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20 KHZ CRACK GROWTH RATE TESTING IN ADVANCED HIGH STRENGTH TOOL STEELS

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Abstract

High nitrogen chromium alloyed PM tool steels display, among other attractive properties, high strength and improved corrosion resistance. Also, powder metallurgy is a manufacturing process that allows the fabrication of near net shape complex geometries and high quality components in an economical way. Nitrogen acts in an effective way replacing the carbon by the formation of hard carbonitride phases and permits higher amounts of chromium in solid solution. The low carbon and high nitrogen contents, where most of the carbon is replaced by nitrogen, suppresses the formation of metal carbides is in favor of the formation of metal nitrides (MX) and carbonitrides (M_2X) allowing a higher nominal amount of chromium in solid solution. As a result of the PM rout well dispersed and fine distribution of nitrides and carbonitrides is created in a martensitic matrix. The microstructure obtained controls the mechanical properties of the steel grade, and a balance of high strength and high toughness is required [1, 2]. In the present study the influence of the nitride and carbonitride distributions on the fatigue properties, and in particular the stress intensity threshold and the early crack growth, was investigated using a 20 kHz ultrasound test equipment.

1. Introduction

The Cr-Mo-V-N alloy used in this work was produced from gas atomized powder, through the high isostatic pressure (HIP) route followed by hot forged material. Powders were subjected to a nitriding process, and at the HIP process a pressure of 150 MPa was applied at 1150°C, and finally the forging took place at 1130°C with an area of reduction at least of 50%. The heat treatment cycles included heating at 1080°C for 30 min, then deep cooling in liquid nitrogen for the retained austenite content to be reduced, and finally tempering at 200°C for two passes of 2h. The nominal chemical composition is illustrated in Table 1.

Table 1- Chemical composition of the studied alloy (wt. %)

Fe	C	N	Si	Mn	Cr	Mo	V
Bal.	0.36	1.55	0.30	0.30	18.2	1.10	3.50

The microstructure consists of dark grey (vanadium rich nitrides, MX) and light grey (chromium rich carbides, M_2X) particles, Fig. 1, The volume fractions were calculated as 6% and 5%, respectively.

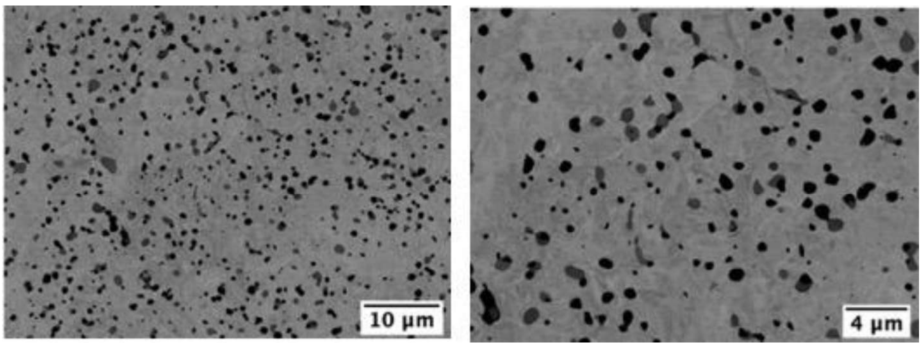

Fig.1 –SEM images of the microstructure; nitride (MX) in dark grey and carbonitride (M_2X) in light colours.

2. Results

The fatigue crack growth was experimentally measured using the 20 kHz ultrasonic fatigue testing system shown schematically in Fig. 2a. The shape of the specimen, test setup and testing procedure are simulated using dynamic FEM simulations for a series of crack lengths. The simulation gives the stress intensity factor for a growing crack by relating the displacement amplitudes to the stress amplitude. Input parameters for the simulation are the E-modulus and shape of the constituent parts.

The testing is displacement controlled and starts at a relatively high load to initiate a crack, and then incrementally (increments of either 0.25mm crack growth or 10^7 cycles, whichever occurs first) decreased until crack growth halts, i.e. reaching the threshold value. After the threshold value is reached, the procedure is reversed and the load is incrementally increased until final failure, see Fig.2b. The crack growth is monitored using a camera system [3].

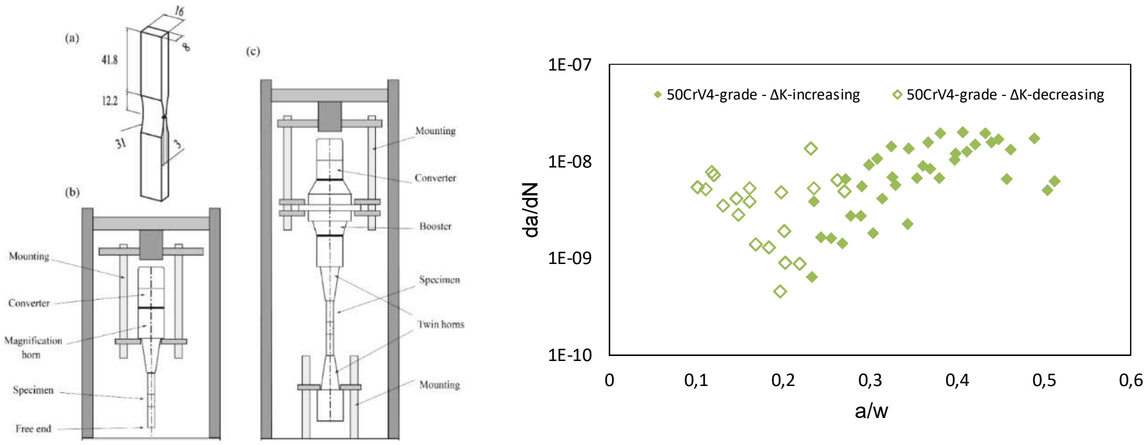

Fig.2 – (a) Geometry of the 20 kHz uniaxial crack growth specimen, and schematic illustrations of the test isetup, and (b) Crack growth results from testing on a high strength tempered martensitic steel.

Subsequent to the crack growth testing the specimen's two fractured halves were studied in a scanning electron microscope for crack growth mechanisms. As well, sections of the crack tip was produced to follow the crack path and its interaction with the microstructure.

3. Conclusions

The 20 kHz crack growth test system proved to work satisfactorily. Working with a high strength and low fracture energy cold-work tool steel was difficult and several test specimens were wasted due to fast fracture.

Acknowledgements
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