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Numerical modelling of the structural behaviour of thin-walled cast magnesium components

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Abstract

Axial crushing, 3-point bending and 4-point bending tests have been performed in order to establish an experimental database of the behaviour of generic high pressure die cast (HPDC) AM60 structural components. In this paper, the experimental data are applied to obtain a validated methodology for finite element modelling of thin-walled cast components subjected to quasi-static loading. The HPDC structural components are modelled in LS-DYNA using shell elements. The cast magnesium alloy is modelled using both the classical J2-flow theory and an elastic–plastic model based on a non-associated J2-flow theory. In the latter, the constitutive model includes the Cockcroft–Latham fracture criterion, which is coupled with an element erosion algorithm available in LS-DYNA. It is further possible to define the fracture criterion as a Gauss-distributed stochastic parameter to allow for heterogeneities in the cast material. The constitutive model and fracture criterion are calibrated with data from tension and compression tests. Comparison of experimental and predicted behaviour of HPDC components gives promising results. It is found that the strength difference between uniaxial compression and tension has little influence on the numerical simulations. The fracture criterion of Cockcroft and Latham seems to be an effective approach to predict failure in HPDC components.

1. Introduction

Growing concerns for economy, environment and functionality have led to increased use of light-metals in the load carrying structure and safety components of cars. With high pressure die casting (HPDC) of magnesium and aluminium alloys, components with very complex, thin-walled geometry, like instrument

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Nomenclature

W	critical "plastic work" in Cockcroft–Latham fracture criterion
σ_1	maximum principal stress
σ_e	von Mises stress
ε_e	equivalent plastic strain
κ	material reference hardening
$\boldsymbol{\sigma}$	Cauchy stress tensor
$\boldsymbol{\varepsilon}$	true strain tensor
$\mathbf{C}$	elastic moduli
$\mathbf{I}$	second order unit tensor
$\boldsymbol{I}$	fourth order unit tensor
λ, μ	the Lamé constants

panels, A and B pillars and front end structures, can be cast with a high production rate. The challenge with the method is to optimise the process parameters with respect to the part design and the solidification characteristics of the alloy in order to obtain a sound casting without casting defects. Unbalanced filling and lack of thermal control can cause porosity and surface defects due to turbulence and solidification shrinkage. These defects can give low ductility compared to for instance extruded materials.

Design and production of thin-walled cast structural components for the automotive industry are challenging tasks, involving development of alloys and manufacturing processes, structural design and crashworthiness analysis. In order to reduce the lead time to develop a new product it is necessary to use finite element (FE) analysis to ensure a structural design that exploits the material. Accurate description of the material behaviour is essential to obtain reliable results from such analyses. To minimise the weight of the structural component while maintaining the safety in a crash situation, the ductility of the material has to be utilised without risking un-controlled failure. Hence, a reliable failure criterion is also required,

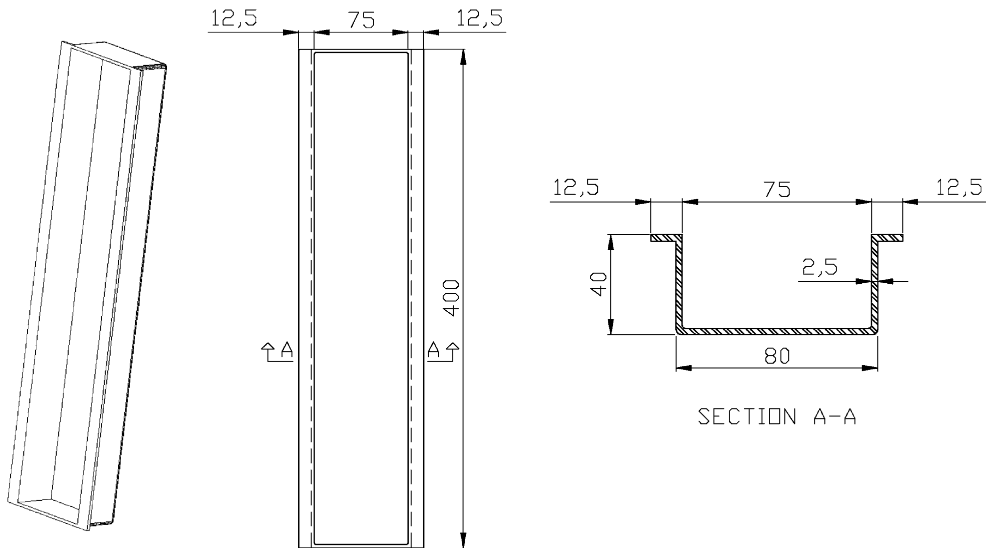

Fig. 1. Generic profile geometry without ribs.