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EFFECT OF MICROSTRUCTURE AND NOTCH ROOT RADIUS ON FRACTURE TOUGHNESS OF AN ALUMINUM METAL MATRIX COMPOSITE

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Considerable work has been devoted recently to the area of metal matrix composites (MMC) due to the need for materials with high specific strength and stiffness. The desired form of the reinforcement (i.e., filament, fiber, particulate, whisker) depends strongly on the intended use and requirements, with continuous reinforcement offering the highest potential strengths and stiffnesses but with marked anisotropy. Although the strength and stiffness of discontinuous reinforced composites are somewhat less than continuous reinforced materials containing equivalent volume fraction of reinforcement, the discontinuous reinforced MMCs hold the additional advantages of possessing more isotropic properties [1], and may be fabricated via powder metallurgy (P/M) or casting techniques [2], followed by conventional metalworking processes such as extrusion, rolling, etc. Although it is well accepted that microstructural changes exert significant effects on deformation and fracture for both ferrous [3,4] and non-ferrous [5,6] monolithic materials, relatively few studies have focussed on the role(s) of microstructure in the deformation and fracture of MMCs. The present work summarizes recent results on the effects of matrix aging condition (i.e., matrix temper) and notch root radius on the measured fracture toughness of a SiC particulate reinforced aluminum alloy.

The powder metallurgy matrix alloy composition used in this work, designated Alcoa MB78, contains 7% Zn, 2% Cu, and 0.14% Zr, balance Al, and was reinforced with 20 percent by volume of F-600 grade (average size prior to blending = 13 μm) SiC particulate. Additional details of the processing of this material via powder metallurgy techniques can be found elsewhere [1,7]. The as-extruded materials were subsequently solution heat treated at 500C/4 hours, cold water quenched, and artificially aged. The aging treatments were selected to provide equivalent matrix microhardness and yield strengths in the composite for both the underaged (UA) and overaged (OA) conditions. Aging to the underaged (UA) temper was conducted at 120C/20 minutes, while the overaged (OA) temper was produced by a double aging treatment: 120C/24 hours, followed by 170C/36 hours. Toughness testing was conducted on bend specimens of nominal dimensions 12.7 mm x 12.7 mm x 75 mm containing notches of the following root radii: 1.0 mm, 0.25 mm, 0.06 mm, and fatigue precracked specimens. The notches were either ground or introduced via a high speed wire saw, while fatigue precracks were started from one of the geometries.

Table I summarizes the values of the stress intensity factors at catastrophic fracture as a function of the notch root radius for the two conditions tested. Figures 1 and 2 show plots of the apparent fracture toughness (K_Q) as a function of the square root of the notch root radius ($\sqrt{\rho}$) for the underaged and overaged composites, respectively. It can be seen that a linear relation between K_Q and $\sqrt{\rho}$ is obtained for both cases until reaching a limiting value of notch root radius below which the value of the apparent fracture toughness is invariant and equal to the value obtained for a fatigue precracked specimen.

The crack tip opening displacement can then be calculated from the appropriate stress intensity factors through the relation [8],

$$\delta = \frac{4K_I^2}{\pi E \sigma_y} \tag{1}$$

where δ is the crack opening displacement, E is the Young's modulus of the material (100 GPa), and σ_y is the yield strength of the material (UA: 381 MPa, OA: 408 MPa). A linear relation between K_Q and $\sqrt{\rho}$ implies a linear dependance of δ on ρ. Such a linear dependance of δ on ρ is suggestive of a strain controlled fracture process [3], while the different absolute values of fracture toughness between the two conditions tested are indicative of the differences in fracture micromechanisms between the two aging conditions. Additional details regarding the fracture micromechanisms in this material can be found elsewhere [1,7].

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Table I. Effects of microstructure and notch radius on fracture toughness K_Q (MPa.m$^{1/2}$).

Material Aging Condition	Notch Root Radius			Fatigue Precrack
	1.0 mm	0.25 mm	0.06 mm	
Underaged	55.4	39.3	25.5	24.2
Overaged	34.4	22.2	16.5	17.0

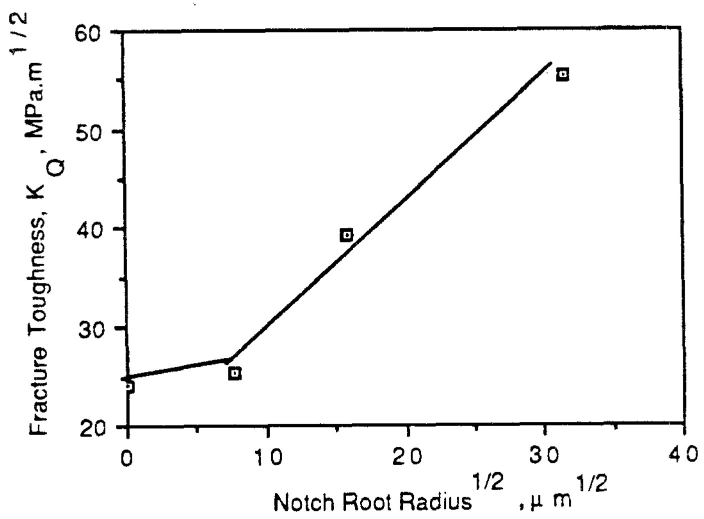

Figure 1. Effect of notch root radius on the apparent fracture toughness of the underaged composite.

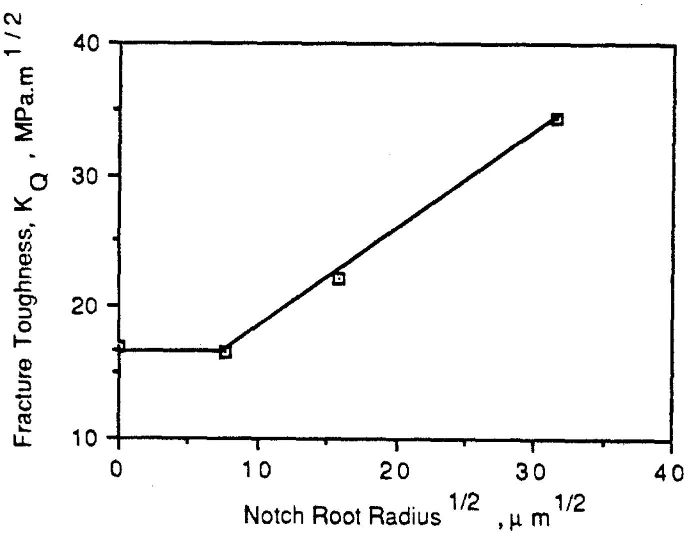

Figure 2. Effect of notch root radius on the apparent fracture toughness of the overaged composite.