Shot Peening of Automobile Parts

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Introduction

Abrasive blasting is a process of impinging abrasive particles with high velocity over metal surface. It is very commonly used as a finishing process in automobile components manufacturing industry. Purpose of this process is descaling, deburring, peening, polishing, stress relieving, deflashing and cleaning. Abrasive particles, cast iron grit and sand particles of irregular shapes are commonly used for cleaning, descaling and deburring. It should be noted that in shot blasting, spherical particles are used for above purposes. Basically, there is no difference between shot blasting and shot peening. The term 'shot peening' is commonly used where above purposes are secondary but the main purpose is to induce residual compressive stresses in the metal surface to improve their fatigue life. Shot peening process involves complex physical processes and results thereof obtained are related to degree of control of peening conditions. Perhaps, the most under-valued process in today's industrial work is shot peening, which may be due to lack of appreciation of its exceptiional merits. This paper deals with greater details about shot peening mechanism, process and applications.

Shot peening is a cold working process in which spherical steel shots or glass beads or shots of suitable material and size are allowed to impinge with relatively high velocity on the surface of metal parts of automobile, aircraft and other machines. This results in plastic deformation of the peened surface thereby residual compressive stresses are included, in the material upto a certain depth which prevents the formation of surface cracks.

It is well-known that a crack will not propagate into a compressed layer. As nearly all fatigue and stress corrosion failure originate at the surface of a part, the layer of compressive stress ,induced by shot peening, produces the tremendous increase in life.

When a shot strikes the metal surface, it results into plastic deformation and forms a dent below the shot. Residual stress distribution, its magnitude and depth below the dent is shown in Fig.1.

The maximum compressive residual stress produced at or near the surface is at least / as great as half the ultimate tensile strength of the material under peening.

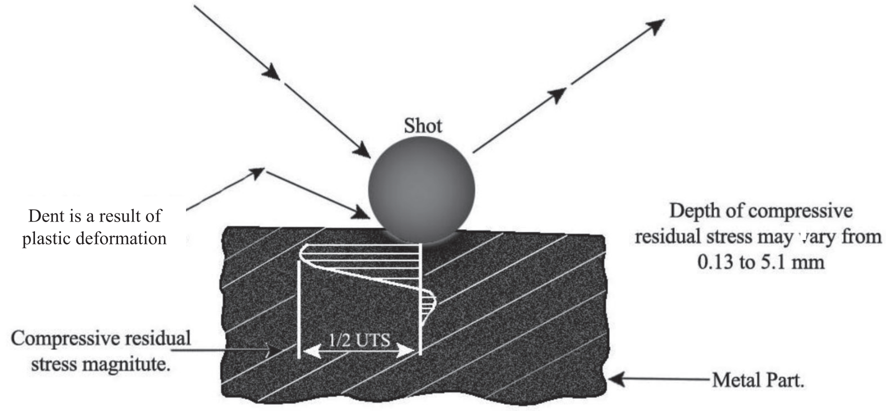


Fig. 1 : Residual stress distribution below the dent produced by impinging a shot over metal surface.

Figure 2 shows the yield zone below the dent which is about eight times the volume of the dent. Yield zone is produced by peening depends upon diameter and velocity of shot. Parts like Compressor and Turbine Rotor and Stator Blades usually require peening of the total surface. Under given peening conditions for a component, shot exposure time for saturation, that is, for full coverage [98% coverage] is to be established. There may be situations in service where controlled peening and spot peening are to be used and there again shot exposure peening time is to be established for required peening intensity in each case.

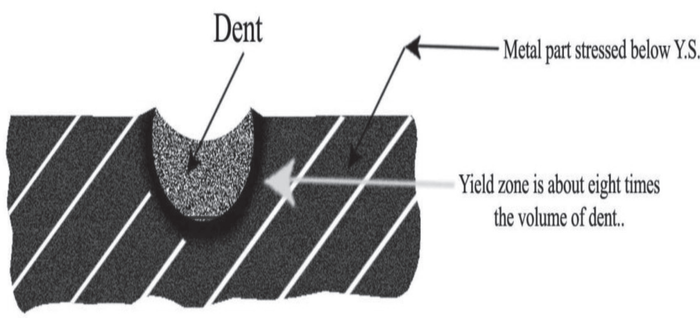


Fig. 2: Yield zone below the dent.

Exposure time beyond saturation or full coverage does not increase the volume of yield zone appreciably but slightly increase it. Figure 3 shows peened surfaces for one saturation time, twice saturation time and thrice saturation time respectively.

Mechanism of Shot Peening Process Leading to Improvement in Fatigue Strength

Fatigue failure of a component usually occurs due to the process of initiation of surface crack, then its propogation and finally fracture in two places without showing any deformation in cross-section. Fatigue cracks usually originate at the surface because [i] surface crystals are inherently weak [ii] maximum stress usually occurs at the surface in most common type of loading as bending, torsion and combination of the two i.e. bending and torsion. These stresses are tensile in nature thus favouring crack initiation, [iii] some stress concentration due to geometry of the object may always be present at the surface.

When a metal part is shot peened, its surface is subjected to slight indentations, causing slight permanent stretching of the metal in the surface and at a short distance below the surface, and strengthen the surface zone of metal by changing the shape and orientation of the crystalline grains so as more effectively to resist flow or fracture. Thus, the metal in the surface zone is made somewhat stronger than the metal underneath this zone.

But the change of shape and orientation of crystalline grains are not the only changes caused by shot peening. As the individual piece of shot strikes the metal each one sets up localised stress – longitudinal, transverse and perpendicular compression at the surface, and at a slight distance below it. After the shot bounces off, some residual stress remains in and near the surface – a longitudinal compressive stress, a transverse compressive stress and probably vertical compressive stress, a little below the surface. The net result of this state of three-dimensional stress tends to offset any logitudinal tensile stress applied by a load or bending moment. Then, since tensile stress of a given intensity has more tendency to cause the starting of a fatigue crack than a compressive stress set by shot peening, in general, it increases the fatigue strength of a shot-peened piece. It is recognised that shot peening, unless very poorly done or carried to an excessive intensity, does cause an increase in the fatigue strength of a metal.

Utility of Shot Peening Process

Shot peening usually eliminates failures of existing designs, or allows the use of higher stress levels, which, in turn, results weight reduction for new designs.

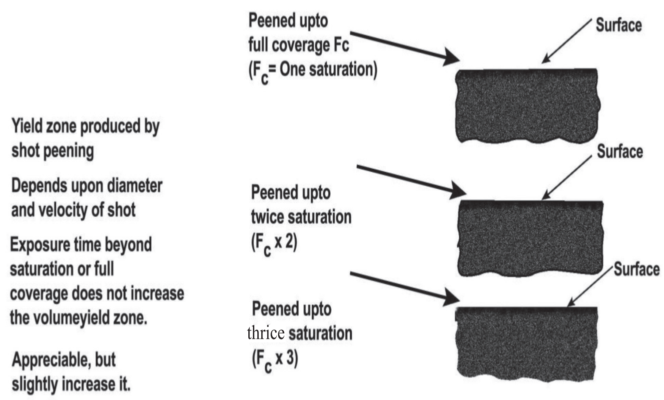
Shot peening has been done commercially to following parts :

- Rotor arms
- Tank pins
- Tank treads
- Jet engine blades
- Axles
- Connecting rods
- Track links
- Chain links
- Steering knuckles
- Helical gears
- Fillets
- Pinion gears
- Bearings
- Bevel gears
- Propeller shafts
- Crank shafts
- Crank cases
- Pivot shafts
- Leaf springs
- Helical springs
- Drill steel
- Milling cutters
- Transmission shafts
- Cylinder block
- Gun extractors
- Impeller parts
- Compressor blades
- Engine quills
- Splines
- Universal joints
- Pistons
- Valve inserts
- Piston pins
- Ring gears
- Valve spring washers

Shot peening is not only commercially used for improving fatigue life of above components, but it is equally good for prevention of stress corrosion cracking i.e. failure by cracking under combined action of corrosion and tensile stress. No stress corrosion cracking has been reported from compressive stresses. Therefore, compressive stresses induced by shot peening will retard stress corrosion cracking of all materials which are susceptible to stress corrosion like high strength aluminium alloys, magnesium, titanium, copper, alloy steels and stainless steel.

Shot peening produces cold worked surface layer which makes austenitic stainless steel more resistant to intergranuler corrosion mode.

The minute pockets that are produced on the surface through shot peening act as oil reservoirs, thus result in longer lubricant retention.



Fi g . 3: Shot Peening over the surface.

It is advisable to shot peen automobile parts which undergo heavy grinding to change residual stress in the surface from tensile to compressive.

Shot peening before chrome plating will counteract the harmful effect of plating on the fatigue life of metal parts.

It is also possible to change the shape of parts with relatively thin cross-section by shot peening selectively. Thus it is used for straightening the parts.

In the same manner in which shot peening has been used to straighten parts, it can be used to form certain parts in production. Integrally stiffened wing skins are an excellent application of shot peen forming.

The heat-affected areas adjacent to weld area are always in tension, which can decrease the fatigue life of welded assembly. Shot peening, by inducing a compressive stress in the surface can substantially increase the fatigue life of welded assemblies.

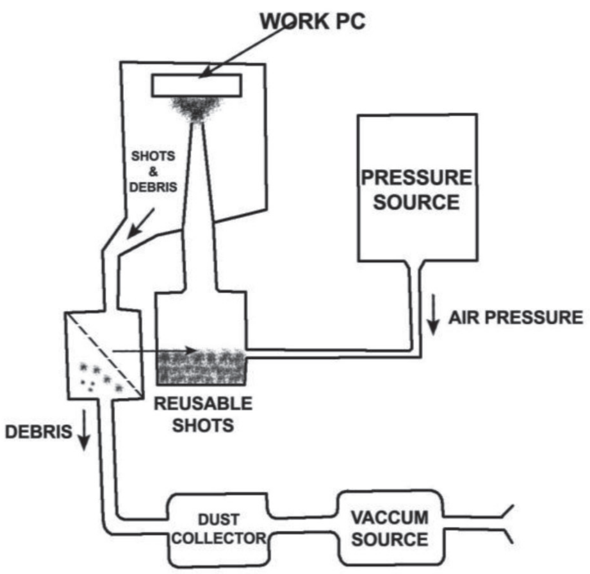


Fig. 4: Schematic view of Induction syphon system.

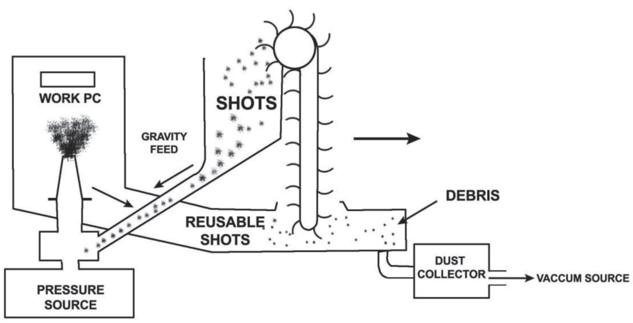


Fig.5: Schematic view of Gravity System.

Many times during Electro Discharge Machining (EDM) due to thermal stresses, plastic deformation and shrinkage induce residual tensile stresses in the work-piece. Shot peening by producing residual compressive stresses have been found to be very beneficial in restoring fatigue strength of parts that have been electro-discharge machined.

It has been observed that during high-cycle fatigue, the components which have undergone Electro-Chemical Machining (ECM) fail at lower stress level due to surface softening occurred in ECM. Shot peening treatment restores the endurance strength.

Shot peening has worked quite successfully for antigalling [anti-adhesive wear] applications on such materials as titanium 6-4 stainless steel type 300 and 400 series, 17-4 PH, Inconel 718 and X750, Monel K-500 and others. It has also been found that shot peening prevents scoring on such parts as tappet faces, cams, gears, etc. which are in sliding contact under high loads.

Auto frettage is internal pressurising of a thick-wall cylinder beyond the yield strength of the material. Inelastic deformation will occur to some distance into the wall from the internal surface during pressurisation. Upon removal of this pressure, the outer wall portion having remained elastic, encapsulates, the inelastically deformed portion producing compressive stress on inner surface. Compressive prestress by either shot peening of auto frettage alone very often increases life tenfold. Initial tests of preconditioning by shot peening of auto frettaged component showed encouraging results. Improvement of life for shot peened preconditioning of auto frettage applications is expected to show life improvement.

Shot peening on the casting leads to breakdown and elongation of grains on its surface. A plastic deformation layer is formed and sub-surface layer structure becomes more compact leading to the enhancement of pressure tightness of the part. This process is especially useful for automobile parts where the die-casting is done by injecting molten metal at high pressure and high velocity into die cavity. The air entered into the die cavity is entrapped in the castings forming gas holes leading to porosity. This causes leakage of die-castings.

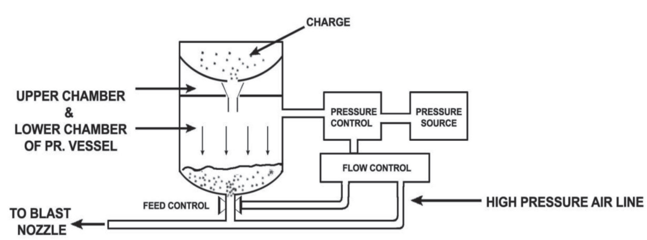


Fig.6: Schematic view of Direct Pressure System.

Shot Peening Processes

Two methods of propelling shot are widely used in shot peening. One is pneumatic, which employs a continuous stream of compressed air also known as Air Blast Method and the other is Centrifugal, a motor-driven bladed wheel rotating at high speed.

[i] In pneumatic or Air Blast Method, three different types of shot peening systems are generally employed.

a) Induction-Syphon System or Suction System (Fig.4)

b) Induction–Gravity System or Gravity System (Fig.5)

c) Direct Pressure System.

a) **Suction System :** Compressed air is directed by an airjet into the nozzle to create a low pressure, high veloicity air flow in a suction line leading to the blast nozzle. The compressed air creates ventury effect in the suction line that draws shot in the line from a hopper which is the bottom section of the peening cabinet. Once the shots reach the nozzle, the remaining air energy propells them against the work with high velocity (Fig.4).

This system is least efficient in quantity of shots moved for Cfm of air used, and produces relatively low shot velocities, where, low intensities are sufficient. It is the least expensive because no elevation system is required to move the shot overhead for gravity feed. Suction system will peen upwards while gravity fed systems are limited in this respect.

b) **Induction Gravity System or Gravity System:** : With gravity-fed systems, the shot feed hopper is located above the gun and shot flows by gravity down a supply hose to a small hopper on the gun. A bucket elevator or equivalent means returns the spent shot from the collecting hopper to the elevated hopper for recirculation. In true gravity systems, shot will flow regardless of whether compressed air is flowing. This system will flow more shot at slightly higher velocities than suction systems. The unobstructed gravity shot flow is sometimes difficult to obtain in traversing nozzle systems (Fig.5).

c) **Direct Pressure System** : Direct pressure system is the most efficient in terms of volume per unit time of air required per kg of shot moved. Of the three principal air systems, direct pressure system produces the highest shot velocity and is the only system that can move shot through long lances and side shooting, nozzles to peen deep holes. It is also the most expensive system (Fig.6).

In this system, the shot must be contained in a pressure vessel wherefrom it will drop through a metering orifice into the high-pressure air line.

When the operation must be continuous, the pressure vessel will have an upper chamber which can be

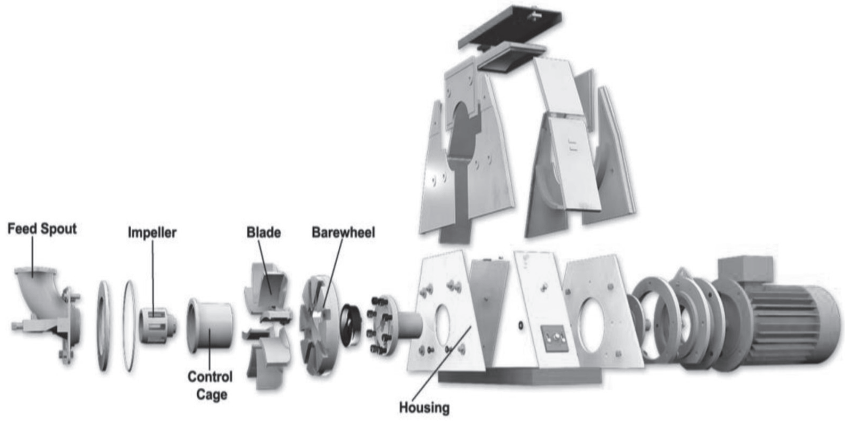


Fig. 7 : Centrifugal wheel assembly.

alternately vented into atmosphere for filling and pressurised for dropping this charge into constantly pressurised lower chamber. The lower chamber in turn feeds continuously into the high pressure air line.

Comparison of Air Blast Systems: There are advantages to each system, depending on the end-use. Direct pressure equipment is said to throw the most types of shots for the lowest consumption of compressed air. With this equipment, blasting/ peening at low pressure is more efficient. The main disadvantages of this system is its intermittent operation.

Suction-induction delivery systems are less expensive and will operate continuously until the shots are consumed. These are constructed with less complex apparatus, can throw very large amount of abrasive and are more simple to maintain compared to direct pressure systems.

Suction equipment is used in automated machines where continuous operation is required, however, it normally takes more air to throw a given amount of abrasive/shot. If the air supply is limited, the use of direct pressure unit may be indicated.

Varying shot velocity is observed in both suction and direct pressure systems due to hose and nozzle shot from centrifugal wheel does not vary their velocity at constant speed.

[ii] **Centrifugal Wheel System or Rotoblast :** With centrifugal system, the shot is propelled onto the work surface centrifugally. The shot is fed from the elevated bin by gravity and deflected by a feed spout into the center of the wheel revolving at high speed, and is accelerated along the blades and onto the work-piece. In practice, the way the shot is fed into the centre of the wheel and on to the paddle blades determines, how it is distributed while striking the work. Direction of the shot stream can be controlled by varying the point where shot is fed on the rotating blades

through control cage. Figure 7 shows the components of the centrifugal peening equipment.

Centrifugal wheels are efficient shot throwing devices. They are used where high production is required and are powered by solid state variable frequency drive units for absolute control of rpm and shot velocity. A 20 HP Rotoblast wheel can project 36,000 lbs of shot per hour. Air nozzle system would require 420 HP air compressor for the same volume of shot. Shot from Rotoblast wheels does not vary in velocity and control is a simple matter of dial settings. With centrifugal wheels velocity imparted to the particle does not diminish as does shot from nozzles and is effective to distance of 10 ft or more. This is a tremendous advantage of wheel peening. Projecting all sizes of shot upto 6.4 mm diameter to very high velocity is possible with centrifugal wheel. Figure 8 gives comparison between efficiencies of the two processes. Pneumatic and Airless shot peening process.

Since large quantity of shot can be thrown with centrifugal wheels, more attention must be paid to type and location of wear plating.

Centrifugal Peening Process is qualitatively better than Pneumatic Shot Peening Process. The total blasting area by Centrifugal Blast Process is very high in comparison to the Pneumatic Shot Peening Process (Fig.8). Due to high production rate, the process is found ultimately economical.

Shot Peening and Alternative Processes : Various processes which can induce residual compressive stresses

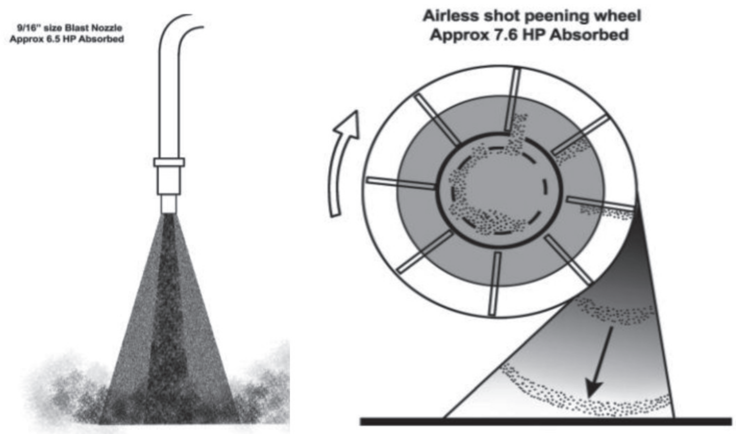


Fig. 8 : Pneumatic & Airless Shot Peening Process.

over metal surface are :

(i) Shot Peening

(ii) Hammer Peening

(iii) Cold Rolling Working

(iv) Auto Frettage

Amongst the above processes of inducing compresses, shot peening has no limitation of shape and size of the work-piece. It is the most efficient compared to others. Hammer peening is time consuming and not applicable for peening deep holes and intricate shapes. Cold working is again limited to cylindrical parts only and is not applicable to unsymmetrical sections and complicated shapes. Auto frettage is suitable for only inside surfaces and not for outside surfaces of components. Thus, shot peening is the most efficient and versatile method of peening of metal parts which improves their fatigue and stress corrosion resistance appreciably (Fig.8)