Mech. Engg. Res. Bull.
Vol. 11,(1988), PP. 14 - 17

Microstructural Variations in Electron Transparent Areas of a Rapidly Solidified High Speed Tool Steel

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ABSTRACT

T1 high speed steel (having C = 0.76%, W = 17.8%, Cr = 3.81% and V=0.98%) has been rapidly solidified by the two-piston technique. Thin areas (which are transparent to electron beam) of rapidly solidified splats have been examined by transmission electron microscopy. The microstructure indicates that solidification occurs in the plane of the splat surface and not perpendicular to it. These areas are found to contain d-ferrite, austenite and martensite. d - ferrite areas are mainly observed with segregation of carbide along dendritic boundaries. The areas which are solidified without segregation of carbide are found to decompose spinodally at room temperature. Austenite is observed either free from segregation or with segregation of carbide along cell boundaries. The areas where the segregation of carbide is more are found as martensite at room temperature.

INTRODUCTION

Rapid solidification has been a field of vigorous research activity in recent years, where molten metal is directly quenched in contact with a solid substrate. Very high cooling rate can be achieved if a very thin layer of molten metal is brought in a good contact with the substrate (1). The areas of a rapidly solidified splat which are transparent to electron beam, being extremely thin, have been considered to have cooled fastest in gun technique (2). It has been postulated that the direction of heat flow is towards the nearest contact point on the substrate and that heat extraction and hence solidification takes place in the plane of the splat/substrate interface(3). Varieties of microstructures have been reported (4) in the electron transparent areas depending on the variations of alloy compositions. Depending on the variation in solidification condition it might be expected to observe microstructural variations in electron transparent areas. The present investigation is an attempt to investigate the variations in microstructure at different places in the electron transparent areas on the same material (T1 high speed tool steel) due to variation in cooling condition.

EXPERIMENTAL METHOD

Splats of T1 high speed steel were produced from molten droplets heated to around 2800^{0}C by the two-piston technique described elsewhere(5). Electron transparent areas were observed near the edge of the splats. Those areas were examined by transmission electron microscopy at an operating voltage of 100 KV.

EXPERIMENTAL RESULTS

Fig.1(a) shows an electron trans-parent area containing all d -ferrite dendrites. Fig. 1(b) is a micrograph from the above area at higher magnification showing precipitation of carbide at the inter dendritic boundaries. This microstructure is similar to that of d-ferrite dendrites obser-

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ved by Sare and Honeycombe(6) in electron transparent area of rapidly solidified M1 high speed steel. 'A' on the micrograph (Fig.1(b))represents the centre of nucleation, at which the solid phase first nucleated and grew in the plane of the splat, indicating that heat extraction had taken place in that plane. The centres of nucleation of d-ferrite dendrites in Fig. 1(a) are very close (~1.5 µm) to each other and the cellular arm spacing is found to be ~0.15 µm. Only in a few areas d-ferrite was found without any precipitation of carbide and those areas are observed to decompose spinodally (Fig.2) giving rise to streaks on the electron diffraction pattern. Fig. 3 shows another electron transparent area containing all austenite grains. These grains are also found to grow in the plane of the splat. The microstructure indicates that the austenite grains growing from both sides meet at a common line. Initially the austenite grains grow without any precipitation of carbide and selected area diffraction patterns from those areas do not show any spot from a second phase, but towards the end of solidification a cellular structure is apparent with linear arrays of precipitates in the cell boundaries.

In some electron transparent areas twinned martensite was observed (Fig.4). These areas are found to contain large

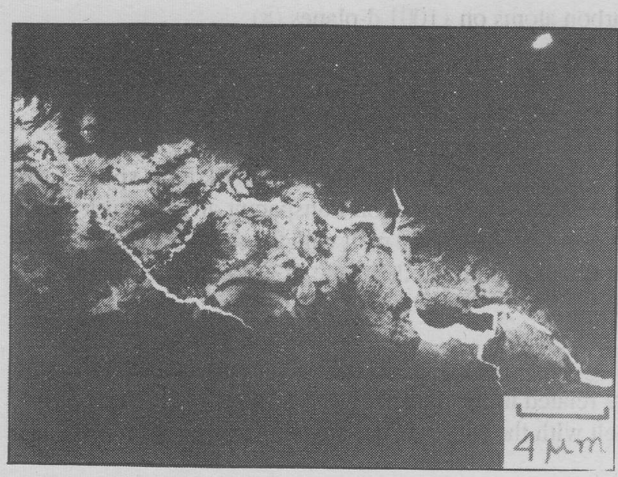

Fig.1(a) Transmission electron micrograph having all d-ferrite dendrites.

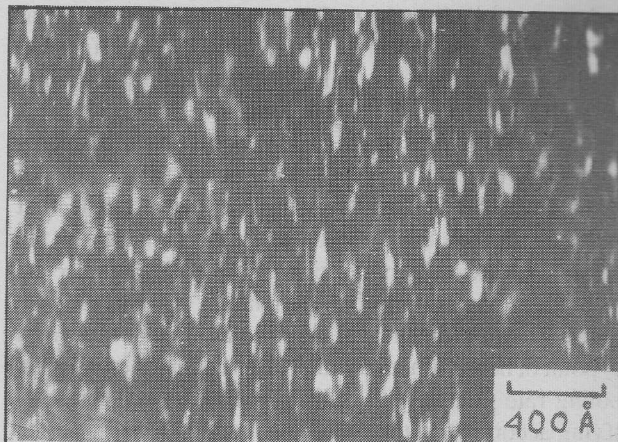

Fig. 2 Transmission electron micrograph containing d-ferrite which apears to have decomposed spinodally.

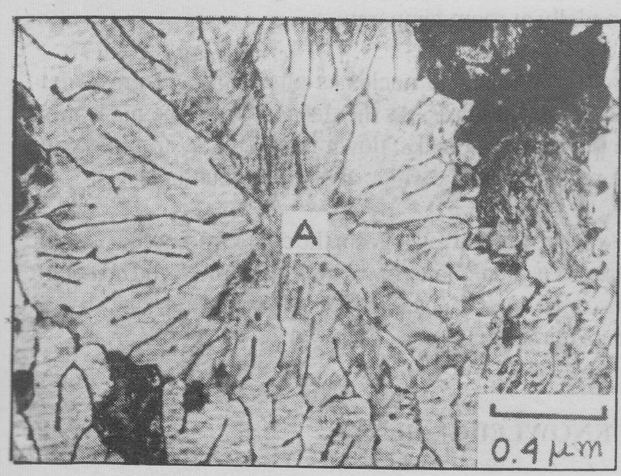

Fig. 1(b) Micrograph from the above area at higher magnification showing precipitation of carbide at the interdendritic boundaries.

Fig. 3 Transmission electron micrograph having all austenite grains.

number of coarse particles. Electron diffraction showed that those particles are M_6C carbide. Those areas initially solidified as austenite with segregation of M_6C carbide and transformed to twinned martensite at ambient temperature.

DISCUSSION

It has been shown previously(7) that in rapid solidification of T1 high speed steel, solidification starts with the nucleation of d-ferrite at those points in direct contact with the substrate. Austenite then nucleates on ferrite as a results of changing thermal conditions or of solute rejection and build-up at the solid/liquid interface. Austenite then grew as a primary phase of solidification. If the points of contact with the substrate (i.e. the centres of nuclei) are very close the melt may completely solidify as d-ferrite before the austenite could nucleate (Fig. 1(a)). On the other hand Fig.3 is found to contain only austenite grains. The micrograph indicates that the nucleation sites are outside this transparent area. Comparing this micrograph with the microstructure of the outer surface layer of the thicker region of splat(7) suggests that d-ferrite first nucleated (outside this transparent area) in contact with the substrate followed by nucleation of austenite. Initially the austenite grows as partitionless, without any carbide precipitation. As the distance of the solid/liquid interface from the point of heat extraction (nucleation centre) increases the cooling rate gradually decreases and austenite starts solidifying according to the following reaction :

LÆ g + M_6C

Starting from a segregation free area the amount of carbide precipitation will gradually increase and the

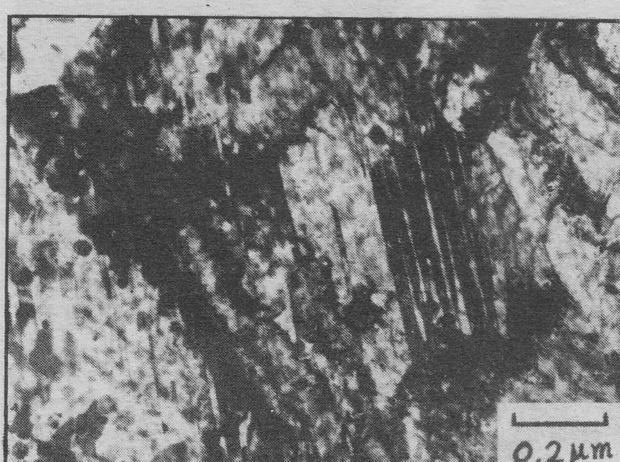

Fig. 4 Transmission electron micrograph having twined martensite.

austenite will be less and less superstaturated as the cooling rate decreases with the increase in distance from the nucleation site. With the lower supersaturation the M_s temperature of austenite increases (above room temperature) resulting transformation to martensite. The austenite which solidifies without precipitation or only with a few precipitates along cell boundaries is highly supersaturated with the alloying elements and has M_s temperature below room temperature. So transformation to martensite does not take place.

Partitionless growth of d-ferrite is very difficult to achieve (7), but where it does occur the modulated structure within the matrix may arise from clustering of carbon atoms on {100} d-planes (8).

CONCLUSION

1. In rapid solidification of T1 high speed steel nucleation in the electron transparent areas occurs at the points of contact of the melt with the substrate and solidification takes place in the plane of the splat/substrate interface.

2. The different types of microstructures observed are related to the distance from the point of contact of the melt with the substrate as follows :

a. At the point of contact d-ferrite nucleates and grows in the plane of the splat with segregation of carbide at interdendritic boundaries. If d-ferrite forms as partitionless due to extremely high cooling rates it decomposes spinodally at room temperature.

b. Austenite nucleates on ferrite and grows initially as partitionless. As the distance from the nucleation site increases it breaks down into cellular structure with fine precipitates of carbide at cellular boundaries.

c. Further away from the contact point (nucleation site) coarse precipitates of carbide are formed and austenite transforms to martensite at room temperature due to less supersaturation.

ACKNOWLEDGEMENTS

M. N. H. is grateful to the ACU, U. K. for a commonwealth scholarship and to the BUET authority for granting study leave over the period in which this research was done. The authors also wish to thank Dr. J. A. Whiteman for his interest and help in the electron microscopy.

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