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SiC whiskers–aluminium 6061 composite: microstructure and mechanical characteristic anisotropy

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The correlation has been studied between the microstructure and the tensile and compressive properties of composite extruded bars of aluminium 6061 alloy matrix reinforced with silicon carbide whiskers. The material was tested before and after being subjected to T6 heat treatment. Different degrees of alignment and breakage in the whiskers and the texture of the metal matrix were observed, corresponding to different ratios of extrusion. The material also showed marked anisotropy in its mechanical characteristics: its compressive strength in the longitudinal direction was considerably higher than in the transverse direction.

1. Introduction

In recent years aluminium alloy composites reinforced with SiC whiskers have been the subject of numerous studies. The reason for this interest has to do with the particular characteristics of these materials. These materials show mechanical strength notably better than aluminium alloys and particle reinforced composites and a greater ductility and ease of fabrication and processing than long fibres reinforced aluminium matrix composites [1, 2]. In addition, they have a good thermal stability because of the low reactivity of silicon carbide with the metal matrix: aluminium carbide Al_4C_3, can be formed as result of the reaction between the melted metal and the silicon carbide only after heating to high temperatures over long periods of time [3, 4]. Despite the absence of any noticeable chemical reactions between the metal matrix and the reinforcement during the fabrication of the composite, the bond between the two is nevertheless strong enough to provide a considerable increase in mechanical strength when compared to that of the metal alloy used in the fabrication of the composite. Interest in these materials can also be attributed to the possibility of producing silicon carbide whiskers from rice hulls at a relatively low cost. By heating rice hulls to high temperatures (1800° C) away from contact with the air [5] it is possible to obtain acicular monocrystals of β-SiC cubic (up to 1 μm in diameter and 50 μm in length) growing in crystallographic direction [1 1 1] [6, 7]. The strength of these whiskers is nearly three times greater than that of silicon carbide fibres [8].

These composites are generally produced in the form of bars or sheets by means of extrusion and rolling from billets, which are in turn obtained by infiltration under pressure of the liquid metallic alloy into preforms containing the reinforcement. Following this process in addition to their partial breakage there is an alignment of whiskers which is more or less marked in certain directions [7, 9]. The data on the mechanical strength of these materials that are reported in the literature do not always agree; probably this can be attributed to the different fabrication methods used by different researchers [9–11]. In addition, the mechanical strength of the materials depends on the direction considered, since the whiskers contribute to reinforcing the composite in different degrees depending on their orientation towards the direction in which the stress is applied [2, 12, 13]. In this paper the microstructure of the material is correlated with its tensile and compressive properties.

2. Materials

Two sets of composite material bars of 6061 aluminium alloy matrix reinforced with 15% vol of silicon carbide whiskers were used. The chemical composition of the 6061 alloy is given in Table 1. The bars were provided by Pechiney Aluminium, Paris. The method of production included the fabrication of billets of 110 mm in diameter and 120 mm long by squeeze casting and subsequent hot extrusion until bars of 50 and 20 mm in diameter were obtained.

3. Experimental details

Samples in the form of discs and thin plates were taken off the bars at various distances from the end of each bar. Double sampling was carried out by taking off specimens both perpendicular and parallel to the axes of the bars. In the case of the 50 mm diameter bar the double sampling was made at the surface and in the core of the material in order to show any lack of homogeneity. These samples were used to characterise

TABLE I Chemical analysis of the 6061 alloy (wt %)

Si	Mg	Cu	Fe	Zn	Cr	Mn
0.44	1.01	0.22	0.29	< 0.01	0.23	0.03

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the microstructure of the material. Microscopic examination was made using a metallography microscope and a scanning electron microscope; X-ray diffraction analyses were also carried out. Since the silicon carbide whiskers are monocrystals with one growth direction [1 1 1], it is possible to determine their orientation within the composite using diffractometric X-ray analysis [7].

An apparatus with a monochromator, variable slit and sample spinner was used to make the diffractometric analysis, using CuKα radiation.

The experimental results were saved and processed on a computer connected on-line to the measuring instrument. The degree of orientation of the whiskers and the texture of the matrix were measured using a method of computation given in previous studies on the texture of the surface layers obtained by boriding and nitriding of steels and titanium alloys [14, 15]. In addition, the size of the whiskers was measured. For this purpose, after dissolution of the metal alloy in dilute hydrochloric acid, the whiskers were collected in a filter, then suspended in water and examined with a laser particle analyser.

The mechanical characteristics of the material were assessed for tensile and compressive strength on an average of at least four tests for each type of sample.

The tensile bars of the type given in norm ASTM E8-81, with a diameter of 6.25 mm, were set so that their axes coincided with those of the extruded bars. For the measurements of compressive strength cylindrical samples with a diameter of 12 mm and a length of 12 and 36 mm were used. The smaller compressive specimens allowed some complex sampling to be made, so that samples were taken longitudinally and transversely to the axes of the extruded bars. The 50 mm bars also allowed for sampling both on the surface and in the core of the bars. The tensile and compressive tests were carried out at room temperature using MTS and Instron equipments with a load up to 100 000 N. A scanning electron microscope was used to examine the fracture surfaces after the tensile test. One part of the composite underwent solution treatment for 2 h at 520° C, quenching in water and ageing at 180° C for 8 h (T6 temper [16]). The treatment was carried out in an oven with a protective argon atmosphere to prevent the samples from oxidation. The microstructural and mechanical characteristics of the treated material were examined as described above.

4. Method of evaluating the preferred orientation of the crystals

In the X-ray diffraction analysis carried out on a plane sample with a Bragg–Brentano diffraction geometry apparatus, a whatever crystallographic plane can only send a diffracted ray to the X-ray counter if it is parallel to the surface of the sample. If the orientation of the crystals in a polycrystalline sample is purely random, statistically, a sufficiently large number of crystals will lie in such a way as to permit the diffraction of each plane family. The intensity of the peaks in the diffraction spectrum will coincide in this case with those of a spectrum of a powder made of the material being examined. These intensity values are known for many substances, and can anyhow be calculated theoretically. In a uniaxial textured material, crystals do not lie in a disordered fashion but tend instead to be oriented, for example, by aligning a particular crystallographic direction $[h'\,k'\,l']$ along with the perpendicular to the surface of the sample undergoing diffractometric examination. In this case the plane $(h'\,k'\,l')$ will be found with more probability than other planes in an ideal position for sending a diffracted ray to the X-ray counter and the intensity of the peak corresponding to this will be reinforced on the diffraction spectrum. In general, with the texture hypothesised above, the probability of finding a generic plane $(h\,k\,l)$ parallel to the surface of the sample will therefore be higher as the angle between the crystallographic directions $[h'\,k'\,l']$ and $[h\,k\,l]$ becomes smaller. The intensity of the peak corresponding to the generic plane $(h\,k\,l)$ on the diffraction spectrum will therefore depend on this angle we shall call λ'. It has been proved that this intensity ($I_{\text{pref.}}$) can easily be calculated by correcting the intensity value of a powder spectrum ($I_{\text{pow.}}$) with an empirical function:

$$I_{\text{pref.}} = I_{\text{pow.}} \exp -(\sigma\lambda'/100) \qquad (1)$$

where the coefficient σ stands for the degree of preferred orientation of the crystals.

The value of the exponential function increases from 0 to 1 as the value of λ' diminishes, that is, with the probability of finding the plane in a position that allows diffraction. Also, the higher the coefficient of preferred orientation σ, that is, the more marked is the texture, the more rapidly increases the value of this function.

After extrusion some metals can show a more complex axial texture: one part of the crystals tends to be oriented so that a precise crystallographic direction $[h'\,k'\,l']$ is aligned with the direction of extrusion, while the remaining part of the crystals tends to align a different crystallographic direction, we can call $[h''\,k''\,l'']$, with the direction of extrusion itself. In this case the diffraction spectrum can be considered the sum of the two spectra, each one corresponding to one of the two populations in which the totality of the crystals can be subdivided according to their differing preferred orientation. The intensity of the peaks in each one of these two hypothesized diffraction spectra can be calculated by correcting the intensity of the powder spectrum using the exponential function shown above. Therefore, the intensity of the diffraction spectrum can be calculated using the empirical formula:

$$I_{\text{pref.}} = I_{\text{pow.}} \exp -(\sigma\lambda'/100) + A\, I_{\text{pow.}} \exp -(\sigma\lambda''/100) \qquad (2)$$

where the coefficient A represents the relationship between the number of crystals belonging to each of the two populations with different preferred orientations; λ' and λ'' indicate the angles between the direction perpendicular to the generic plane $(h\,k\,l)$ (to which the calculation of intensity refers) and the directions $[h'\,k'\,l']$ and $[h''\,k''\,l'']$, respectively; σ indicates the coefficient of preferred orientation defined above.

With a marked texture it is sufficient to compare the experimentally determined relative intensities of the peaks with those of the powder spectrum in order qualitatively to distinguish the type of texture, that is, to find out which crystallographic direction or directions show a tendency to be aligned in a particular direction (for example, in the direction in which the material was machined).

After calculating the angles λ' and λ'' for each family of planes, using the empirical formula given above, it is possible to calculate the values that the intensity of the peaks in the X-ray spectrum will have for different values of the coefficients A and σ. These series of intensities, each of which corresponds to differing pairs of values for A and σ, or to differing values for σ in the simplest case, can then be compared with the experimental values. It has been proved that the empirical method adopted allows for the generation of a diffraction spectrum that agrees with that obtained by experiment.

The correlation coefficient R was used as a criterion for evaluating the fit of the agreement between the two spectra. R was defined as:

$$R = \frac{\Sigma_n |I_{\text{pref.}} - I_{\text{exp.}}|}{\Sigma_n I_{\text{exp.}}} \quad (3)$$

where n is the number of peaks in the diffraction spectrum and $I_{\text{exp.}}$ are the intensities observed experimentally.

The values of σ and A, corresponding to the calculated spectrum that best fits the experimental one, give a computation of the degree of orientation of the crystals and of the relative size of the two populations of crystals with differing preferred orientations, respectively.

5. Results

5.1. Microstructure

The materials as-supplied present a fairly uniform distribution of the reinforcement within the composite. In fact, only a few of the samples examined under the microscope showed any particular lack of homogeneity in whisker distribution: in these cases areas show up where either no reinforcement is present or where groups of whiskers have not been perfectly infiltrated by the metal matrix (Figs 1 and 2). Figures 3 and 4 show the general appearance of the longitudinal and transverse section of the bars, respectively. In the longitudinal sections we can observe many whiskers aligned in the direction of extrusion (Fig. 3). These whiskers are of very different lengths indicating considerable fragmentation that presumably occurred during the extrusion process. The laser particle analyser examination of the size of the whiskers showed that reinforcement is more damaged in the 20 mm diameter bars than in the larger 50 mm bars. In addition, the maximum length of the whiskers found in the 50 mm bars was less than 15 to 20 μm.

After lightly etching the surface to remove a thin layer of the metal matrix, the scanning electron microscope examination of the transverse sections of the bars showed the alignment of the whiskers to be in the direction of extrusion (Figs 5 and 6). The degree of whisker orientation was measured using X-ray diffraction. The acicular whiskers were grown with their [1 1 1] crystallographic direction parallel to their major axes, then their [1 1 1] direction was aligned in the direction of extrusion. As a matter of fact the X-ray

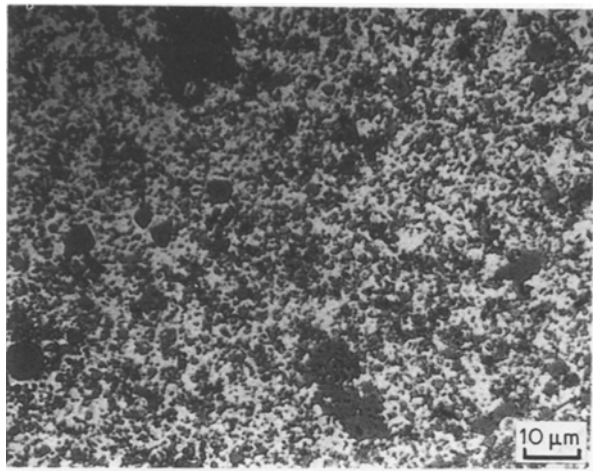

Figure 2 Transverse section of Al 6061–SiC whiskers bar: not homogeneous distribution of whiskers.

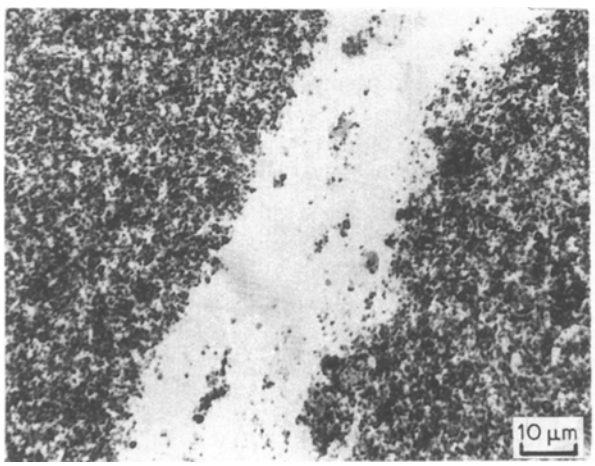

Figure 1 Transverse section of Al 6061–SiC whisker bar: area without reinforcement.

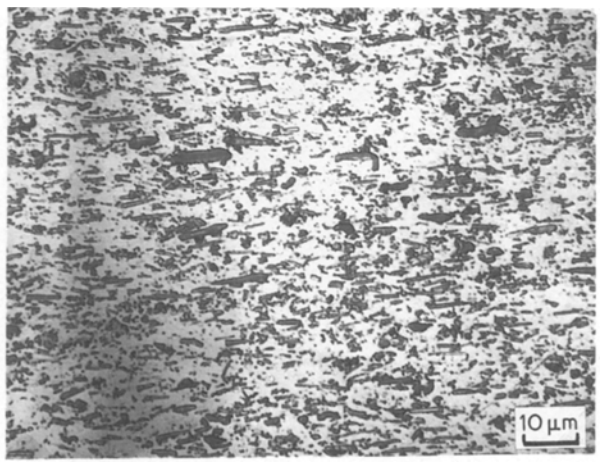

Figure 3 Longitudinal section of Al 6061–SiC whiskers bars (20 mm diameter): general appearance.

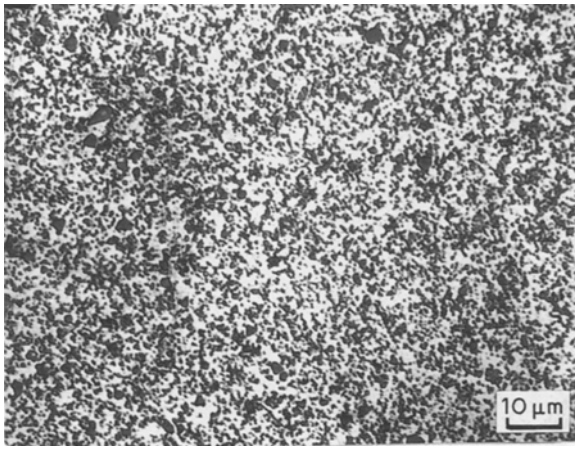

Figure 4 Transverse section of Al 6061–SiC whisker bars (20 mm diameter): general appearance.

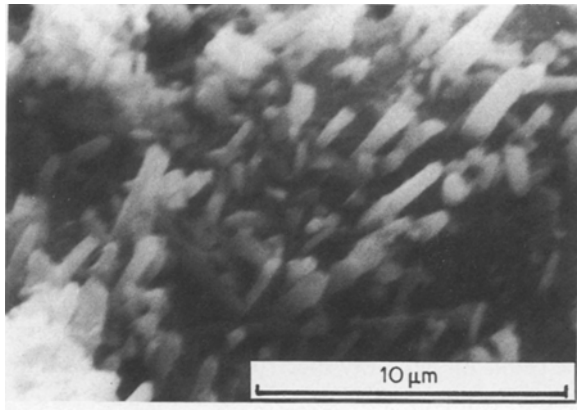

Figure 6 SEM micrograph of composite: transverse section of the 50 mm diameter bar after etching the metal matrix.

diffraction spectra of the transverse samples showed a reinforcement of the peak (1 1 1), as a consequence of the high probability of finding the SiC reticular planes of the (1 1 1) type parallel to the surface of the sample. The comparison of the experimental intensities of the silicon carbide peaks with those calculated theoretically using the method given above allowed the value of the coefficient of preferred orientation σ to be measured on an arbitrary scale. If there were a total orientation of the crystals, peak (1 1 1) would be the only one present on the diffraction spectrum. This situation would be obtained experimentally if the intensity of the peak were about 1000 times higher than any other; according to the proposed calculation model these relative intensity values would correspond to a value for σ of about 20. The results obtained were also confirmed by analysing the longitudinal samples: since the reticular planes ($\bar{1}$ 1 0) and 1 $\bar{1}$ 0) are perpendicular to plane (1 1 1), these samples have a high probability of showing these planes parallel to the surface, and hence the intensity of the type (1 1 0) peak is reinforced on the X-ray diffraction spectrum. The values of the coefficient of preferred orientation σ obtained from the transverse samples from the 50 and 20 mm diameter bars are given in Tables II and III respectively. Figures 7 and 8 show that the coefficient of preferred orientation does not remain absolutely constant when distance from the end of the bar changes, but it is kept within a range of values which is quite small considering the possibility of experimental error and above all the type of material being examined. In these two figures the vertical segments, which are proportional to the correlation factor R, represent an estimate of the reliability of the measurement for each point.

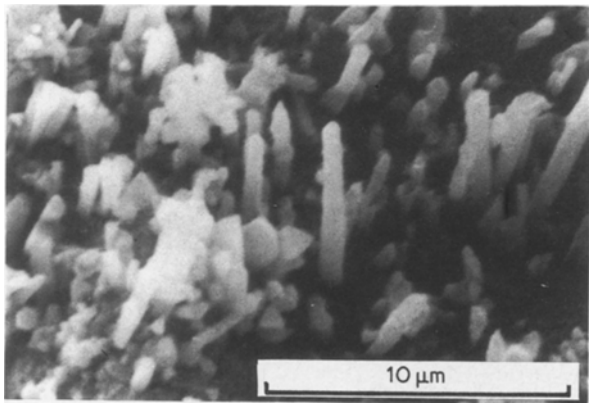

Figure 5 SEM micrograph of composite: transverse section of the 20 mm diameter bar after etching the metal matrix.

The value of the coefficient of orientation lies between 3.2 and 4.4 for the 50 mm diameter bar, and it is considerably higher for the 20 mm diameter bar, between 6.2 and 7.3. The coefficient of whisker orientation was measured on transverse samples taken from either the centre or near the surface of the 50 mm bar: very slight differences were found between these two types of samples that we deem only slightly significant (see Table II).

During the extrusion process the metal matrix also takes on a particular texture [17, 18]. A double axial texture is obtained, where the aluminium alloy crystals tend to align their crystallographic directions [1 1 1] or [1 0 0] to the direction of extrusion and therefore to the axes of the bars. It follows that on the X-ray diffraction spectra of the transverse sections of material, the relative intensities of the (1 1 1) and (1 0 0) type peaks are larger than those of a powder spectrum. Between the two possible textures prevails the one with the alignment of the direction [1 1 1] with respect to the direction of extrusion: this texture affects between 70 and 85% of the crystals as shown in Table III and IV. In the longitudinal sections there should be an increased probability of finding parallel to the surface of the sample planes of types ($\bar{1}$ 1 0) and (1 $\bar{1}$ 0), that are perpendicular to plane (1 1 1), and planes of type (0 1 0) and (0 0 1), which are perpendicular to (1 0 0). The X-ray diffractometric analysis of the longitudinal samples confirmed this forecast. For reasons of symmetry, in the cubic lattice, planes (1 1 0), ($\bar{1}$ 1 0) and (1 $\bar{1}$ 0), like planes (1 0 0), (0 1 0) and (0 0 1), are crystallographically equivalent and reflections of types (1 1 0) and (1 0 0) were reinforced on the diffraction spectra.

Tables III and IV and Figs 7 and 8 give the values of the coefficients of the preferred orientation of the matrix in the transverse samples taken from the two sizes of bars. These values are arranged according to the distance of the sample from the end of the bar. The

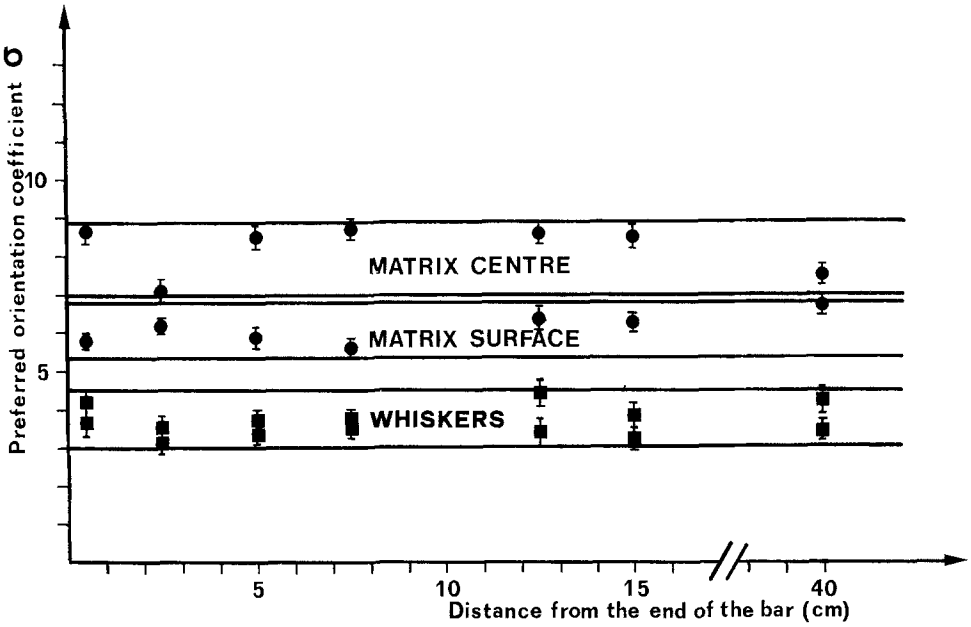

Figure 7 Preferred orientation coefficients of the metal matrix and the SiC whiskers against the distance from the end of the 50 mm diameter bars.

matrix of the bars that were extruded into a 20 mm diameter have a higher coefficient of preferred orientation than that found in the 50 mm bars. Figure 7 shows that the degree of texture found in the bars with the larger diameter also differed considerably from the surface to the centre of the bar. On the surface the preferred orientation of the crystals is less marked, probably because of the vortices that can be created during extrusion [19] in the outer layers of the material when the plastic flow is affected by contact with the drawing machine.

5.2. Heat treatment

The possible influence of T6 heat treatment on the microstructure of the material was analysed using X-ray diffraction. Two series of six samples were tested both before and after heat treatment to examine the orientation of the whiskers and the texture of the metal matrix.

The results for both series of bars, expressed as the mean value of the coefficients of preferred orientation for the matrix and reinforcement before and after heat treatment, are given in Table V. The coefficients of orientation do not show appreciable variation following heat treatment of the samples. This result was easily predictable in the case of the whiskers, while in the case of the matrix it indicates that during treatment the aluminium alloy does not recrystallize to any appreciable extent. Probably recrystallization is prevented by the presence of the reinforcement which limits the possible movement of the grain boundaries.

6. Mechanical characteristics

6.1. Tensile tests

The results of the tensile tests carried out on the samples taken parallel to the axes of the bars before and after T6 treatment are given in Table VI. The silicon carbide whiskers provide a considerable increase in yield strength and ultimate tensile strength with respect to the values of the aluminium alloy matrix: on the other hand this reinforcement diminishes its ductility. In addition, T6 treatment entails an increase in the tensile strength both of the aluminium alloy and of these composites. The samples obtained from the 20 mm diameter bars had a higher tensile strength than the samples taken from the 50 mm diameter bars. This was particularly evident in the samples that were heat treated.

The slight differences in strength found in the two series of untreated bars showed that the degree of whiskers orientation, which differed remarkably between the 20 and 50 mm diameter bars, is not the only parameter that can influence the mechanical characteristics of the material. In fact, the greater the

TABLE II Preferred orientation of the SiC whiskers measured on transverse sections taken from centre and near the surface at differing distances from the ends of the 50 mm bars

Distance (cm)	Coefficient of orientation (σ)		Coefficient of correlation ($R \times 10^{-2}$)	
	Centre	Surface	Centre	Surface
0.5	3.7	4.2	6	6
2.5	3.2	3.6	5	6
5.0	3.4	3.7	6	6
7.5	3.5	3.7	5	6
12.5	3.4	4.4	7	7
15.0	3.2	3.8	5	7
40.0	3.5	4.2	4	6

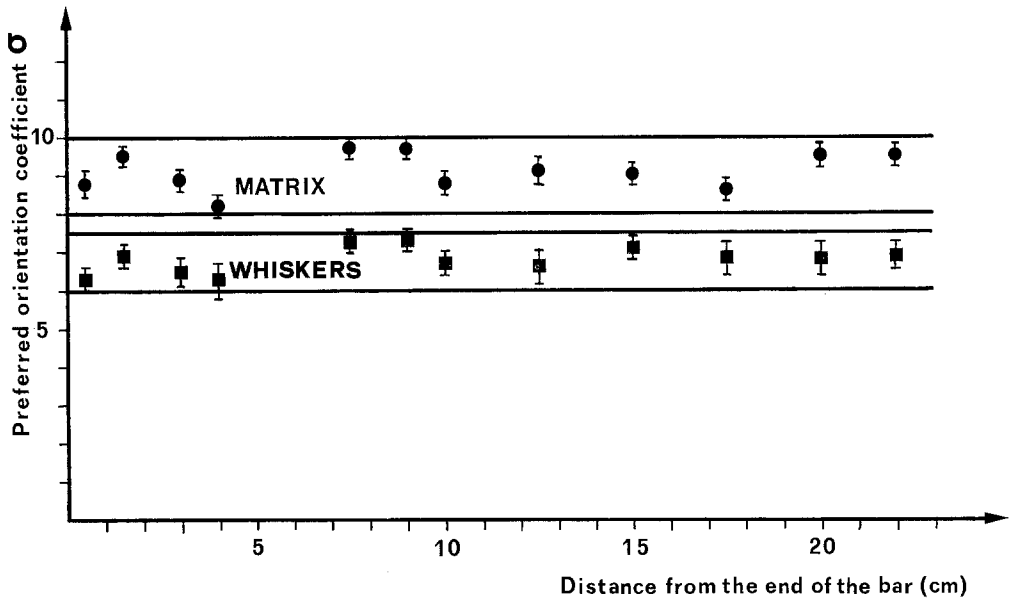

Figure 8 Preferred orientation coefficients of the metal matrix and the SiC whiskers against the distance from the end of the 20 mm diameter bars.

plastic deformation during extrusion, the greater the degree of whisker alignment and the greater the breakage of the reinforcement, as it was shown when measuring the whisker sizes. The degree of orientation and the fragmentation of the reinforcement exert an opposite effect on the strength of the longitudinal tensile bars. After T6 treatment, the difference in tensile strength between the two series of bars was more consistent. Probably the differing degree of hardening in the matrix and the differing size of the reinforcement can influence the kinetics of the processes carried out on the material during T6 treatment. Other sources [20] have also noted that the optimal parameters during this treatment for the aluminium alloys

TABLE III Texture of the metal matrix in directions [1 1 1] and [1 0 0] and degreee of orientation of the SiC whiskers in sections taken transversely from 20 mm diameter bars

Distance (cm)	Coefficient of orientation of the matrix (σ)	Population (%) of crystals in directions		Coefficient of orientation of the whiskers (σ)	Coefficients of correlation ($R \times 10^{-2}$)	
		[1 1 1]	[1 0 0]		Matrix	Whiskers
0.5	8.8	77	23	6.3	6	6
1.5	9.5	77	23	6.9	5	6
3.0	8.9	78	21	6.5	5	7
4.0	8.2	77	23	6.3	6	8
7.5	9.7	79	21	7.3	5	6
9.0	9.7	81	19	7.3	5	5
10.0	8.8	78	22	6.7	6	7
12.5	9.1	82	18	6.6	7	9
15.0	9.0	81	19	7.1	6	6
17.5	8.6	79	21	6.8	6	9
20.0	9.5	81	19	6.8	6	9
22.0	9.5	84	16	6.9	5	7
32.0	9.2	81	19	6.7	6	9
42.0	9.2	83	17	6.2	6	10

TABLE IV Texture of the metal matrix in directions [1 1 1] and [1 0 0] on sections taken from the centre and near to the surface at differing distances from the end of the 50 mm diameter bars

Distance from the end of the bar (cm)	Coefficient of orientation (σ)		Population (%) of oriented crystals				Correlation coefficient ($R \times 10^{-2}$)	
	Centre	Surface	Centre		Surface		Centre	Surface
			[1 1 1]	[1 0 0]	[1 1 1]	[1 0 0]		
0.5	8.6	5.8	70	30	80	20	5	4
2.5	7.1	5.2	86	14	69	31	6	4
5.0	8.5	5.9	77	23	71	29	6	5
7.5	8.7	5.6	82	18	81	19	5	5
12.5	8.6	6.4	81	19	83	17	5	5
15.0	8.5	6.3	69	31	83	17	6	5
40.0	7.5	6.7	79	21	78	22	5	5

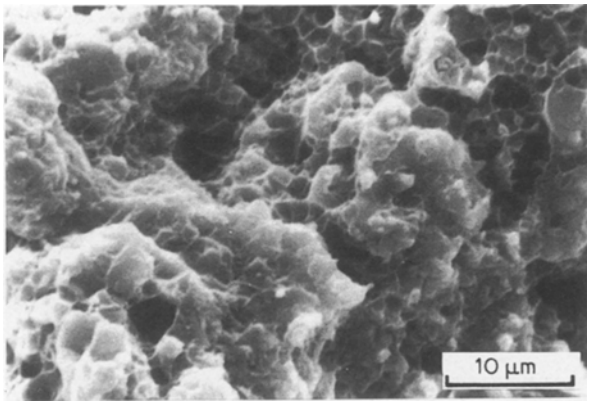

Figure 9 Fracture surface of composite.

(time and temperature) should be redefined for composite materials taking into account their method of production, in order to obtain each time maximum possible strength.

Scanning electron microscope examination of the fracture surface of the tensile specimens did not show the presence of whiskers not adhering to the matrix following breakage of the bond with the matrix itself (see Fig. 9). Thus, contrary to what others have observed [9, 21], in whiskers of this size, bonding to the matrix was strong enough to prevent pull-out.

6.2. Compression tests

Table VII shows the mean values of the yield strength under compression for various types of samples and bars. The samples taken from the centre of the 50 mm diameter bar showed a compressive strength equal to that of the samples taken near the surface of the bar. The mean values of the strength of the two types of samples is given in Table VII. The compressive strength of the samples taken longitudinally to the axes of the bars was systematically higher than that of the transverse samples; this behaviour was characteristic of every type of bar, whether it had undergone heat treatment or not. Because of the orientation of the reinforcement, in the longitudinal samples the whiskers lay parallel to the axis of the cylindrical sample and therefore in the direction in which load was applied. In this case, the entire surface of the whiskers was involved in the shear stresses transferred from the matrix to the reinforcement, while on the contrary, for the transverse samples, only part of the surface of the whiskers was involved. For this reason, compressive strength in the transverse direction was only equal to 70% of that observed for the longitudinal direction.

Despite the fact that the composite showed greater whisker alignment in bars that were more deformed during extrusion (the 20 mm bars), a greater anisotropy could not be found in their mechanical characteristics with respect to the 50 mm bars. This behaviour can be explained by the differing degree of whisker fragmentation in the two types of bars.

It should finally be noted that the bars with the smaller diameter showed systematically higher strength, which was particularly evident after T6 heat treatment, probably for the reasons given above in the discussion of the tensile tests.

7. Conclusions

The results obtained in this study allow us to present some general conclusions.

1. The Al 6061–SiC_w composite examined is characterized by marked anisotropy in its microstructure and therefore in its mechanical properties.

2. The extrusion process used to produce the bars determines for the metal matrix the introduction of the characteristic texture of the extruded aluminium alloys. Also the silicon carbide whiskers do not lie in random directions within the material but are aligned in the direction of extrusion. The degree of orientation of the matrix and reinforcement crystals increases as

TABLE V Influence of T6 treatment on composite crystal orientation: mean values for coefficient σ obtained on samples taken from the centre of 20 and 50 mm diameter bars

Bar diameter (mm)	Thermal treatment	Average orientation coefficient values (σ)		Average correlation factor values ($R \times 10^{-2}$)	
		Matrix	Whiskers	Matrix	Whiskers
50	–	8.3	3.8	6	6
50	T6	8.4	3.6	5	6
20	–	9.0	6.7	6	7
20	T6	8.9	6.0	9	10

TABLE VI Tensile strength of samples taken longitudinally from bars with different degrees of extrusion before and after T6 treatment

Material	Thermal treatment	Yield strength (MPa)	Ultimate tensile strength (MPa)	Young's modulus (GPa)	Elongation (%)	Preferred orientation coefficient σ for SiC_w (arbitrary units)
Al 6061*	Annealed	55	124	–	30	–
ϕ = 20 mm bars	As-received	186	378	114	5.2	6.2 ÷ 7.3
ϕ = 50 mm bars	As-received	182	365	103	5.4	3.2 ÷ 4.4
Al 6061*	T6	275	315	69	17	–
ϕ = 20 mm bars	T6	410	547	115	2.1	6.0
ϕ = 50 mm bars	T6	342	495	108	2.4	3.6

*Metals Handbook [16].

TABLE VII Compressive strength of cylindrical samples taken longitudinally and transversely from bars of different diameters before and after T6 treatment

Sample	Sample's dimension $h \times \phi$ (mm)	Thermal treatment	Yield strength (MPa)	
			ϕ = 20 mm bars	ϕ = 50 mm bars
L	12 × 12	–	218	210
L	36 × 12	–	–	203
T	12 × 12	–	145	140
T	36 × 12	–	–	132
L	12 × 12	T6	502	400
L	36 × 12	T6	–	396
T	12 × 12	T6	331	306
T	36 × 12	T6	–	275

the diameter of the extruded material decreases. In addition, during the process the reinforcement undergoes breakage proportional to the amount of deformation caused in the material.

3. The strong bonding at the interface between whiskers and matrix (as evidenced by the absence of whisker pull-out during the tensile tests) causes a considerable increase in tensile and compressive strength of the composite material with respect to the aluminium alloy used as a matrix; its ductility on the other hand is considerably reduced.

4. The composite's compressive strength in the transverse direction with respect to the alignment of the whiskers is equal to only 70% of the strength in the longitudinal direction.

5. The strength of the material not only depends on the degree of orientation of the reinforcement; the degree of whisker fragmentation and the microstructure of the matrix, which in turn depends on the production process and on the heat treatments carried out, significantly influence the mechanical performance of the composite.

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