

Microstructure-Based Finite Element Model for High-Pressure Die-Cast Al–Si–Cu Alloys: Effect of α -Al Particle on Plasticity and Ductile Fracture

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Abstract. This study presents an enhanced finite element simulation framework for predicting the flow stress and ductile fracture behavior of high-pressure die-cast (HPDC) Al–Si–Cu alloys. In HPDC alloys, the applicability of the secondary dendrite arm spacing (SDAS) as a representative microstructural descriptor is limited due to dendrite fragmentation induced by high-speed turbulent filling. To address this issue, the present work introduces the size of fragmented α -Al particles as the primary microstructural variable. The proposed multi-scale model is developed based on a previously established framework in which eutectic Si particle fracture is described by Weibull statistics coupled with the Gurson–Tvergaard–Needleman (GTN) ductile fracture model. The key extension of this study is the incorporation of the α -Al particle size dependence into the constitutive description of matrix flow stress. The predictive capability of the model is evaluated through tensile and fracture experiments conducted on specimens with different particle sizes. The results demonstrate that the proposed approach effectively captures the characteristic microstructural features of HPDC alloys and enables accurate prediction of both flow stress and fracture behavior, highlighting the essential role of α -Al particle size in fracture modeling of HPDC alloys.

Keywords: HPDC · Al–Si–Cu alloys · α -Al particle · Ductile fracture · GTN model

1 Introduction

High-pressure die-casting (HPDC) is an essential manufacturing process for producing complex-shaped aluminum components in the automotive industry. The mechanical properties of these alloys are highly dependent on their microstructural features. As shown in Fig. 1, the microstructure typically consists of...

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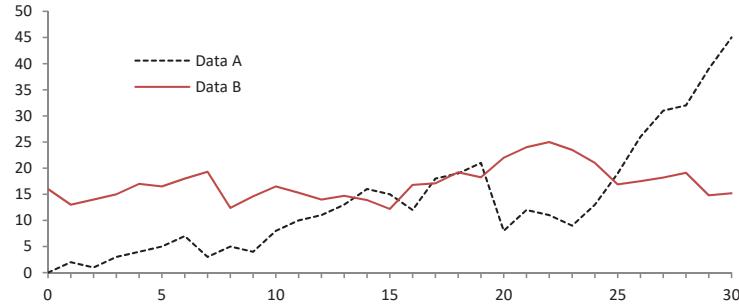


Fig. 1. Microstructure of the HPDC Al–Si–Cu alloy showing fragmented particles.

2 Conclusion

This study successfully developed an enhanced FEM framework that incorporates α -Al particle size. The results highlight the importance of...