ENERGETIC ASPECTS OF LOW CYCLE FATIGUE AND FRACTURE MECHANICAL PROPERTIES OF AlMg3 ALLOY

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INTRODUCTION

Among aluminium materials the AlMg3 alloy is the most frequently used for constructing structures because of its suitable strength and toughness properties in wide temperature range (from -180 to +150 °C) and at the same time it has good corrosion resistance, weldability and capability to surface treatments. In case of thick-walled (15-30 mm) tanks and vessels having enhanced reliability requirements it is necessary to know the safety of this alloy against brittle fracture and to determine the resistance to low cycle fatigue which characterizes the working conditions in many times.

Two methods were used for determining the $K_{IC}$ value on hot-rolled material. One of them was the three-point bending test for COD and the other the NOD technique based on the Czoboly-Radon (1) conception which utilizes the plastic zone dimension ($L_o$) and specific fracture energy for unnotched specimen ($W_C$) in the relation of

$$K_{IC} = \sqrt{L_o \cdot W_C \cdot E} \quad \ldots \ldots \ldots (1)$$

Using 5-5 parallel measurements the average $K_{IC}$ value for COD is 1359 N/mm² and for NOD is 1105 N/mm². At the same time tensile tests were performed on notched cylindrical specimens with different notch-tip radius. Determining the specific fracture energy of the notched ones ($W_m$) and representing in function of stress-concentration factor ($K_1$) the Figure 1 could be get with an exponential feature which should be characterized with a limit value of $W_m \approx 10$ J/cm³ in the region of $K_1 > 10$. On the basis of Gillemot (2) conception the width of the plastic zone (b) around the tip of notch with infinitely small radius (considered like a crack) should be estimated, which was nearly the same as the $L_o$ height in the given alloy (and probably in all aluminium materials having greater plasticity). According to results the b and $L_o$ are 0,22 and 0,18 mm respectively. Supposing a toroidal-form plastic zone and substituting $L_o$ with b the $K_{IC}$ can be simply estimated and applied to study the technology caused changes in $K_{IC}$ by the way of utilizing a smooth and some sharply notched cylindrical specimens with small dimensions taken from places to be investigated.

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Low cycle fatigue tests were performed on a computer controlled Instron 1195 type machine with transverse strain measurements on cylindrical specimens. The n and C constants of Coffin-Manson equation (\( \varepsilon_p N_t = C \)) which describes the process) as well as the n' hardening coefficient for one cycle were determined. During the low cycle fatigue the absorbed energy for one cycle (\( W_d \)) could be estimated with the relation as follows:

\[
W_d = \frac{1}{4 \pi n'} \cdot \frac{\Delta \varepsilon}{2} \cdot \sigma_p \quad \text{........(2)}
\]

It should be supposed that cracks form only in that case when the absorbed specific energy reaches \( W_r \). By this way the energy for crack propagation (\( W_r \)) can be accounted as shown in Figure 2:

\[
W_r = W_d \cdot N_t - W_c \quad \text{........(3)}
\]

Analyzing the energy balance of specimens broken in different cycle numbers it should be experienced that in case of small \( N_t \) (when \( \Delta \varepsilon_p \) is great) the \( W_r \) is nearly equal with the total energy, while in case of great \( N_t \) (\( \Delta \varepsilon_p \) is small) the role of \( W_r \) becomes important. The phenomena mentioned is similar to that Havas (3) experienced in connection with steels.

**SYMBOLS USED**

- \( E \) = modulus of elasticity (MPa)
- \( K_{tc} \) = plain strain fracture toughness (N/mm)
- \( K_0 \) = stress concentration factor
- \( L_0 \) = height of plastic zone (mm)
- \( n' \) = cyclic hardening coefficient
- \( N_t \) = number of cycles to fracture
- \( W_d \) = specific fracture energy of plain specimens (J/cm³)
- \( W_p \) = specific absorbed energy for one cycle (J/cm³)
- \( W_m \) = specific fracture energy of notched ones (J/cm³)
- \( \varepsilon_p \) = plastic strain amplitude
- \( \Delta \varepsilon_p \) = total plastic strain range
- \( \Delta \sigma \) = change of stress amplitude (MPa)

**REFERENCES**

Figure 1 Change of the specific fracture energy in function of stress-concentration factor

Figure 2 The absorbed energy in low cycle fatigue