View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by KITopen

ICILLS 2011
3rd International Conference on
Impact Loading of Lightweight Structures
June 28th–July 1st 2011, Valenciennes, France

Numerical modelling of aluminium die-castings using a probabilistic approach

Octavian Knoll[1,2], Odd Sture Hopperstad[1], Magnus Langseth[1], Karl Schweizerhof[2]

[1]*Structural Impact Laboratory (SIMLab) and Department of Structural Engineering,*
Norwegian University of Science and Technology
N-7491 Trondheim, Norway
Email: octavian.knoll@ntnu.no, odd.hopperstad@ntnu.no, magnus.langseth@ntnu.no

[2]*Institute of Mechanics*
Karlsruhe Institute of Technology
D-76131 Karlsruhe, Germany
Email: octavian.knoll@kit.edu, karl.schweizerhof@kit.edu

Weight reduction and crash requirements combined with cost reduction are the most important items in the car body design. Therefore, light metals such as aluminium alloys are of special interest. The aluminium space-frame concept becomes more and more attractive. This concept allows the large scale production of complete aluminium integral car bodies. A successful example is the AUDI A8.

High Pressure Die Castings (HPDC) components made of aluminium alloys offer various advantages in automotive applications. These are for example, the cost efficiency of the casting process as well as the possibility to cast thin-walled components of complex geometries. The best known production process is the vertical cold chamber vacuum HPDC method. Currently HPDC components are used in the car body as connectors, rocker rails, A- and B-pillars. One of the main challenges with the HPDC production method is to optimize the process parameters regarding the part design and the solidification characteristics of the used alloy to obtain sound casting without or at least with a minimum of casting defects. Defects are caused by the process chain as well as the geometry of each component [1]. Typical defects are porosity due to turbulence and solidification shrinkage, gas porosity, oxide films and cold flow areas. The distribution of the defects is not homogeneous but systematic (global) and stochastic (local) [2]. As a consequence the mechanical behaviour, especially the fracture behaviour, is of a stochastic character [3], [4].

To reduce the lead time and the costs for the development of a new product, it is necessary to use virtual development tools. One of the most important is the Finite Element (FE) method which allows the simulation of the mechanical behaviour of a continuum body. Only reliable FE models can predict the mechanical behaviour in an accurate way. This involves, in addition to the FE mesh generation, the selection of the element formulation and the modelling of the boundary conditions, a qualified constitutive model as well as a problem oriented failure criterion. To use the full potential of HPDC components it is necessary to utilize the ductility of the material without risking uncontrolled failure. Especially the prediction of failure is of foremost importance for a functional design in crash situations.

The present paper is focused on a normalized aluminium HPDC alloy. The alloy is characterized by a high strength and a distinctive quasi-brittle material behaviour in cast condition. Here, the lack of heat treatment and the following process steps additionally reduce the production costs. Quasi-static tensile tests with specimens cut from a generic HPDC component were performed to analyze the scatter of the mechanical properties. Based on this material characterization the global as well as the local scatter were observed. Especially the local scatter demonstrated the stochastic character of HPDC alloys.

EVA-STAR (Elektronisches Volltextarchiv – Scientific Articles Repository)
http://digbib.ubka.uni-karlsruhe.de/volltexte/1000025018

In this paper, the stochastic character of the aluminium HPDC alloy and its influence on numerical simulations is presented. Using the experimental database and the work by Dørum et al. [5], a probabilistic methodology for FE modelling is introduced to analyze HPDC components. The elastic-plastic material behaviour is described by a constitutive model consisting of a high exponent, isotropic yield criterion, the associated flow law and a isotropic hardening rule. The phenomenological ductile fracture criterion by Cockcroft-Latham is used. It is assumed that the fracture parameter follows a modified weakest link Weibull distribution. Based on the Weibull statistics a probability of fracture can be determined and used to evaluate FE simulations of HPDC components. FE simulations of tensile tests are compared with the experimental database in order to check the accuracy of the constitutive model and the input data as well as the probabilistic methodology. In addition, the results of three point bending and axial crushing tests of the generic HPDC component are used for the validation of the material model and the probabilistic methodology.

References

[1] Treitler, R., Vom Gießprozess zur Festigkeitsberechnung am Beispiel einer Aluminium-Magnesium-Druckgusslegierung, PhD Thesis (in German), Institute for Reliability of Components and Systems, University Karlsruhe, Germany 2005.
[2] Lee, S., Gokhale, A.M., Patel, G.R., Evans, M., Effects of process parameters on porosity distributions in high-pressure die-cast AM50 Mg-alloy, Material Science and Engineering A 427 (2006) 99-111.
[3] Teng, X., Mae, H., Bai, Y., Wierzbicki, T., Statistical analysis of ductile fracture properties of an aluminium casting, Engineering Fracture Mechanics 75 (2008) 4610-4625.
[4] Gokhale, A. M., Patel, G.R., Analysis of variability in tensile ductility of a semi-solid metal cast A356 Al-alloy, Materials Science and Engineering A 392 (2005) 184-190.
[5] Dørum, C., Hopperstad, O.S., Berstad, T., Dispinar, D., Numerical modelling of magnesium die-castings using stochastic fracture parameters, Engineering Fracture Mechanics 76 (2009) 2232-2248.