8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

A PROBABILISTIC APPROACH FOR MODELLING OF FRACTURE IN DIE-CASTINGS

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Key Words: *Aluminium castings, Ductile Fracture, Automotive, LS-DYNA.*

ABSTRACT

Increased demands with respect to fuel consumption in the automotive industry force designers to search for solutions with both low weight and low cost. In this respect, high-pressure die-casting of lightweight metals such as aluminium and magnesium alloys has attracted attention as being a competitive production method. A 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 containing few defects. In the work presented here, a new method for FE modelling of fracture in castings is being developed. The method is based on the classical Weibull theory [1] in combination with the well-known ductile fracture criterion proposed by Cockcroft and Latham [2]. The model has been implemented in the commercial explicit FE-code LS-DYNA [3].

The cast aluminium alloy AlSi4-T1 is modelled using the classical J_2 flow theory and the Cockcroft-Latham fracture criterion. The J_2 flow theory consists of the von Mises yield criterion, the associated flow rule and a non-linear isotropic hardening rule. The fracture criterion is coupled with the element-erosion algorithm available in LS-DYNA. As the fracture criterion is reached in one layer of an element, this element is removed (eroded) from the finite element model. The Cockcroft-Latham fracture criterion can be expressed as

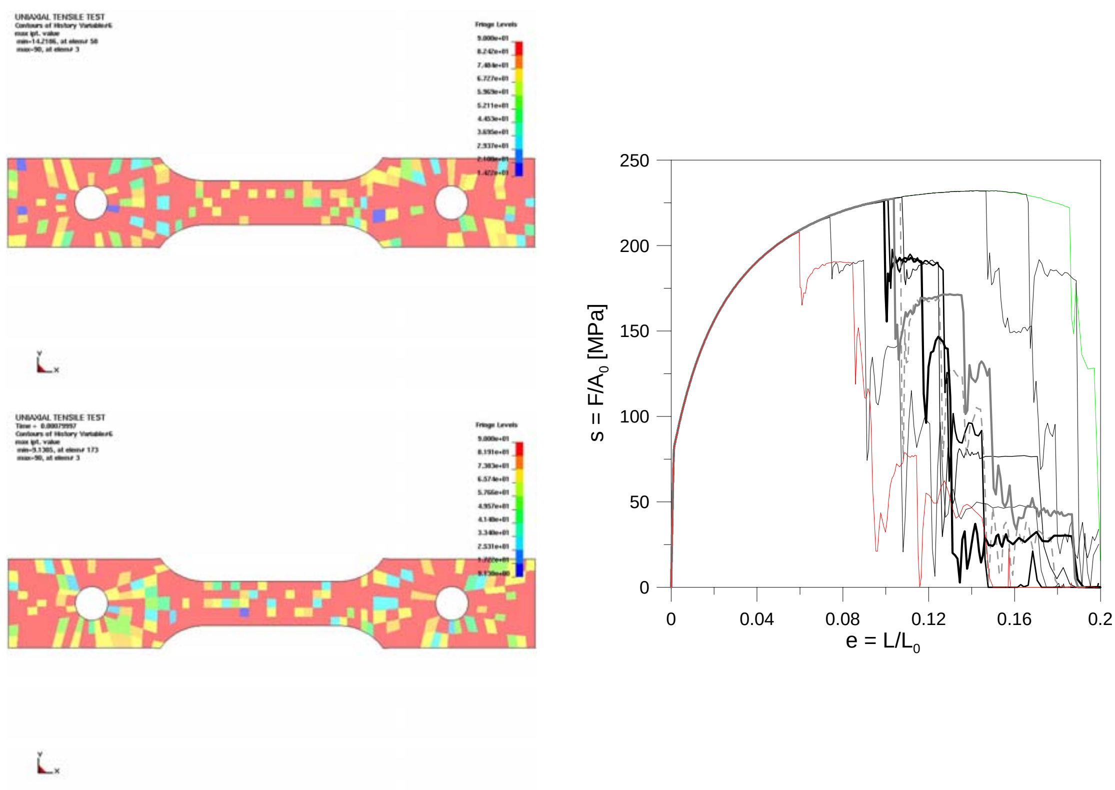
$$W = \int \max\left(\sigma_1, 0\right) d\varepsilon_e \leq W_c$$

where σ_1 is the major principal stress, ε_e is the effective plastic strain and W_c is the critical value of the integral W. By comparing the values of the fracture parameter W_c obtained from shear tests with those obtained from uniaxial and plane-strain tension tests, it has been found that the former values are significantly higher. This indicates that the Cockcroft-Latham criterion is not generally valid. However, it should be noted that the volume of material tested in the shear tests was only a small fraction of the volume tested in uniaxial and plane-strain tension. Thus, owing to statistical effects, the probability of testing a part of the material having a defect of a given size and

orientation is much smaller in the shear tests, which should lead to increased ductility. By taking advantage of the "weakest-link" methodology provided by the Weibull theory, the size effect with respect to fracture modelling of die-cast materials can be investigated in more detail. The Weibull distribution is often used in fracture mechanics, and gives the fracture probability of a material volume under effective tensile loading σ. By combining the Weibull approach with the Cockcroft-Latham ductile fracture criterion, the fracture probability of a material volume can be given as:

$$P(W_c) = 1 - \exp\left(-\left(\frac{V}{V_0}\right)\left(\frac{W_c}{W_{c0}}\right)^m \right)$$

where V is the volume, V_0 is the scaling volume, W_0 is the scaling fracture parameter, and m is the Weibull modulus. By using a random number generator and inverse sampling, a Weibull distribution of fracture parameters can then be assigned to the integration points in the FE mesh. With this approach, a small element in the FE model will most probably be given more ductile material properties than a larger element. The figure below shows numerical results from uniaxial tensile testing, which reproduces the experimental scatter very well.



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