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Experimental Investigation of Fatigue Life of Suspension Arm after Shot Peening

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Abstract: Fatigue is one of the important mechanical properties of a material concerned with civil, mechanical constructions that need to be analyzed to avoid the failure of system before its expected life. Shot peening is a surface treatment process which is used to produce a compressive residual stress layer and modified mechanical properties. This study investigates effect of shot peening on 7075-T6 Aluminum alloy. The specimens are in the dumb bell shape and bombarded with cast steel shots. This study focuses on the effect of the cast steel ball shot intensity on the fatigue life of the Aluminum alloy. Shot Peening is widely used to improve the fatigue life of the components. In this process, shot that strikes the material acts as a tiny peening hammer, imparting to the surface a small indentation or dimple. The surface of the material yield in tension to create dimple on the surface.

Keywords: Shot peening, fatigue life, shot size, Taguchi method, Al 7075 T6, DOE

I. INTRODUCTION

Shot peening is a process in which specific areas of a specimen are bombarded with small spherical elements called as shots. Shot peening is used to develop compressive residual stress layer and reconstruct mechanical properties of materials. Shot peening is similar to the sand blasting, excluding that it operates by the mechanism of plasticity rather than abrasion. Each particle functions as a peening hammer. Peening a surface deforms it plastically, that causes changes in the mechanical properties. In particular it avoids the generation of micro cracks in surface [1].

Shot peening is performed by accelerating spherical media near the surface of a specimen. When the media hits the specimen, a small dent is formed, extending the surface of the part. The material surrounding that dent resists this, and makes a region of compressive stress. When the surface region has these minor dents, there is a constant level of compressive stress on the surface of the part. This interchanges the tensile stress on the surface with a compressive layer. The compressive layer prevents the fatigue cracks and stress corrosion that naturally start at the surface of the part. Nearly all fatigue failures originate at the surface of a part, but cracks will not initiate or propagate in a compressively stressed zone. In this study peening is done on the specimen of “Al 7075 T6” material which is widely used in automobile industry to make parts like suspension arm [5].

II. METHODOLOGY

A. Selection of Material

Aluminum alloys are widely replacing steel materials in Automobile industry due to its advantage of low density along with high strength. Al 7075 T6 is one such alloy having applications in aircraft, gears and shafts, regulating valve parts, worm gears, missile parts, aerospace and defense. Al 7075 T6 is having ultimate tensile strength of 515-545 MPa and yield strength of 440-490 MPa. Chemical composition of Al 7075 T6 is shown in table 2.1

Table 2.1 Chemical composition of Al 7075 T6

Component	Wt %	Component	Wt %
Al	87.1-91.4	Mn	Max 0.3
Cr	0.18-0.28	Zn	5.1-6.1
Cu	1.2-2	Si	Max 0.4
Fe	Max 0.5	Ti	Max 0.2
Mg	2.1-2.9	Other, each	Max 0.05

For Al 7075 T6, Cast steel is selected as shot material [14].

Size of test specimen is shown in figure 2.1

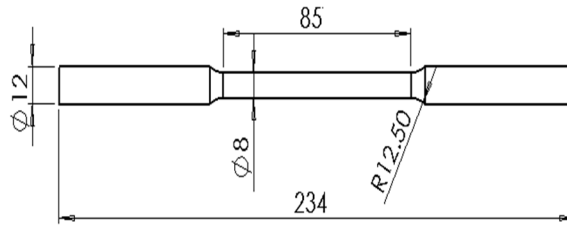


Figure 2.1 Al 7075-T6 test specimen

B. Selection of Process Parameters

Shot peening is dependent on impingement of shot ball on the specimen material. Various parameters which control the process are as follows:

- 1) Shot material and size
- 2) Pressure
- 3) Velocity
- 4) Coverage
- 5) Angle of incidence
- 6) Spindle speed
- 7) Distance between nozzle and material
- 8) Time of peening

From these parameters controllable and influential parameters like shot size (diameter), pressure of compressed air used to impinge shots on specimen are varied in two levels. Other parameters like spindle speed (72 rpm), coverage (200%), incidence angle (90°) were the constant parameters. Parameter like velocity is difficult to control with Experimental setup we have used but control of air pressure will give the desired control. Time of peening was also difficult to control to a fixed value. Therefore, we moved the nozzle over specimen by lead screw mechanism of shot peening machine manually and approximately at constant speed until we can complete two passes.

C. Design of experiment:

Design of experiment is statistical method to analyse complex, multivariable process with less number of trials. Full factorial design is one of the approach to design of experiment. A full factorial design is an experiment in which there are two or more factors. The value of these factors varied in levels; generally two but more levels can also be selected. Full factorial design allows analysing effect of each factor on the variable as well as the effect of levels selected.

Table 2.2 Selected factors and their levels

Factors	Lower Level 1	Higher Level 2
Shot diameter (mm)	0.85	1.18
Standoff distance (cm)	4	7
Pressure (bar)	2.5	4.5

D. Actual Peening Process

Shot peening machine Experimental setup is used for peening of the material.

Following are the components of the shot peening machine used

- 1) Motor: AC Motor (1/4 HP), 1440 rpm speed, Crompton greaves make
- 2) Gearbox: Worm gear drive was used to reduce the speed.
- 3) Nozzle: Nozzle of diameter 1.8 mm was used.
- 4) Spindle and center: Specimen was held between 3 jaw Chuck spindle and center.

In process, first sample specimen is held in between rotating spindle and centre rotated at constant speed of 72 rpm. A nozzle through which shots will impinge on the sample is fitted just above the sample specimen. Nozzle is rigidly connected to pipe through which shots are feeded constantly and slowly during its working. Compressed air is given in the nozzle to accelerate the shots striking on the specimen.



Figure 2.2 Peening arrangement

E. Fatigue Testing

Shot peening is a cold working process whose prime aim being to vanish any crack on newly machined or old components so that it will lead to increase in fatigue life of the components. To determine this increase in fatigue life, fatigue testing is need to be done. Testing is done on total 9 specimens on fatigue machine at constant motor speed and at a constant load. Improvement in fatigue life of the components was found out in terms percentage.

$$\% \text{ improvement in fatigue life} = \frac{\text{fatigue life of peened component}}{\text{fatigue life of unpeened component}} \times 100$$



Figure 2.3 Fatigue testing machine

III. RESULTS AND DISCUSSION:

The graphical results are obtained from the observations and their outcome is discussed further.

Table 3.1 Results of fatigue test considered in analysis

Rod No.	Shot size (S)	Stand Off distance (D)	Pressure (P)	Cycles
1.	0.85	4	2.5	33043
2.	0.85	7	2.5	26359
3.	1.18	4	2.5	23435
5.	0.85	4	4.5	41239
(9) un-peened.				19084

Readings are obtained from fatigue testing after shot peening of material and graph were plotted to compare the results. Total 5 observations are considered in this analysis.



Fig 3.1 Specimen before shot peening



Fig 3.2 Specimen after shot peening

A. Variation of fatigue life with respect to shot size

Comparison of fatigue life in terms of no. of cycles is done for two different shot sizes (0.85mm, 1.18mm) by keeping pressure and standoff distance constant. Pressure value for the readings was 2.5kg/cm² and standoff distance was 4 cm. Effect of variation in shot size on fatigue life for Rod no.1 and Rod no.3 is shown in table 3.2

Table 3.2 Variation of fatigue life with respect to shot size

Rod No.	S (mm)	P (kg/cm ²)	D (cm)
1	0.85	2.5	4
3	1.18	2.5	4

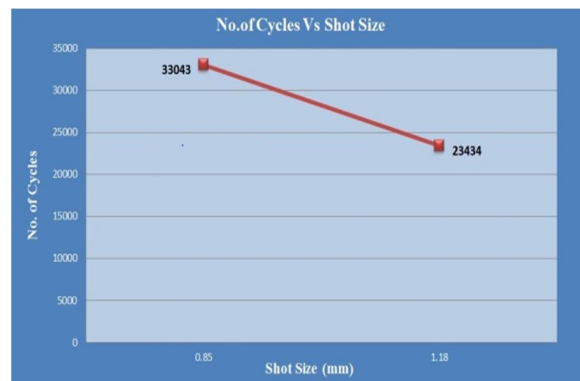


Fig 3.3 Variation of fatigue life with respect to shot size

Rod no.1 and Rod no.3 are considered to analyze effect of variation in shot size on fatigue life. As shot size decreases fatigue life goes on increasing. The reason behind that the smaller shot size causes fine distribution of the residual stress as compared to bigger size. More amount of stresses are induced which reduces the tensile residual stresses.

B. Variation of fatigue life with respect to pressure:

Rod no.1 and Rod no.4 are considered to analyze effect of variation in pressure on fatigue life. Shot size and standoff distance was kept constant as 0.85mm and 4cm respectively.

Effect of variation in pressure on fatigue life for Rod no.1 and Rod no.3 is shown in table 3.3

Table 3.3 Variation of fatigue life with respect to pressure

Rod no.	S	P	D	Cycles
1	0.85	2.5	4	33043
4	0.85	4.5	4	41239

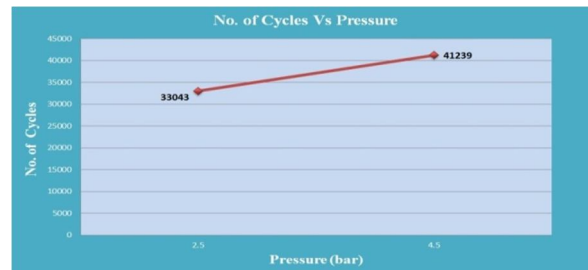


Fig 3.4 Variation of fatigue life with respect to pressure

It is observed that for pressure value 4.5 kg/cm² we get more fatigue life than that of 2.5kg/cm². Intensity of peening is more for 4.5kg/cm² so that large amount of compressive stresses are induced which reduces the amount of tensile stresses in the specimen. The effect is to increase the fatigue life

C. Variation Of Fatigue Life With Respect To Standoff Distance

Rod no.1 and Rod no.2 are considered to analyse effect of variation in standoff distance on fatigue life. Shot size and pressure was kept constant as 0.85mm and 2.5kg/cm² respectively.

Table 3.4 Variation of fatigue life with respect to standoff distance

Rod no.	S	P	D	Cycles
1	0.85	2.5	4	33043
2	0.85	2.5	7	26359

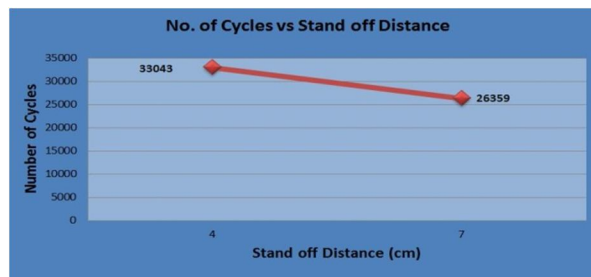


Fig 3.5 Variation of fatigue life with respect to standoff distance

It is observed that as standoff distance increases fatigue life decreases. Intensity of peening is more when the standoff distance is less and shots would cover more area of the specimen as that the large amount of compressive stresses are induced which reduces the amount of tensile stress in the specimen. The effect is to increase the fatigue life.

D. Concluding test based on ideal results:

Rod no.5 gave maximum fatigue strength of 41239 cycles.

Parameter for this rod were,

Pressure = 4.5kg/cm²

Shot size = 0.85mm (S-330)

Standoff distance = 4cm

E. Result

After concluding ideal reading

At pressure = 4.5kg/cm²

Shot size = 0.85mm

Standoff distance = 4 cm

- 1) Fatigue life before shot peening = 19084 cycles
- 2) Fatigue life after shot peening = 41239 cycles
- 3) % improvement in fatigue life = $\frac{\text{fatigue life of peened component}}{\text{fatigue life of unpeened component}}$
= $\frac{41239}{19084} \times 100$
= 216.09%

IV. CONCLUSIONS

- 1) As shot size reduces fatigue life goes on increasing the reason behind that is smaller shot size produces full coverage more rapidly. The distribution of compressive residual stresses produces on a large area as shot peening is uniform.
- 2) Standoff distance of 4 cm gives better results. Because lower the standoff distance intensity of peening is more.
- 3) Pressure of 4.5kg/cm² gives good results as compared to 2.5kg/cm², the reason behind this is intensity of pressure is more for 4.5 kg/cm² to produce more compressive stresses. But on contrary with more pressure deep dimples are formed on the surface which can be clearly observed visually. Also there are chances of crack generation which is responsible for fatigue failure. So, it is desirable to keep pressures within limits

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