The influence of primary precipitates on the tensile strength of unidirectionally solidified \((\text{Fe, Cr})-(\text{Cr, Fe})_7\text{C}_3\) in-situ grown composites containing 30 wt % Cr

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The influence is investigated of metal dendrites and primary carbide needles on the tensile strength of the \((\text{Fe, Cr})-(\text{Cr, Fe})_7\text{C}_3\) in-situ grown composite containing 30 wt % Cr. It is found that these irregularities in the aligned structure diminish the tensile strength of the in-situ composite both at room temperature and at 900°C. The maxima in the tensile strength versus composition curves occur at different compositions for these temperatures. A possible explanation of this behaviour is given.

1. Introduction

Faults in in-situ grown composites, such as grain boundaries, banding and primary precipitates, can have a pronounced effect on the strength properties. These faults may induce fractures due to inhomogeneous distribution of the solid phases, misalignment of primary precipitates, absence of one of the phases in the bands etc.

In this paper the results are reported of an investigation into the influence of primary precipitates on the tensile strength of the in-situ grown \((\text{Fe, Cr})-(\text{Cr, Fe})_7\text{C}_3\) composite. This composite consists of hexagonal \((\text{Cr, Fe})_7\text{C}_3\) rods, with the rod axes parallel to the crystallographic c-axis, in a \(\gamma\) (fcc) or an \(\alpha\) (bcc) matrix of Fe and Cr.

In the ternary Fe-Cr-C system a whole curve exists, giving the compositions of samples, exhibiting aligned eutectic structures after unidirectional solidification in steady state conditions (curve AB in Fig. 1). Samples with composition B exhibit the smallest diameter of the carbide rods, when compared with similarly prepared samples on AB. They also show a high, reproducible tensile strength [1]. Therefore bars with compositions close to B were selected for an investigation of the influence of metal dendrites and primary carbide needles on the tensile strength of the composite.

2. Experimental

Bars of composition \((70-x)\) wt % Fe 30 wt % Cr and \(x\) wt % C were prepared by unidirectional solidification at a rate of 30 cm h\(^{-1}\), using the floating zone technique in an atmosphere of H\(_2\). The purity of the starting materials was the same as that described earlier [1]. The carbon content \(x\) was varied from 2.7 to 3.3 wt %, the limiting values being given by the points C and D in Fig. 1. B corresponds to \(~2.9\) wt % carbon.

The tensile strengths of the bars were measured both at room temperature and at 900°C using a method which will be described in a forthcoming paper [2].
3. Results

The results obtained for the dependence of the tensile strength on the composition at both temperatures are given in Tables I and II, and are plotted in Fig. 2 and on a normalized scale in Fig. 3. Figs. 4, 5 and 6 show micrographs of the longitudinal sections in the neighbourhood of the fracture surface for bars containing 2.8, 2.9 and 3.0 wt % C respectively. These show the presence of metal dendrites (Fig. 4), the absence of primary phases (Fig. 5) and the presence of primary carbide rods (Fig. 6). In Fig. 4 it can be seen that a crack has started at a surface in which a metal dendrite is present and Fig. 6 shows that primary carbide rods act as starting points for cracks.

The carbide rods in the samples with regular structures are several hundred microns long and the average thickness is \( \approx 2 \mu m \).

Both types of primary phases decrease the tensile strength of the material (Fig. 4). From the normalized curves in Fig. 3 it is evident that the influence of the primary phases is different at both temperatures. The maximum value of the tensile strength versus the C content at room temperature is found at 2.92 \( \pm 0.03 \) wt % C whereas at 900°C it is situated at 3.04 \( \pm 0.03 \) wt % C.

4. Discussion

4.1. The influence of growth rate and temperature gradient