SHOT PEENING

For longer fatigue life

Shot Peening allows metal parts to accept higher loads or to endure a longer fatigue life in service without failure. In usual applications shot peening can be done without changing the part design or its material.

If you strike a part surface with a rounded object at a velocity, sufficient to leave an impression and continue until you completely cover (cold work) the entire surface then you will have peened that part.

In modern usage peening is applied by throwing tiny cast steel balls or "shot" at high velocity hence the term "shot peening".

Actually the effect of peening was discovered centuries ago by sword smiths and black smiths who found the peening the surface of a sword or wagon spring would greatly increase its resistance to breaking when bent or loaded repeatedly. The reasons for this improvement were not then understood. The round knob of the "ball peen" hammer was the smith's tool for applying this process to cold (not hot) parts.

WHERE IS SHOT PEENING USED?

Most people do not know that in the car they drive all the coil, leaf and valve springs have been shot peened as well as the torsion rods, drive shafts, axles, and gears. IN some vehicles the connecting rods, and crank shaft are peened as well.

If you fly, shot peening also contributes to the integrity of many of the planes parts and to your safety for shot peening works its wonders on a aluminum and titanium as well as steel parts. The wind sins and structural members will have been shot peened to improve their fatigue properties as well as to prevent stress corrosion cracking. The landing gear is shot peened and most parts in the jet engines also.

If the plane is a wide body type the wing skins will have been formed to the airfoil contours by a process called "peen forming". This amazing process is so cost affective and versatile that the wings of new aircraft designs are possible the forming of very long tapered skins including positive or negative dihedral breaks virtually without tooling, and the side effects (addition of compressive stresses) are beneficial not detrimental.

When a thin part is peened on one side the compressive stress layer has the effect of trying to elongate the peened surface and thereby curves the part. The curve then will develop with the convex side toward the incoming shot. Peen forming is based on this effect.

Peening has little or no effect on statically loaded structures such as building s or bridges. It works best for cyclically loaded parts (where load reversals occur frequently).

Railroad wheels, rotary printing press plates, aircraft propellers, high strength fasteners, rock drilling bits, and drill rods are typically peened parts.

Shot Peening For Longer Fatigue Life

It is rare that we go from one place to another by road and not find a vehicle, either a lorry or a car brokedown on the road due to fatigue failure of axle shaft or the spring and so on, thus creating obstacles in the flow of traffic and sometimes resulting in serious accidents. These fatigue failures can be reduced and are being almost eliminated in the Western countries by the adoption of shot peening process for increasing the fatigue life of various components subjected to fatigue stress.

Shot peening is just one of the applications of shot blasting for increasing the fatigue life of various components subject to fatigue stress. The reduced fatigue failures result in low maintenance and replacement cost for parts like springs, gears, axles and knuckle joints etc.

As is well known, the part which h fails in fatigue, fails mainly due to its failure in tensile strength. Just as in pre-stressed concrete at the end of shot peening, the parts are left with residual compressive stress. When the component is subjected to the tensile load, a portion of the tensile stresses set by the load is neutralized by the residual compressive stresses left by the shot peening. Thus the effective load is greatly reduced, resulting in an increased fatigue life even to the extent of 1,500 per cent, or more.

Manufacturers of swords and brass utensils are well known for their denting the surface of the swords or the utensils for better life by round-headed hammers called ball peen-hammers. Today this is not done by hammers but by very fast moving metallic shots. Shot peening is a cold-working method accomplished by pelting the surface of a metal part with round metallic shot thrown at a relatively high velocity, by means of an Airless Wheelabrator Centrifugal wheel.

Each shot acts as a tiny peen-hammer, making a small dent in the surface of the metal and stretching the surface radially as it hits. The impact of the shot causes a plastic flow of the surface fibres extending to a depth depending upon the degree of impact of the shot and the physical properties of the work. Depths varying from .005” to .030” are rather common, but values either higher or lower than this range can be practical. There is momentary rise of temperature of the surface due to transformation of energy, possibly enough to affect the plastic flow of surface fibres; however, the effect of shot peening is known as “cold working” to distinguish it from metal flow at high temperatures.

The fibres underneath the top layer, however, are not stretched to their yield point and, therefore, retain elasticity, the under fibres are, of course, bonded to the stretched surface layer and after the inner fibres force the outer fibres to return to a shorter length than that at which the stretched fibres would tend to remain, in the equilibrium which results, the surface fibres are in residual compression while the inner fibres are in tension.

The surface compression stress is several times greater than the tension stress in the interior of the section; so that when working stresses are applied that would ordinarily impose a tension stress on the surface, that tension is offset by the residual stress in the surface layer, and since as mentioned before the fatigue failures generally result form tensile stresses, not form compressive stress, the net result is considerably greater fatigue strength.

Shot peening is nowadays used with hundreds of different components some of which are given here. Railway leaf springs, automobile leaf springs, helical springs of all types, Gears of all types, axle bearings, crankshafts, pneumatic drills, milling cutters, connecting rods, cylinder blocks and value springs washers etc..

Most of the shot blasting equipment could be utilized for shot peening with the proper arrangement of the shot separator. Besides there are special shot peening machines to suit the specific requirement of particular sizes and shapes of the product and the quantity of the product to be shot peened.

HOW DOES SHOT PEENING HELP?

When a round part (steel ball) strikes a part of surface at high velocity the contact area is a point. This concentrates the impact energy in a very small area. Part of this energy is wasted in deforming and bouncing the ball but a significant amount is transferred into the part being struck causing a radial plastic flow at the impact point and may even leave a small visible crater. This plastic flow or movement of metal leaves compressive stresses in the part. Complete coverage of the with overhauling ball impacts leaves a thin permanent compressive stress layer in the part surface.

Metals fail under tension (pull apart) loads and not under compressive (push together) loads and not under compressive (push together) loads. The failure crack will usually initiate at the part surface where tension stresses are highest and a stress riser exists (scratch, dent, machine mark, etc..) . When parts which have been shot peened are loaded , the failure producing tensile stresses are thus reduced by the amount of the compressive stresses pre-existing in the part surface. This lowering of the effective tensile stress will then allow the part to accept higher loading or to extend its service life significantly.

When the depth of the induced compressive stress layer exceeds the dept of all surface discontinuities (stress risers) their ability to start a crack is effectively masked. This is a very important secondary benefit.

SHOT PEENING TODAY IS A PRECISION PROCESS

Shot peening is the bombarding of a metal component by small spherical or non-cutting particles, resulting in plastic deformation and the setting up of a compressive stress in the peened surface. It is a cold working process most commonly used to prevent fatigue failure and to increase the fatigue life of components under cyclic stress conditions. The compressive stress imparted in the surface by peening serves to inhibit or reduce tensile stresses in the area where material failure would normally develop. The resulting increase in the component fatigue life is in some cases known to be as high as 1500%.

Peening can be achieved by propelling the shot centrifugally by means of an impeller, or pneumatically in high pressure airstream using a pressure fed or ejector nozzle. Modern automatic peening machines are capable of projecting millions of steel or glass beads in seconds.

There are numerous applications where the compressive stress produced by peening, which can be as much as half the yield strength of the material, is of size and condition of the peening media, the time the workpiece is exposed to the blast stream, the size and configuration of the nozzles, angles, distances and other related factors it is possible to control accurately the depth of the compressed layer, the distribution o f stress and in consequence, the greater life expectation of the workpiece.

In the aerospace industry, for example, where parts such as aircraft undercarriage legs are shot peened, the shot peening legs are shot peened, the shot peening needs to be carried out to very strict specifications to meet safety requirements laid down by airlines and air craft manufacturers. This is an extreme case, and there are many applications of shot peening where the control is not so vitally important, but nevertheless it is still required to ensure consistency of peening intensity from one component to the next to meet quality control requirements.

SHOT PEENING INTENSITY:

If one imagines a stream of spherical particles leaving a blast nozzle or a centrifugal blasting machine and striking a metal surface, the work done to the surface depends on a number of factors. Size and material of the spherical shot is important, as is its velocity and the rate and angle at which the blast pattern sweeps across the surface. The relative work done to the surface is called the 'Peening intensity'. Obviously it is impractical to count and weigh the particles and measure their velocity, so a simpler comparative method has been deviced to measure peening intensity.

If a flat strip of metal is shot peened on one side only it will slightly curl away from the side which has be treated and produce a convex surface. If a standard strip is used, the degree of curvature is a measure of the peening intensity, the stripe curling more at higher intensities. The standard strip is called an 'Almen Strip' after the man who first formalized this method. It is made from spring steel of carefully controlled quality to a size within close tolerances. It is used in three thickness called C, A and N. The C strip is thickest and N strip the thinnest. The curvature or are height, of the strip is measured with the aid of a dial gauge Fig.1 after the strip is placed and retained magnetically against two pairs of ball contacts a fixed distance apart. The gauge is zeroed with the unpeened strip in position. After peening peening the strip is replaced against the contacts with the unpeened side towards the dial gauge stem and the Almen are height is read directly in thousandsths of an inch or millimeters.

The three different strip thicknesses are to cater for different extremes of peening intensity. For most applications an A strip would be used, and if this gave a deflection after peening of 0.015 in this would be expressed as 0.015 in A, lighter peening, giving less than 0.006 in A, an N strip would be used. The C strip is for heavy peening of an intensity, greater than 0.23 in A. Generally, are height N is three times are height A and a C reading is 0.3 of that on an A strip. In practice, 80% of all peening requirements lie between 0.012 in A and 0.020 in A.

When peening intensity is measured it is important to subject one side of the Almen strip to exactly the same blast conditions as the object to be peened. To do this the strip is clamped by the heads of four screws to a heavy flat block of hardened tool steel, called an Almen block, Fog. . The assembly is then passed through the blast stream in the same manner and relative position as the part to be peened. On irregularly shaped components often more than one strip is used, each one positioned on a difference face requiring treatment.

PEENING SATURATION

Although peening intensity depends on a factors concerned with the shot blast equipment (pressure, shot size, and so on) the time of exposure to a shot blast stream is also very important. The graph, Fig. 3 shows how peening intensity (Almen are height) increases with exposure time. The peening intensity increased with time until a saturation points is reached where any increase in exposure time of the samples to the blast only results in a marginal increase in peening intensity. If continued blasting for a long period of time does not produced a required Almen arc height, than saturation point has been reached and either a larger shot size is required or a higher shot velocity to increase the Almen arc (at saturation). In practice, specifications of peening intensity should always be for saturation values.

PEENING COVERAGE:

It is essential if the maximum benefit from shot blasting is to be obtained that the surface is completely and uniformly covered by the minute indentations resulting from bombardment by the peening media. Generally, a peening specification should state the percentage coverage required and this would be estimated by inspecting the peening surface with the aid of magnifying glass or preferably, a microscope. Most specifications, particularly those used in the safety conscious aerospace industry, will call for a 100% coverage. At least 90% coverage will probably be required for less stringent requirements. A sample of stainless steel peened to 100%coverage is shown in Fig. . The characteristic cratered appearance can be clearly seen in the illustration.

PEENING MEDIA

To accomplish a shot peening job efficiently, shot of the correct material and size maintained in a condition free of cutting edges, should be used. Shot of peening is available in a variety of materials depending on the nature of the job in hand.

Cast steel shot is generally used for peening ferrous components - leaf or coil springs, for example - or for the treatment of non-ferrous articles when the possibility of ferrous contamination is acceptable. It is however possible to blast components with angular non ferrous abrasive after peening with cast steel shot to remove any ferrous contamination. This is not generally done, since it would probably be cheaper to peen the article with glass beads in the first instance.

Glass beads are widely used for peening non-ferrous components or where very low intensities may be required, for example on aluminum and its alloys, titanium and stainless steel, particularly in the aerospace industry where peening is widely used to increase the fatigue life on non ferrous components. The regularity of size and shape can be clearly seen in Fig. 5.

Copped wire is less widely used for peening and consists of spring steel wire, or piano wire, shopped into lengths equal to its diameter. Before being used for peening it has to be blasted against a steel plate to blunt the sharp cut ends.

SHOT SIZES

Apart from considerations of peening intensity, which are directly affected by shot size the size of shot should be small enough to fit the smallest inside radius or fillet being peened, preferably less than one third of the fillet radius, Fig. 6. In addition, its diameter should not exceed one third of the fillet that of the smallest used including of course, the nozzle through which the shot is propelled.

To maintain the required standard of peening intensity it is vitally important that the size range of shot is that virtually all shattered particles are removed. In better quality shot blast equipment this is achieved by an efficient air wash system which removes undersize particles by passing a controlled airstream through a falling stream of peening media which ahs been precipitated by centrifugal means in a cyclone. For final elimination o f oversize unwanted debris, the reusable particles pass through a vibrated sieve.

PEENING AND THE DESIGNER

Main application of shot peening is to increase the fatigue life of components under cyclic stress. The process will provide optimum benefits at the design stage of a component. Peening can be usefully employed within the context of extending fatigue life in two ways. Either the fatigue life of an existing component which has revealed premature failure can be reduced considerably to give the same fatigue life. It is the latter concept that is of interest to the designer.

Generally speaking he is not interested in unnecessarily increasing the component's fatigue life. He is, however, very interested in unnecessarily increasing the component's fatigue life. He is however, very interested in reducing its size, and hence cost, in the first instance while still retaining the same life characteristics. In addition, component weight will be reduced which is of course vital in the aerospace industry.

SELECTIVE TREATMENT:

It is not always necessary to peen an article all over. This is particularly true where a component has an area of f particularly high stress, in which case only the highly stressed area need be peened. If selected areas only are being peened care must be taken when blending the peened and unpeened areas. An instance is where an article could be experiencing a changing stress which is not cyclic in as much as the stress does not reverse. A case in point is a motor vehicle lead spring, where one side is constantly under tension which (is a motor vehicle) is always fluctuating during use. In this case, fatigue failure could still occur, but only form the tension side and peening need only be carried out on the tension side to produce a layer under compressive stress. If one visualizes the loaded spring, the other side is always under compressive stress. Even greater benefit can be obtained by peening with the component under stress. When the component is then released, the depth of the peened compressive layer is greater then would have been the case for normal peening and a greater fatigue resistance results.

AIR BLAST CENTRIFUGAL

Main difference between air blast and centrifugal machines is that the latter do not propel each particle to a velocity as high as that with air blast, but they produce a blast pattern containing many more particles. This means that they can handle a much greater throughput of work than an air blast machine, but to obtain the same peening intensity a larger shot size would probably need to be used. Additionally, the larger pattern of blast with varying shot velocities from the centre to the edges of the pattern produces variable peening intensities over the total which for some components would be unacceptable. For many items, however, when peening to saturation, this is not a critical factor.

Centrifugal machines are widely used for heavy peening applications. Typical examples are large coil springs, torsion bars and leaf springs. For more delicate components like valve springs, push rods and rocket arms, the precision of air blast systems may be preferred.

It is important to have air pressure regulation on an air blast machine. With this facility any required peening intensity can easily be achieved by a selected combination of shot size and air pressure. Equally important is the rate of feeding of the shot through the nozzle. It is important that an even controlled feed is maintained, and that the orifice through which the shot passes into the compressed air stream is either fully adjustable, or designed to accommodate a wide variation in shot size while still keeping the appropriate feed rate. Further considerations are the orifice and angle of the nozzle from the workpiece. To reproduce peening intensities accurately all these factors should be specified.

Generally centrifugal machines are used with steel shot or cut wire. Until recently it has not been possible to use glass beads on them to avoid contamination of non ferrous workpieces. Main reason for this is that the lighter beads could not be reclaimed but were drawn into the dust collection system to be wasted. This is particularly undesirable since glass bead peening media is more expensive than iron or steel shot. An additional difficulty is that the beads, being lighter than steel spheres, are slowed down by atmospheric drag on leaving the impeller, with consequent reduction in peening intensities.

The difficulty of reclaiming glass beads for further use has been solved in two ways, by using a centrifugal precipitator through which all air must pass before reaching the dust collector, and by conveying the beads for reuse on a fluidized bed incorporating an efficient classifying system for removing any remaining dust and broken bead particles. A tubular impeller has been developed for propelling the beads so as to offset the slowing down caused by air drag (see metal working production, April 1973, P. 101). The use of impeller tubes instead of flat blades has two advantages. Firstly, the track width produced parallel to the axis of the wheel is version, with a much greater, up to 100%, peak intensity at the centre. Secondly, distribution of the blast pattern over its length normal to the axis of the wheel, shows a greater area of high intensity than from a bladed version. This is especially noticeable when using fine media.

PEENING IS VERSATILE

Often a technique becomes associated with a strictly limited number of applications. This leads to be the case with shot peening, where everyday procedures such as the treatment of crankshafts, gears and springs is thought by many to be the full extent of the process. In scope and scale the variety of shot peening applications is considerable. It ranges from the treatment of large aircraft undercarriage components to delicate miniaturized electronic, components subject to stress, which are shot peened with tiny glass spheres ranging from 45 to 75 micron.

Nor are the applications confined to the classis fatigue situation, where a component undergoes a cyclic stress and shot peening increases fatigue life. There are other surface defects that cause metal to fail which can be inhibited by a carefully controlled peening process. Stress corrosion cranking is a problem that occurs as a result of applied stress on a component in a corrosive environment. Failure would not occur in the corrosive environment alone nor under the applied stress only. It is the combination that causes the problems. If failure cannot be prevented by peening, life to failure will be certainly increased.

The peening of bearings to improve fatigue life is an obvious application, but simultaneously the bombardment results in a cratered surface formation in which lubricants are retained. This is of importance in any situation where two metal surfaces are moving in relation to each other.

The controlled hammering effect of shot peening has been proved to close the pores of metal surfaces. Vacuum chambers need to have a nonporous surface to reduce outgassing during pumpdown and glass bead peening is the acknowledged treatment. The treatment of castings is another obvious area where the problem of porosity can be reduced. Surface scratches and machining marks and similar tiny imperfections acting as stress raisers are the cause of premature failure and treatment with spherical peeining media can remove these imperfections. In many instances it is necessary to relieve tensile stress induced in the surface by grinding or welding during manufacture. These stresses can be modified by peening the workpiece in the appropriate areas.

Treatment by glass bead blasting is a fast effective and inexpensive method of burr removal which can be carried out in manually operated or fully automated plants. Where the components are designed for uses under stress, peening and debarring can be undertaken in the same operation.

The effect of peening which causes the Almen strips to bend can be used on metal sheets that have to be formed into a curved surface. By peening one side only and at different intensities in different places, the sheet can be induced to follow a complex curve. Even if treated on one side only, both surface layers will be under compressive stress, with a resultant improved fatigue resistance. When peen forming it is possible to machine off the microscopically cratered surface caused by the peening action, if a machined finish is required. The principle of peen forming can, of course, be applied to straightening deformed components of thin section. Compared to mechanical methods of straightening, which can produce tensile stresses, the resultant compressive surface layer can be off benefit.

So far no mention has been made of product appearance. The finish that result from glass bead peening can be a powerful sales feature. Depending on blast intensity, varying finishes can be obtained, from a satin pearl reflective surface to a pleasing hammer effect.