Fatigue Behavior of Aluminum Alloys Requested by a Simple Overload: Environment Influence

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***Abstract*—** In this study we were interested in the behavior of two aluminum alloys (2024 T351 and 7075 T7351) requested by a simple overload with an aim of determining the number of cycles of delay of each one and of comparing their behavior various environments (air and vacuum).For that, we carried out fatigue tests stopped by a simple overload with a rate of overload τ = 2 and reports/ratios of loads R=0,1 and R=0,5.The results obtained show that the number of cycles of delay of alloy 2024 T351 is higher than that of the alloy 7075 T7351 and that the number of cycles of delay is more significant in the vacuum than with the air for two materials.This observation will lead us to make a judicious choice as for the industrial use (aeronautical) of two materials.

***Keywords*—**fatigue, overload, aluminum alloy, a number of cycles of delay.

I. Introduction

THE influence of the spontaneous load change on fatigue crack behavior in a structure is a natural phenomenon which suddenly appears. For this reason several authors such as Schijve [1],Von Euw and Al. [2], Wei and Al [3] and Bathias [4] were interested to overloads phenomenon and they defined some governing factors of this phenomenon.

Among these factors are:

- ΔKpic : amplitude of the stress intensity factor corresponding to the overload in [$MPa.m^{1/2}$] ;
- Nd : number of delay cycles ;
- a_d: crack length disturbed by the overload in [m].

Some authors tried to explain other aspects relating to the overloads they show that 2024 T351 alloy for a overload rate τ the delay decreases if the load ratio R increases, for Ri > 0 and for τ = 2, the crack can be blocked definitively [5] . In the field of negative charge ratios (Ri < 0) and for a given overload rate, the delay decreases when the load ratio R increases [6].

II. Experimental conditions

A. Materials

In this study, we used two high-strength aluminum alloys which chemical properties and the mechanical characteristics are given, respectively, in tables I and II.

TABLE I
CHEMICAL PROPERTIES

Elements%	Si	Fe	Cu	Mn	Mg	Cr
2024 T351	0.10	0.22	4.46	0.66	1.50	0.01
7075 7351	0.70	0.16	1.52	0.04	2.55	0.20

TABLE II
MECHANICAL CHARACTERISTICS

Material	$\sigma_{0.2}$ (MPa)	σ_R (MPa)	A (%)	K	n
2024 T351	318	524	12.8	652	0.104
7075 T7351	470	539	11.7	960.5	0.051

B. Specimens

All the tests were carried out on CTX specimen with:

- For 2024 T351, X = 75mm, B= 10 and 4 mm, the geometry of some specimen was modified by Ranganathan to be able to take opening measurements vertically of the axis of loading (figure 1)

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- For 7075series, X = 38,4 mm, B=12mm

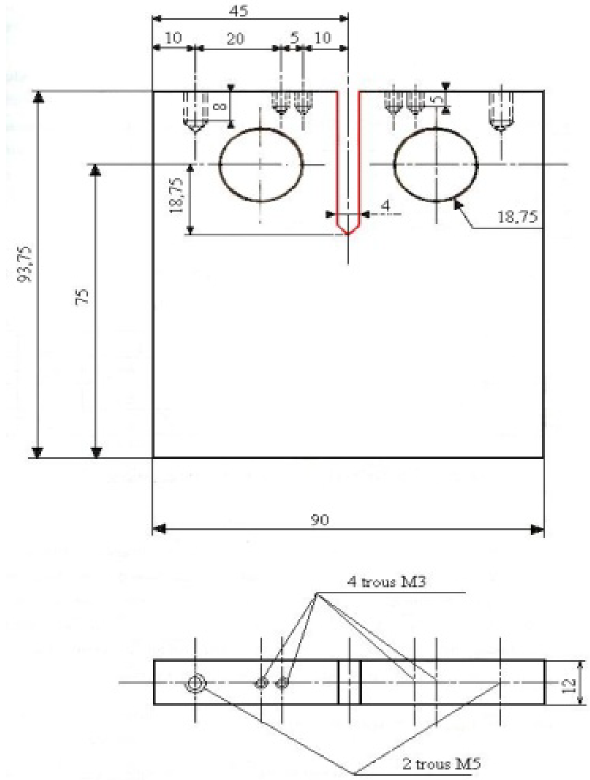

Fig. 1 specimen geometry

For this geometry, the stress intensity factor K is given by:

$$K = \frac{p}{B\sqrt{w}} f\left(\frac{a}{w}\right) \qquad (1)$$

Where P: is the applied load (N)

B: specimen thickness (mm)

W: spicemen width (mm)

Two compliance functions $f\left(\frac{a}{w}\right)$ were used and are given by:

- **For $0,3 < \frac{a}{w} < 0,7$:**

$$f\left(\frac{a}{w}\right) = 29,6\left(\frac{a}{w}\right)^{\frac{1}{2}} - 185,5\left(\frac{a}{w}\right)^{\frac{3}{2}} + \ldots \qquad (2)$$

- **For $0,2 < \frac{a}{w} < 0,3$**

$$f\left(\frac{a}{w}\right) = 4,55 - 40,32\left(\frac{a}{w}\right) + 414,7\left(\frac{a}{w}\right)^{2} - \cdots \qquad (3)$$

- **For $\frac{a}{w}$ > 0, 3** the equations (2) and (3) give appreciably the same results.

III. Results And Discussions

A. *Delay curves*

We observed three types of delay:

- *Immediate delay*

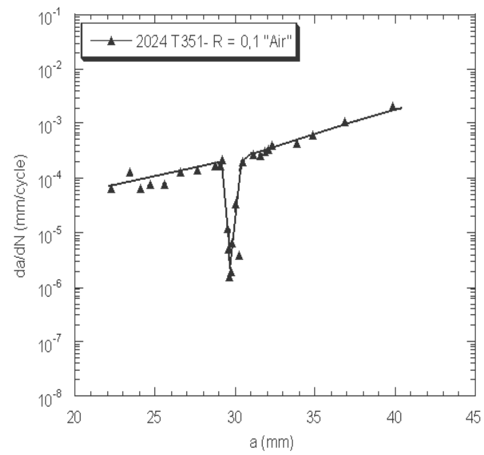

Fig. 2 Immediate delay (R=0.1 under Air)

- *Differed delay*

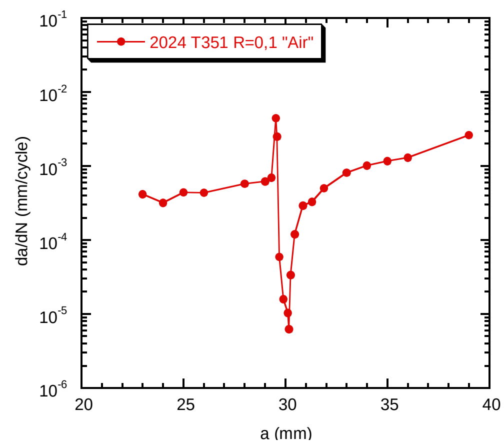

Fig. 3 Differed delay (R=0.1 under Air)

- *Blocking*

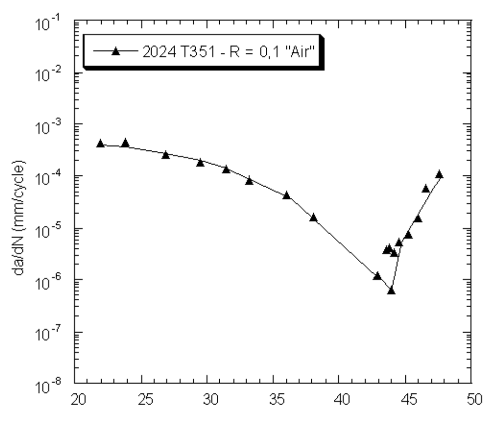

Fig. 4 Blocking (R=0.1 under Air)

B. Evolution of the number of delay cycle

To characterize the effect of material, of the report/ratio of load and the environment, we presented the evolution of the number of cycle affected N_d by the overload according to the amplitude of the stress intensity factor ΔK.

- *Material and load ratio effect*

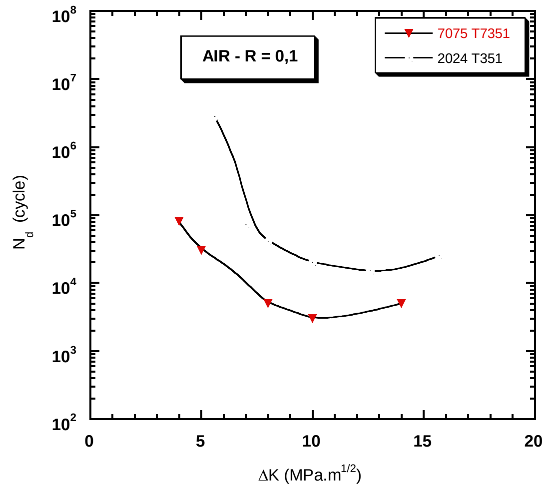

Fig. 5 Evolution of delay cycle N_d according to ΔK for R=0.1 under Air

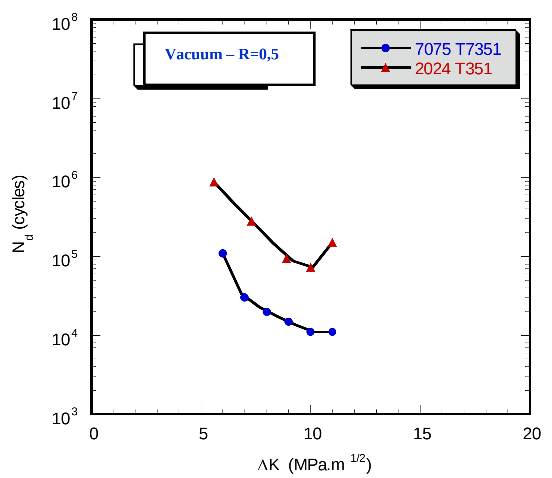

Fig. 6 Evolution of delay cycle N_d according toΔK for R=0.5 under Vacuum

We note that:

- The delay propagation is more important in R=0,1 than in R=0,5;
- The two materials present, overall, the same shape of U as what was observed by Vecchio & Al [7] and Ranganathan & Al [5].

- *Environment influence*

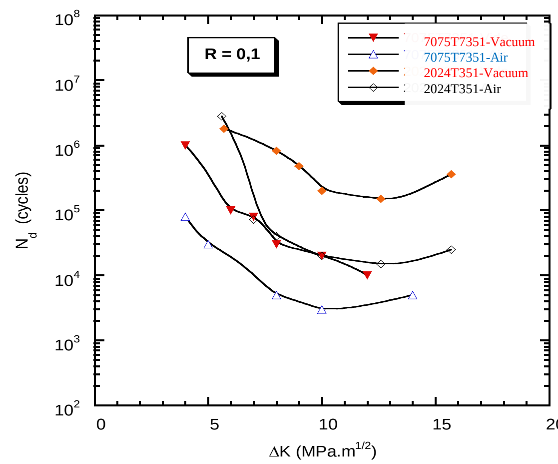

Fig. 7 Evolution of delay cycle N_d according to ΔK for R=0.1 and R=0.5 under Air and vacuum for 2 materials.

IV. Conclusion

In this study we highlighted the number of delay cycles due to the effect of a simple overload.

We studied the material effect, the load ratio effect and the environment influence. We noted that overall the two materials take the same form out of U. The 7075T7351alloy present a delay ten times weaker than 2024T351 for 7 < ΔK < 14 MPa $\sqrt{m}$ with R = 0, 1 and for 7< ΔK < 10 MPa $\sqrt{m}$ with R = 0, 5.

This behavior can be explained by the fact that the 2024T351 alloy presents a strong cyclic consolidation and that for low values of ΔK the crack tends to deviate of its axis of propagation after the application of the overload.

The delay under vacuum is more important than under air for two studied materials with R=0, 1.

References

[1] Schijve, Prediction Methods for Fatigue Crack Growth in Aircraft Material.ASTM STP 700, 1979 pp.3.

[2] E.F.J. Von Euw et Col., Stress Analysis and Growth of Cracks: Proceedings of the 1971 National Symposium on Fracture Mechanics: Part 1, ASTM STP 513, 1972 pp.230.

[3] R.P. Wei et Col., load interaction effects on fatigue crack growth , NASA CR. 1973, pp2239

[4] C. Bathias, Effects of overload on fatigue crack growth Insomealuminium alloys, International Conference of Mechanical Behavior of Materials 16-20 1976. Boston

[5] Ranganathan et Col. , Overload Effects in Aluminum Alloys: Influence of Plasticity and Environment", Journal of ASTM International, Journal of ASTM International, vol.1, Issue 10, 2004

[6] R.I. Stephens et Col., 1976, ASTM STP 595, P. 27.

[7] R.S. Vecchio et Col., 1984, Fat. Of Eng. Matls and St., V. 7, p. 181.