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MECHANICAL INTERACTIONS BETWEEN FATIGUE CRACKS AND MICROSTRUCTURAL CONSTITUENTS

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Abstract: *This paper is concentrated on some microstructural issues concerning the mechanical interactions between fatigue cracks and microstructural constituents of an aluminium alloy subjected to fatigue cycles. A diffusion process involving different manganese compounds developed within the immediate area of the fatigue cracks has been also revealed.*
Keywords: *crack, fatigue, microstructural constituent*

1. INTRODUCTION

The present-day fatigue research is concentrated on materials cracks behavior, considering that such cracks are present to some degree in all mechanical structures. They may exist as basic defects in the constituent materials – assimilated to material deficiencies in the form of pre-existing flaws – or they may be induced in a certain engineering structure during the service life. The whole life time of a certain structure subjected to fatigue cycles (or to static loads as well) depends upon the way in which material cracks do propagate until the final failure. In Fig. 1 and Fig. 2 two fatigue crack surfaces have been represented. It is to be noted the direct influence of the fatigue crack propagation on the material grains structures. This is why the fatigue phenomenon gives a great importance to the interaction between the fatigue cracks and the microstructural constituents of the investigated alloy. A direct and an important consequence of such a position is that Miner's linear criterion of damage mechanics loses its validity.
This paper has been focused on the mechanical interaction between fatigue cracks and microstructural constituents of an aluminium alloy (6061 T651) subjected to fatigue cycles.

2. PHYSICAL ASPECTS OF THE MECHANICAL INTERACTION BETWEEN FATIGUE CRACKS AND MECHANICAL STRUCTURE

The analysis of mechanical interaction between the microstructural components of the aluminium alloy Al 6061 T 651 and the fatigue cracks has been done within an original fatigue testing program, using specialized specimens. The specimens material used for the experimental investigations – aluminium alloy 6061 T651 was in form of rolled plates with initial crack (Fig. 3).

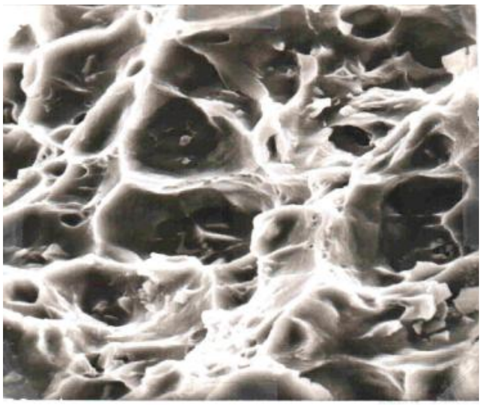


Figure 1: Fatigue crack surface (x3000)

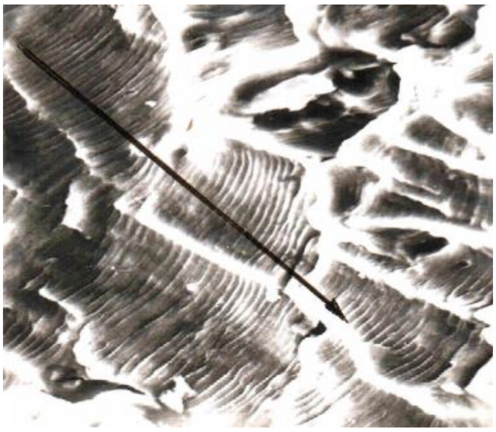


Figure 2: Fatigue crack surface (x2000)

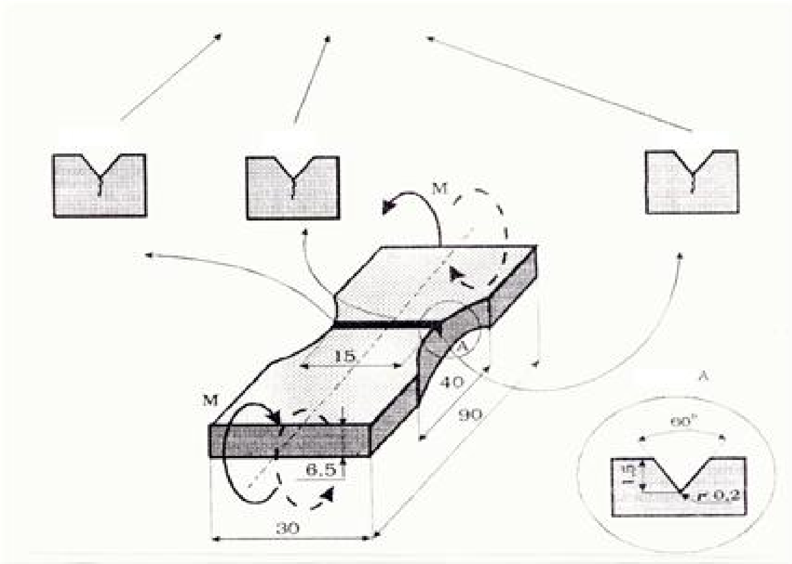


Figure 3: Specimens used within investigations

Figure 4: Microstructure of Al 6061 T651 (x300)

Figure 5: Microstructure of Al 6061 T651 (x300)

In Fig. 4 and Fig. 5 the structures of the considered aluminium alloy, before subjected to fatigue cycles have been represented. In Fig. 6 different types of fatigue cracks interacting the microstructural constituents of the investigated aluminium alloy have been presented. For a small number of fatigue cycles the cracks produced may be very fine and short (~0.04-0.07mm) - propagating along a single direction (Fig.6 a,b) or may be short and rough, with a bifurcation at end (Fig.6c). One may also notice that in Fig. 6a the crack stopped in its interaction with an above presented chemical compound. There are also cracks which are fine but long (0.1-0.3 mm) that usually propagate at the level of inter-granular area, following the grains borders and passing through the fine precipitated compounds or rounding the components.

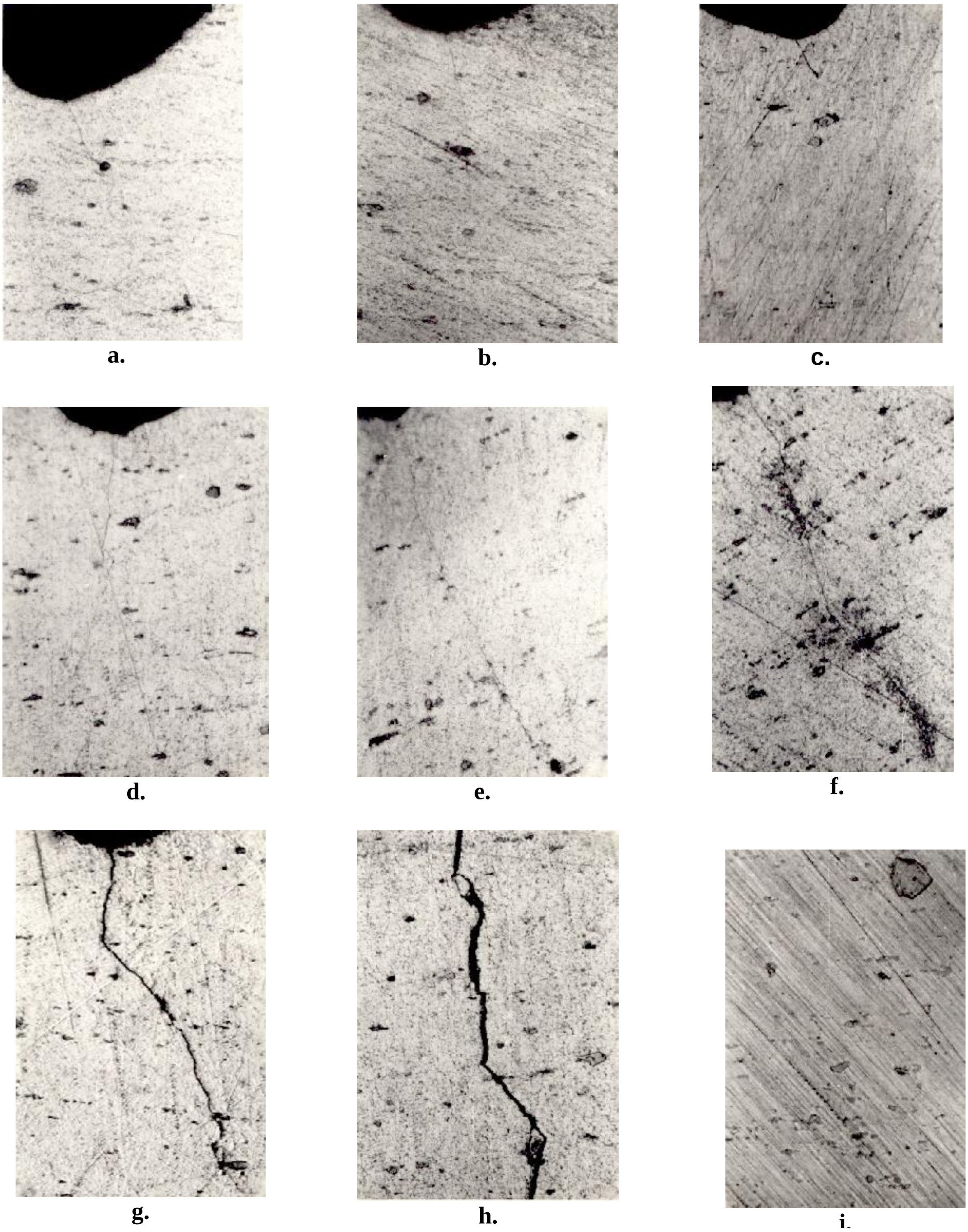
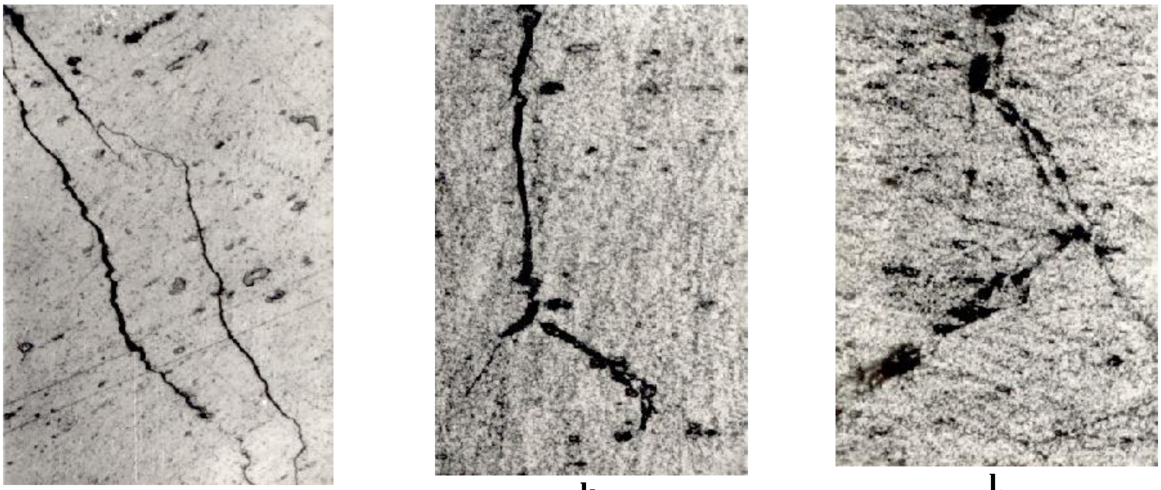


Figure 6: Mechanical interaction between fatigue cracks and microstructural constituents



j. k. l.

Figure 6: Mechanical interaction between fatigue cracks and microstructural constituents (continued)

In Fig. 6d,e,f it is to be noticed that the crack propagated along the direction with an increased chemical unhomogeneity. For a large number of fatigue cycles the cracks are long, thick and linearly propagated (Fig.6 g,h,l) or present short bifurcations when meeting a structural constituent. In Fig. 6h,i,j,k one could observe that the crack does round the chemical compound in form of Chinese letter – identified as being $Fe_3Si_2Al_{12}$ and shown in Fig. 4i. At the same time, different manganese compounds have been observed at the level of the investigated fatigue surfaces that could be the result of a diffusion process involving different one-dimensional faults (interstitial atoms, foreign atoms, second-phase particles etc.) with very important consequences for the fatigue crack propagation and short crack growth (Fig. 6f).

3. CONCLUSIONS

All the above presented aspects concerning the interaction between fatigue cracks and microstructural constituents of the investigated alloy may represent the physical base in creating a mathematical model for fatigue cracks propagation analysis.

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