JOURNAL OF MATERIALS SCIENCE 22 (1987) 757–760

Effect of magnesium addition on the mechanical properties of metallic composite materials based on the eutectic Al–5.7% Ni alloy

N. TERAO, E. GROGNA
Laboratory of Physical Metallurgy, Faculty of Applied Sciences, Catholic University of Louvain, B-1348 Louvain-la-Neuve, Belgium

J. DILLE
Laboratory of Physical Metallurgy, University of Lubumbashi, Zaïre

We have examined the effect of magnesium addition on the mechanical properties of metallic dispersion hardening materials, prepared from the binary eutectic Al–5.7 wt% Ni alloy by casting and isostatic extrusion. A small amount of magnesium addition increases significantly the tensile strength and fracture elongation, and especially stabilizes the alloy structure for annealing at high temperature.

1. Introduction
A new type of dispersion hardening materials based on the eutectic Al–5.7 wt % Ni alloy was developed in our previous work [1–3]. The preparation method is as follows: the materials are first prepared by simple casting of a eutectic alloy which consists of a ductile aluminium matrix and strong, fine Al_3Ni fibres. They are transformed into dispersion-hardened materials by isostatic extrusion in which the Al_3Ni fibres are aligned in the extrusion direction and then they are broken to form fine, dispersed particles in the ductile matrix.

These materials present a good mechanical strength comparable with those obtained by the unidirectionally solidified eutectic Al–Al_3Ni alloy. We further observed that the mechanical strength of these materials is remarkably increased by the addition of a small amount of copper or manganese [4]. It attains about 400 MPa by the addition of 2 to 3 wt % Cu, and more than 500 MPa by the addition of 3 wt % Mn.

We examined in this work the influence of magnesium addition, which is observed to be also useful for the improvement of mechanical properties of our metallic composite materials.

2. Experimental procedures
The alloy specimens were prepared by casting and isostatic extrusion in a similar way as that described in [4], with the amount of additional magnesium varying from 0 to 2.2 wt %. By this magnesium addition, a new phase appears with a small needle form which is probably the intermetallic phase of the Al–Mg system, Al_8Mg_5. The extrusion ratio R, expressed by the ratio of the sectional area of cylindrical ingots before and after extrusion, is 4.8. The cast alloys become brittle with increase of magnesium content and in some cases the samples were broken during the isostatic extrusion for the 2.2% Mg alloys.

The 0.2% offset yield strength σ_E and the ultimate tensile strength σ_R and the fracture elongation A were measured on engineering tensile stress–strain diagrams as in our previous work. In a first series of experiments, the tensile tests were carried out at room temperature and at high temperatures (200 and 260° C). In a second series, the tensile properties were examined at room temperature on the alloy specimens which were annealed during 500 h at 200, 300, 400 and 500° C, respectively.

3. Results
3.1. Al–5.7% Ni–Mg alloys
The results of tensile-test are summarized in Fig. 1 as a function of magnesium content. The tensile strength at room temperature attains its maximum value, more than 400 MPa, at about 2 wt % Mg. At high temperatures, 200 and 260° C, the tensile strength does not change appreciably with the magnesium content. The fracture elongation increases with the increase of magnesium content, thus showing that the materials become more tough.

Fig. 2 shows examples of the variation of mechanical properties as a function of testing temperature for the Al–5.7% Ni–0.3% Mg and the Al–5.7% Ni–1.8% Mg alloys. The tensile strength decreases almost linearly as the temperature increases, while the fracture elongation increases appreciably at high temperature.

3.2. Effect of annealing treatment
Fig. 3 summarizes the results of tensile-tests carried out at room temperature on the alloy specimens which were annealed during 500 h at 200, 300, 400 and 500° C, respectively. This figure is to be compared with the Fig. 6 for the Al–5.7% Ni–Mn alloys in our previous paper [4]. The mechanical strength decreases and the ductility increases by annealing. These changes

0022–2461/87 $03.00 + .12

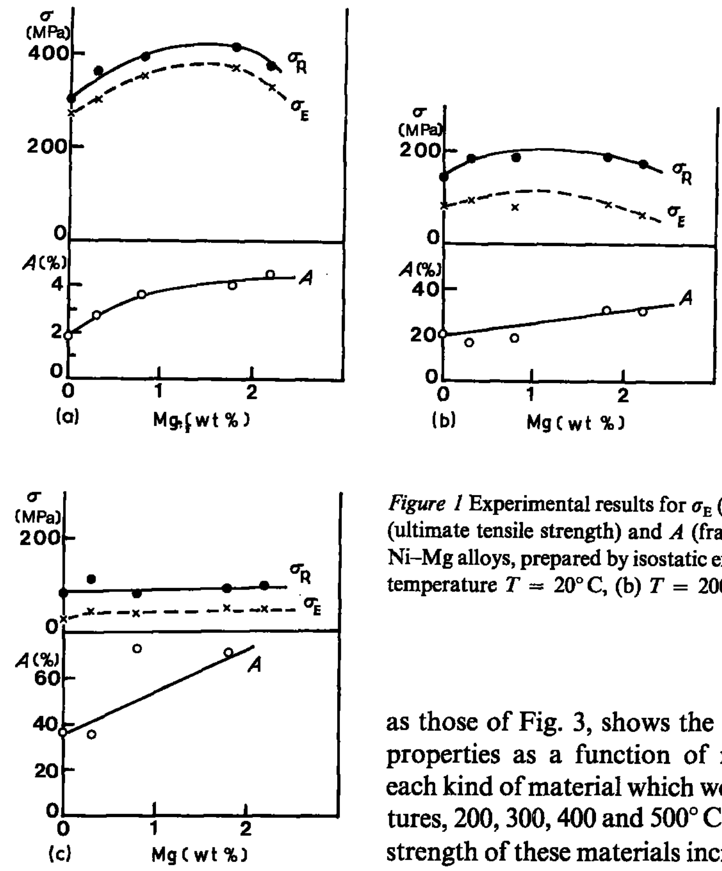

Figure 1 Experimental results for σ_E (0.2% offset yield strength), σ_R (ultimate tensile strength) and A (fracture elongation) of Al–5.7% Ni–Mg alloys, prepared by isostatic extrusion with R = 4.8: (a) test temperature T = 20° C, (b) T = 200° C, and (c) T = 260° C.

appear more remarkably for the low magnesium-content alloys by heat treatment at temperatures above 350° C. The optical and electron microscopic observations show that these are due to the modification of the alloy structure which is especially visible by the spheroidization of the Al_3Ni fibres. In comparison with the Al–5.7% Ni–Mn alloys, however, the decrease of mechanical strength by increase of annealing temperature slows down as the magnesium content increases and the materials containing the 1.8% Mg or 2.2% Mg still keep the ultimate tensile strength above 200 MPa even after 500 h heating at temperature 400 to 500° C. These results show that the magnesium addition increases the stability of alloy structure during the annealing treatment.

Fig. 4, obtained from the same experimental results as those of Fig. 3, shows the variation of mechanical properties as a function of magnesium content for each kind of material which were annealed at temperatures, 200, 300, 400 and 500° C, respectively. The tensile strength of these materials increases as the magnesium content increases, but the fracture elongation shows a peculiar behaviour. When the annealing temperature is low (200 or 300° C), the fracture elongation increases as the magnesium content increases as shown in Figs 4a and b, but it decreases for the high annealing temperature, 400 or 500° C.

In reality, a similar variation was also observed in the case of Al–5.7% Ni–Mn alloys in our previous work. Fig. 5 shows two typical cases of these alloys: (a) low temperature annealing and (b) high temperature annealing. These results are probably due to the two factors which influence the mechanical properties of composite materials differently as a function of annealing temperature. One is the annealing effect of the alloy matrix, which increases the ductility of materials. The other is the spheroidal growth of the Al_3Ni phase at high temperature above 350° C, which induces the premature fracture by the decohesion

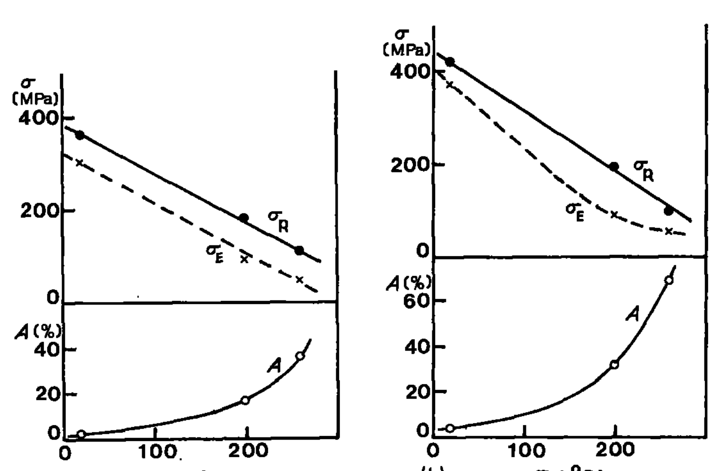

Figure 2 Variation of mechanical properties as a function of testing temperature T. (a) Al–5.7% Ni–0.3% Mg, and (b) Al–5.7% Ni–1.8% Mg.

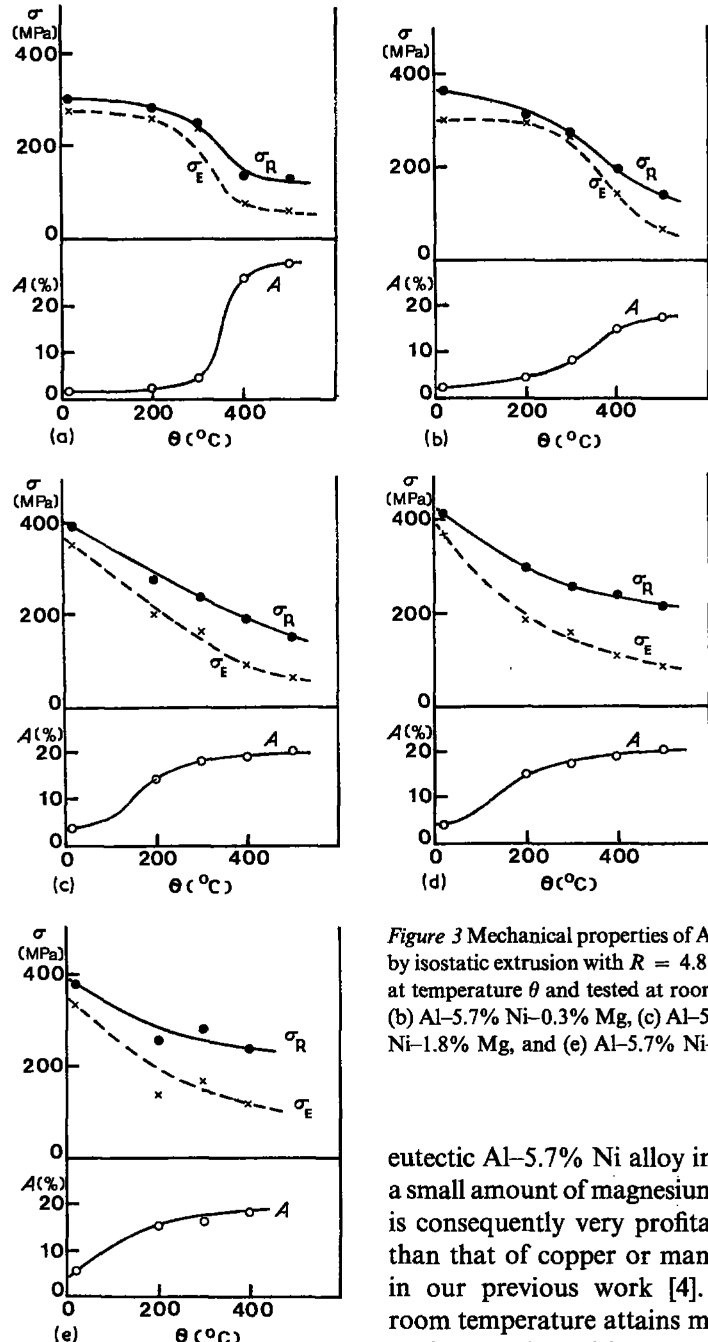

Figure 3 Mechanical properties of Al–5.7% Ni–Mg alloys, prepared by isostatic extrusion with $R = 4.8$ followed by annealing for 500 h at temperature θ and tested at room temperature. (a) Al–5.7% Ni, (b) Al–5.7% Ni–0.3% Mg, (c) Al–5.7% Ni–0.8% Mg, (d) Al–5.7% Ni–1.8% Mg, and (e) Al–5.7% Ni–2.2% Mg.

at the interfaces of large particles and matrix, as observed by electron microscopy and discussed in [4].

4. Conclusions

Both the tensile strength and the fracture elongation of the metallic composite materials based on the eutectic Al–5.7% Ni alloy increase by the addition of a small amount of magnesium. The effect of magnesium is consequently very profitable, but it is slightly less than that of copper or manganese addition reported in our previous work [4]. The tensile strength at room temperature attains more than 400 MPa by isostatic extrusion with $R = 4.8$ and by the addition of about 2 wt % Mg. The magnesium addition, however, stabilizes the alloy structure much more than copper or manganese for the annealing treatment at high temperature and we obtained a tensile strength higher than 200 MPa even after annealing at 400 to 500° C for 500 h.

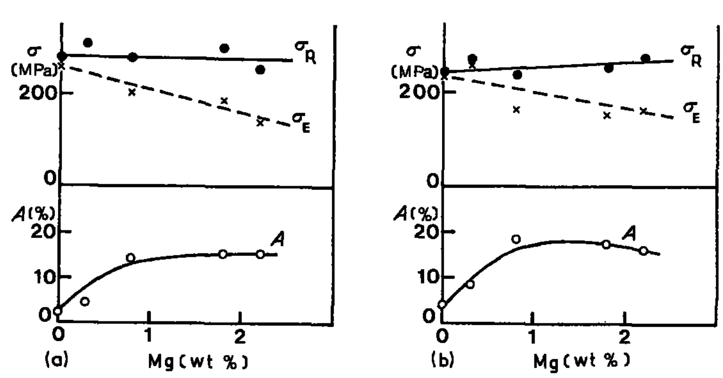

Figure 4 Mechanical properties of Al–5.7% Ni–Mg alloys, annealed for 500 h and tested at room temperature, as a function of magnesium content. (a) Annealing temperature $\theta = 200°$ C, (b) $\theta = 300°$ C, (c) $\theta = 400°$ C, and (d) $\theta = 500°$ C.

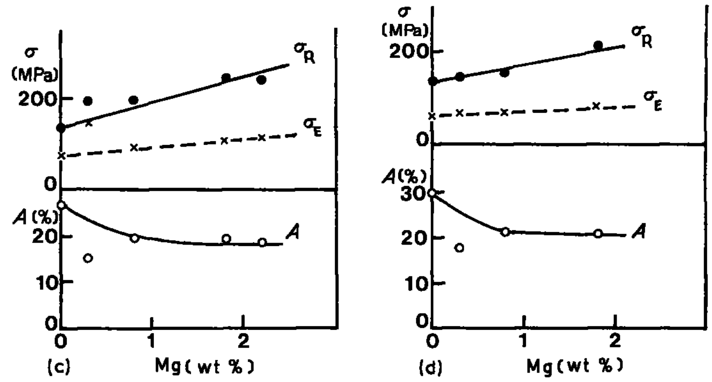

Figure 4 Continued.

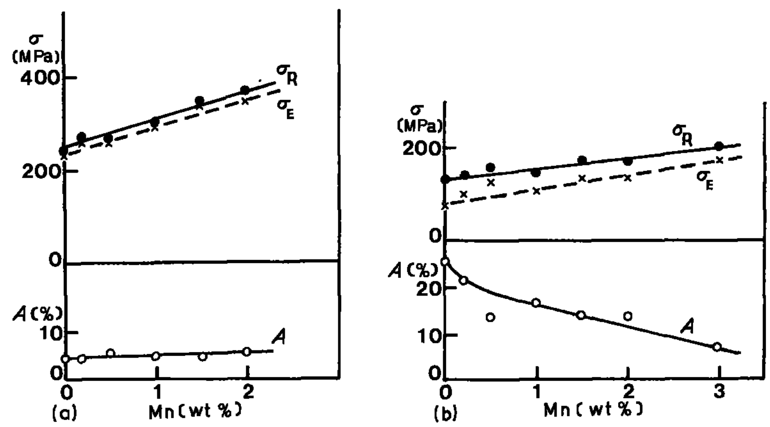

Figure 5 Mechanical properties of Al–5.7% Ni–Mn alloys, annealed for 500 h and tested at room temperature as a function of manganese content. (a) Annealing temperature $\theta = 200°$ C and (b) $\theta = 400°$ C.

Acknowledgements

The authors would like to express their thanks to R. Ghislain and K. Butkovic for their technical assistance.

References

1. A. BERGHEZAN, J. DILLE, R. DESCHAMPS, G. VIELVOYE and N. TERAO, *CR Acad. Sci. Paris* **293** (II) (1981) 417.
2. N. TERAO, Z. WEN, J. DILLE and A. BERGHEZAN, *ibid.* **295** (II) (1982) 459.
3. N. TERAO, J. DILLE, G. VIELVOYE and A. BERGHEZAN, Proceedings of the 4th International Conference on Composite Materials, Tokyo, 25–27 Oct., 1982 (Japan Society for Composite Materials) p. 1585.
4. N. TERAO, *J. Mater. Sci.* **20** (1985) 4021.

Received 8 April
and accepted 30 June 1986