



Analysis of the Effects of Aggressive Shot Peening on Fatigue Life of 7075 – T6 Aluminum Alloy

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Abstract

For many years controlled shot peening was considered as a surface treatment. It is now clear that the performance of control shot peening in terms of fatigue depends on the balance between its beneficial (compressive residual stress and work hardening) and beneficial effects (surface hardening).

The overall aim of this paper is to study the effects of aggressive shot peening on fatigue life of 7075 – T6 aluminum alloy. The fatigue life reduction factor (LRF) due to the aggressive shot peening was established and empirical relations were proposed to describe the behavior of LRF, roughness and fatigue life. The benefits of shot peening in terms of fatigue life are dependent on the shot peening time (SPT). The higher SPT is the lower the benefit is. Higher roughness results in lower fatigue life.

Keywords: aggressive shot peening, fatigue life , LRF , 7075 – T₆ Al-alloy.

1. Introduction and Review

Shot peening treatments are widely used in mechanical and aeronautical engineering to improve the fatigue performance of components . There have however been reports of extensive variations in the fatigue life results for peened components and , in some cases a decrease in fatigue life has been observed [1] .

Peening attempts to spread material near the impact point against the resistance of neighboring material , thus introducing a complex sub- surface residual stress distribution in which generally , the surface is in elastic compression . There is a rapid transition to elastic tension at a deeper level , produced by the "enlarged" surface layer . This tension decays in deeper regions towards zero as shown in Figure (1) [2] .

Significant effect of peening intensity on fatigue life is also been noted ; there appears to be an optimum peening intensity to achieve the longest improvement in fatigue life .This intensity varies with the type of aluminum and heat treatment [3] [4] .

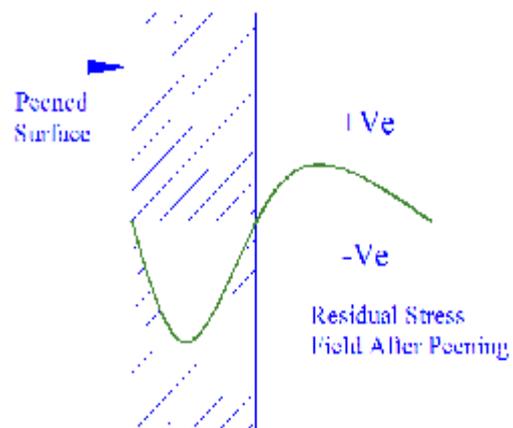


Fig. 1. Schematic of Residual Stress Distribution below a Peened Surface. Compressive Layer Generally Extends 200 – 400 μ m below the Surface [2].

Alalkawi et al. studied the effect of shot peening on two aluminum alloys 2024 and 5052 . The cumulative fatigue life of 2024 aluminum alloy is increased by shot peening while the

fatigue life of 5052 aluminum alloy is reduced due to high surface roughness and consequently high tensile residual stresses [5]. The predictions of the continuum damage modeling (CDM) were compared to the experimentally observed mechanical response and to the micromechanical characterization of damage. The comparison showed good agreement for 2024 – T₃₅₁ aluminum alloy plate subjected to multi – acid stress states [6].

Aggressive shot peening tends to increase the surface roughness which can be detrimental to fatigue performance .

The higher roughness creates short crack growth and reduce the fatigue life [7] [8].

This paper discusses the fatigue behavior of 7075 – Al – alloy under different shot peening times (SPT) and summarizes the improvements in peening arisen from this research.

2. Material

Aluminum alloy AA 7075 – T6 is used in the present work which has low specific weight and high strength to weight ratio. This alloy is widely used in industry and in particular in aircraft structure and pressure vessels [9] is presented in Table (1) chemical composition of 7075 – T6 Al – alloy wt% [10] ; While the mechanical properties were effected at the center of standardization and quality control are illustrated in Table (2) .

Table 1,
Chemical Composition of 7075 – T6 Al – alloy wt%.

Si	Fe	Cu	Mn	Mg	Zn	Cr	Al
0.16	0.32	1.8	0.1	2.3	5.4	0.2	Rem

Table 2,
Mechanical Properties of 7075 – T6 Al – alloy.

Properties	S _u (MPa)	S _y (MPa)	EI %	HB
Experimental	600	521	11	158
Standard	570	505	9	150

3. Fatigue Testing Specimens

All fatigue specimens were prepared according to DIN 50113. The shape of the fatigue specimen is hour – glass type in order to obtain stress concentration in the middle of the specimens (minimum diameter). Fig. (2) Shows the fatigue specimen configuration

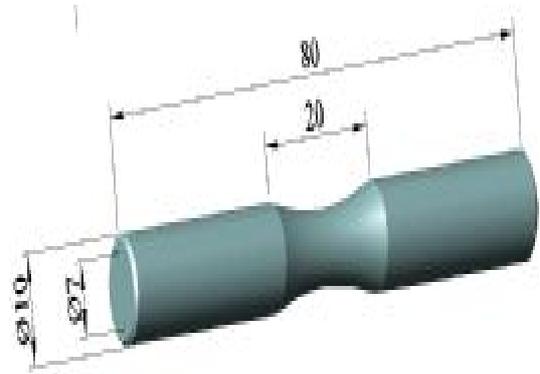


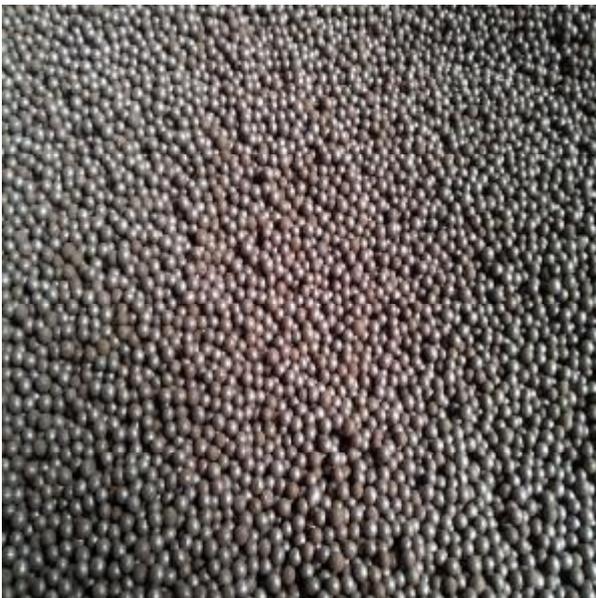
Fig. 2. Fatigue Specimen (All Dimensions in mm) According to DIN 50113.

4. Shot Peening

Shot peening was carried out for different times using spherically ball of 1mm in diameter at constant distance between the nozzle and the specimen of 10 cm. The specimen is rotating continuously during peening to ensure 100% coverage. Shot peening technique was performed using spherical steel balls of 1mm diameter. The ball hardness is 48 – 50 HB 12 bar average blasting pressure, the ball speed is 40 m/s , 100% coverage . The shot peening device used was (shot tumblast control model STB – OB) machine No. 03008 05 type. Fig (3) shows the shot peening device with shot balls used.



(a)



(b)

Fig. 3. (a) Shot Peening Device. (b) Shot Balls.

5. Roughness Measurement

Surface roughness measurements were carried out at the labs, Of Malaysia Pahang University using surface roughness testing machine type Perthometer 52. More details can be found in Ref [11]. Table (3) gives the average roughness (Ra) for different conditions of shot peening time (SPT).

Table 3,
Average Roughness Before and After (SPT) for 7075 – T6 Al. alloy.

SPT (min.)	Ra (µm)*	SPT (min)	Ra (µm)
Zero**	0.25	35	4.6
15	2.5	45	5.5
25	3.8	55	6.7

* The data are an average of 5 readings.

** Zero SPT i . e before shot peening or as received.

6. Fatigue Life Tests

12 specimens are tested under constant rotating bending amplitude stress , $0.6 S_u$ (360 MPa) , and at room temperature with stress ratio $R = -1$. Table (4) shows the experimental results versa surface roughness (Ra) and SPT .

Table 4,
Comparison of Fatigue Life and Surface Roughness for a Number of SPT.

Spec. No.	SPT (min)	Surface roughness Ra (mm)	Fatigue life , N_f cycles
1 , 2	0	0.25	62800 , 59200
3 , 4	15	2.5	200600 , 188000
5 , 6	25	3.8	52800 , 57900
7 , 8	35	4.6	41200 , 39600
9 , 10	45	5.5	30800 , 32600
11 , 12	55	6.7	28000 , 26700

The results appear to show a direct correlation between SPT and fatigue life of peened 7075 – T6 Al. alloy. As SPT increases (from zero to 15 SPT) the fatigue life increases.

But as roughness increases, fatigue life decreases (from 25 to 55 SPT). It is therefore considered that it might be possible to quantify the effects of peening on fatigue life by measuring surface roughness. The conclusion, at this stage is that some correlation exists between roughness and fatigue life for SPT from 25 to 55 , but where

the history of the part may have included some peening , from zero to 15 SPT , this relationship is unreliable . Fig (4) shows the roughness against fatigue life for SPT from 25 to 55.

The best fit formula which describes the above relation can be written by the empirical equation

$$Ra = 22803 N_f^{-0.8} \quad \dots(1)$$

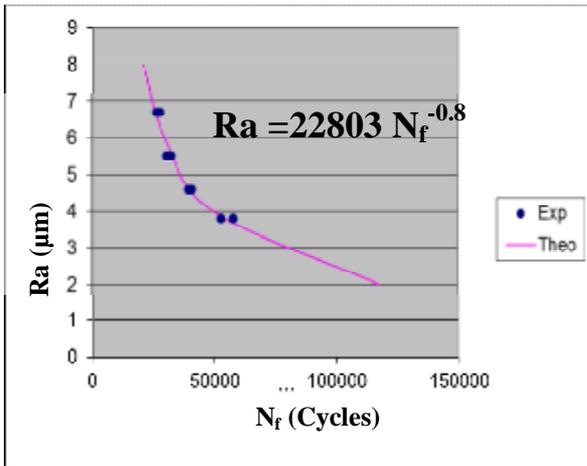


Fig. 4. The Relationship between Measured (Ra) and Fatigue Life N_f For 25 To 55 SPT.

Based on the results of Table (4), the mean life improvement factor (LIF) for SPT 15 minutes is 3.185 . This value is obtained from Table (4) as

$$LIF = \frac{N_f \text{ average 15SPT}}{N_f \text{ average zero SPT}} = \frac{194000}{61000} = 3.185$$

which obays the work of Sharp , et al. [12] . They proposed formula which described the relation between LIF and applied stress based on the experimental results for aluminum alloys as:

$$LIF = 6 * 10^{15} (\text{Stress})^{-5.8749} \quad \dots(2)$$

At 400 MPa Sharp et al. found that the LIF was 3.192 at the same SPT used in this work. For SPT 25 to 55 the effect of peening is inversially proportional to fatigue life, i . e when SPT increases the fatigue life decreases . Because of the greater damage to the material, the surface finish (roughness and defects) is also recognized as a critical influence on fatigue life. The LRF (Life reduction factor) for specimens peened at SPT 25 to 55 is tabulated in Table (5)

Table 5, LRF due to High SPT.

Spec. No.	Average life cycles	Average (Ra) µm	LRF *
5 , 6	55350	3.8	1.102
7 , 8	40400	4.6	1.509
9 , 10	31700	5.5	1.924
11 , 12	27350	6.7	2.230

* LRF is calculated based on unpeened Average fatigue life 61000 (specimens 1,2).

The results of Table (5) appear to a direct relation between surface roughness and LRF of peened aluminum alloy 7075 – T₆ . As (Ra) increases, LRF increases as shown in Figure (6). It is clear that the relation between LRF and N_f is inversely proportional as shown in the formula:

$$LRF = 89743 N_f^{-1.037} \quad \dots(3)$$

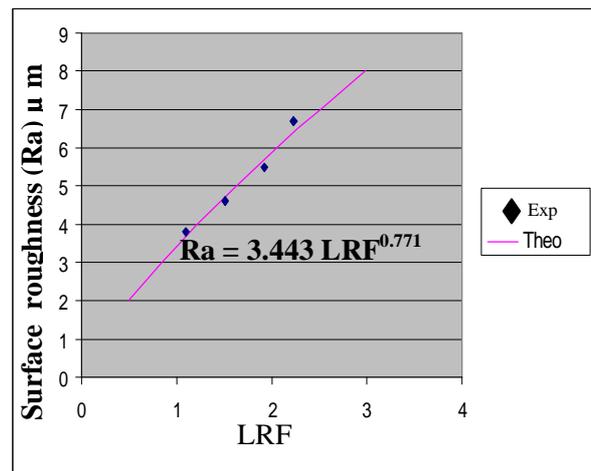


Fig. 6. Roughness against LRF for 7075-T6 Al – Alloy.

The problem of excessive or aggressive peening leads to defects buried insub – surface and to very deep laps , which do influence the surface roughness measurement , while greatly reduces fatigue life [13] . The relation which describes the surface roughness with LRF can be written as

$$Ra(\mu m) = 3.443 LRF^{0.771} \quad \dots(4)$$

7. Conclusions

In this work the effects of aggressive SPT are analyzed and modeled according to their effects on fatigue life. Surface roughness is modeled with fatigue life reduction factor (LRF). The analysis reveals that:

- 1- The benefits of shot peening in terms of fatigue life are dependent on the SPT. The higher the SPT is the lower the benefit is for time $0 < t < 15$ min.
- 2- The fatigue life improvement factor (LIF) is limited up to 15 SPT and equals to 3.185 .
- 3- After 25 SPT, fatigue life is reduced with time and the LRF is appeared.
- 4- After 25 SPT , increasing LRF leads to increasing the average roughness (Ra) and reducing the average number of cycles for failure (Nf)
- 5- An empirical formula which described the relation between (Ra) and LRF is proposed as:

$$Ra = 3.443 (LRF)^{0.771}$$

8. References

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تحليل تأثيرات القذف بالكريات المفرط على عمر الكلال لسبيكة الالمنيوم T6 – 7075

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الخلاصة

لعدة سنوات عملية القذف بالكريات المسيطرة كانت تعتبر معاملة سطحية اما الآن فتوضح بان اداء عملية القذف بالكريات المسيطرة بدلالة الكلال يعتمد على الموازنة بين ما هو مفيد (الاجهادات الضغطية المتبقية) وعملية التصليد السطحي والتأثيرات المفيدة (لتصليد السطح) .
الهدف الكلي لهذا البحث هو دراسة تأثيرات القذف المفرط على عمر الكلال لسبيكة الالمنيوم T6 – 7075 . تم ايجاد عامل تخفيض عمر الكلال (LRF) نتيجة للقذف المفرط وتم اقتراح علاقات رياضية معتمدة على التجارب العملية لتصف تصرف (LRF) والخشونة وعمر الكلال . فوائد القذف بدلالة عمر الكلال تعتمد على زمن القذف بالكريات (SPT) . اما زمن القذف الكبير يعطي فائدة قليلة وخشونة عالية والتي تعطي عمر كلال واطيء .