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TEXTURE DEVELOPMENT IN HOT-ROLLED 8090 ALUMINIUM ALLOY-SIC METAL-MATRIX COMPOSITES

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INTRODUCTION

Aluminium alloy based metal-matrix composites (MMC) offer an excellent opportunity to study the effect of second phase particles on texture development, since control can be exercised on both the size and volume fraction of the particulate second phase. In this paper some results from the initial phase of such an investigation will be reported to illustrate the effect of volume fraction of 3μm SiC particles on texture development in 8090 Al-Li MMC's. A secondary point will be to stress the need to bear in mind the interference between SiC and matrix reflections during pole figure measurements.

EXPERIMENTAL

The composites were prepared by BP International by the mixing and blending of the 8090 alloy and SiC powders, followed by canning, vacuum de-gassing and consolidation by HIPing and then hot rolling at the Royal Aerospace Establishment to plate and sheet. Samples of the composites containing 0, 2.5, 5, 6.7, 7.5, 10, 15 and 20 wt% of 3μm SiC particles were sectioned to mid-thickness for X-ray diffraction and texture analysis. Incomplete (maximum tilt=85°) (111), (200), (220) and (311) pole figures from the aluminium matrix were then processed using the series expansion method to produce three-dimensional orientation distribution functions (ODF)[1]. The degree of texture in the SiC particles was also measured.

RESULTS

Diffractograms. The presence of SiC particles in the 8090 alloy introduces the problem of possible overlap between reflections from the SiC and those of the matrix. This is most noticeable with the (111) reflection, so much so that the (111) pole figure for an aluminium alloy MMC containing SiC will always be a combined matrix-particle figure, although the magnitude will depend on volume fraction. The effect this has on the pole figure will be shown below. Note that the other matrix reflections are not so markedly affected.

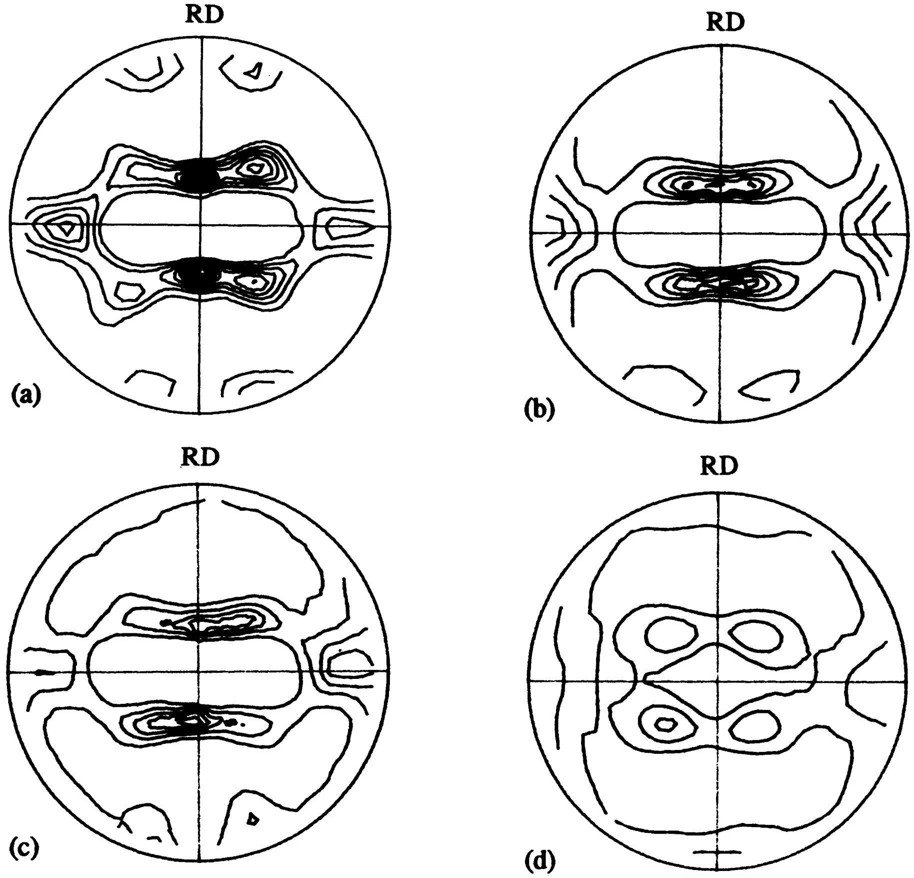
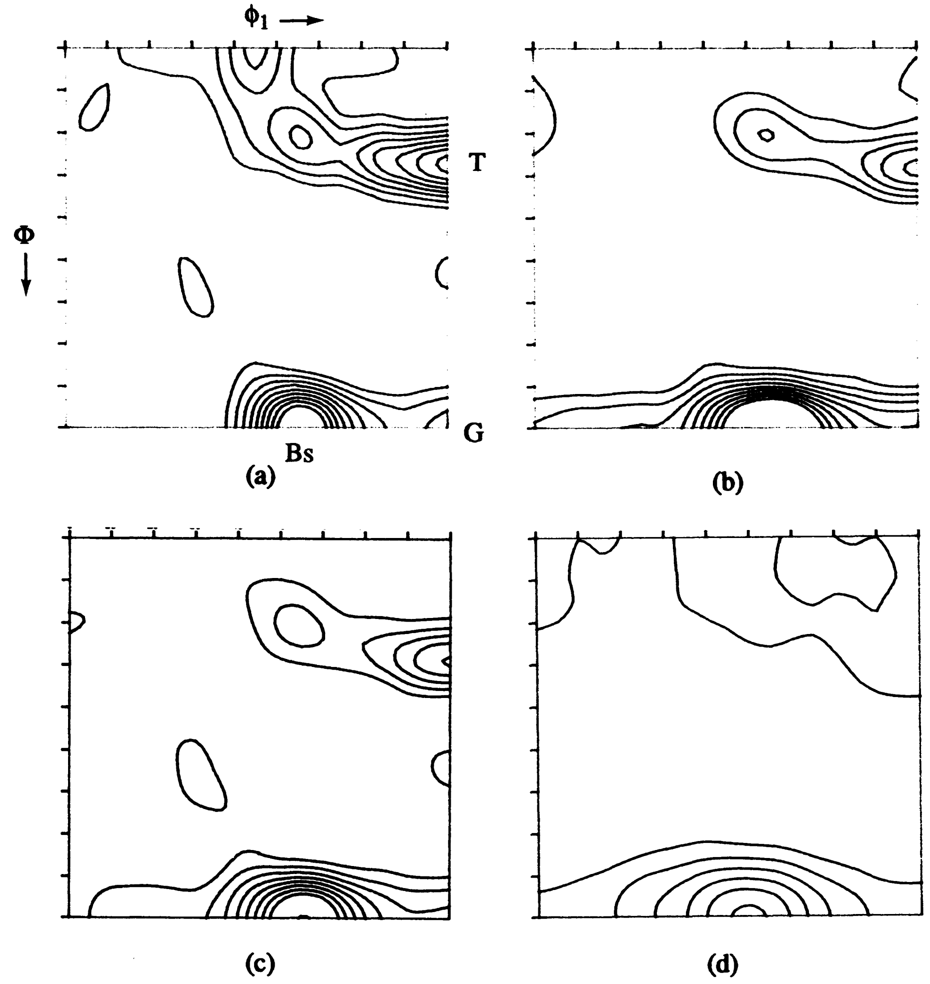


Figure 1. Experimental (111) pole figures for the 8090 alloy matrix with (a) 0%SiC, (b) 2.5%SiC, (c) 6.7%SiC and (d) 20%SiC particles. Contours: 1,1.5,2,2.5,3 etc (xrandom). RD=Rolling Direction.

Pole figures. All pole figures for both the 8090 and 8090+SiC billets showed no preferred orientation. Thus the starting conditions were essentially random. Pole figures for the rolled plate and sheet showed that the initially strong deformation texture in the absence of particles (Figure 1a) decreased in intensity with increasing volume fraction (Figures 1b-d). Pole figures for SiC reflections free from matrix interference showed that the SiC did not develop any noticeable preferred orientation during rolling.

ODF analysis. This showed the following:

- in all cases the texture consisted essentially of the β-fibre texture going from the {110}<112> (Brass) to the {4,4,11}<8,8,11> (Taylor) deformation textures (Figures 2a-d and Figure 3a) (with some {110}<001> (Goss) recrystallisation texture in the absence of SiC particles, in agreement with ingot-made 8090 alloys[2]).
- all of these components decreased in intensity with increasing volume fraction of SiC. This decrease was fairly uniform along the β-fibre texture (Figure 3a).



(a) (b) (c) (d)

Figure 2. ϕ_2=45° sections through the ODF for the 8090 alloy matrix with (a) 0%SiC, (b) 2.5%SiC, (c) 6.7%SiC and (d) 20%SiC particles. Contours: 1,1.5,2,2.5,3 etc (xrandom).

- the gradient in texture, which is very marked in ingot-made[2] 8090, is much reduced in the MMC's (Figure 3 b).
- the texture sharpness[1] (J) decreased quite rapidly up to ~5%SiC but thereafter the decrease was more gradual (solid line, Figure 4).

From the ODF coefficients it was possible to reconstruct theoretical (111) pole figures, which, when compared with experimental ones, illustrate the effect of superimposed SiC and matrix (111) reflections. The contribution of the SiC reflection, since it is not textured, makes a constant contribution to the intensity of the (111) reflection, but relative to the intensity of the (111) reflection the contribution will vary and be most noticeable where the (111) reflection is weakest ie the effect will be seen in the tails of peaks and in the background of the experimental (111) pole figure.

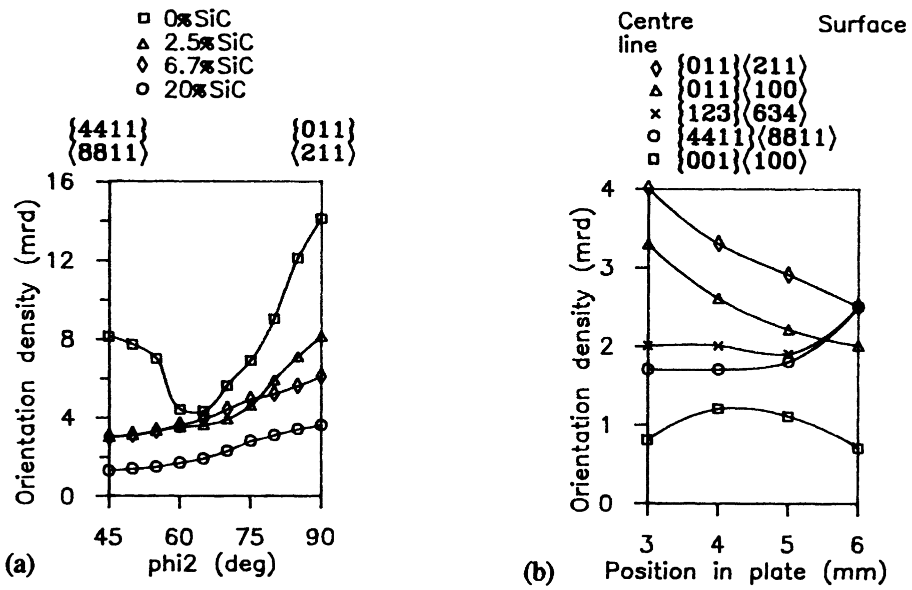


Figure 3. Texture density (a) along the β-fibre texture at mid-thickness as a function of wt% SiC in the 8090 alloy matrix, and (b) as a function of position in the 5mm thick plate of the 8090 alloy matrix containing 5%SiC.

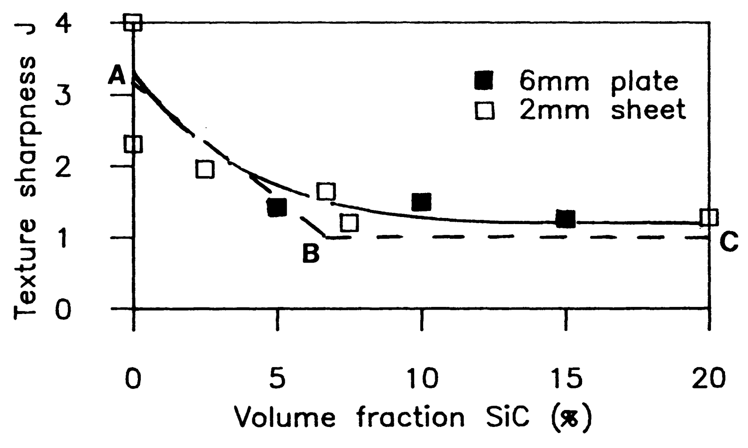


Figure 4. Texture sharpness, J, for 8090 alloy metal-matrix composites.

DISCUSSION

The addition of SiC particles to the 8090 Al-Li alloy in order to produce an MMC clearly reduces the texture intensity in the alloy matrix. Moreover, the effect is marked at values below about 5%SiC but becomes more moderate at larger volume fractions. Only isolated reports of similar effects can be found in the literature (mainly on alloys containing low volume fractions of hard non-deformable particles, see eg refs 3 and 4), but it is possible

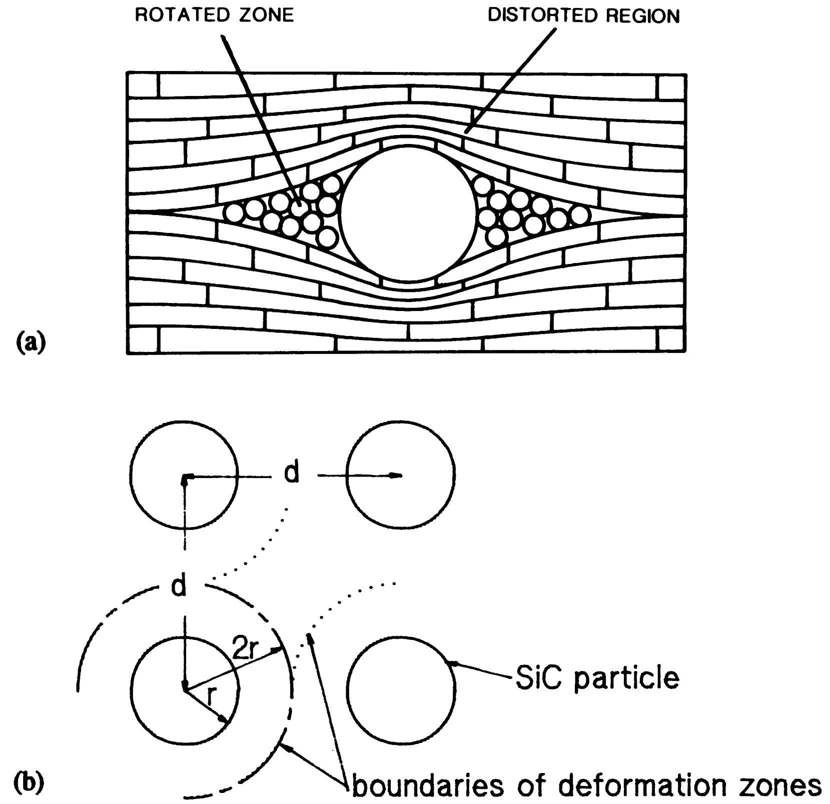


Figure 5. Schematic representation of (a) structure around a non-deformable particle after deformation, and (b) idealised particle distribution showing effective volume of deformation zone and condition for zone impingement.

to draw upon this work in order to explain, at least qualitatively, the trend in Figure 4.

It has been shown, by Humphreys[5] amongst others, that the effect of hard particles is to alter the texture locally since the matrix deforms in the immediate vicinity of the particle to relieve the strain induced by particle rotation. One such model[6] (Figure 5a) shows that after deformation this local relief produces two distinct zones: a rotated zone (where rotations probably exceed 15°) and a more long-range distorted region (where rotations are probably less than 15°). If we assume a regular array of particles on a cubic lattice with particles of radius r, spacing d and effective deformation zone radius 2r (Figure 5b), then these deformation zones will impinge when d=4r and the volume fraction (V_f) of particles is ~6.5%. Whilst there is still uncertainty about the precise textures in these deformation zones (macro-texture (pole figure) results indicate weak or random textures but micro-texture results indicate a spread about the rolling texture in certain crystallographic directions but with a net weakening in the overall texture[7]) it is likely that above V_f~6-7% the texture will be almost random because there will be very little "free" matrix available (ie matrix free to deform independently of a particle).

For a constant particle size and at strains of the order of 1.5 needed to produce these plates and sheets, one could then predict that as the volume fraction of particles is increased, the texture sharpness (represented here by J) would decrease linearly with increasing number of particles up to ~6-7%, and thereafter show little change because of deformation zone impingement. Such a prediction agrees very well with the trend shown in Figure 4, where it could be argued that the results are, in fact, composed of two regions: a linear decrease in texture sharpness (dotted line AB), followed by a constant sharpness (dotted line BC) where the texture is almost random (J=1).

Whilst this explanation lacks much experimental data, work currently underway should permit a more quantitative explanation and answer queries such as:

- what is the effect of particle size (small particles may increase texture intensity[4,8])?
- is the curvature observed experimentally in Figure 4 due to the two-region deformation zone shown in Figure 5a?
- what are the interactions between deformation zones, from the same and adjacent particles?
- what is the texture development in the deformation zone?

CONCLUSIONS

1. Increasing volume fraction of 3μm SiC particles progressively reduces the texture intensity of the matrix in 8090 aluminium alloy MMC's, and reduces the severity of texture gradients.
2. The reduction in texture intensity, which can be predicted qualitatively assuming a deformation zone radius twice that of the particles, is linear with increasing volume fraction up to ~7%SiC. Thereafter, texture intensity is effectively constant because of deformation zone impingement.
3. The close proximity of SiC and (111) aluminium reflections means that caution must be exercised in the interpretation of these pole figures.

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