Strength improvement in high pressure die castings for automotive components

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This project is sponsored by Jaguar Land Rover to develop and commercialise the next generation of high strength cast aluminium alloys produced by high pressure die casting (HPDC) for light duty engines and other structural components.

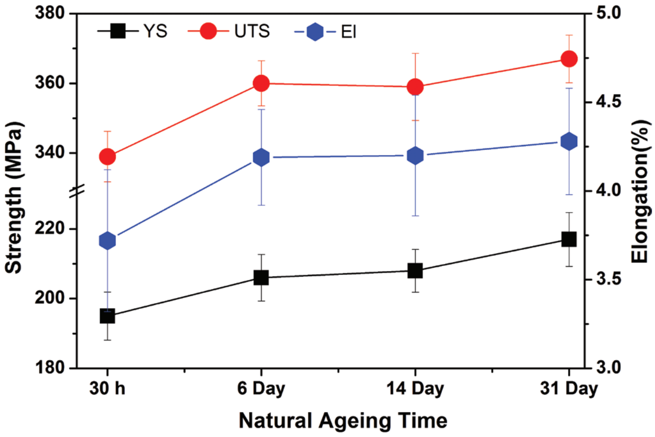

FIGURE 1. The effect of natural ageing on the mechanical properties of the newly developed alloy.

Mechanical properties	YS (MPa)	UTS (MPa)	El (%)
Current alloy	145	329	5.17
Developed alloy	217	367	4.25

TABLE 1. The mechanical properties of the current and developed alloys.

As lightweighting automotive structures are always required for transport manufacturing, the mechanical properties of existing commercial aluminium alloys for the HPDC process does not meet industry requirements. Therefore, the development of new high strength aluminium alloys for HPDC is necessary for automotive OEMs. In this project, a cam carrier is selected for this case study. The current commercially available aluminium alloy is EN AC-46000, which has a yield strength (YS) of 145 MPa, ultimate tensile strength (UTS) of 329 MPa and elongation of 5.1 %. The new high strength HPDC aluminium alloy has to meet the required properties of UTS>300 MPa, YS>200 MPa, El>2 % in casting body and >4 % in 6.35 mm Ø die-cast tensile samples at room temperature. Such requirements must be met only in the as-cast condition without any heat treatment.

Generally, the increase of strength is obtained at the sacrifice of elongation. Therefore, the biggest challenge of this project is to maintain the elongation at an acceptable level (>4 %) as the strength is increased by 38 %. In Al-Si-Cu-Mg alloys, the two main strengthening phases are Q-$Al_5Cu_2Mg_8Si_6$ and θ-Al_2Cu intermetallic compounds. The θ-Al_2Cu phase exists in the form of (1) large individual blocks, or (2) fine Al-Al_2Cu lamellar eutectics along the boundaries of α-Al grains; while Q-$Al_5Cu_2Mg_8Si_6$ only exists within the eutectic mixture. The experimental results reveal that the addition of Cu (Cu< 3%) increases the elongation, but a further increase in the level of Cu induces a decrease in elongation. A series of alloying additions, including Si, Cu, Mg, Zn, and other elements of Zr, Ni, Ti were studied to determine the optimum combination of alloying elements and final composition. The Fe level should be limited to no more than 1wt.% to avoid the formation of large α-AlFeMnSi phase and needle-like β-AlFeSi phase. It was also found that too much modifying or refining elements (Mn, Ti and Sr) are deleterious to the properties.

The natural ageing of the developed alloy can simultaneously improve the YS, UTS and elongation. It is believed that the high cooling rate during the HPDC process induced a degree of solid solution of solute-atoms and then the natural ageing leads to the precipitation of fine Q-$Al_5Cu_2Mg_8Si_6$ phase within α-Al grains. It has been confirmed that fine Q-$Al_5Cu_2Mg_8Si_6$ precipitates are distributed within α-Al matrix, which are responsible for both strength and elongation improvement. After a few day's natural ageing, the developed alloy has the stable properties: YS >210MPa, UTS >350MPa and El >4.0 %. The tensile property of the developed alloy has good repeatability.

In the future, trial castings of the developed alloy with a shape off box will be produced and the Weibull statistical model will be used to analyse reliability of the castings. This will then allow for the developed alloy to be fully implemented within industry.