is applied to prevent the plasma from expanding away off the surface thereby increasing the intensity of the shock wave. These overlays, also known as the confining medium, can be water ,quartz or glass.*

Laser Shot Processing (peening) (LSP) is a surface treatment technology, which consists of irradiating a metallic target with a short and intense laser pulse in order to generate, through high-pressure surface plasma, a plastic deformation and a surface strengthening.

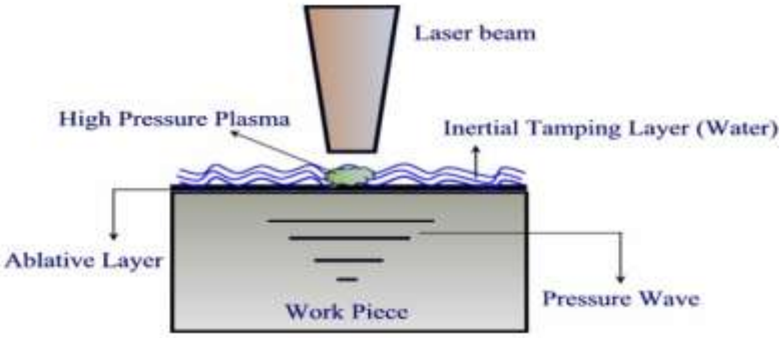



**Fig:** Laser Shot Peening Process

Laser peening is not a replacement for old-style shot peening, which has solved fatigue failures for 50 years in a profitable manner. Laser peening fills an important negated by serving fatigue applications that go beyond the current limits of shot peening. Shot peening uses the shot-stream energy (which consists of the shot mass and velocity) to impart a residual compressive stress into the surface of a metal part. Laser peening directs a strong beam of light to the critical surface. This creates high-pressure plasma that generates a shock wave, driving the compressive stress deep into the surface. The laser-peening process has exclusive aspects when compared to shot peening. The first aspect is the surface to be peened is under a laminar flow of water. The water layer is commonly called a tamping layer. Its primary purpose is to act as an inertial stop when the high-pressure plasma is formed. The plasma is formed in nanoseconds and the mass of the water prevents it from expanding, thus driving the energy into the work piece surface. The second aspect is the use of an ablative layer. Unlike a mask used in shot peening (to prevent surfaces from being hit with shot-peening dimples), an ablative layer is applied in the locations requiring laser peening. The ablative layer acts as a sacrificial layer, preventing a insignificant burning of the surface that would occur without it. Shot peening is a random, spray-type process where the surface is showered with a stream of shot media. Laser peening is a CNC-controlled, single-spot

process where relatively large spots are placed alongside each other with a slight overlap. Laser spot sizes are typically 3 x 3 mm up to 5 x 5 mm. Laser spots are typically applied at rates of 3-6 Hz depending on component application. The primary differences on the work piece from the peening processes are the depth of the residual compressive layer and amount of cold work.
The properties, which may be increased by laser peening:

- fatigue strength
- Stress corrosion cracking
- Corrosion fatigue
- Resistance to Intergranular corrosion

The components, which are normally laser peened,: aircraft gas turbine engine fan blades, airframe structures, helicopter transmission gears, jet engine rotors, disks, gears and shafts, oil tools (drill collars, bits, mud pumps).

**Quality Control:**
Quality control issues for laser shock peening can be addressed in numerous ways. A number of the laser beam parameters can be monitored and recorded for each shot in real time. In addition, there are process parameters that can be monitored using features on the material surface, measurement of material properties, or other characteristics of the process. Periodic evaluations of the process can be made by sampling the residual stress distributions and property changes in processed parts. Many of these process-related parameters can be measured and used to contr6l the process in real time. For these, acceptable limits of their values can be defined, and corrections made immediately if they drift outside of these limits during processing.

## IV. CONCLUSION

Shot peening is an important treatment of technical parts with continually growing areas of application. Also, to increase fatigue life, hardness etc., and compressive subsurface residual stresses are possessed near the surface of the work-piece. In order to obtain optimal results the process has to be controlled properly.. There can be tremendous increase in the applications as peening process is versatile i.e. many properties are influenced by this process so a number of application in manufacturing industries. Also small components can also be machined by this process.

## REFERENCES


[1]. S. Timoshenko, Strength Of Material, (Third Edition, Part 2, Advanced Theory and Problems, 1986).
[2]. U. C. Jindal, Introduction to Strength of Materials, (Galgotia, 1996)
[3]. S. Kalpakjian, S. R. Schmid, Manufacturing Processes for Engineering Materials, (Pearson Education, 4th Edition, 2007).
[4]. Allan H. Clauer, Laser Shock Peening For Fatigue Resistance, The Metal Society of AIME, (1996) pp. 217-230
[5]. Zhang, X.C.; Zhang, Y.K.; Lu, J.Z.; Xuan, F.Z.; Wang, Z.D.; Tu, S.T. Improvement of fatigue life of Ti- 6Al-4V alloy by laser shock peening. Mater. Sci. Eng. A 2010, 527, 3411–3415.
[6]. Rubio-González, C.; Gomez-Rosas, G.; Ocaña, J.; Molpeceres, C.; Banderas, A.; Porro, J.; Morales, M. Effect of an absorbent overlay on the residual stress field induced by laser shock processing on aluminum samples. Appl. Surf. Sci. 2006, 252, 6201–6205.
[7]. Golden, J.; Hutson, A.; Sundaram, V.; Arps, J. Effect of surface treatments on fretting fatigue of Ti-6Al-4V. Int. J. Fatigue 2007, 29, 1302–1310.
[8]. J. Liu and R. Liao, "Simulation of Shot Peening Process Using Combined Hardening Model," *E-Product E-Service and E-Entertainment (ICEEE), 2010 International Conference on*, Henan, 2010, pp. 1-4.
[9]. H. Mano, S. Kondo and A. Matsumuro, "Microstructured surface layer induced by shot peening and its effect on fatigue strength," *2006 IEEE International Symposium on MicroNanoMechanical and Human Science*, Nagoya, 2006, pp. 1-4.