Cost and Strength Competitive Aluminium Alloys for Automotive Applications

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According to Ford, Jaguar and Land Rover there are significant cost and mechanical performance targets that must be achieved by aluminium alloys if their use is to be extended into mass-produced vehicles. Otherwise, aluminium vehicles like the P2000 Ford Contour demonstrated as part of the US government's Partnership for New Generation of Vehicles (PNGV) project back in 1997 and shown in Figure 1 will never go into production. The aluminium-intensive Contour weighed 909 kg; a 40% overall reduction in curb weight that could mean a dramatic 30 to 40% reduction in fuel consumption and carbon emissions. Additionally, its unitary body design made it immediately amenable to high-volume manufacturing. Figure 2 illustrates the sensitivity of fuel consumption to vehicle mass and shows that to achieve <100 g CO_2 per km, curb weight should be less than 1000 kg. In addition to the requirement for low-cost aluminium sheet for body-in-white (BIW) applications in vehicles like the P2000 Contour, increased safety demands particularly for side-impact crash resistance, are resulting in the use of more and more high strength steel in automotive structures. This requirement has resulted in new steel grades being made available with tensile strengths up to 950 MPa. Presently, the strength requirements for these high-impact components are beyond the range of conventionally processed affordable aluminium alloys particularly at the upper end of that strength range (500 – 950 MPa). Jaguar and Land Rover, as the flagship brands for Ford's aluminium intensive vehicle developments, have specified requirements for high-strength aluminium (250 – 300 MPa) to replace high-strength steel for reinforcements in their lightweight vehicles like the Jaguar XJ saloon. They also wish to replace the present alloy (AA5754) in BIW structural applications with an alloy having a tensile strength of more than 200 MPa. These alloys must also be cost competitive with steel for the production of equivalent performance vehicle structures. The aim of this article is to present the opportunities that Innoval Technology is pursuing, both for high-strength aluminium alloys for crash resistant structures and for low-cost aluminium sheet alloys for BIW applications that are cost competitive with steel.

Addressing the high-strength applications first: the direct chill rheocasting (DCRC) process developed at Brunel University represents a step-change in technology that offers the possibility of producing high-strength aluminium alloys without resorting to the established complex routes based on the consolidation of alloy powders. Potentially these DCRC materials could compete both in terms of strength and cost with both the range of ultra high-strength steels for use in crash resistant automotive structures and the more conventional vehicle applications as envisaged by Jaguar and Land Rover.

Significantly, the UK's Department of Trade and Industry has recently supported a three year, £2.1 million project that will start early in 2006 with the main objective to establish a DCRC facility to cast a range of aluminium alloys for extreme service applications. The project team, led by Innoval Technology, includes VAI Siemens, Alcan, Novelis, Luxfer, Brunel University and NAMTEC. The first application to be considered will be high-strength aluminium alloys for crash resistant automotive applications. Following this, other potential developments include alloys for high-pressure gas bottles, alloys with high temperature resistance and alloys with high wear resistance.

The DCRC equipment, shown in Figure 3, consists of three components; twin-screw slurry makers, a slurry accumulator and a DC caster. The slurry makers convert liquid metal into high quality semi-solid slurry that is fed via the accumulator, providing a continuous flow, into the DC caster. The advantages of the DCRC technology are as-cast aluminium blocks and billets with a uniform microstructure across the entire cross-section and a refined as-cast grain size. This fine and uniform microstructure not only aids subsequent component production steps, but also ensures enhanced mechanical properties and improved mechanical performance in the finished product. Compared with the conventional route for wrought alloy processing, the DCRC process reduces processing steps to a minimum as there is much less need for conventional thermo-mechanical processing. The DCRC process can also be used to process a much wider range of aluminium alloys than the conventional DC process and this allows the development of alloys with exceptional properties for demanding applications.

To tackle the sheet cost issue, Innoval Technology is examining the feasibility of producing aluminium automotive alloys from recycled beverage can scrap. This is inspired by the quantity of three billion used aluminium beverage cans (UBCs) that are sent to land-fill in the UK each year (alarmingly, more than 50 billion UBCs are similarly lost in the US). Coupling this with the fact that the energy consumed in the conversion of recycled aluminium back to finished product is only 5% of that required for manufacturing from primary sources, makes an attractive prospect. Recovery of this “lost” aluminium represents a tremendous opportunity to produce economically a large quantity of low CO_2 vehicles each year that could have a dramatic impact on global carbon emissions. Initial assessment suggests that this development could have a greater impact on carbon emissions from the UK than the adoption of biofuels. This project could also take advantage of the family of rheoforming technologies being developed at Brunel University, particularly if this enabled the use of twin-roll continuous casting of aluminium alloys like AA5754, AA6016 and AA6111. Figure 4 shows the relative composition of these alloys and returned can scrap. The cost of aluminium automotive sheet could certainly be made cost competitive with steel sheet if the appropriate can collecting strategies were put in place.