RESEARCH ARTICLE

The Effect of Temperature on the Formability of High Strength Aluminium Alloys

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A pressing need to reduce CO_2 emissions and improve motoring efficiency is driving aggressive weight reductions in automotive design. This makes high performance aluminium alloys, with their high strength to weight ratio, the materials of choice for future sheet metal body structures. Alas, their adoption is hindered by poor cold formability and a drastic loss of performance after warm forming. This project, which is a collaboration with Constellium, aims to understand the limits of formability of 7xxx alloys by a combination of mechanical testing, deep drawing and advanced microstructural characterisation.

The high strength of 7xxx aluminium alloys make cold forming effectively impossible, unless it is performed immediately after solution heat treatment. This is both difficult and impractical, making it a costly option. However, since these alloys rely on precipitation strengthening for their performance, warm formability is a complex process. Since the microstructure will change during forming, formability will not simply increase with temperature. A naturally aged material, in the T4 condition, will continue to age and strengthen during forming whereas a peak aged material, in the T6 condition, will lose strength as it overages.

This is readily demonstrated by the results of tensile tests carried out between 150ºC and 250ºC, shown in Figure 1. It is clear that in the T4 condition (naturally aged) increasing temperature leads to a complex change in properties, with a non-linear change in strength work hardening and ductility. In the T6 (peak aged) condition, increasing temperature leads to a decrease in strength. This behaviour is a consequence of complex precipitation and coarsening sequences taking place in this material.

Although tensile tests are informative, deep drawing tests are a more useful measure of formability: the results of these tests are shown in Figure 2 where the effects of warm deformation on microstructure instability are again evident. Although in the T6 condition increasing the temperature always leads to an increase in drawability, drawing was successful at both 190ºC and 250ºC in the T4 condition, but not at other temperatures. This is a counterintuitive finding, but one which offers the promise of a way to warm form these materials in a practical and cost effective manner.

This work is now being followed by detailed microscopic analysis, including TEM work and fracture surface analysis as shown in Figure 3. This analysis, in combination with microstructural modelling, will help establish whether warm formability can be exploited in an industrial setting with existing alloys and how this new understanding of the fundamental deformation mechanisms can be used to develop high strength aluminium alloys with good formability.

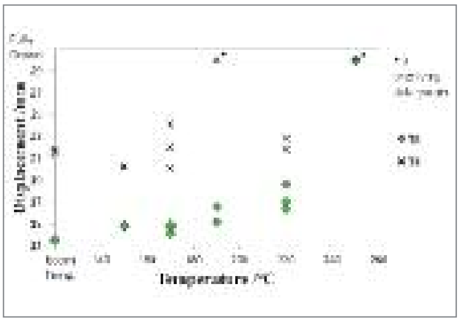

Fig. 2 Deep drawing test results for material in the T4 and T6 conditions at different temperatures.

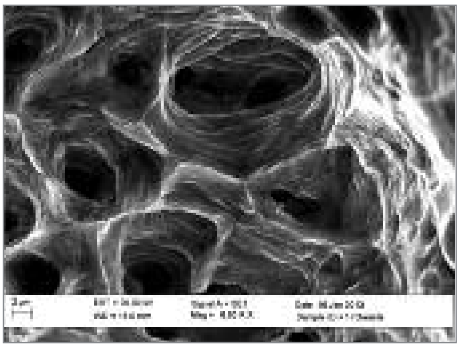

Fig. 3 Fracture surface of the material tested at 170ºC in the T4 condition.

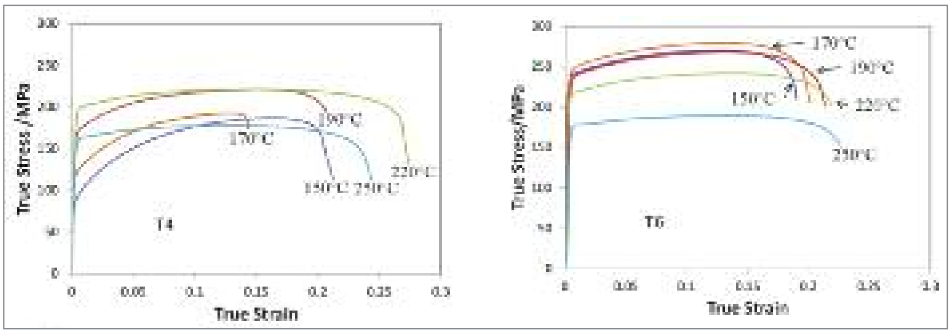

Fig. 1 Tensile test results for material in the T4 (left) and T6 right) conditions at different temperatures.

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