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Experimental Studies the Effect of Flap Peening Process on Aluminum Alloys

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Abstract

The effects of flap peening on surface characteristics of aluminum alloy (7075-T6) is used in a wide range in airframes and structured; it has high ability for corrosion, since the corrosion resistance for this type of metal is relatively small. Flap peening is a process applied to add residual compression stresses in metallic surfaces with the intent of improving the material when exposed to corrosion due to stress and fatigue. Some studies about the effect of the flap peening process, on the fatigue resistance, bending fatigue behavior and residual surface stress in the aluminum alloys, have been performed. However, the effect of the flap peening process parameters on the corrosion and oxidation resistance of the aluminum alloys is not well known. In the present study, the influence of flap peening treatment on hardness and corrosion behavior of aluminum alloy (7075-T6) is investigated, compared with sand blasting process. In addition, the effect of the flap peening process parameters on the corrosion and oxidation resistance of the aluminum alloys is investigated. The obtained results show that the aluminum alloy (7075-T6) samples, treated with flap peening, presented a significant modification on the surface morphology, as seen by Scanning Electron Microscopy (SEM) photos. According to the hardness measurement results, the shot peening treatment increases the surface hardness and an important decrease of oxidation and corrosion resistance was noted, evidencing that the flap peening process compromises the chemical and physical properties of the surface.

Keywords: ...

1. Introduction

Aircraft manufacturers have implemented many key design improvements over the past 30 years, ranging from the use of more corrosion-resistant materials, to improved adhesive bonding processes, to the use of sealants in fastener holes and on faying surfaces, to the control of spillage of galley and lavatory fluids as a result the design service life of new generation aircraft was moved from 20 to 40 years [1]. Despite of these improvement, aluminum alloys 7075-T6 and 2024-T3 which are corrosion- and stress corrosion cracking-prone alloys; but they are still widely used in aircraft industry [1, 2].

Flap peening, also known as "flapper peening" or "roto peening", employs 1 mm tungsten carbide balls bonded to a flexible polymeric flap. As seen in Figure (1), flap peening is a cold working process in which the surface of a part is bombarded with small spherical media called shot. Each piece of shot striking the material acts as a tiny peening hammer, imparting to the surface a small indentation or dimple. [3-6] In order for the dimple to be created, the surface fibers of the material must be yielded in tension. Below the surface, the fibers try to restore the surface to its original shape, thereby producing below the dimple, a hemisphere of cold-worked material highly stressed in compression. Overlapping dimples develop an even layer of metal in residual compressive stress.

Maximum compressive residual stress, produced at or under the surface of a part by flap peening, is at least as great as half the yield strength of the material being peened. Many materials will also increase in surface hardness due to the cold working effect of flap peening [5, 12].

Benefits obtained by flap peening are the result of the effect of the compressive stress and the cold working induced. Compressive stresses are beneficial in increasing resistance to fatigue failures, corrosion fatigue, stress by corrosion cracking, hydrogen assisted cracking, fretting, galling and erosion caused by cavitations. Benefits obtained due to cold working include work hardening, inter granular corrosion resistance, surface texturing, closing of porosity and testing the bond of coatings. Both compressive stresses and cold-worked effects are used in the application of flap peening in forming metal parts.

The effectiveness of peening depends in large measure on the flap peening intensity. The latter is a function of numerous variables, including work piece material, flap material, flap size, type of flap peening machine, and time of peening. Sizes and types of flap, to be selected for a certain peening application, depend on the material to be peened, desired peening intensity, fillet size, hole size, etc., for most peening applications. [4, 8, 9, 10, 11, 12]

On the other hand, sand blasting is the use of sand material to clean or textures a material, such as metal or masonry. Sand is the most widely used for blasting. Metal is sand blasted to remove corrosion and sharp edges or as away to enhance adhesion of coatings and adhesives. The sand material used in the process is aluminum oxide (alumina Al2O3) with a diameter of 250 µm, the air pressure used in the process is 4 bar, sand hardness is 1440kg/mm².

In the present work, we apply flap peening and sand blasting procedures on selected work specimens to study their effects on the material properties on rising the mechanical properties of the material, i.e., hardness, microstructure and investigate if the sand blasting process can compensate flap peening process since it is less expensive. Also, we study the effects of the rotational speed and the flap standoff distance for flap peening on the material properties, mainly hardness and microstructure.

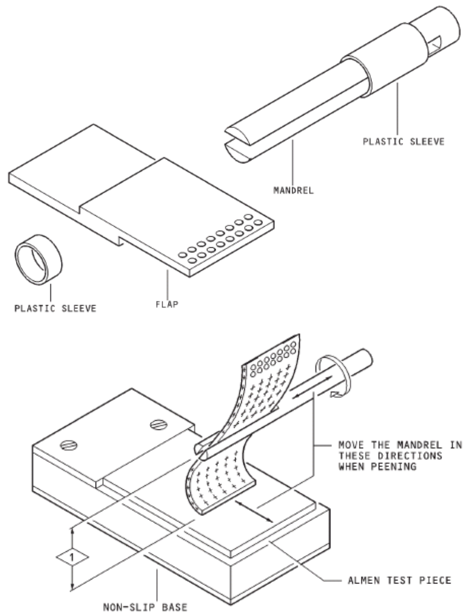


Figure 1. Flap peening process's main parts

Experiment

Specimens

The specimens selected for the present study are from aluminum alloy type (7075-T6) because this type of alloy is used in a wide range in airframes and it has a high ability for corrosion, since the corrosion resistance for this type of metal is relatively small.

Two groups of specimens were selected in the present work; the first group was for the comparison between flap peening procedure and sand blasting procedure; the second group, however, was selected to study flap peening process's main parameters, namely the effects of the rotational speed and the flap standoff distance on the material properties.

Group no. 1

18 specimens were prepared for this group; these specimens were taken from **AIRBUS (A340-200/-300)** aircraft from forward passenger cabin compartment (upper floor panel structure).

The thickness of the specimens was 2mm, as shown in Figure (17). Three types of these specimens were selected for this process: Type (A) new parts, Type (B) used parts and Type (C) badly corroded parts.

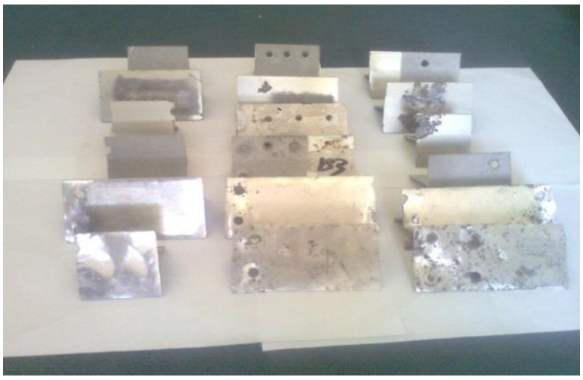


Figure 2. Specimens of the first group

Tables (1), (2) and (3) show the preparation work done on these three types of specimens. The specimens were tested before and after work for hardness and microstructure. A grinding process is used to remove the primer and corrosion off the specimens using the corrosion disk. The flap peening process is done on this specimens group using the small flap and with a specified rotational speed and standoff distance which is recommended by the manufacturer (12.5 mm). Also, a paint remover is used to remove the paint and primer from the surface of the metal without making any effects on the metal; this material does not remove the corrosion on the metal.

Table 1: Specimens type A (new parts)

No	Type of work done on the specimens
A1	Grinding using the corrosion disk
A2	Grinding + flap peening
A3	Sand blasting
A4	Removing primer using paint remover
A5	Removing primer + flap peening
A6	Removing primer + Sand blasting

Table 2: Specimens type B (used parts)

No	Type of work done on the specimens
B1	Grinding using the corrosion disk
B2	Grinding + flap peening
B3	Sand blasting
B4	Removing primer using paint remover
B5	Removing primer + flap peening
B6	Removing primer + Sand blasting

Table 3: Specimens type C (badly corroded parts)

No	Type of work done on the specimens
C1	Grinding using the corrosion disk
C2	Grinding + flap peening
C3	Sand blasting
C4	Removing primer using paint remover
C5	Removing primer + flap peening
C6	Removing primer + Sand blasting

Group no. 2

16 new sheets specimens (3x5 cm and 2 mm thickness) were prepared for this group, as seen in Figure (3). The large flap was used on this group and with 4 speeds and 4 standoff distances worked out on this group. Table (4) shows the values of these parameters. To ensure that the standoff distances are steady throughout the work, stands between the mandrel and the specimens were used. The specimens were tested for hardness and microstructure.

Table 4. Samples values of the parameters

Specimen no	Rotational speed (rpm)	Flap standoff distance mm
F1	3000	14
F2	3000	12
F3	3000	10
F4	3000	8
F5	6000	14
F6	6000	12
F7	6000	10
F8	6000	8
F9	9000	14
F10	9000	12
F11	9000	10
F12	9000	8
F13	12000	14
F14	12000	12
F15	12000	10
F16	12000	8

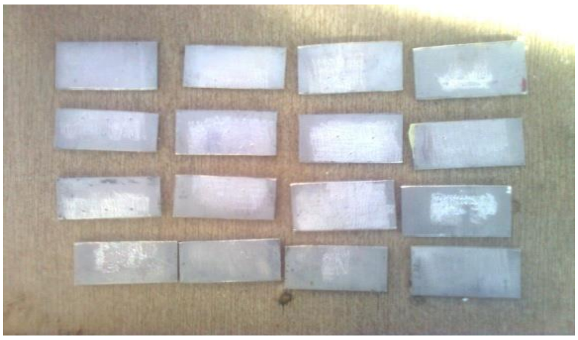


Figure 3. Specimens of the second group

Hardness Test

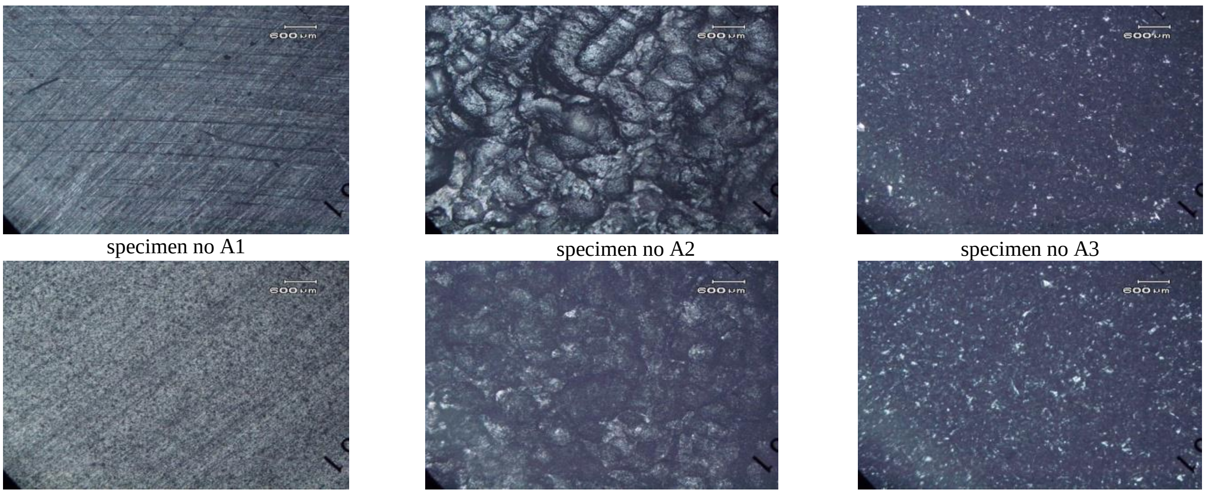
Hardness test was carried out on the two groups of specimens to see the effect of these parameters on the metal hardness. Rockwell (C) hardness test was used due to the thickness of the specimens. 3 different places were tested for the hardness, and the average of these values were calculated. Table (5) shows the hardness values of the first group specimens. Table (6) shows the minimum and maximum values of the two variables and the specimen hardness of the second group.

Table 5. Hardness values in (HRC) of the first group specimens

Specimen no	Hardness test (1)	Hardnes s test (2)	Hardnes s test (3)	Average Hardness
A1	18	18.5	17.5	18
A2	21	20.5	22	21.16
A3	15	16	15.5	15.5
A4	23.5	25	30	26.16
A5	17.5	19	18.5	18.33
A6	14	17	17.5	16.16
B1	19	20	19.5	19.5
B2	20.5	21.5	23	21.66
B3	14	16	17	15.66
B4	15.5	15	17	15.83
B5	20	21.5	22	21.16
B6	18	17	17.5	17.5
C1	15	16	16	15.66
C2	17	16.5	18	17.16
C3	13	12.5	13	12.83
C4	17	14.5	18	16.5
C5	21.5	16.5	20	19.33
C6	11.5	14	10.5	12

Microstructure Test

Microstructure test was carried out on the two groups of specimens to see the effect of these parameters on the metal surface. Figures (4) through (6) show the SEM pictures of the first group specimens. Figures (7) through (1)0 show the images of the second group.

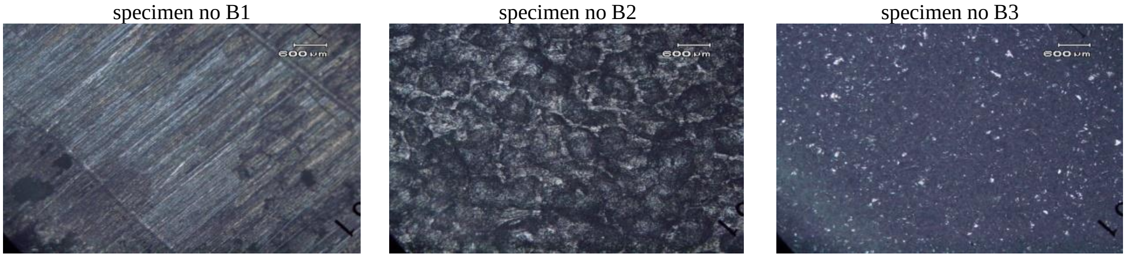


specimen no A1 specimen no A2 specimen no A3

specimen no A4 specimen no A5 specimen no A6

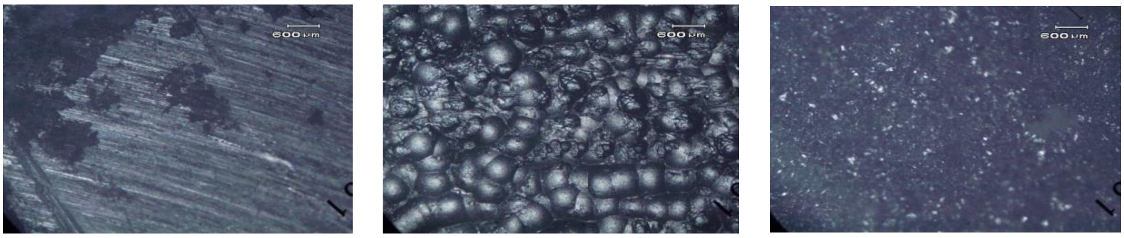
Figure 4: Scanning electron microscope images of different samples in group A

specimen no B1 specimen no B2 specimen no B3

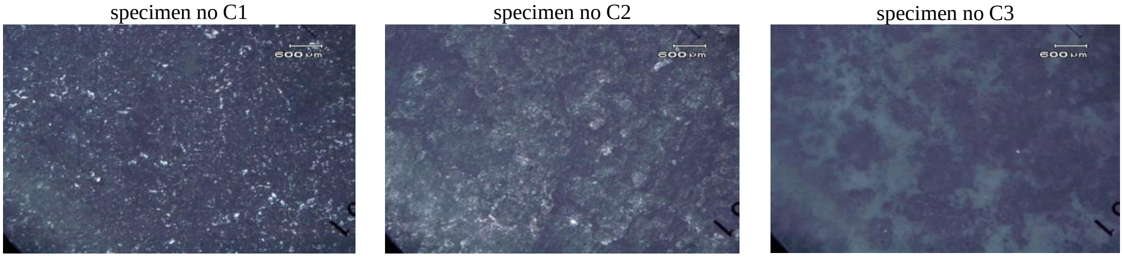


specimen no B4 specimen no B5 specimen no B6

Figure 5. Scanning electron microscope images of different samples in group B

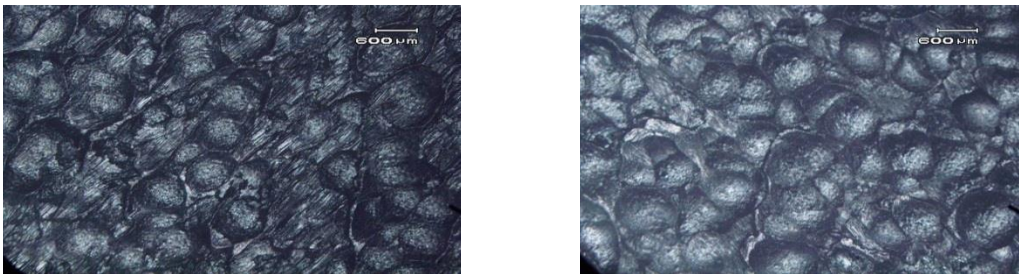


specimen no C1 specimen no C2 specimen no C3

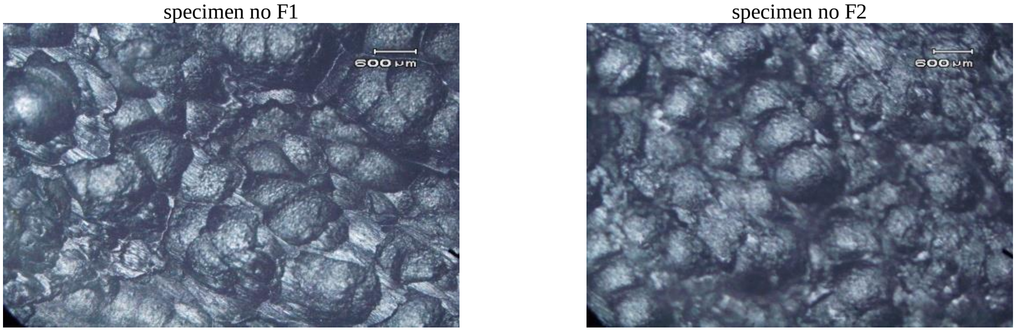


specimen no C6 specimen no C5 specimen no C4

Figure 6. Scanning electron microscope images of different samples in group C



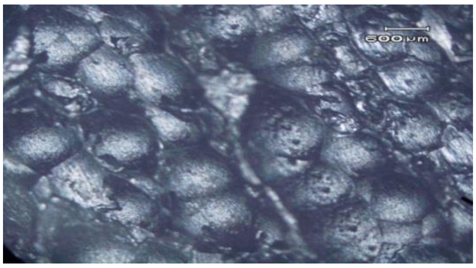
specimen no F1 specimen no F2

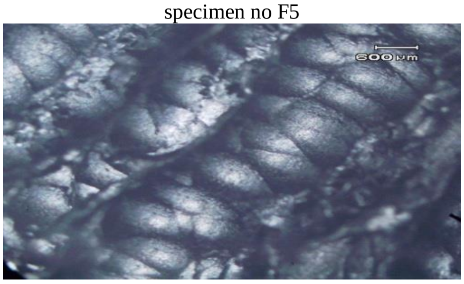


specimen no F3 specimen no F4

Figure 7. SEM images of different samples With Rotational speed 3000 rpm


specimen no F5


specimen no F6


specimen no F7

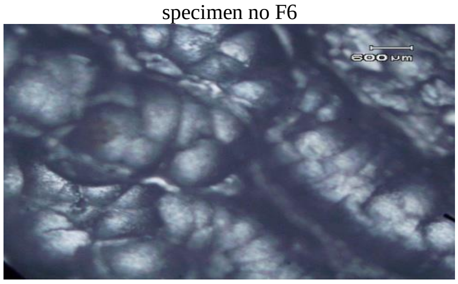
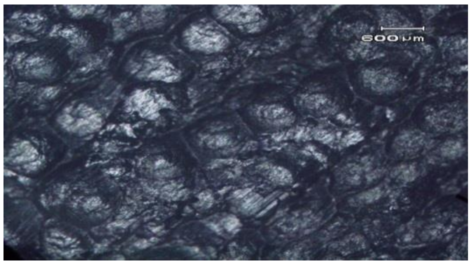

specimen no F8

Figure 8. SEM images of different samples With Rotational speed 6000 rpm


specimen no F9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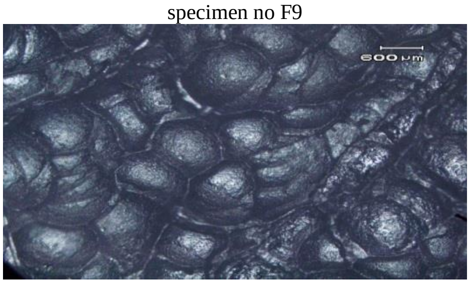

specimen no F11

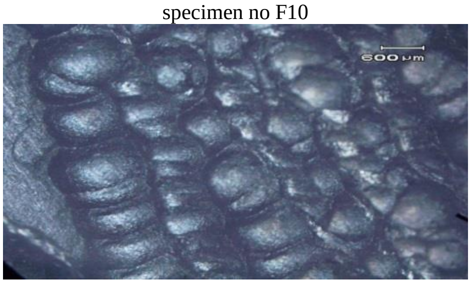
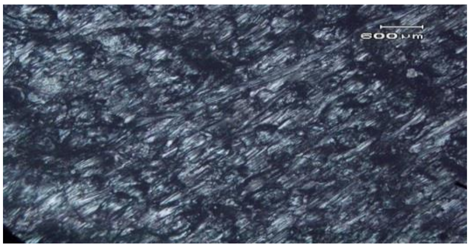
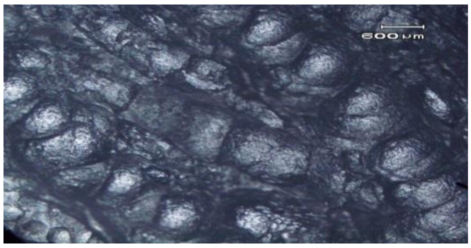
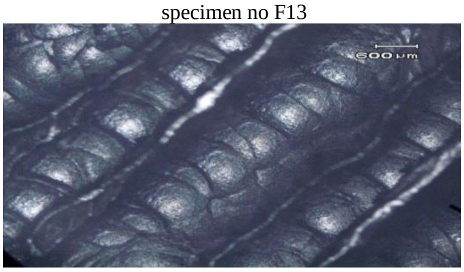

specimen no F12

Figure 9. SEM images of different samples With Rotational speed 9000 rpm


specimen no F13


specimen no F14


specimen no F15

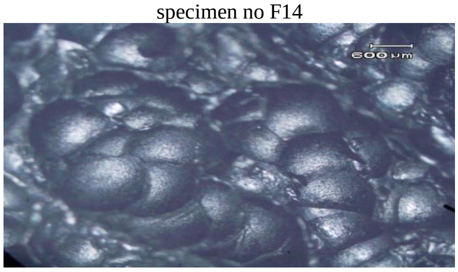

specimen no F16

Figure 10. SEM images of different samples With Rotational speed 12000 rpm

Results and Discussion

Group no. 1

(A) Microstructure Test

Refer to Figures (4) to (6) for the microstructure test. Comparing between specimen (A1), which reveals the surface of the specimen after the grinding process, and specimen (A4), which reveals the surface of the specimen after removing the primer using the paint remover, shows that the paint remover does not remove the anodized layer on the surface of the specimen (A4). So, the grinding process is used to remove the anodized layer. Same results can be noted between samples (C1) and (C4).

Specimens (A1), (B1) and (C1) were grinded while specimens (A2), (B2) and (C2) were flap peening; the overlapping dimples that develop the compressive stresses, induced by flap peening, were noted, which in turn provides a considerable increase in parts fatigue life.

Comparing the intensity of specimens (A2), (B2) and (C2) surface, after the flap peening process, it is noticed that specimen (C2) has a bigger intensity and specimen (A2) the smallest; this shows that specimen (C2) has accepted the biggest intensity of compressive stresses because it has the lowest hardness among the other two, which means that the peening time under a specified speed and standoff distance is constant.

Specimens (A5), (B5) and (C5) show the surface after the flap peening process (without the grinding process), the flap peening process cannot remove the anodized layer or corrosion from the surface of the metal.

Comparing specimens (A4), (B4) and (C4), which reveal the anodized layer and corrosion on the surface of the specimen after removing the primer using the paint remover, with specimens (A3), (A6), (B3), (B6), (C3), and (C6), which show the surface of the specimens after the sand blasting process, we can see that the sand blasting process can remove the anodized layer and corrosion from the surface of the metal; it also shows that the abrasive particles or the sand penetrates the surface of the metal, which, in turn, causes a decrease in the parts hardness, which, in turn, decreases the fatigue life of the parts.

(B) Hardness Test

Table (5) shows the hardness values in (HRC) of the first group specimens. The average hardness of the specimens before the work is (18 HRC) for type (A), (19.5 HRC) for type (B) and (15.66 HRC) for type (C). Therefore, the hardness of specimens type (B) is more than that of specimens type (A) because they are used parts so they have been work hardened due to operation. For specimens type (C), however, their average hardness was reduced to a value less than that off specimens type (A) because of the high fatigues and stress corrosions on them. This shows, however, that the selection of the specimens was good. Figure (11) shows the increasing and decreasing on the average hardness for the three types of specimens before the work.

After the flap peening procedure was done on specimens number (A2), (B2) and (C2), the values of their average hardness were (21.16 HRC), (21.66 HRC) and (17.16 HRC), respectively. This means that the hardness of the specimens increases after flap peening, and this, in turn, causes the fatigue life of the specimens to increase. Figure (12) shows the increase on the average hardness for the three types of specimens.

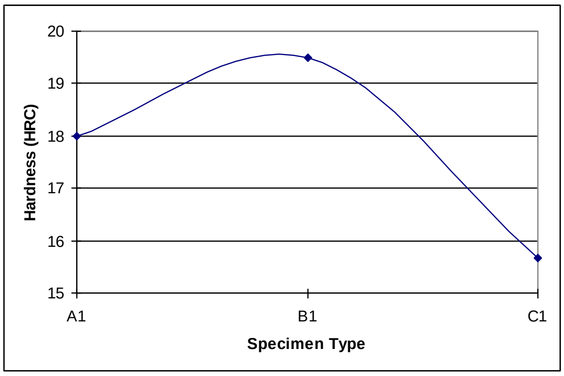


Figure 11. Average hardness for the three types of specimens before test

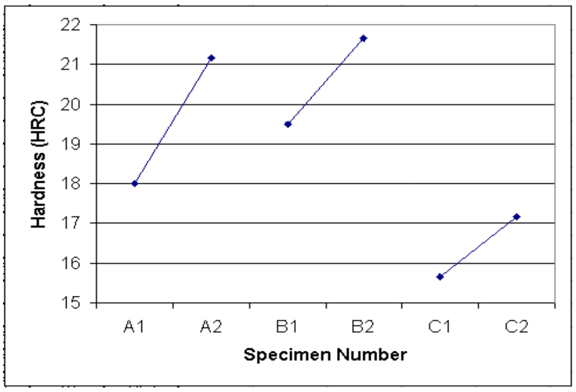


Figure 12. Average hardness for the three types of specimens

After the sand blasting procedure was done on specimens number (A3), (B3) and (C3), the values of the average hardness on them were (15.5 HRC), (15.66 HRC) and (12.83 HRC), respectively. This means that the hardness of the specimens decreases after sand blasting, and this, in turn, causes the fatigue life of the specimens to decrease. Figure (13) shows the decrease on the average hardness for the three types of specimens.

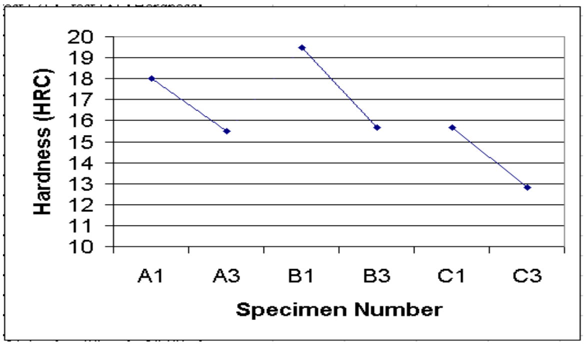


Figure 13. Average hardness for the three types of specimens

Group no. 2

(A) Hardness Test

Two plots are introduced for the mandrel speed (rpm), the flap standoff distance and the hardness, as a result of using such values for the two variables. The average hardness of each specimen, before the flap peening test, was 18 HRC. Table (6) shows the hardness values before and after the flap peening. The maximum hardness of 13 HRC was at speed of 12000 rpm and a flap standoff distance of 8 mm. The minimum hardness of 2 HRC was at speed of 3000 rpm and a flap standoff distance of 14 mm.

Figures (14) and (15) are a plot for the flap peening test with the two variables and the average hardness.

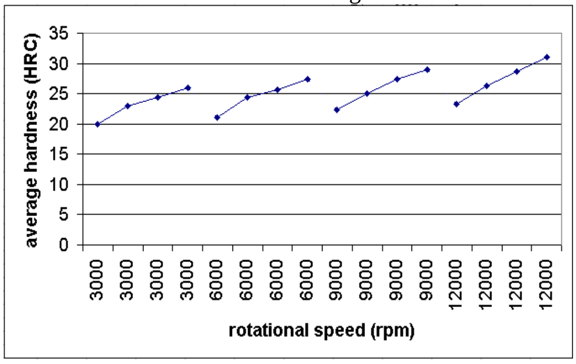


Figure 14. Flap peening test with the rotational speed variables and the average hardness

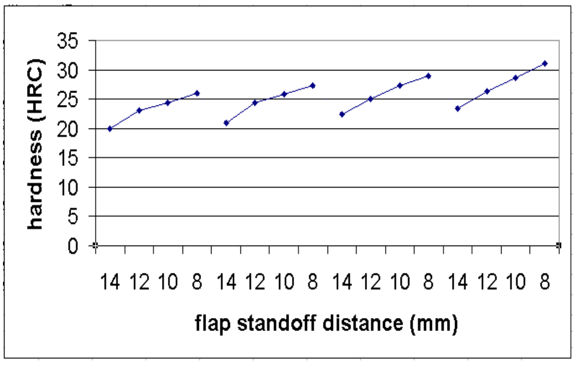


Figure 15. Flap peening test with the flap stand off distance and the average hardness

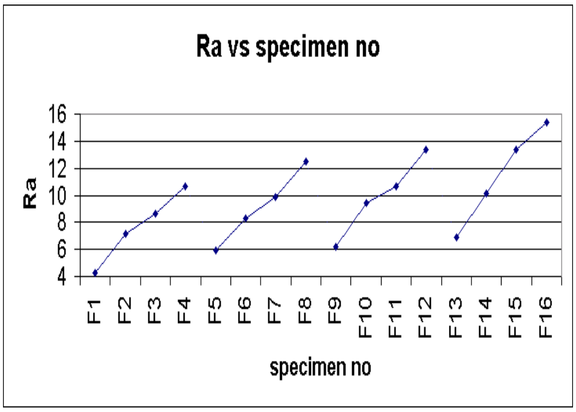


Figure 16. Surface roughness for flap peening test samples

Table 6. Samples with hardness before and after the flap peening

Specimen no	Rotational speed (rpm)	Flap standoff distance mm	Hardness test (1)	Hardness test (2)	Hardness test (3)	average Hardness (HRC)	difference in hardness (HRC)	Ra (µm)
F1	3000	14	20	19.5	20.5	20	2	4.3
F2	3000	12	22	23.5	23.5	23	5	7.13
F3	3000	10	25	24	24	24.33	6.33	8.62
F4	3000	8	27	24	27	26	8	10.68
F5	6000	14	20	22	21	21	3	5.93
F6	6000	12	23	25	25	24.33	6.33	8.26
F7	6000	10	23	27	25	25	7	9.84
F8	6000	8	28	27	27	27.33	9.33	12.51
F9	9000	14	24	20	23	22.33	4.33	6.22
F10	9000	12	24.5	25.5	25	25	7	9.43
F11	9000	10	26	25	29	27.33	9.33	10.64
F12	9000	8	30	29.5	27.5	29	11	13.39
F13	12000	14	22	25	23	23.33	5.33	6.93
F14	12000	12	26	27	26	26.33	8.33	10.13
F15	12000	10	27	28	31	28.66	10.66	13.35
F16	12000	8	32	30	31	31	13	15.41

(B) Microstructure Test

Figures (7) to (10) show the differences in intensity between the tested specimens; the maximum intensity occurs in specimen no (F16), which has the maximum hardness; the minimum intensity occurs in specimen no (F1), which has the minimum hardness. This means that the highest hardness occurs at the highest intensity.

Figure (16) shows the surface roughness for the different samples where we can note that sample (F16) has the higher Ra value.

Conclusions

Group no. 1

From the above results, we can conclude the following points:

- Flap peening process increases the hardness of surface of the metal; so, this, in turn, causes the fatigue life of the metal to increase.
- Sand blasting process reduces the hardness of surface of the metal; so, this, in turn, causes the fatigue life of the metal to decrease, and this is due to the small particle size of the sand material which penetrates the surface of the metal.

Group no. 2

- In the first group, the maximum hardness on the new parts (specimens type A), accomplished by the flap peening process under the recommended speed and standoff distance, was 21.16 HRC. But after entering variable speeds and standoff distances on the second group, the maximum hardness accomplished was 31 HRC. So, a difference in hardness of approximately 10 HRC was increased after entering those variables on the second group. This, in turn, gives more rising in the fatigue life of the metal.
- Rotational speed of the tool and standoff distance, controlled by operator, are the major variables of intensity control. The type of rotary tool used has a major effect on controlling the flap speed and, hence, intensity. Standoff distance has a significant effect on intensity control. It is concluded that the maximum hardness increases when the maximum mandrel speed and an 8 mm standoff distance is used. The minimum was at 3000 rpm of mandrel speed and a distance of 14 mm.
- The increase in hardness is directly proportional with the increase in intensity.

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