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DUCTILITY IMPROVEMENT ON $Al_{67}Ti_{25}Mn_8$ INTERMETALLIC ALLOY VIA HOT-WORKING

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Introduction

In recent years, efforts have been made to overcome the brittleness of the Al_3Ti intermetallic compound by appropriately alloying it with Fe, Ni, Mn or Cr, etc., so as to transform the tetragonal DO_{22} structure of Al_3Ti into the cubic $L1_2$ structure(1-3). These ternary $L1_2$ intermetallics have received considerable attention because they exhibit appreciable compressive ductility at room temperature(4). However, the studies so far have been mostly conducted with cast or PM-prepared samples, and the results reported are limited to compressive properties, as the materials remain extremely brittle in tension. Only recently, Kumar et al. have performed tension studies on forged Al_3Ti-base alloys(5). In their tests, cylindrical "buttonhead" tensile specimens were used, and the tensile ductility of $Al_{66}Ti_{25}Mn_9$ at ambient temperatures was determined to be about 0.2%. This is quite encouraging even though the tensile deformation is so small. However, the result is doubtful since the plastic elongation was obtained from the load-displacement curves. The precision of this method is not sufficient to determine such a small elongation with reasonable confidence.

In the present paper, the role of hot-working on the ductility improvement of an $L1_2$ $Al_{67}Ti_{25}Mn_8$ alloy has been studied, and the tensile elongation of the hot-worked alloy precisely measured by the electrical-resistance strain gage is reported.

Experimental

The ingot of $Al_{67}Ti_{25}Mn_8$ alloy was melted and cast under argon atmosphere in an induction melting furnace and was homogenized at 1373K for 50h. Blocks of 30x30x30mm cut from the ingot were hot pressed at 1273K to a total reduction of 70% by 2 or 3 reheating cycles using a 3000 kN hydraulic press. Some other blocks were hot pressed to various reductions for studying the influence of reduction on ductility. The hot-pressed pieces were annealed at 1273K for 2h to remove the remaining work-hardening after hot-working.

Compression specimens with dimensions 4x4x7mm were cut from the annealed pieces and compression tests were conducted with a crosshead speed of 0.1mm/min. Plate specimens (Fig. 1a) were used for tensile tests, which were cut from the 70% pressed and annealed pieces and polished

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with emery papers. The cross-section of the specimen is 3x2mm rectangular and the gage length 6mm; a crosshead speed of 0.1mm/min was used for tensile tests. Load-strain curves were recorded from the output of electrical resistance strain gages which were glued to gage length portion of the tensile specimens. The fracture surfaces after tensile tests were characterized by SEM.

Results and discussion

Room temperature compression tests of the induction melted, cast and homogenized $Al_{67}Ti_{25}Mn_8$ alloy gave a compressive ductility of about 12%, which is much lower than the value of the same alloy, but prepared by arc-melting in a water-cooled copper crucible, i.e. about 17%. Microstructural examination showed that the cast structure of the induction-melted ingot (Fig. 2a) contains more internal flaws, such as oxide inclusions and microporosity, than that of the arc-melted button ingot. However, hot-working improves the property appreciably. The compressive plastic strain increases from 12% for the cast specimens to 19% of the hot-worked sample which had undergone a total reduction of 70% via three operation cycles and was then annealed at 1273K for 2h. The microstructure of the hot-worked material is shown in Fig. 2b, where it can be seen that even though the ingot structure was broken down and grain refinement was made by the hot-working process, the inclusions still remain but are aligned into strings along the flow direction. So it is believed that if the induction melting process is improved and the quality of ingot is well controlled, the ductility of the material can be further increased.

To explore the influence of the amount of hot-deformation on ductility improvement, compression tests were conducted for the samples hot-pressed to various reductions. The results are shown in Fig. 3. It can be seen that the ductility is not improved until the reduction is greater than about 30%, and appreciable improvement is made when the reduction is over 50%. Typical load-deformation curves are shown in Fig. 4, where the improvement in mechanical property by hot-working is apparent.

Specimens of hot-worked $Al_{67}Ti_{25}Mn_8$ alloy (70% total reduction and annealed) were tensile tested at room temperature. The results displayed small but definite plastic strains before fracture. Figure 5 is a typical stress-strain curve recorded from the output of resistance strain gage, which revealed an elastic deformation region followed by the smooth parabolic portion of the curve. The measured plastic strain is 0.28% and the fractured specimen is shown in Fig. 1b. Since no local necking was formed during the test, and the fracture did occur outside the strain gage measuring portion, the value measured must be the uniform plastic strain of the tensile tested specimen. Macrofractography of the tensile tested specimen (Fig. 6a) showed that the origin of fracture was usually located near the specimen surface, and that the fracture propagated radially along the rectangular section as shown by the radial marks on the fracture surface. Neither fibrous zone nor shear lip could be found on the fracture surface, indicating the brittle response of the material. SEM high-magnification inspection revealed that the fracture mode of the tensile specimen is predominantly transcrystalline cleavage, but some traces of plastic deformation could be found in the cleavage ledges as shown in Fig. 6b. This feature, associated with the small but definite plastic strain in the tensile tests, provided evidence that the hot-worked Al_3Ti-base alloy may have potential tensile ductility.

Conclusions

1. Hot-working improves the compressive ductility of $Al_{67}Ti_{25}Mn_8$ alloy appreciably. The ductility improvement is directly related to the extent of hot-worked reduction of the samples.
2. Room temperature tensile tests of the hot-worked $Al_{67}Ti_{25}Mn_8$ specimens with resistance strain gage glued on one side resulted in a small but definite plastic strain before fracture. SEM fractography revealed a transcrystalline cleavage fracture mode with some traces of plastic deformation.

Acknowledgements

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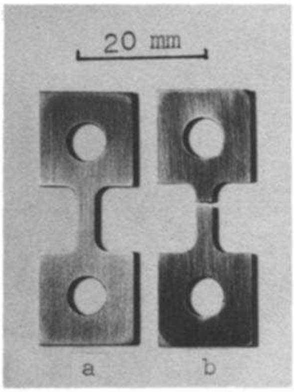

Fig. 1 Tensile specimens of $Al_{67}Ti_{25}Mn_8$ alloy (a) before and (b) after test

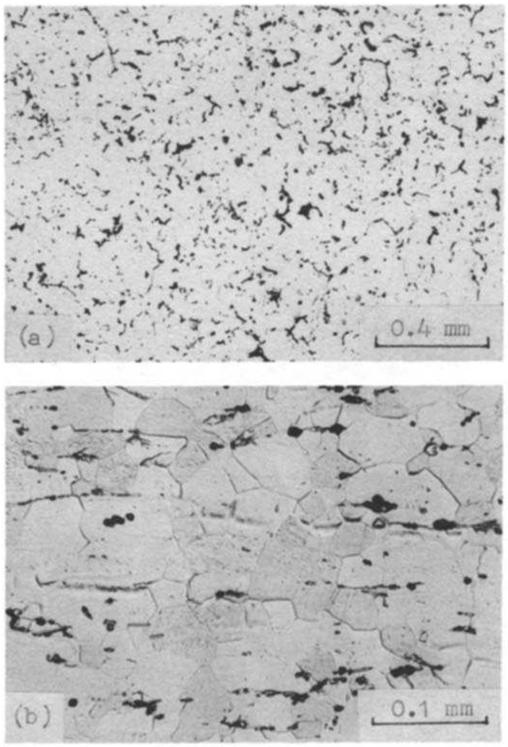

Fig. 2 Micrographs of induction-melted $Al_{67}Ti_{25}Mn_8$ alloy (a) as-cast and homogenized (b) 70% hot-pressed and 1273K/2h annealed

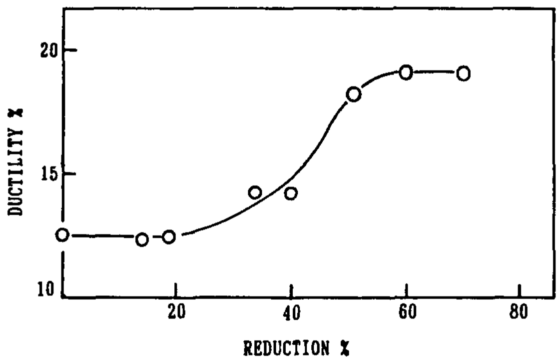

Fig. 3 Room temperature compressive ductility of hot-pressed and annealed $Al_{67}Ti_{25}Mn_8$ alloy as a function of reduction

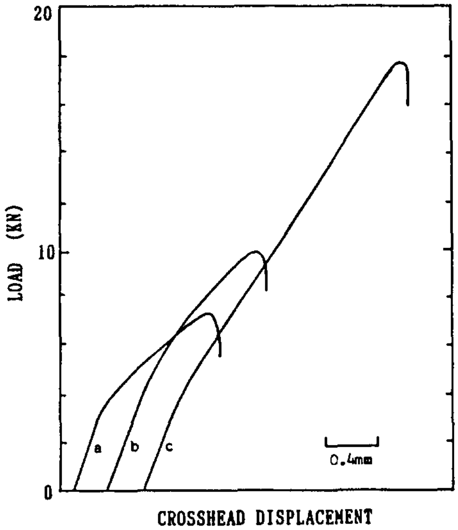

Fig. 4 Typical load-deformation curves of the $Al_{67}Ti_{25}Mn_8$ alloy compression tested at room temperature
(a) as-cast and homogenized
(b) 19% hot-pressed and 1273K/2h annealed
(c) 70% hot-pressed and 1273K/2h annealed

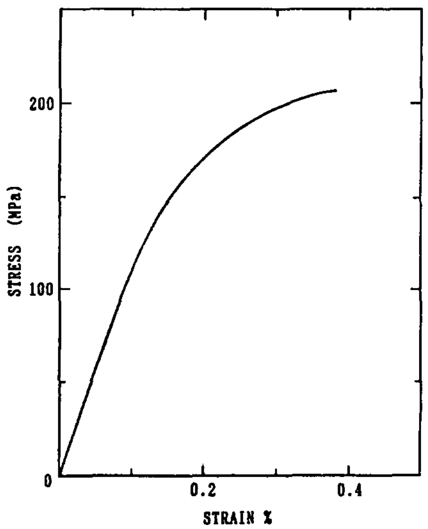

Fig. 5 Typical tensile stress-strain curve of the $Al_{67}Ti_{25}Mn_8$ alloy, 70% hot-pressed and 1273K/2h annealed

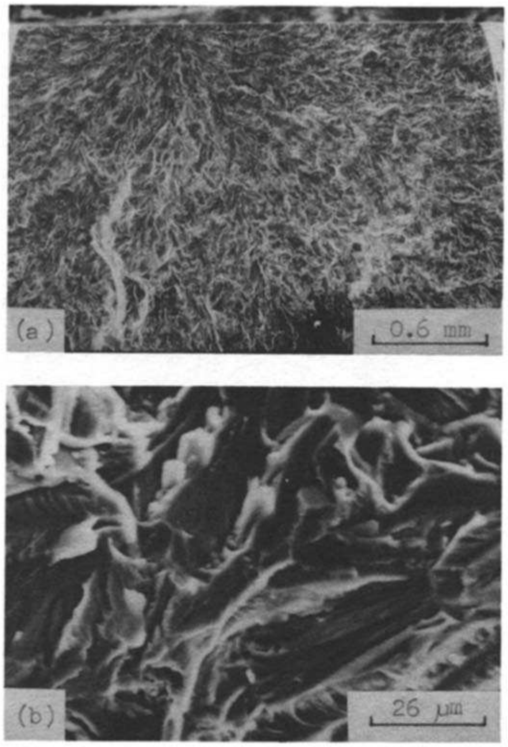

Fig. 6 SEM fractographs of tensile tested specimen of $Al_{67}Ti_{25}Mn_8$ alloy