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Introduction to Fatigue Strength Technique:Shot Peening

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Abstract: Shot Peening allows metal parts to accept higher oads 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. 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. Shot peening is considered among the most-efficient techniques. The goal of this paper is, first to describe the mechanical characteristics due to shot peening, then to list the main parameters, in order Structural Analysis Of Shot Peening On Aluminum Alloy Plates, finally to summarize the effects of the loading parameters on the improvement level.
Keywords: Aluminum Alloy Plates, Shot Peening, Structural Analysis.

I. INTRODUCTION

In order to achieve the final aircraft shape, some structural components are subject to forming processes, such as shot peening. Such a process introduces plastic deformation and residual stress inside the material. Benefits obtained by shot peening are the result of the effect of the compressive stresses and the cold working induced. Shot peening process increase fatigue life, and resistance to corrosion fatigue and cracking, fretting, etc.

Shot peening is a cold working process performed at room temperature in which the surface of the work-piece following the impact of small spherical balls, usually made of steel, plastically deforms. The balls are projected against the surface being peened, indenting the work surface causing plastic flow within the surface zone.

In order to deform permanently the surface of the work-piece, the material must be yielded in tension, producing elastic stretching of the upper surface and local plastic deformation that manifests itself as a residual compressive stresses. Upon unloading, fibers placed below the indentation, try to restore their position to their original shape, but the surrounding material does not allow this to occur. Therefore, a region of compressive stresses is generated. A uniform layer of residual compressive stresses in the metal is achieved by multiple and progressively impact of the work-piece.

The main advantage of the shot peening process is that all surface stresses generated are of a compressive nature.

It is well known that cracks will not initiate or propagate in a compressively stressed zone. Since, nearly all fatigue and stress corrosion failures originate at the surface of a part, compressive stresses induced by shot peening provide considerable increases in structural component life.

The maximum compressive residual stress produced at or under the surface of a part by shot peening can be as great as one half the yield strength of the material being formed.

Moreover, parts formed by shot peening exhibit increased resistance to flexural bending fatigue. Fabrication methods may give rise to stress raisers unpredicted in the original design estimate. Shot peening will reduce accidental stress concentrations. But, regardless of the quality of the production, shot peening, properly applied, will be effective in reducing fatigue and therefore increasing the useful life of the component. The aim is to obtain high compressive

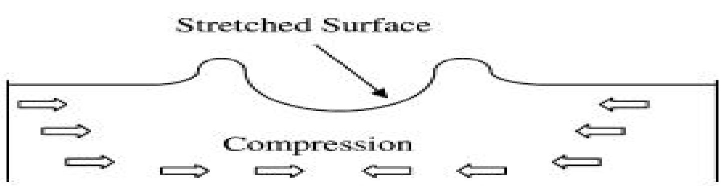

Fig. 1. Stress field generated by the process.

Fig 1: Stress field generated by the process residual stress as deeper as possible into the work-piece.

Moreover, this treatment leads to an increase of the surface hardness due to the cold working effect of shot peening.

If welded structures are subject to shot peening to achieve the final shape, the effect of welding-induced-changes will be lowered. Significant decreases of residual stress distribution and distortion can be achieved. The level of reduction is strongly dependent on many factors, such as plate thickness, material properties, ball speed, material and diameter (Fig. 1).

II. LITERATURE SURVEY

M. Meo et al. Studied, Shot peening is a manufacturing process intended to give aircraft structures the final shape and to introduce a compressive residual state of stress inside the material in order to increase fatigue life. This paper presents the modeling and simulation of the residual stress field resulting from the shot peening process. The results achieved show that a significant decrease of welding induced tensile residual stress magnitude can be obtained. Good agreement between experimental and numerical results was achieved [1].

Y. H. Yang et al. Studied, The Key Laboratory of Contemporary Design & Integrated Manufacturing Technology, Ministry of Education, North western Polytechnical University, It is very significant to investigate the shot peening mechanism in ensuring a good resistance to fatigue and stress corrosion. This paper reviews the recent advancements in shot peening process. Emphasis is put on the application of numerical simulation techniques and finite element method in residual stress prediction during shot peening process. Different methods related to shot peening modelling and prediction of plastic deformation and surface integrity are reviewed. Some key issues such as algorithms and simulation procedures are discussed [2].

S.A. Meguid et al. Studied, Engineering Mechanics & Design Laboratory, Department of Mechanical and Industrial Engineering, University of Toronto,5 King+s College Road, Toronto, Ontario, M5S 3G8 Canada" Metal Improvement Company, 10 Forest Avenue, Paramus, New Jersey, 07652 USA This investigation is devoted to the modelling and simulation of the residual stress Held resulting from the shot-peening process. In this dynamic elasto-plastic analysis, single and twin spherical indentations were examined using the Þniteelement method. The contact between the shots and the target was modelled using contact elements of the penalty function type. Attention was devoted to three related issues. The Rust is concerned with the eject of the shot velocity, size and shape upon the plastic zone development and growth, and unloading residual stresses [3].

Andrew Levers et al. Studied, The shot peening process is largely used for the surface treatment of metallic components with the aim of increasing surface toughness and extending fatigue life. A secondary consequence of the process is that the residual stress distribution developed within the material may induce distortion of the component. This effect may therefore be used constructively in the straightening and forming of thin flexible metallic structures. In this paper, the various techniques available for modelling the effect of peening with finite elements are discussed. In particular, a method of simulating the effect of peening on large flexible panels is presented. Analyses are shown in which a novel loading is applied to finite element meshes in order to produce the desired residual stress distribution. Results from tests are compared to finite element analyses and preliminary results of large scale analyses are presented [4]. Royston et al. Studied, Shot peen forming is a production process used to create curved metal partsfiom sheet. It is commercially important despite the fact that its mechanisms are not fully understood; peen forming programmes are currently generated using experience and trial and error. The purpose of this work is to increase the predictability and range of application of the process by advancing its understanding. Finite element analysis proved to be a satisfactory procedure for studying shot peen forming. The stress distribution in a sheet arising from multiple indentations, as occur in shot peen forming, was modelled. [5].

Chang Feng Yao et al. Studied, to study the effect of different milled surfaces on shot peening surface integrity (roughness, residual stress, hardness, and microstructure), research on the change of surface integrity is carried out using the same shot peening process for different milling surfaces of 7055-T77 aluminum alloy. Surface integrity measurements, fatigue fracture analysis, and fatigue life tests are conducted to reveal the effect of surface integrity on crack initiation and fatigue life. The results show that shot peening can reduce the dispersion and instability of surface integrity brought by milling processing, although it increases the surface roughness; the maximum residual compressive stress and depth of residual stress layer increase significantly after shot peening, and the residual stress and hardening distribution are very good; larger surface roughness and irregular surface scratches of milling samples before shot peening easily lead to cracks and gouges produced on shot peening surface [6].

III. SHOT PEENING

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.

A. 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.

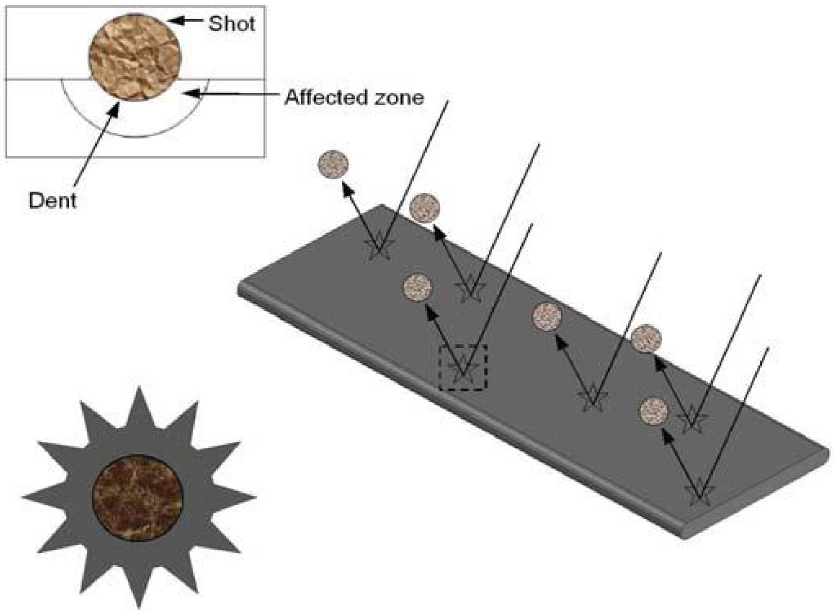

Figure 2: Schematic diagram showing shot peening.

B. 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 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 preexisting 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.

C. 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 of 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.

D. 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

IV. METHODOLOGY FOR SHOT PEENING:

A. Equipment used for shot peening

1) *Equipment:* The equipment used in shot peening is essentially the same as that used in abrasive blast cleaning, except for certain auxiliary equipment made necessary by the more stringent controls imposed in the shot peening process. The principal components of shot peening equipment are a shot-propelling device, shot recycling and classification arrangements, and a work handling conveyor. All portions of equipment that are exposed to the stream of shot are enclosed to confine the shot and permit it to be recycled.
2) *Propulsion of Shot:* Two methods of propelling the shot are used widely in shot peening. One uses a motor-driven bladed wheel, rotating at high speed. The other uses a continuous stream of compressed air.

a) The wheel method: shot is propelled by a bladed wheel that uses a combination of radial and tangential forces to impart the necessary peening velocity to the shot. The position on the wheel from which the spot is projected is controlled to concentrate the peening blast in the desired direction. Among the advantages of the wheel method of propulsion are easy control of shot velocity when equipped with a variable-speed drive, high production capacity, lower power consumption, and freedom from the moisture problem encountered with compressed air.

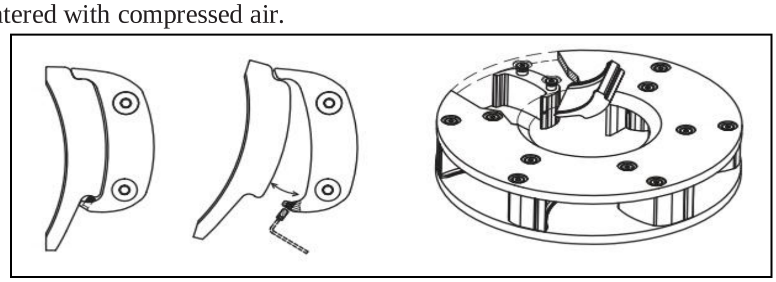

Figure 3 : wheel used for shot peening

V. CONCLUSION

From this study we can conclude that with the help of this method that the components subjected to forming process can have effective compressive stresses with the use of shot peening that increases fatigue life, and resistance to corrosion fatigue and cracking, fretting, etc.

VI. ACKNOWLEDGMENT

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