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Effect of shot peening and anodizing on fatigue crack growth of aircraft material Al 7050-T7651

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Abstract. The rate of fatigue crack propagation of the 7050-T7651 aircraft material subjected to automatic shot peening machine and chromic acid anodizing (CAA) has been studied and compared with previous research results. Al 7050-T7651 is made into specimens according to ASTM E647 standard treated with automatic shot peening machine (with steel shot material, 0.017inch diameter, shot flow 30%, 3 bar pressure, Almen intensity 0.0082 A with 100 mm shooting range and 90° angle of shot) and CAA (operating standard) in surface treatment area of Indonesian Aerospace. The fatigue cracking test with a load of about 200 kg, with a stress ratio of $R = 0.1$. The results of the fatigue crack growth test resulted in the constant of Paris $A = 3.654 \times 10^{-9}$ and $n = 1.67$, indicating that the automatic shot peening machine and chromic acid anodizing treatment decreased the fatigue life and increased the fatigue crack growth rate compared to the automatic shot peening machine, manual machine with or without CAA, and without treatment.

1. Introduction

Al 7050-T7651 belongs to the type of aluminum alloy with the composition of Al 87.3-90.3%; Zn 5.7-6.7%; 1.9-2.6% MG; Cu 2-2.6%; Zr 0.08-0.15% and other alloy elements which are given heat treatment with a 477°C solution temperature and aging temperature 121-177°C based on ASM (Aerospace Specification Metal) Material Data Sheet [1].

Shot peening is the surface treatment by firing shot material so that the dimple is formed and residual stress arises on the surface of the working specimen to increase resistance to fatigue failure. Whereas CAA Chromic Acid Anodizing is the treatment of aluminum surface oxidation or its electrolysis alloy, chromic acid is used as an electrolyte solution to form a protective aluminum oxide / hydroxide layer and is applied to improve corrosion resistance and paint adhesion, but hard and brittle. Several specimen tests with shot peening and CAA combined treatments have been shown to increase fatigue life and reduce the rate of fatigue crack propagation [2-3].

Types of materials similar to Al 7050-T7651 treated with manual shot peening and CAA have also been tested for fatigue, and showed that the combination of treatments increased fatigue life and reduced the fatigue crack growth rate [4]. Fatigue crack propagation test is one standard that can be used in most aircraft constructions, such as the fuselage component, upper and lower spar, upper and lower wing, horizontal stabilizer, etc. [5].

The purpose of this paper is as a follow-up study to deepen the analysis of previous author's research, in this case the specimen was treated with automatic shot peening [6] and added data



analysis of the combination treatment of automatic shot peening and CAA applied to the surface treatment at Indonesian Aerospace.

2. Experimental Procedures

Al 7050-T7651 specimen material was formed according to ASTM E647 standard type L-T [7] as shown below

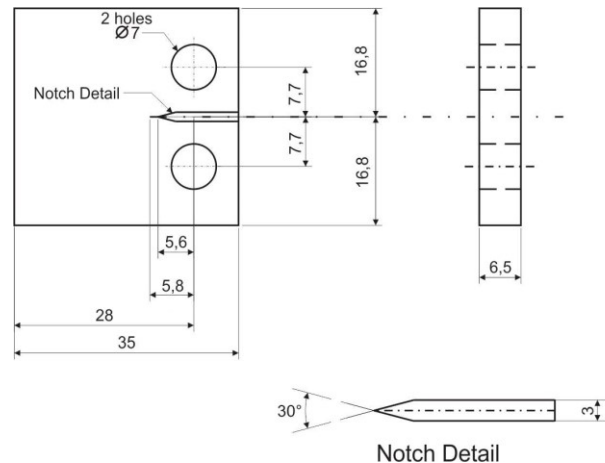


Figure 1. Specimen according to ASTM E647 [8].

Automatic machine shot peening process and CAA are carried out at the Directorate of Aerostructure, Sub Directorate of Surface Treatment Indonesian Aerospace with the following shot peening treatment parameters

Shot material	: Steel
Shot ball diameter	: 0,017 inch
Shot flow	: 30%
Pressure	: 3 bar
Almen Intensity	: 0,0082 A
Shooting distance	: 100 mm
Shooting angle	: 90°

Anodizing Process with specifications

Tank Volume	: 37000 Lt
Level	: 20 cm
Free CrO ₃	: 30 gr/L min
Total CrO ₃	: 30-100 gr/L
Cl-as NaCl	: 0,2 gr/L max
SO ₄ -as Na ₂ SO ₄	: 0,5 gr/L max
Temperatur	: 40±2 °C
Time	: 40 minutes
Voltage	: 40±1 Volt
Catode Plate	: Titanium

While the fatigue testing process is carried out at the Material Engineering Lab. Mechanical and Industrial Engineering Department, Engineering Faculty, UGM with a servopulser machine

Merk	: Shimadzu
Machine Type	: Mesin Servopulser
Model	: 4825

Crack Visual : *microscope travelling optic*

Pull-press loading parameters, 200 kg and R (ratio) = 0.1.

Fatigue crack growth rate can be calculated using the Paris equation with the ASTM E647 specimen [9],

$$\frac{da}{dN} = A(\Delta K)^n$$

$$\left(\frac{da}{dN}\right) = \frac{b_1}{A_2} + 2b_2 \left(\frac{N_i - A_1}{A_2}\right)$$

$$\Delta K = \frac{\Delta P}{B\sqrt{W}} \frac{\left(2 + \frac{a}{W}\right)}{\left(1 - \frac{a}{W}\right)^{\frac{3}{2}}} \left[0,866 + 4,64\left(\frac{a}{W}\right) - 13,32\left(\frac{a}{W}\right)^2 + 14,72\left(\frac{a}{W}\right)^3 - 5,6\left(\frac{a}{W}\right)^4 \right]$$

$$\Delta P = P_{\max} - P_{\min}$$

with

a = crack length
 N = cycles amount
 A, n = Paris constant
 b₁, b₂ = regression constant
 ΔK = different stress intensity factors
 P = load
 W = width of specimen
 B = thick of specimen

Fatigue crack propagation test is carried out by observing each increase in crack length that occurs on the front side of the specimen (a_i), where these data are used to see the relationship between the addition of crack length (a) and the number of cycles (N), processed using incremental polynomial methods for get relationship with / dN-ΔK. Trendline relationships with / dN-ΔK are obtained by making a graph with log scale on d / dN and ΔK, so that a line equation can be used to determine the characteristics of fatigue crack propagation (Paris A and n constants).

3. Results and Discussion

Figures 2 and 3 and Table 1 show a comparison of data distribution, Paris trendline and constants from previous studies [4] and [6] and additional recent research data. In naming the type of specimen some new names are used to clarify the different treatments used.

Previous analysis stated that the automatic shot peening machine treatment was effective in reducing the rate of fatigue crack propagation compared to manual shot peening machines, although the data distribution and BMSPAuto trendline position were above and BMSP with a higher Paris A constant, but the gradient line for the BMSPAuto trendline was lower or higher slope than BMSP seen from the lower Paris constant n. This shows that there is a decrease in the rate of fatigue crack propagation and increasing fatigue life. This will be obvious if applied to predict fatigue life using the Paris constant.

The effect of Almen intensity increase (one of the shot peening parameters) from 0.006 A [4] to 0.0082 A [6] turned out to be able to reduce the rate of fatigue crack creeping, but to some extent if the intensity of Almen increases, it will increase surface roughness and reduce resistance. fatigue (increasing crack propagation rate) [9].

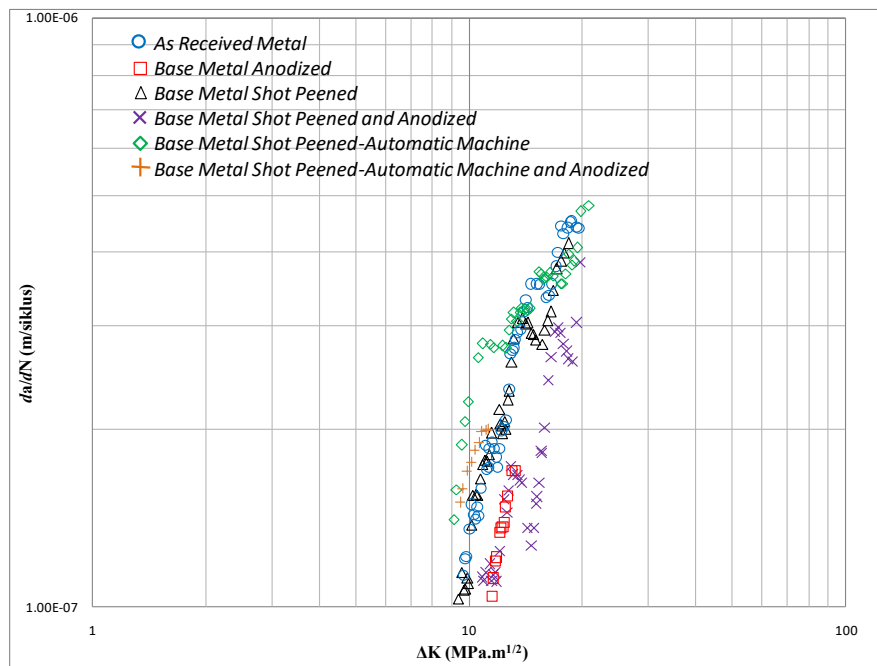


Figure 2. Relationship between da/dN and ΔK .

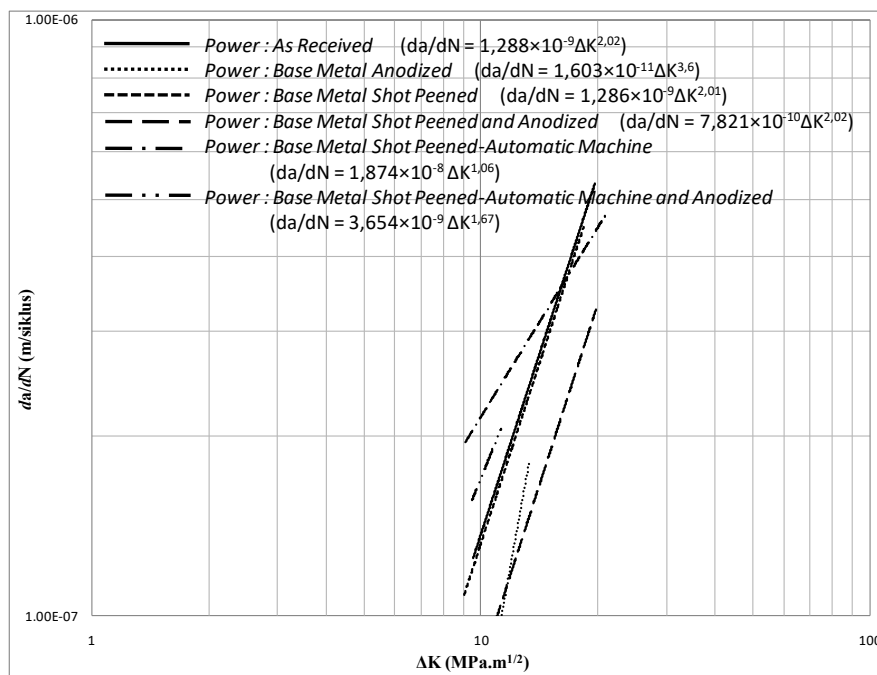


Figure 3. Relationship between da/dN and ΔK in trendline

However, when testing the BMSPA_{AutoA} fatigue crack rate compared to BMSPA, it appears that the data distribution and BMP_{Auto} trendline position are quite far above BMSPA with the Paris A constant higher, but the line gradient is not too significant difference, then BMSPA_{AutoA} treatment actually decreases fatigue life and Fatigue crack rate is increasing. As a result of the larger dimple and increasing surface hardness, due to the effect of increasing Almen intensity plus anodizing treatment it actually reduces fatigue resistance.

Table 1. Test results of fatigue crack propagation Al 7050-T7651.

Kategori	Paris Constants	
	A	n
<i>As Received Material (AR)</i>	1.288×10^{-9}	2.02
<i>Base Metal Anodized (BMA)</i>	1.603×10^{-11}	3.6
<i>Base Metal Shot Peened-Manual Machine (BMSP)</i>	1.286×10^{-9}	2.01
<i>Base Metal Shot Peened-Manual Machine and Anodized (BMSPA)</i>	$7,821 \times 10^{-10}$	2.02
<i>Base Metal Shot Peened-Automatic Machine (BMSPAuto)</i>	1.874×10^{-8}	1.06
<i>Base Metal Shot Peened-Automatic Machine and Anodized (BMSPAutoA)</i>	3.654×10^{-9}	1.67

4. Conclusions

Basically, the lower the relationship trendline position da/dN dan ΔK and the more gradient sloping line, the lower the rate of propagation of fatigue cracks, both of them are interconnected and influence each other. Shot peening treatments and CAA reduce fatigue life and increase the rate of creeping fatigue cracks with Paris constant $A = 3.654 \times 10^{-9}$ and $n = 1.67$.

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