Chapter 3

Influence of Structural Parameters on the Resistance on the Crack of Aluminium Alloy

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1. Introduction

The propagation of the cracks occurs through the formation and the intensification of a plastic zone at the crack tip. This mechanism is accompanied by energy dissipation.

The energy dissipated per cycle is representative for the state of the material at the crack tip.

Many works based on energetic approach have been made by different authors in orders to characterise the behaviour of the material in propagation state.

Ikeda and al. [1] have used hysteresis loops near the crack in order to determine the energy for surface creation and compared them to those obtained on smooth specimens. They deducted the limits of the equivalent stresses corresponding to local loops; thus, the plastic work is given by:

$$U = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} U_{XY} dX dY \tag{1}$$

$$U_{XY} = \frac{1}{da/dN} \left\{ \int_{\varphi 1}^{\varepsilon 2} \sigma_u d\varepsilon - \int_{\varphi 1}^{\varepsilon 2} \sigma_\theta d\varepsilon \right\} \tag{2}$$

U_{XY} is the local plastic work at the plastic zone of X and Y coordinates.

These authors have only taken into account the deformations which are perpendicular to the crack.

This is confirmed since Izumi and Fine [2] have demonstrated that the plastic work in the direction parallel to the crack represents only 10% of the plastic work in the perpendicular direction to the crack.

The micro gage measures are only possible for distances lesser than 100μm from the crack tip, Izumi and Fine have used an in interpolation function of the type :

$$\Delta\varepsilon_p \;\alpha\; \log\Delta r \tag{3}$$

Davidson and al. [3] elaborated another method for measuring U from sub grains size which are formed after the passing of the crack using the retro diffused electrons method in an electronic microscope.

The comparison of the two methods done by Liaw and al [4] show a difference between the plastic work values of only 15%.

These authors show that 70% of the total is dissipated in the zone located at distance greater than 100μm from the crack tip.

Weertman [5] developed a theoretical model with a crack growth rate, energy and stress intensity factor relationship such that:

$$\frac{da}{dN} = \frac{\pi\Delta K^4}{8\mu U\sigma_c} \tag{4}$$

Izumi and Fine [2] had expressed the crack growth rate with respect to the stress intensity factor and the energy by:

$$\frac{da}{dN} = \frac{A\Delta K^m}{\sigma^2\mu U} \tag{5}$$

where m is Paris coefficient.

These authors note that in the case of alloys for which m=4, U is independent of ΔK and also when m<4, U is an increasing function of ΔK.

Recently Ranganathan [6] showed for, an aluminium alloy 2024 T351, that the specific energy Q is proportional to the stress intensity factor amplitude to the power 4 (ΔK^4) and that the crack growth rate is related according to a power to energy law.

2. Materials under study

The materials studied are aluminium- Zinc- Magnesium- Copper alloys under different forms and whose characteristic are given in table 1.

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Alloy	Sense	Grain size (μm)	σE MPa	A%	K_{IC} MPa$\sqrt{m}$	σR MPa
X7075	LT	8000	392	16	76,9	464
	TL	350	395	13,4	59,9	474
7175F	LT	300	462	11,7		534
	TL	90				
7175M	LT	1700	472	12,9		550
	TL	550				

Table 1. Characteristics of 7075 alloys (high purity, with smaller and bigger grain size F and M)

3. Experimental method

The tests were conducted on CT40 specimen of thickness B=6 mm taken in the sense TL and LT. The specimen were paper polished then with diamond paste till 1μm to permit the optical follow up of the crack. All the test were conducted for a ration R=0,10 with a frequency from 10 to 40 Hz. The stress intensity factor is calculated according to the ASTM E647 [7]. Crack closure measurements had been made for different lengths of the crack using the global compliance variation method established by Kikukawa and al. [8] (fig. 1).

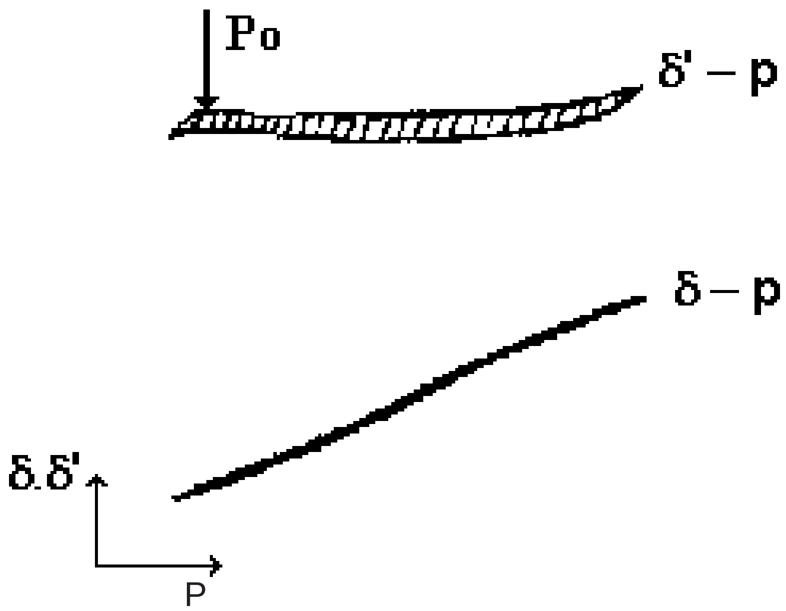

Figure 1. Curve Pδ (measurement of energy)

The hysteretic energy Q dissipated through one cycle is obtained by integration of the Pδ′ curves; and the specific energy U is given by the relation:

$$U = \frac{Q}{2B\frac{da}{dN}} \qquad \left[\mathrm{J/m^2/cycle}\right] \tag{6}$$

4. Experimental results and discussion

4.1. Influence of the material purity and the grain size

Fig. 2 shows the evolution of the specific energy U with respect to the stress intensity factor amplitude for the tree materials.

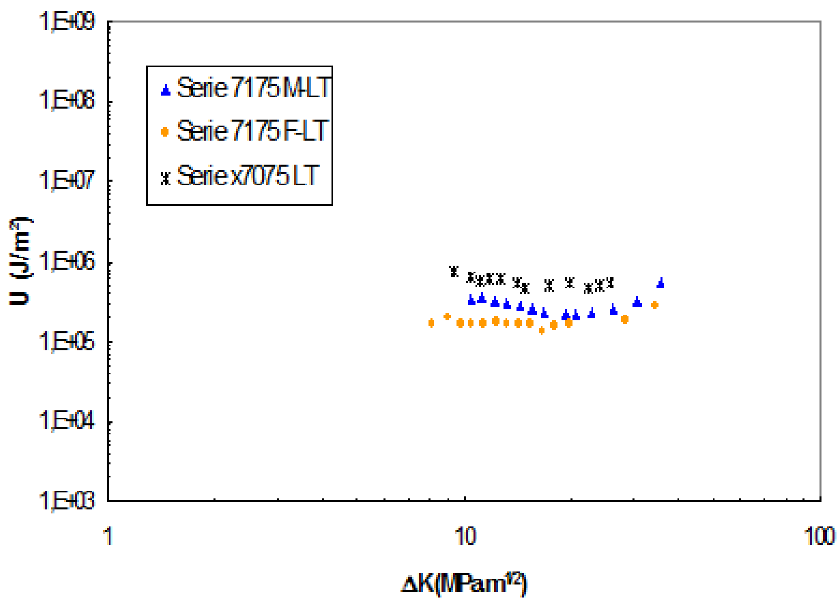

Figure 2. Evolution of energy U with respect to Δ K

We note that U is constant for crack material this result is comparable to that obtained by Ranganathan [6] for the aluminium 2024 T351.

We notice that for a pure material (X7075), the energy is four times greater than that obtained for material of ordinary purity (7175 M).

The evolution of the dissipated energy Q with respect to ΔK is given in fig. 3.

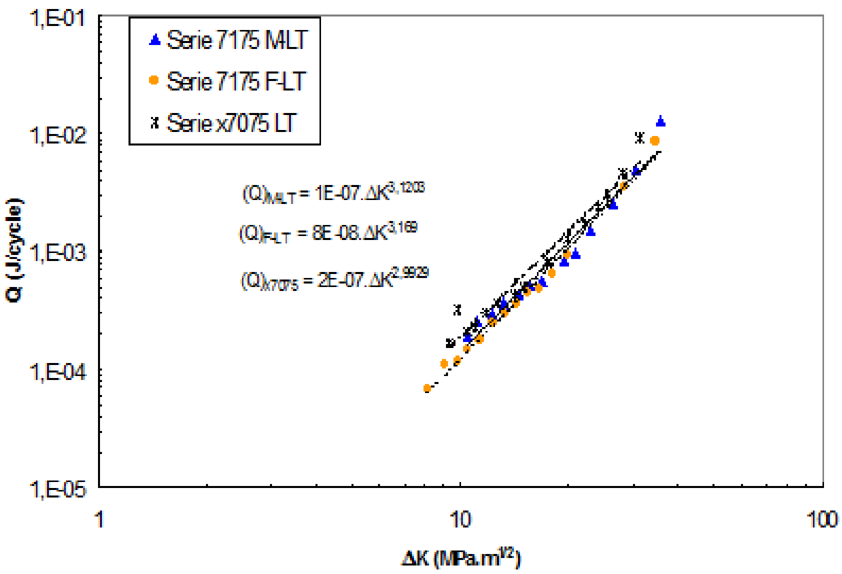

Figure 3. Evolution of energy Q with respect to Δ K

We note that Q obeys to a power law of the form Q = A ΔK^m for the three material. The variations of the crack growth rates with respect to Q show that growth rates obtained for the 7175 M and 7175 F materials (fig. 4).

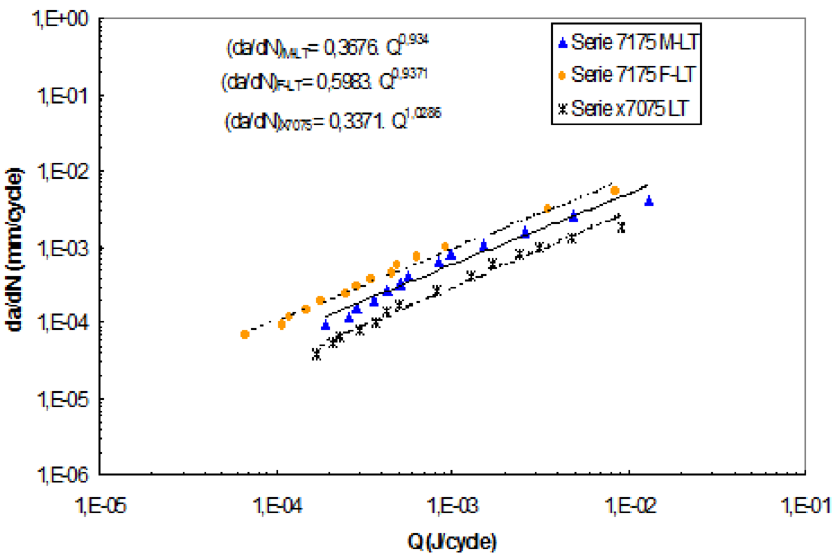

Figure 4. Evolution the speed of cracking with respect to Δ K

4.2. Influence of grains orientation

Figures 5 and 6 show the variation of the crack growth rates with respect to the energy Q and that of the specific energy U with respect to ΔK for 7175 F alloy in two different grain size orientations LT and TL.

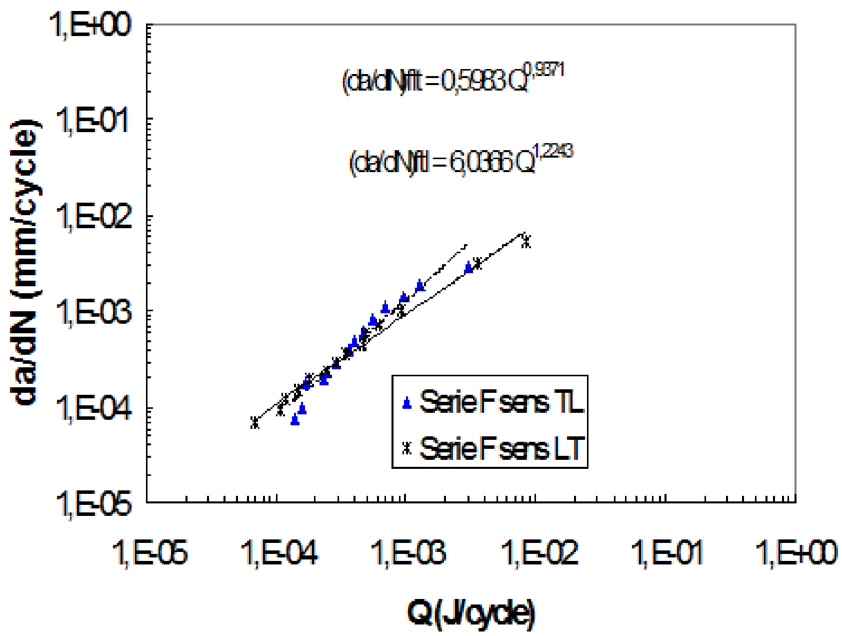

Figure 5. Evolution the crack growth rate with respect to Q

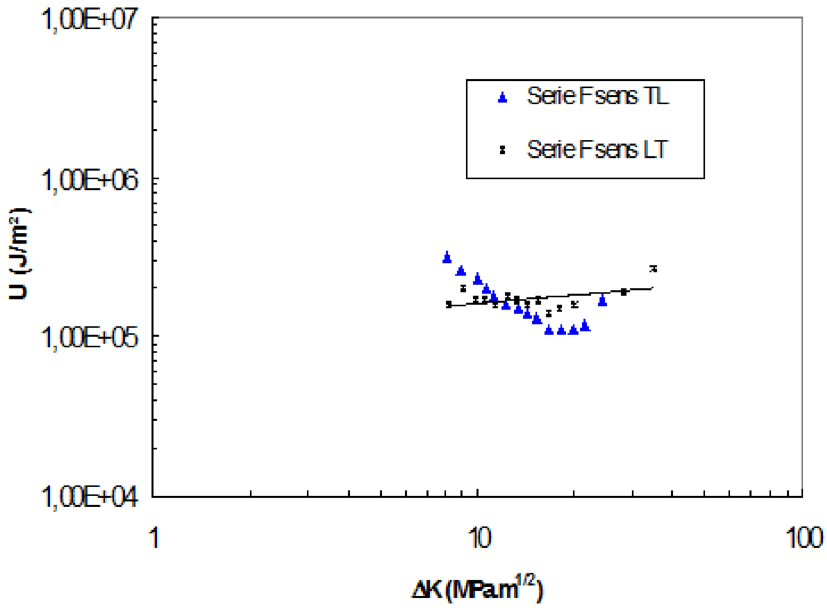

Figure 6. Variation of energy with respect to Δ K for two different orientations (TL and LT)

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We note that the evolution of U is constant and equal to 2.10^5 for the LT orientation. The crack growth rates linearly vary with respect to Q.

5. Conclusion

The present study permits to investigate the influence of three characteristic parameters of materials on the evolution of the energy and on the crack growth rates.

From which the following conclusions can be drawn:

- pure alloys present a higher energy and lower crack growth rates;
- the grain size has a predominant influence on the specific energy;
- the grain orientation has not a consequent influence on these two parameters (energy and crack growth rates).

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