Study the effect of cold working on the mechanical properties of aluminum alloy 2024 T4

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Abstract

This paper studied the effect of cold working process on (AA2024-T4). Shot peening and burnishing processes were utilized in this work. Different times of peening (2, 4, 6, 8, 16, and 24 min) and two parameter of burnishing process (feed rate, spindle speed) were used to analysis the effect of these processes on the mechanical characteristic of aluminum alloy 2024 T4. Fatigue strength, surface hardness and surface roughness were studied. It was observed the shot peening and burnishing process leads to improve fatigue strength of AA2020 T4. The best value of fatigue strength (219 MPa) was obtained in burnishing process at spindle speed (720 rpm) and constant feed rate (0.1). This improvement in fatigue life due to compressive residual stresses introducing on alloy's surface. The highest values of surface hardness and roughness were (394 HVN) and (8.1 μm) that obtained at (24 min) times of shot peening process.

KEYWORDS: fatigue strength, cold working, AA2020 T4, surface roughness, surface hardness

1. Introduction

Aluminum is commonly utilized in wide range of applications because of high strength, light weight, good thermal and electrical conductivity, easy recycling and other beneficial properties [1]. Because of Fatigue failure is one of the most problems in industries parts. Wide studies have been conducted to analysis fatigue behavior of aluminum alloys over the years [2]. Cold working is a very important process of aluminum alloy to improve the fatigue strength. The improvement in fatigue strength is due to strain hardening which increases the yield stress of the material and residual compressive stresses in surface layers [3]. Alalkawi H. J. M, Talal Abed-Aljabar and Safaa H. Alokaidi 2011) [4] carried out the influence of shot peening on mechanical properties of AA2024 T351. It shown that the existence of (SP) improve mechanical properties as well fatigue life up to a limit value of SP and then the static strength decrease when (SP) increase. Adnan N. Abood1 and Ali H. Saleh 2013 ) [5] investigated the influence of peening process on AA2024 T4. Different times of peening were used to analysis the effect of time on fatigue life. The result showed that the fatigue strength improved with increase the time of peening until certain value of time. Kwang Keun Oh1,
Yeon Wook Kim1, and Jae Hoon Kim 2015) [6] investigated the effect of peening on the fatigue behavior of 7075-T6 and Al 2024-T4 aluminum alloys. Shot peening process was carried out at various states for every materials. Results showed that the enhancement fatigue strength of AA 7075 T6 was slight while the enhancement fatigue strength of AA 2024 T4 was highest. Harish D.Shivalingappa, Vishnu.P and Sampath kumaran 2018 )[7] Studied the influence of burnishing process on aluminum alloy 2024 . Ball burnishing on surface of aluminum alloy were conducted in order to improve important properties such as surface hardness and roughness , these improvements are accomplished by inducing residual compressive stresses in the material. Results show significant enhancement in hardness and reduction in surface roughness. M. Mhedhbi, M. Khlif and C. Bradaï 2017) [8] investigated the influence of cold rolling and annealing on microstructural and mechanical characteristic of aluminum alloy. Microstructures, microhardness and tensile tests were analyzed. Results showed the optical micrographs with rising cold rolling reduction rate, the equiaxed grains are elongated along the rolling direction obviously . Nashwa Abdul 2016) [9] analyzed the influence of peening on fatigue characteristic of AA2024 T4 .it was established the fatigue strength enhanced after penning of the surface. This enhancement due to the residual compressive stresses at the surface. Firas M. F. Al Quran2015) [10] Investigated the influence of cold working on surface hardness and roughness of Aluminum Alloy. Surface texture and micro hardness tests were applied to analysis the influence force and feed rates of the burnishing on the roughness and hardness of aluminum alloy. The preferable results were gained at the smallest value of feed and maximum force of burnishing process . M. Mhaede, M. Wollmann and L. Wagner 2008) [11] investigated effect of burnishing process on fatigue and corrosion fatigue of aluminum alloy. The burnishing process used in order to improve the properties of 2024 and 6082 aluminum alloys. Ball burnishing increase the fatigue life at high stress amplitudes. The corrosive environment reduces the fatigue life for Al 2024 T4 and Al 6082 T4. Xin Liu, Jinxiang Liu, Zhengxing Zuo and Huayang Zhang 2019) [12] Investigated the effect of shot peening on fretting of AA7075 T6. The results show that the relaxation of residual stress is take place near the trailing edge of contact area, and the samples with greater peening intensity subjected to greater residual stress relaxation. The residual stress near the contact region rises with the rising of loading cycles because of the fretting wear.

The purpose of this work is to investigate the effect of cold working process especially (shot peening and burnishing ) on the mechanical characteristic of AA2024 T4 .

2. Experimental work

2.1 Material

Material utilized in this work is AA 2024 T4 , is generally characterized from 2XXX series. This alloy is characterized by having good strength, machinability, workability and other important properties [13] .The chemical analysis is given in table (1). The samples was stress relived at 300 °C for 1 hour . The microstructure of AA2024 T4 is explained in Figure 1.

| Element | Si % | Fe % | Cu % | Mn % | Mg % | Cr % | Zn % | Al % |
|---------|------|------|------|------|------|------|------|------|
| 2024 T4 ASTM B209[14] | 0.5  | 0.5  | 3.8-4.9 | 0.3-0.9 | 1.2-1.8 | 0.1  | 0.25 | Bal  |
| 2024 T4 experimental | 0.25 | 0.37 | 4.07 | 0.473 | 0.421 | 0.052 | 0.120 | Bal  |
2.2 Tensile test

Tensile test is utilized to predict the behavior of a material under forms of loading. It is accomplished by determining the force required to elongate a sample to its breaking point. This test was carried out for the samples of aluminum alloy (2024 T4) after finishing stress relieve process of all samples. To get accurate values of tensile test the average of three of tensile test are obtained. The results of mechanical properties of tensile test is given in Table 2.

Table (2). Mechanical properties of AA2024 T4

| Element     | Tensile Strength (M Pa) | Yield Strength (M Pa) | Elongation (%) |
|-------------|-------------------------|-----------------------|----------------|
| 2024-T4     | 469                     | 325                   | 20             |
| 2024-T4 Experimental | 416         | 306                   | 18             |

2.3 Fatigue test

The samples of fatigue tests were manufactured according to DIN (50113) respectively as shown figure 2. Fatigue tests were conducted out by machine type of (HSM20) is the rotating bending type as shown in figure 3. Fatigue test are performed for three groups consist of as received shot peening and burnished samples. These tests are performed at stress ratio (R = -1) and different value of applied stresses depending on the tensile test. The amplitude of the load (P) is determined by Newton (N), applied to a sample for known value of stress (σ) is determined by (M Pa) and gained from the equation below:

\[ \sigma = (32 \times L \times P) / (\pi \times d^3) \]
Where:
P = the force in (N),
L = arm of the force which is equal to (127) mm
d = minimum diameter of sample in (mm).

![Figure 2](image1.png)

**Figure 2.** Fatigue test sample according to DIN (50113)

![Figure 3](image2.png)

**Figure 3.** Device of Fatigue test

2.4 **Shot peening process**

Shot peening (SP) is common cold working process in which small spherical shots or beads with velocities of 20-100 m/s are impacted against the surface of the workpiece [15]. It is used to improve the properties of the surface that subjected to fatigue failure. This improvement is accomplished by introducing residual compressive stresses at the surface. Shot peening process is performed by air-blast machine (Shot tumblast Control Panel). A ball shot of steel with the hardness of (55) HRC (hardness Rockwell C) with diameter (1mm). Figure 4 illustrates the shot peening device. In shot peening process different values of time were used to analysis the effect of time on fatigue resistance (2, 4, 6, 8, 16 and 24 minutes), figure 5 explained the samples after shot peening. Data of peening has been obtained by using ten specimens for every condition.
Figure 4. Shot Peening Device (a) from outside (b) from inside with the samples and shots

Figure 5. Samples of fatigue (a) before shot peening (b) after shot peening

Table (3). S – N curve fatigue data for AA2024 – T4 of shot peening process

| (applied stress) Mpa | Fatigue life of as received | Fatigue life at (2min) | Fatigue life at (4min) | Fatigue life at (6min) | Fatigue life at (8min) | Fatigue life at (16min) | Fatigue life at (24min) |
|---------------------|----------------------------|------------------------|-----------------------|-----------------------|-----------------------|-------------------------|-------------------------|
| 99.47               | 2.6x10^6                   | 2.7x10^6               | 2.9x10^6              | 3.1x10^6              | 3.3x10^6              | 5.9x10^6                | 2.4x10^6                |
| 119.36              | 1.9x10^6                   | 2.1x10^6               | 2.4x10^6              | 2.5x10^6              | 2.7x10^6              | 4.7x10^6                | 1.7x10^6                |
| 129.26              | 1.1x10^6                   | 1.5x10^6               | 1.7x10^6              | 1.9x10^6              | 2.5x10^6              | 3.9x10^6                | 9.8x10^7                |
| 139.28              | 7.5x10^5                   | 9.8x10^5               | 1.2x10^6              | 1.6x10^6              | 2.3x10^6              | 3.1x10^6                | 7.3x10^7                |
Burnishing process was accomplished by using lathe machine and samples are treated with special burnishing tool that applied with lathe machine as showed in figure 6. There are two variables used in this process, feed rate and spindle speed. This process was carried out on sixty samples of fatigue specimens, first group of these samples consist of thirty samples in which spindle speed parameter is constant and feed rate parameter is variable (feed rate values used were (0.04, 0.08, 0.1) mm/rev at (125) rpm constant spindle speed). Second group consist of thirty samples in which feed rate parameter is constant and spindle speed parameter is variable (spindle speed values used were (320, 520, 720) rpm at 0.1mm/rev constant feed rate). Figure 7 show the sample during burnishing process.

| Sample  | 1.7×10^7 | 1.9×10^7 | 2.5×10^7 | 2.9×10^7 | 3.1×10^7 | 4.6×10^7 | 1.6×10^7 | 1.1×10^8 | 2.5×10^8 | 8.9×10^7 | 4.0990 | 41925 | 42992 | 4.4×10^8 | 4.6×10^8 | 5.7×10^8 | 40121 |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 149.154 | 3.5×10^3 | 3.7×10^3 | 4.1×10^3 | 1.4×10^6 | 1.6×10^6 | 2.4×10^6 | 3.3×10^6 | 9.9×10^3 | 2.7×10^3 | |
| 159.102 | 2.9×10^3 | 3.4×10^3 | 3.8×10^3 | 4.3×10^7 | 4.5×10^7 | 9.9×10^7 | 2.7×10^7 | |
| 169.04  | 2.3×10^5 | 2.8×10^5 | 3.1×10^5 | 3.5×10^7 | 3.7×10^7 | 5.6×10^7 | 2.1×10^7 | |
| 179.32  | 1.7×10^5 | 1.9×10^5 | 2.5×10^5 | 2.9×10^7 | 3.1×10^7 | 4.6×10^7 | 1.6×10^7 | |
| 189.94  | 9.1×10^4 | 9.3×10^4 | 9.6×10^4 | 9.9×10^4 | 1.1×10^5 | 2.5×10^5 | 8.9×10^4 | |
| 198.91  | 40990   | 41925   | 42992   | 4.4×10^8 | 4.6×10^8 | 5.7×10^8 | 40121   | |

Figure 6. Roller burnishing tool
Figure 7. Show the sample during making burnishing process

Table 4. S – N curve fatigue data for AA2024 – T4 of burnishing process

| Applied stress Mpa | Fatigue life of as received | Fatigue life at 0.04mm/rev feed rate and 125rpm | Fatigue life at 0.08mm/rev feed rate and 125rpm | Fatigue life at 0.1mm/rev feed rate and 125rpm | Fatigue life at 0.1mm/rev feed rate and 320rpm | Fatigue life at 0.1mm/rev feed rate and 520rpm | Fatigue life at 0.1mm/rev feed rate and 720 rpm |
|--------------------|-----------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| 99.47              | 2.6×10⁶                     | 3.2×10⁶                                      | 3.5×10⁶                                      | 5.6×10⁶                                      | 4.5×10⁶                                      | 4.7×10⁶                                      | 1×10⁷                                        |
| 119.36             | 1.9×10⁶                     | 2.7×10⁶                                      | 2.9×10⁶                                      | 3.6×10⁶                                      | 3.9×10⁶                                      | 4.3×10⁶                                      | 7.1×10⁶                                      |
| 129.26             | 1.1×10⁶                     | 1.6×10⁶                                      | 1.9×10⁶                                      | 2.2×10⁶                                      | 2.7×10⁶                                      | 3.9×10⁶                                      | 6.4×10⁶                                      |
| 139.28             | 7.5×10⁶                     | 9.1×10⁷                                      | 1.2×10⁷                                      | 1.7×10⁷                                      | 1.9×10⁷                                      | 3.1×10⁷                                      | 5.1×10⁶                                      |
| 149.15             | 3.5×10⁷                     | 8.5×10⁷                                      | 9.9×10⁷                                      | 1.5×10⁸                                      | 1.6×10⁶                                      | 2.5×10⁶                                      | 4.2×10⁶                                      |
| 159.10             | 2.9×10⁷                     | 6.7×10⁷                                      | 7.7×10⁷                                      | 1.2×10⁸                                      | 1.3×10⁶                                      | 1.6×10⁶                                      | 3.1×10⁷                                      |
| 169.04             | 2.3×10⁷                     | 5.1×10⁸                                      | 5.9×10⁷                                      | 9.9×10⁸                                      | 9.1×10⁸                                      | 9.5×10⁸                                      | 2.5×10⁸                                      |
| 179.32             | 1.7×10⁷                     | 3.6×10⁷                                      | 3.9×10⁷                                      | 5.1×10⁸                                      | 6.3×10⁷                                      | 7.2×10⁷                                      | 8.1×10⁷                                      |
| 189.94             | 8.3×10⁷                     | 9.1×10⁷                                      | 1.1×10⁸                                      | 1.3×10⁹                                      | 1.5×10⁷                                      | 1.7×10⁷                                      | 1.9×10⁷                                      |
| 198.91             | 40990                       | 4.5×10⁹                                      | 4.9×10⁹                                      | 6.1×10⁴                                      | 6.5×10⁴                                      | 6.9×10⁴                                      | 7.1×10⁴                                      |
2.6 Micro hardness test

Micro hardness is accomplished to analysis the influence of cold working on surface hardness of the workpiece. Vickers hardness test is used in this test, it composed of indentation the test sample with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between obverse faces exposed to a load of 1 to 100 kgf. The load is applied for 10 seconds. This test is carried out by using (INNOVA test) as shown in the figure 8. To get accurate values of microhardness test the average of ten readings are obtained for each condition.

![Microhardness test](image)

Figure 8. Microhardness test (a) (INNOVA test) (b) The depth of indentation

| Cases | Treatment | Surface hardness average (HVN) |
|-------|-----------|--------------------------------|
| A     | With out treatment | 122.12                          |
| B     | Shot peening for (2 min.) | 130                             |
| C     | Shot peening for (4 min.) | 139                             |
| D     | Shot peening for (6 min.) | 145                             |
| E     | Shot peening for (8 min.) | 159                             |
| F     | Shot peening for (16 min.) | 283                             |
| G     | Shot peening for (24 min.) | 394                             |
| H     | Burnishing (spindle speed 125rpm, feed rate 0.04mm/rev) | 148                             |
| I     | Burnishing (spindle speed 125rpm, feed rate 0.08mm/rev) | 158                             |

Table (5). The values of hardness test for samples of (AA 2024T 4)
2.7 Surface roughness

The surface roughness measurements are important to predict fatigue life of the test material. The surface roughness test is accomplished by device namely (Pocket surf Mahr) as shown in the figure 9. To obtain accurate values of surface roughness the average of ten readings are obtained for each condition of as received and shot peening. Table show the values of surface roughness.

| Cases | Treatment                     | Surface roughness average (μm) |
|-------|-------------------------------|--------------------------------|
| A     | Without treatment             | 0.8                            |
| B     | Shot peening for (2 min.)     | 1.1                            |
| C     | Shot peening for (4 min.)     | 2.3                            |
| D     | Shot peening for (6 min.)     | 2.9                            |
| E     | Shot peening for (8 min.)     | 5.5                            |
| F     | Shot peening for (16 min.)    | 6.9                            |
| G     | Shot peening for (24 min.)    | 8.1                            |
|   | Burnishing (spindle speed 125rpm, feed rate 0.04mm/rev) | 0.19 |
|---|------------------------------------------------------|------|
| I | Burnishing (spindle speed 125rpm, feed rate 0.08mm/rev) | 0.17 |
| J | Burnishing (spindle speed 125rpm, feed rate 0.1mm/rev) | 0.152 |
| K | Burnishing (spindle speed 320rpm, feed rate 0.1mm/rev) | 0.141 |
| L | Burnishing (spindle speed 520rpm, feed rate 0.1mm/rev) | 0.131 |
| M | Burnishing (spindle speed 720rpm, feed rate 0.1mm/rev) | 0.120 |

3. Results

3.1 Fatigue test

In shot peening process fatigue strength increase with increase time of shot peening until reach certain value of time of shot peening times (16 minutes) after this value the fatigue strength was decrease. This improvement in fatigue life because of compressive residual stress that introducing on the component's surface which lead to increase tensile and yield strength. This residual stresses leads to deny initiation and propagation of cracks [16]. The reason for decrease in fatigue strength after 16 min, the shot peening after (16 min) will have double effect, residual stresses and strain hardening as a result of increase the density of dislocation. In burnishing process, it was found in first group of samples that treated with constant spindle speed and variable feed rate the fatigue strength increase with increase feed rate at constant speed, this increasing in fatigue strength due to producing residual compressive stresses and strain hardening by achieving plastic deformation on surface layer of the samples during burnishing process. In the second group of burnished samples that treated with variable spindle speed and constant feed rate, the fatigue life enhance with increase the spindle speed and highest value of fatigue strength is obtained in this case, it was (219 MPa) at (0.1 feed rate and 720rpm spindle speed). This enhancement in fatigue strength is due to plastic deformation caused by burnishing process which compressing the grains at the surface layers of the sample. Figure 10 illustrated S-N curve for as received shot peened and burnished samples.
3.2 Hardness tests

The results show that surface hardness improved for the samples generally treated with shot peening. This improvement in surface hardness of sample due to residual compressive stresses, which increased the density of dislocations and led to increase the alloy surface hardness. The highest value of surface hardness was (394.5 HVN) for samples treated with (24 minutes) time of peening as explained in the figure 11.

Figure 11 . Effect time of shot peening on surface hardness

Figure 12 explained the effect of feed rate of burnishing process on surface hardness. The surface hardness increased with increase feed rate values, this is because of work hardened by plastic deformation and residual compressive stresses. These stresses are most important in burnished material due to their direct influences on performance of service. This will produce smooth and harden the surface, creating a finish which will last longer life than material that
hasn’t been burnished [17]. The highest value of the surface hardness (179) HVN was obtained at feed rate value (0.1) mm/rev and constant spindle speed (125) rpm.

Figure 12. Effect of feed rate on surface hardness

Figure 13. explained the influence of feed rate of burnishing process on surface hardness. The surface hardness increased with increase spindle values. This enhancement because of the plastic deformation produce by burnishing process which cause displacement of the work piece in the peaks which cold flows under pressure into the valleys [17]. The highest value of the surface hardness (210) HVN was obtained at spindle speed (720) rpm and constant feed rate value (0.1) mm/rev.

Figure 13. Effect of spindle speed on surface hardness
3.3 roughness tests

It was found the shot peening have very strong and significant effect of on surface roughness. specimens' roughness increase with increasing time of shot peening. This increasing in surface roughness because of valleys and peaks that produce on metal's surface with increasing the temperature of the surface. The temperature of the surface increase when time of shots incident increase and this will be lead to losses fineness of the surface. The highest value of surface roughness was (8.1) μm for samples treated with (24 minutes) time of peening as explained in the figure 14.

![Figure 14. Effect time of shot peening on surface hardness](image)

Figure 14. Effect time of shot peening on surface hardness

Figure 15 showed the influence of feed rate on the surface roughness of the samples. Surface roughness decreased with increase of feed rate values. This enhancement in surface roughness due to plastic deformation which results in smoother surface of the sample where the peaks of the material gains plastic deformation and fill in the valleys. The lowest value of the surface roughness (0.152) μm was obtained at feed rate (1) mm/rev and constant spindle speed (370) rpm.
Figure 15. Effect of feed rate on surface roughness

Figure 16. showed the effect of spindle on the surface roughness of the samples, surface roughness decreased with increase spindle speed. This improvement in surface roughness is due to plastic deformation that form near surface is displaced from peaks to fill the valleys which causing smoother surface. The highest value of the surface roughness (0.120) μm was obtained at spindle speed 700 rpm and at constant feed rate (1) mm/rev.

Figure 16. Effect of spindle on surface roughness
4. Conclusion

1- The fatigue strength of (AA2024-T4) is enhanced by cold working process especially (shot peening and burnishing). This enhancement because of compressive residual stresses at the introduce on the surface

2- The favourite value of fatigue strength was obtained at 720rpm spindle and constant feed rate (0.1).

3- The highest value of surface roughness was obtained at (24mint) times of shot peening and the lowest value was achieved in burnishing process at (720 rpm) and constant feed rate (0.1).

4- The highest value of surface hardness was obtained at (24mint) times of shot peening and the lowest value was achieved in burnishing process at (720 rpm) and constant feed rate (0.1)

4- the enhancement in the surface roughness and hardness due to compressive residual stresses and strain hardening that form in the surface during cold working process.

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References

[1] Ö. KARAKAŞ1 and J. SZUSTA .(2015) . Monotonic and low cycle fatigue behavior of 2024-T3 aluminum alloy between room temperature and 300 °C for designing VAWT components ”. Fatigue and fracture of engineering materials and structures , vol.39, p. 95–109.

[2] Tianwen Zhao, Yanyao Jiang (2008) . Fatigue of 7075-T651 aluminum alloy . International Journal of Fatigue, vol. 30 .p p 834–849.

[3] G. H. Fa.nuHr, J. L. Lrnnu and D. Counqr (1995) . Effect of shot peening on residual stress and fatigue life of a spring steel ”. Fatigue and Fracture of Engineering Materials and Structures ., Vol. 18, pp.211 220.

[4] Alalkawi H. J. M, Talal Abed-Aljabar and Safaa H. Alokaidi, (2011) . Analysis the Effects of Shot Peening Upon the Mechanical and Fatigue Properties of 2024-T351 Al-Alloy, journal of engineering and technology , vol 30.

[5] Adnan N. Abood1, Ali H. Saleh2, Raid K. Salem1, Ghaith A. Kadhimi1 and Zainab W. Abdullah (2013) . Strain Life of Shot Peening AA 2024-T4 “. Journal of Materials Science Research, Vol. 2.

[6] Kwang Keun Oh1, Yeon Wook Kim1, and Jae Hoon (2015) , High cycle Fatigue characteristics of aluminum alloy by shot peening”. journal of Advanced Materials Research , Vol. 1110, pp 142-147.

[7] Harish, D.Shivalingappa, Vishnu.P and Sampath kumaran (2018), Impact of Ball burnishing process parameters on surface Integrity of an Aluminum 2024 Alloy ” Materials Science and Engineering , vol.376.

[8] M. Mhedhbi, M. Khlif and C. Bradaï (2017) , Investigations of microstructural and mechanical properties evolution of AA1050 alloy sheets deformed by cold-rolling process and heat treatment annealing ” Journal of Materials and Environmental Sciences , Vol. 8, p.p 2967-2974.

[9] Hussain J. M. Alalkawi Rawaa ,Hamid Al- Kalali and Shatha M.R. Abdul Jabbar (2016) , Investigation of fatigue behavior using surface shot peened technique for 2024 – T4 Al-alloy, The Iraqi Journal For Mechanical And Material Engineering, Vol.16.

[10] Firas M. F. Al Quran (2015), The Effect of Roller Burnishing on Surface Hardness and Roughness of Aluminum Alloy ” International Journal of Mechanics and Applications , Jordan.

[11] M. Mhaede, M. Wollmann and L. Wagner (2008 ), Influence of ball-BURNISHING burnishing fatigue of Al 2024 AND Al 6082 ”, Conf Proc: ICSP-10 Tokyo, Japan.

[12] Xin Liu, Jinxiang Liu, Zhengxing Zuo and Huayang Zhang (2019) ,Numerical study on residual stress redistribution of shot-peened aluminum 7075-T6 under fretting loading " International Journal of Mechanical Sciences vol.160 ,pp156–164 .

[13] YASHPAL , C.S. JAWALKAR and SUMAN KANT (2015 ) . A review on use of aluminum alloys in aircraft Components . Journal on Material Science, Vol. 3.

[14] Annual Book of ASTM Standards (2009), Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate”, American Society for Testing and Material, Vol. 02.02, pp298 .

[15] Uroš Zupanc1, Janez Grum (2011) , Surface Integrity of Shot Peened Aluminum Alloy 7075-T651 ” Journal of Mechanical Engineering volum.57, P.P379-384.

[16] Arken J. Lu, J. Flavenot (1990) , Effect of Glass Beads Nature on the behavior of shot peered " 4th internal conference ob shot peening (ICSP-4), Japan.
[17] Anvesh, Sagar Hegde, Pavana Kumara and Shreyas M Shetty (2018), "Analysis on effect of ball burnishing processes on aluminum 6061" Volume 4, international journal of advance research ideas and innovation in technology.