IN-SITU OBSERVATION OF FATIGUE CRACK GROWTH IN CARBON STEEL

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Summary In this paper authors present results of their observation of crack development under cycling loading, using optical microscope. All measurements were made for ferritic/pearlitic carbon steel. This observation can help to clearly understand processes of cracking in multi-phases materials.

INTRODUCTION

One of the main features associated with small fatigue crack growth is that they frequently exhibit deceleration when they approach microstructural barriers such as grain boundaries. In-situ observation of crack propagation can give interesting information about crack development in multi-phases materials, especially when each phase has different mechanical and morphological properties [1,2].

MATERIAL AND EXPERIMENTAL PROCEDURE

For measurements it was chosen ferritic/pearlitic carbon steel (0.45% of carbon). Material had microstructure with higher volume fraction of pearlite (Fig. 2). Metallographic observation and stereological analyses confirmed that grains were rather equiaxial. Rectangle specimens of cross section 2.1mm thickness and 5.5mm width were used for testing. As optical observation device was used standard metallographic microscope, equipped with CCD camera connected to digital acquisition system. Digital acquisition was employed to precise measurement of crack length. Initial crack length was 1,2 mm. What is showed in Fig 1. Such prepared specimen was mounted into testing machine holders (Fig.4).

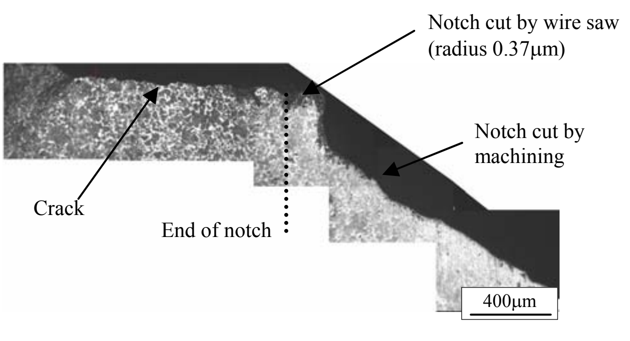

Fig. 1. Cross-section of specimen with notch and crack.

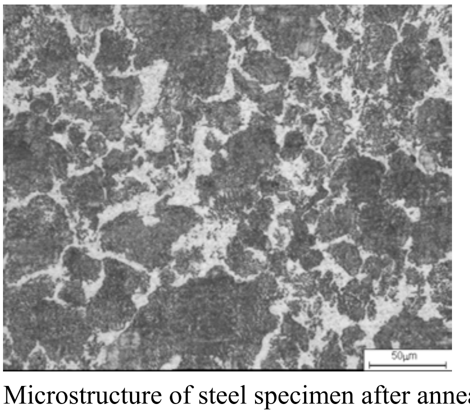

Fig. 2. Microstructure of steel specimen after annealing.

Cycling loads were forced by MTS hydraulic actuator connected to PC station which controlled force, displacement of actuator. It was also used as a data acquisition device. Whole frame was made in horizontal arrangement in order to easier mount standard metallographic microscope. As a feedback signal mini-extensometer was applied. It was attached to the specimen on notch side. Main experimental devices are presented in Fig. 3.

RESULTS AND DISCUSSION

For the material several crack inhibitory mechanisms were observed during experiments. Crack growth rate was slower when crack tip reached grains boundary as well as between pearlite-pearlite and ferrite-pearlite. In same cases cracks changed their direction because of crack- grain boundary interrelation (Fig. 5).

Main mechanism which caused limitation of crack propagation rate was plastic deformation on a crack tip. Process of plastic deformation was more intensive in ferrite grains than in pearlite. It is related to the lower yield strength of ferrite. After several hundreds of loading cycles as a result of strain haredning process in ferrite grains, crack started propagating farther. In figures below it is shown changing of crack propagation rate in areas of different phases in carbon steel specimens.

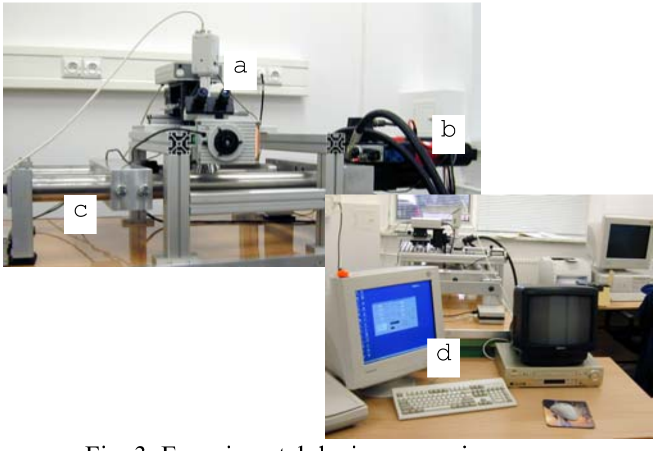

Fig .3. Experimental devices; a - microscope,
b – actuator, c – frame, d – image acquisition system

Fig. 4. Specimen in holders during observation.

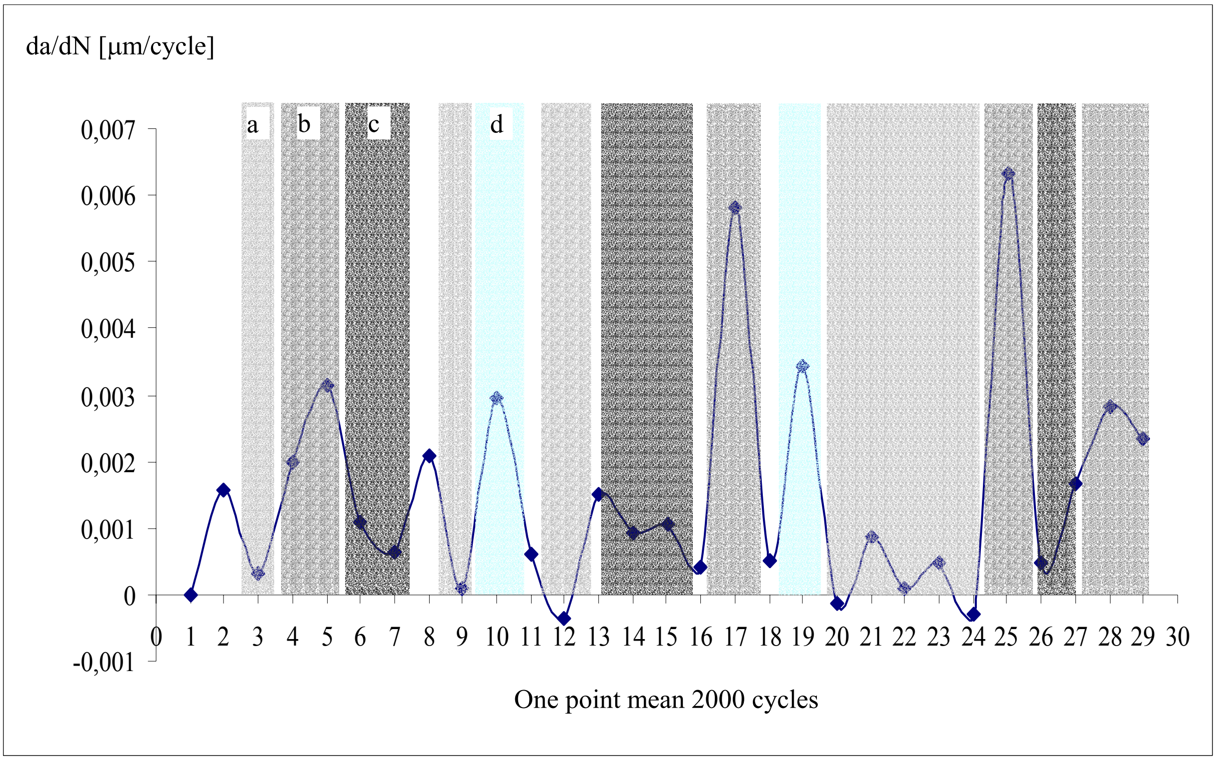

Fig. 5. Crack growth rate in different structure areas for short crack; a – area of ferrite, b – area of pearlite, c – area of grain boundaries perpendicular to crack line, d – areas of grain boundaries parallel to crack line.

CONCLUSION

Used technique gives opportunity to see closer mechanisms of crack propagation as a local process with relation to the materials structure.

ACKNOWLEDGEMENT

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