STUDY ON FATIGUE CRACK GROWTH ACROSS STEEL PLATES SUSCEPTIBLE TO LAMELLAR TEARING

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INTRODUCTION

In butt-welded joints the fatigue crack is initiated usually at the toe of weld reinforcement and grew in thickness direction of a parent material. In the steel plates of usual quality the propagated fatigue cracks cross or pass near the flat elongated non-metallic inclusions being perpendicular to the crack path. These inclusions were coherentless with metallic matrix, being by their projections partially overlapped, and they were sufficiently close to each other. In the course of fatigue crack growth on the so located inclusions can be nucleated an propagated the lamellar tearings of steel plate (1). In the present study the growth characteristic of small lamellar tearings which appeared on the fatigue crack surface were investigated in order to clarify the effect of main fatigue crack growth on the nucleation and growth of lamellar tearings of steel plate.

EXPERIMENTAL PROCEDURE

The normalized 12 mm thick plates of 15G2Anb steel contained flat elongated non-metallic inclusions grade 1,7 as established by standard PN-64/H-04510, and MAG welding were performed to produce test assemblies with butt welds. Specimens for fatigue test were extracted from the welded joints transversely to the weld. The specimen surfaces which were the rolled ones of the plate were not machined.

The fatigue tests were carried out on a 40 kN servo-controlled electro-hydraulic testing machine operating of 25 Hz under constant amplitude of the axial sinusoidal tension-compression load cycling in laboratory air at room temperature. In specimens a fatigue crack was initiated at the toe of weld reinforcement and grew perpendicularly to the plate surface.

The fatigue fracture surface were examined with a scanning electron microscope. The corss-sections of specimens fracture surface running transversely to the start line of main fatigue crack were examined with an optical microscope. Length of lamellar tearings on the

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cross-sections, and their opening on the fracture surface were measured by a workshop microscope.

EXPERIMENTAL RESULTS AND DISCUSSION

The microscopic examination showed many lamellar tearings on the real fatigue fracture area which nucleated on the tip flat elongated non-metallic inclusions (mostly of sulphidic type), on/or being depth up to 0.2 mm from the fracture surface in distance above 0.5 mm from the start line of crack and boundary of final rupture surface, and grew sometimes in tipical cascade form being generally oriented paralelly to the plate surface. Length of these tearing on cross-sections "l" and their opening on the real fatigue surface area "w" vs the stress intensity factor range ΔK are shown in Figs 1 and 2.

It can be seen that this characteristic of lamellar tearings grew with increasing ΔK from about 1 MPa $\sqrt{m}$ to same values, and with further increasing ΔK decreased to zero at the boundary of final rupture surface. Max values of these characteristics as a function of K can be evaluated by the following equation:

$$l_m(w_m) = \frac{c}{a} \exp \frac{(\Delta K-b)^2}{2a^2} + d, \text{ (mm)} \quad \ldots\ldots\ldots (1)$$

where a, b, c, d, are constans. For examined fatigue fracture the constants had the following values:

- for l_m : a=0.398 b=5.342 c=4.369 d=0.267
- for w_m : a=0.467 b=5.372 c=0.225 d=0.011

Relationship l_m vs K, and w_m vs K are given in Figs 1 and 2 by dashed lines.

The lamellar tearings grew not only in the surfaces in which appeared the non-metallic inclusions that nucleated these tearings but passed sometimes on the surface of other near inclusions. The coupling cracks between these lamellar tearings caused sometimes slightly tear fragment of material near the main fracture surface (Figure 3). Presence of the stration pattern on same surfaces of lamellar tearings proves that tearing can be grown as fatigue crack, and proves relation between the lamellar tearings and the growth of main fatigue crack.

No lamellar tearings on the inclusions was found on the final rupture surfaces. This proves additionally that the factor affecting the lamellar tearings was a cyclic triaxial stress state in the plastic zone at the fatigue crack tip.

REFERENCES

(1) Rosochowicz, K., Zeszyty Naukowe Politechniki Gdanskiej, No 403, 1986, pp. 169-180.

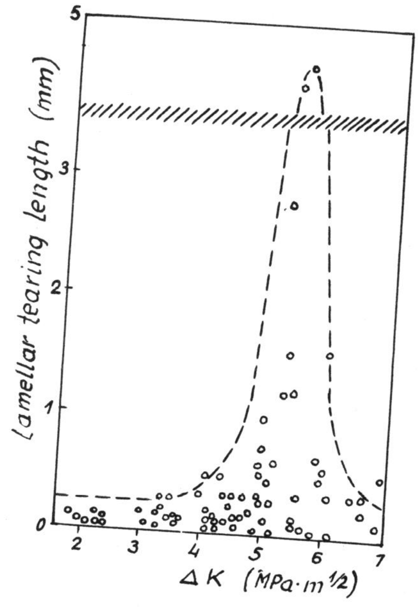

Figure 1. Relationship between lamellar tearing length and stress intensity factor range ΔK

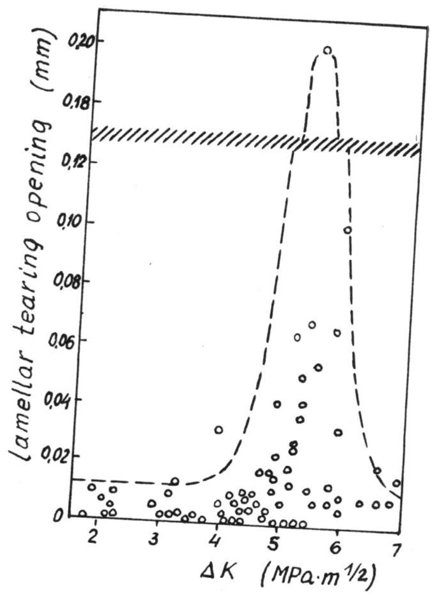

Figure 2. Relationship between lamellar tearing opening and stress intensity factor range ΔK

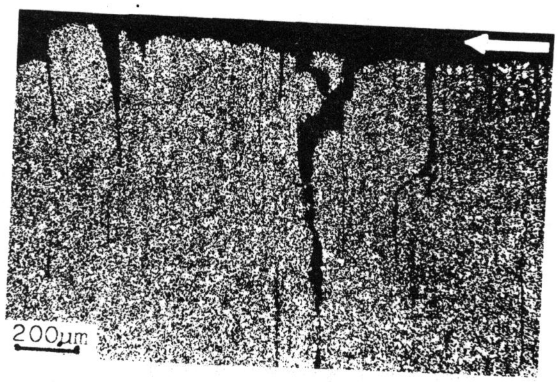

Figure 3. Microsection of real fatigue fracture area on distance about 6 mm from the start line of main fatigue crack. Arrow indicates the direction of crack propagation