SEM STUDY OF CRACK INITIATION AND PROPAGATION IN HIGH SPEED STEEL

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The 20 to 720^{0}C crack initiation and propagation behaviour of a wrought M2 type HSS, heat treated to maximum hardness, has been studied by means of SEM. Void and/or crack nucleation occurs by interface decohesion of carbides, carbides cracking and cavitation at the former austenite grain boundaries. Some stable void growth may take place before void coalescence. Void coalescence by void-impingment and void-sheet formation occurs concurently with crack growth by linking of voids and/or cracked carbides by quasi-cleavage fracture through the matrix and along prior austenite and carbide/matrix boundaries. Intergranular crack growth is more pronounced above 550^{0}C. Numerous carbides are on, or near, the grain boundaries, but a grain boundary impurity embrittelment agent is not to be excluded.

INTRODUCTION

High speed steels are macroscopically brittle (1), but the micromechanism does not have to be necessarily brittle (2). The available experimental evidence is not always conclusive in regard to the role played by dimpled rupture. While some evidence of voids (3,4) and void coalecence (4) is reported, the crack initiation and propagation is usually associated with brittle micromechanisms (1,3,4). The purpose of the present paper is to report some results on the role of dimpled rupture in fracturing HSS.

EXPERIMENTAL

A wrought M2 type HSS (4.31Cr, 4.74Mo, 6.10W, 1.90V), supplied by Steel Work, Nikšić, Yugoslavia, is heat treated to maximum hardness before being tested in tension at 20 to 720^{0}C, or by impact loading. Fractured as well as polished and etched surfaces are examined in a SEM.

RESULTS

The fractured surfaces revealed, in addition to numerous carbides and quasi-cleavage facets, two distinct population of voids (Figs. 1 to 3).

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The first type, in the form of deep cavities (Figs. 1 and 2), is associated with residual primary carbides debounded from the matrix (denoted by C1). The second type in the form of fine voids (Fig. 3), is associated with secondary carbides. Deep voids range from approximately the same size as the corresponding carbides (V1), to a size which seems to be limited by impingment of neighbouring voids (V2). In contrast to this, some voids are separated by quasi-cleavage facets (QC). A number of carbides remain bound to the matrix (C2), and among them the larger ones are cleaved (C3). The polished and etched surface revealed a number of small cavities at austenite grain boundaries, which apparently bear no relation to the carbides (Fig. 4). Samples tested at elevated temperatures revealed no important differences except that above 550°C a pronounced intergranular cracking (Fig. 5), in addition to transgranular cracking (Fig. 6), is observed.

DISCUSSION

The room temperature as well as the elevated temperature crack nucleation process is dominated by interface decohesion of both grain boundary carbides and carbides within the former austenite grains, leading to voids formation, while carbide cracking is less frequently encountered in the present steel. Some carbides are, however, neither debounded from the matrix nor cracked. Stable void growth before void coalescence does not seem to be completely suppresed, at least locally, in spite of this steel exibits very low macroscopic ductility. Void coalescence by void-impingment, as revealed by closely spaced equiaxed voids, and void-sheet formation, as revealed by two distinct void size popilations, seems to occur concurently with the crack growth by linking of voids and /or cracked carbides via quasi-cleavage fracturing through the matrix or along prior austenite and carbide/matrix boundaries. The intergranular cracking is more pronounced above 550°C. Numerous carbides are on, or near, the grain boundaries thus providing a continuous low-energy fracture path for crack growth but a contribution from grain boundary embrittelment agent is not to be excluded.

CONCLUSION

In addition to brittle micromechanism, usualy encountered in fracturing the high speed steels, some basicaly ductile micromechanisms, such as void nucleation by carbides debonding, stable void growth, and void coalescence by void-impingment and void-sheet formation, may play an important role.

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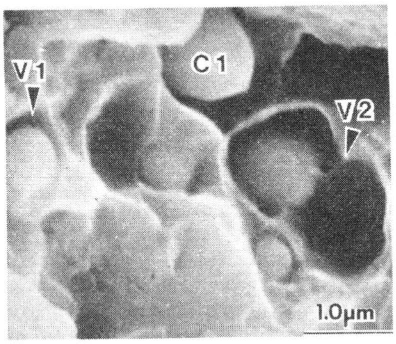

Fig. 1 - SEM fractograph; impact test at 20°C.

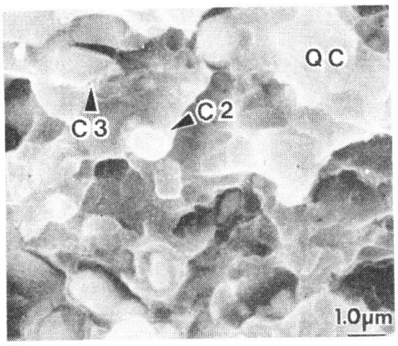

Fig. 2 - SEM fractograph; imact test at 20°C.

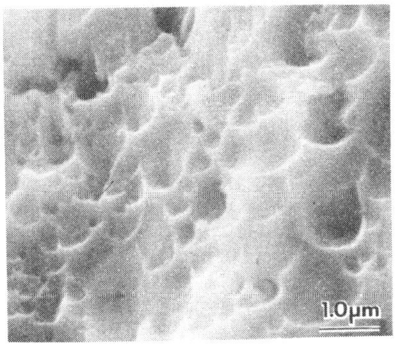

Fig. 3 - SEM fractograph; impact test at 20°C.

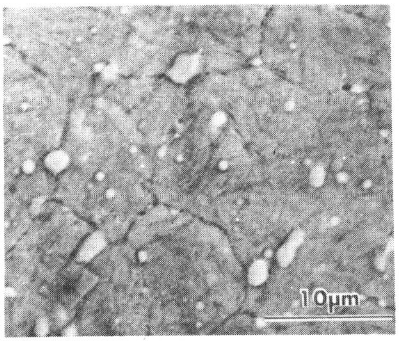

Fig. 4 - SEM micrograph; tensile test at 360°C.

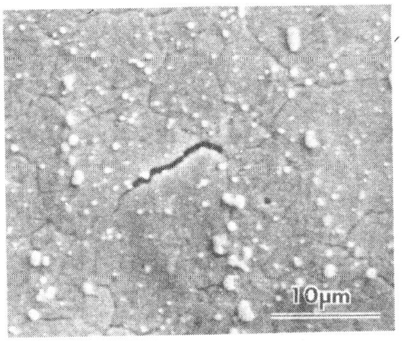

Fig. 5 - SEM micrograph; tensile test at 550°C.

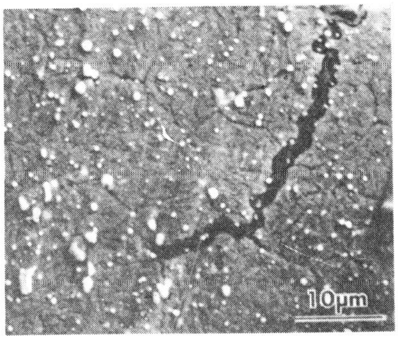

Fig. 6 - SEM micrograph; tensile test at 650°C.