Synthesis of aluminium composite reinforced with continuous SiC fibre obtained from the precursor fibre of an organosilicon polymer

Yajima *et al.* have developed SiC fibres with high tensile strength and Young's modulus and also high heat resistance, using an organosilicon polymer [1, 2]. SiC fibres were at first obtained with ~ 600 mm length, but recently continuous fibres of 300 to 500 m have been made industrially. The present authors prepared aluminium matrix composites reinforced with the SiC fibres by the liquid pressing method; the tensile strength and bending strength of the composites were examined.

The matrix materials used were 6061 aluminium sheets of size 80 mm × 50 mm × 0.1 mm. Their tensile strength was 136 MPa and their density 2.7 g cm^{-3}. The reinforcement fibres were "yarns" consisting of 500 continuous SiC fibres 300 m long and of 10 μm diameter. Their tensile strength was 2000 MPa and density 2.6 g cm^{-3}.

SiC fibre yarns were coated together using a polystyrene resin. The coated yarns were wound around a drum of 300 mm diameter and 300 mm width at pitches one yarn per 1 mm. After the resulting yarns were introduced between hot rolls, a sheet of SiC fibre yarns oriented unidirectionally could be obtained. The sheet was cut into pieces of area 80 mm × 50 mm. These sheets and aluminium sheets were stacked up alternately. The laminate was placed in a stainless steel vessel of dimensions 100 mm × 70 mm × 15 mm. After sealing, the vessel was evacuated to 133.3 Pa (1 Torr) through a nozzle at its end. Under this vacuum, the vessel was heated at 500° C and retained at this temperature for 30 min to evaporate the polystyrene. Subsequently, the temperature was raised to 720° C and the vessel maintained at this value for 10 min. The heated vessel was then immediately pressed at a pressure of 19.6 MPa. By removal from the vessel, a sheet of aluminium composites reinforced unidirectionally with SiC fibres (SiC fibre/Al), about 80 mm × 50 mm × 1.5 mm in size was obtained.

The longitudinal tensile strength of the SiC fibre/Al specimen was measured on a sample of size 80 mm × 8 mm × 1.5 mm with a gauge length of 20 mm and a cross-head speed of 1 mm min^{-1}. Measurement of bending strength was made using a sample of size 50 mm × 8 mm × 1.5 mm by a three-point bending with a span of 40 mm and a cross-head of speed 1 mm min^{-1}.

The longitudinal tensile and bending strength of the SiC fibre/Al composites versus volume fraction of SiC fibre (V_f value) at room temperature is shown in Table I. The deviation ratio, the measured tensile strength to the value which obeys the rule of mixture prediction (ROM), is also shown in the table. The reduction of measured strength to the ROM strength above $V_f \approx 40\%$ may be caused, as described by Pepper *et al.* [3], by fibre misalignment and contact between fibres at higher fibre content.

Kasai *et al.* [4] prepared aluminium composites unidirectionally reinforced using SiC fibre 600 mm long and a tow composed of 4 to 5 thousand fibres developed by Yajima. The fabrication method was the developed powder slurry–liquid phase pressing technique. The longitudinal tensile strength of Kasai's composites is reported to obey the ROM prediction up to $V_f = \sim 20\%$. The present result is considered to be better than Kasai's in comparison with the deviation ratio shown in Table I. It is caused mainly by mechanical factors such as fibre misalignment. As the SiC fibre used by Kasai is 600 mm long and a tow composed of 4 to 5 thousand fibres, it is difficult to unidirectionally

TABLE I Tensile strength and bending strength of SiC fibre/Al versus fibre volume fraction

		V_f (%)					
		25	32.5	38	40	45	50
Tensile strength (MPa)		630 ± 50	–	750 ± 90	700 ± 80	–	760 ± 50
Bending strength (MPa)		940 ± 100	–	1080 ± 20	1120 ± 100	–	1180 ± 60
Deviation ratio	This work	1.04	–	0.89	0.79	–	0.71
	Kasai *et al.*	1.00	0.92	–	0.75	0.69	–

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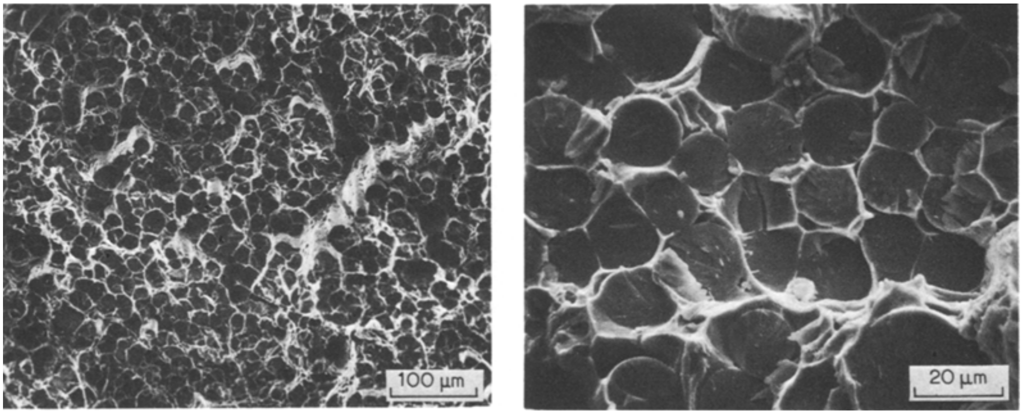

Figure 1 Scanning electron micrographs of fractured surfaces in $V_f = 38\%$ SiC fibre reinforced 6061-Al after tensile tests.

align the fibres. In the present method, by using SiC fibres of 300 m length, the fibres could be easily aligned unidirectionally.

Fig. 1 is a scanning electron micrograph of the fracture surface of SiC fibre/Al after tensile tests. The specimen broke off with SiC fibre and 6061-Al together, the SiC fibre not being pulled out. Aluminium metal was well permeated among the fibres, exhibiting excellent wettability between the SiC fibre and 6061-Al. The strength of the SiC fibre extracted by dissolving off completely the Al metal with 30% NaOH solution from the specimen after the tensile test was the same as that of the SiC fibre before reinforcement. The SiC fibres contain excess carbon [5], but the Al_4C_3 compound, which is detrimental to strength, could not be detected in the SiC fibre/Al by detailed X-ray diffraction.

The SiC fibres obtained from an organosilicon polymer were successfully incorporated into 6061 aluminium matrix by the liquid pressing method. The SiC fibres were 300 m long and in yarns of 500 so that the SiC fibre unidirectionally reinforced aluminium composite was easily produced. The tensile strength of this composite virtually obeyed the rule of mixtures to fibre volume fraction of 38%.

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