Investigation on the effect of shot peening process using glass beads in the improvement of fatigue strength of AA 2024-T3

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Abstract

Designing of aerospace and automobile components without failures is an important requirement nowadays. Due to the variable loading conditions in the real time application, the components failure is mainly because of fatigue failure. Useful functional life of any material depends on its strength. Improving fatigue strength of materials will be useful in increasing the life span of components made of that material. Literature survey has revealed that the fatigue life of a component can be considerably improved through the use of shot peening process. In this paper, out of different types of shot peening process, material peening process is preferred. Aluminium alloy 2024-T3 is chosen as the target material and glass beads are selected as shot material. Experiments are conducted based on the combination of parameter values. High cycle fatigue tests are conducted for the prepared specimens with ASTM standard before and after shot peening process. The test results shown a significant improvement in the fatigue strength.

Keywords: AA2024-T3, shot peening, glass beads, fatigue strength.
1. Introduction:

Shot peening is a cold working process which imparts a compressive residual stress layer onto the specimens and alters the microstructure of base material. The bombardment of shots on the specimen using highly compressed air creates a plastic deformation by stretching the top layer of the specimen. This results in enhancement of fatigue, flexural strength and hardness of the base material. Recent works proved that shot peening increases the fatigue strength [1, 2] and hardness by inducing a compressive stress layer in the specimens. This compressive stress layer is induced because of the shot peening intensity during the process. Therefore, fatigue life depends on various factors like relaxation of the stress layer, type of surface modification created by shot peening and the compressive residual field induced [3]. Experimental investigations showed that increase in fatigue life was mainly due to crack arrest during the process. Trends have also grown to concentrate on surface hardening and electroplating techniques because most of the failure occurs due to imperfections in surface. An experiment showed massive improvement in fatigue life of AA7075-T7451 when electroplated and shot peened [4] using ceramic and glass beads. Shot peening effect on aluminide diffusion coating were also studied at different temperature ranges and results showed that activation energy is lower for a peened surface as diffusion through grain boundary is larger in peened surface [5]. Apart from conventional compressed air shot peening developments were made in laser peening, ultrasonic peening and cavitation peening. Effect of laser peening on AA6061-T6 was studied. laser was used for peening and an improvement of 190% in surface compressive stress was observed [6]. Comparative study was done between shot peened and unpenned specimen focusing on the microstructure and strain developed on the surface. Fatigue life and hardness were also enhanced when shot peened using laser source on Ti834 [7] and Ti6Al4V alloys [8].

It was also found that the material used for shot peening also had a great influence on the outcome of results. Wide range of materials like ceramic shots, glass beads are used for peening. Proper selection of peening material will result in surface alloying. A study showed that zinc was surface alloyed with AA2024 at certain peening conditions. These led to enhancement in hardness and anti-corrosion properties of AA2024 material [9]. Efforts are continuously taken to improve the shot peening process each day, alternatively fine particles ranging from 5-100microns in diameter were used for shot peening and named as Fine particle shot peening (FPSP) and fatigue life was one order magnitude higher than peened using normal peening particles [10].It is also found that superior material properties are obtained when severe shot peening was carried out on steel samples. This was due to the result of nanostructured surface layer of material that was formed during the peening process [11].

Almen strip intensity verification, coverage and trajectory of peening are all influencing factors. Therefore, effects of trajectory were also studied and reported [12]. Hence optimization on peening parameters to control the fatigue life were also
carried out for controlled shot peening process [13]. Another study reported the enhancement of surface properties by using an optimization technique known as response surface methodology [14]. Shot peening techniques are now being used as correction techniques apart from enhancing mechanical properties. Shot peening was carried out to restore the specimen to its shape due to buckling while welding. As shot peening also enhances the hardness and modifies surface roughness. Peening was carried out using ultrasonic methods after welding 5A06 Aluminium alloy to restore the buckling effect [15].

Improvements in shot peening technique and its applications prove the necessity to develop the process further. Hence an experimental study using glass beads as shot material on Aluminium 2024-T3 specimens were carried out and effect of shot peening on the fatigue strength of AA 2024-T3 specimens were reported. Shot peening was carried out using compressed air as a source for creating impact and imparting compressive stress layer. Comparison on fatigue strength before and after shot peening was done for better understanding.

2. Experimental Procedure

Out of different types of shot peening process, material shot peening process is preferred. In material shot peening process, the target material is fixed in a position. Following two shot peening process parameters are taken in to account.

1. Distance (D) between the nozzle and target material.
2. Pressure (P) of the shot peening process.

The experimental set-up is shown in Fig. 1. The Shot Material was glass beads made from Soda Lime with a mesh size of 18-350. Diameter Glass beads was within a range of 0.6mm to 0.8mm. A shot peening gun with a nozzle diameter 8mm was used. Based on ASTM E466 standards specimen was prepared using AA2024-T3 material. Specimen dimension is shown in Fig. 2. The chemical composition of AA 2024-T3 is given in Table 1.

![Fig.1 Photograph of shot peening process](image-url)
Fig. 2  Specimen dimension.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peening pressure</td>
<td>0.06 Mpa</td>
</tr>
<tr>
<td>Peening distance</td>
<td>65 mm</td>
</tr>
</tbody>
</table>

Table 1  Chemical composition of AA 2024 T3 (% Wt.)

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Ti</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA2024 T3</td>
<td>0.05</td>
<td>0.5</td>
<td>3.8</td>
<td>0.3</td>
<td>1.2</td>
<td>0.25</td>
<td>0.9</td>
<td>1.8</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Parameter ranges are shown in Table 2. Shot peening process was performed with a peening intensity of 4 mm/A.

3. Fatigue Test Studies

The high cycle fatigue test was carried out by using multi axial fatigue testing machine shown in fig. 4. The test was carried on the specimens before shot peening process and after shot peening process. During the fatigue test, specimen was made to run for $10^7$ cycles or until breakage. The test was started with a lower stress value to higher stress value and the cycles were noted.
4. Results and discussion

The fatigue test was conducted having stress values starting with 20% to 100% of the specimen’s ultimate tensile strength with an increment of 10% for each test. The test results are plotted as S-N curve shown in figure 5 and 6.

![Fig. 4 Fatigue testing machine.](image)

![Fig. 5 S-N curve before shot peening](image)
5. Conclusion

An experimental investigation on fatigue strength of AA2024-T3 specimens were done by using shot peening technique. Compressed air was used as a source for shot peening and glass beads shots were used for peening. Before shot peening the actual specimens, tests were conducted on Almen strips to maintain a constant maximum intensity delivery throughout the process. The Almen arc height was found to be saturated around 130s. Hence this time was taken into account and used for peening. Shot peening was done using various air pressure and nozzle to specimen distance.

The results of fatigue tests revealed that there is a significant improvement in the fatigue strength of the specimen made of AA2024-T3 after shot peened by glass beads. As an average of 17.14 % of increase in the fatigue strength is obtained after shot peening process. The optimum peening parameters will be obtained using Design expert software in future. Best combinations will be identified and optimum value will be selected.

References


