ENERGETIC ASPECTS OF LOW CYCLE FATIGUE AND FRACTURE MECHANICAL PROPERTIES OF AlMg 3 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 utilizies the plastic zone dimension (L_o) and specific fracture energy for unnotched specimen (W_c) in the relation of

$$K_{Ic} = \sqrt{L_o \cdot W_c \cdot E} \qquad \ldots\ldots..(1)$$

Using 5-5 parallel measurements the average K_{Ic} value for COD is 1359 $N/mm^{3/2}$ and for NOD is 1105 $N/mm^{3/2}$. 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_t) the Figure 1 could be get with an exponential feature which should be characterized with a limit value of $W_m \sim 10$ J/cm3 in the region of $K_t > 10$. 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 heigth 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 ($\varepsilon_p . N_t^n = C$ - 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:

$$W_d = \frac{1}{1+n'} \cdot \frac{\Delta\sigma}{2} \cdot \Delta\varepsilon_p \quad ....(2)$$

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

$$W_r = W_d . N_t - W_c \quad ....(3)$$

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_c 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_{Ic} = plain strain fracture toughness (N/mm)
K_t = stress concentration factor
L_o = heigth of plastic zone (mm)
n' = cyclic hardening coefficient
N_t = number of cycles to fracture
W_c = specific fracture energy of plain specimens (J/cm3)
W_d = specific absorbed energy for one cycle (J/cm3)
W_m = specific fracture energy of notched ones (J/cm3)
W_r = specific energy for crack propagation (J/cm3)
ε_p = plastic strain amplitude
$\Delta\varepsilon_p$ = total plastic strain range
$\Delta\sigma$ = change of stress amplitude (MPa)

REFERENCES

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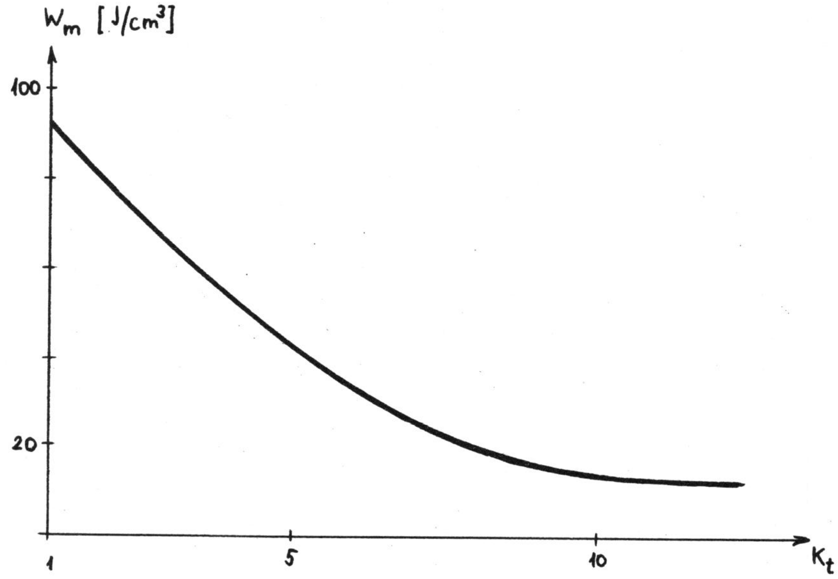

Figure 1 Change of the specific fracture energy in function of stress-concentration factor

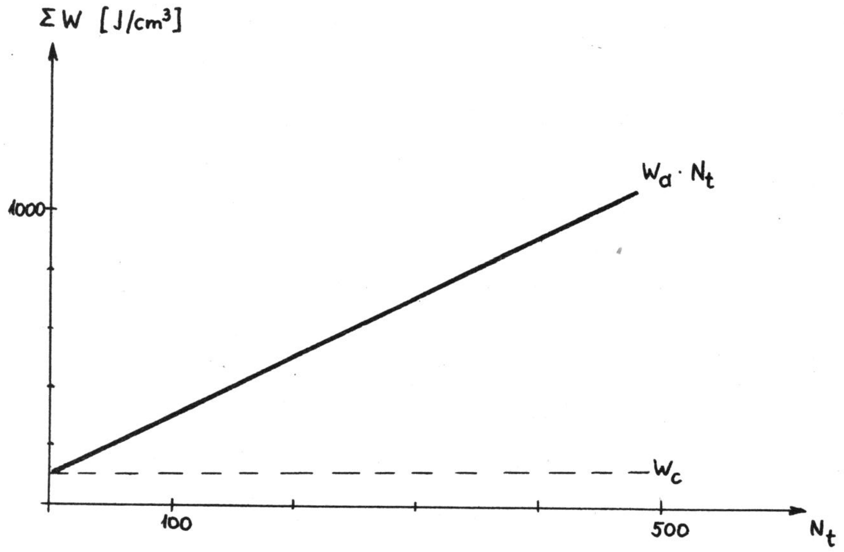

Figure 2 The absorbed energy in low cycle fatigue