Development of high strength multicomponent aluminium based die casting alloys

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There is an increasing demand for lightweight vehicles in the automotive industry to reduce fuel consumption and lower emissions. This has led to a rapid growth in the use of aluminium parts produced by high pressure die casting (HPDC). Currently, existing aluminium die casting alloy compositions are based on binary Al-Si or Al-Mg systems with additions of minor alloying elements.

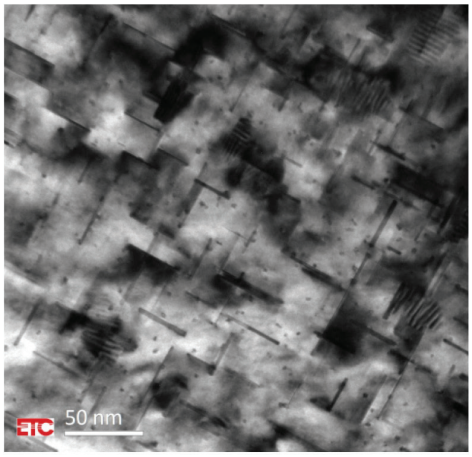

FIGURE 1. Ultrafine precipitates in the α-Al matrix of HPDC Al-Cu-Si-Mg-Mn-Fe alloy heat treated at peak aged condition.

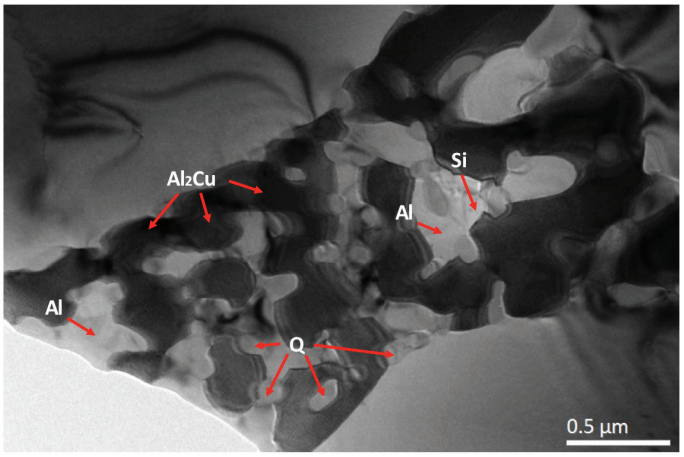

FIGURE 2. Nanocrystalline eutectic mixture in as-cast HPDC Al-Cu-Si-Mg-Mn-Fe alloy

However, their yield strength and ultimate tensile strength are limited to 120-250 MPa and 250-330 MPa. Hence, there is an urgent need to develop HPDC aluminum alloys with strength properties beyond those currently available for the ever-demanding automotive engineering components.

Recently, near-eutectic ternary Al-Cu-Si [1] alloys have received increasing attention due to a combination of ultrahigh strength and good plasticity, which are attributed to the nano/ultrafine structure composites containing either micron-sized dendrites embedded in ultrafine eutectic matrix or multi-scale bimodal eutectic microstructure. However, there are very limited studies on the use of high-order multicomponent eutectic aluminium alloy systems for the design of high strength casting aluminum alloys.

The aim of this project is to develop high strength multicomponent aluminium die casting alloys that offer a combination of various strengthening mechanisms (e.g. grain boundary, second phase or precipitate hardening) with reasonable ductility and good fluidity via low melting point of liquid phase. The objective is to design a series of hypoeutectic compositions in Al-Cu-Si-Mg-Mn-Fe multicomponent eutectic systems for high pressure die casting, to exploit the high hardness of nanocrystaline eutectic mixture and the soft α-Al dendrites to yield a combination of high strength and good ductility properties.

It has been demonstrated that the yield strength and ductility can be tailored according to alloy composition. The yield strength increases from 219 MPa to 267 MPa, while the ductility decreases from 7.7 % to 3.1 % with increasing amount of nanocrystalline eutectic mixture from 13 % to 24 % respectively. Upon peak ageing heat treatment of these casting alloys, their yield strength increase at the expense of the ductility. This research work has demonstrated that the yield strength of 395 MPa and ductility of 1.8 % can be achieved in the peak aged HPDC Al-Cu-Si-Mg-Mn-Fe hypoeutectic alloy with 24 % nanocrystalline eutectic mixture. Such exceptional high strength in this material is attributed to a combination of nanoscaled precipitates in the α-Al matrix and hard intermetallic phases in the eutectic mixture, as shown in Figures 1 and 2. Future work is to explore the high-order multicomponent eutectic concept in the development of high strength copper-free aluminium die casting alloys.

REFERENCES:

[1] J.T. Kim, S.W. Lee, S.H. Hong, H.J. Park, J.Y. Park, N. Lee, Y. Seo, W.M. Wang, J.M. Park and K.B. Kim. Understanding the relationship between microstructure and mechanical properties of Al–Cu–Si ultrafine eutectic composites. *Materials and Design*, 92 (2016), 1038. DOI: 10.1016/j.matdes.2015.12.080.