Optimized Test Program for Calibration of 3D-GISSMO for Die-Cast Aluminum

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Abstract

Accurate crash simulations of die-cast aluminum components require fracture models that capture stress-state dependence. This paper proposes an optimization framework and a cost-effective specimen combination for calibrating 3D-GISSMO. Using a ground-truth Modified Mohr-Coulomb (MMC) fracture surface and a library of literature-based specimens, we evaluate specimen combinations via numerical optimization. Results show that an optimized program with six specimen types achieves equal or higher calibration accuracy than a conventional ten-specimen program. The approach reduces cost and lead time while maintaining fidelity of fracture calibration of 3D-GISSMO.

1 Introduction

Die-cast aluminum is increasingly applied in automotive structures due to its strength-to-weight ratio. Reliable crash simulations depend on calibrated material cards. In this study, 3D-GISSMO was assumed. 3D-GISSMO requires a three-dimensional fracture surface in terms of triaxiality and Lode parameter, typically described by the modified Mohr-Coulomb (MMC) criterion with six parameters. Capturing this surface conventionally demands many specimen types, raising cost and lead time. This motivates an optimized test design balancing accuracy and efficiency.

2 Methods: Optimization Framework

The optimization framework was built on a ground-truth fracture surface defined by the Modified Mohr–Coulomb model (MMC), which represents fracture strain as a function of stress triaxiality and the Lode parameter. A stress-state library of approximately 80 points was compiled from literature sources, covering a wide range of specimen geometries. To simulate experimental variability, synthesized noise was added to the stress-state library. Using the dataset, the optimal specimen sets were identified using combination optimization. To ensure practical feasibility, each optimized program was constrained to include a uniaxial tension (UT) specimen, since UT testing results are essential for defining the hardening curve in the material card.

3 Summary of Result

The optimization identified efficient test programs. The numerical optimization results indicate that the six-specimen optimized program achieves accuracy comparable to that of the ten-specimen baseline. However, these findings are based solely on numerical studies that assume the MMC model as the true fracture strain surface. The optimized combinations must therefore be validated through experimental testing to confirm their practical applicability, which will be addressed in future work.

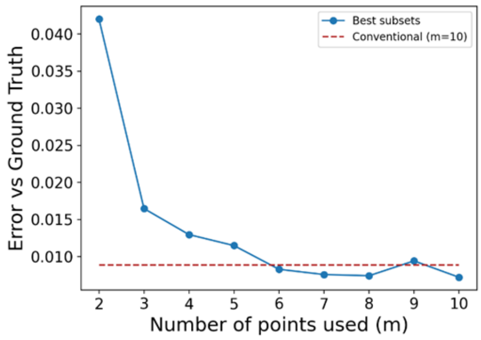

Fig. 1: Errors of optimized specimen combinations relative to the ground truth

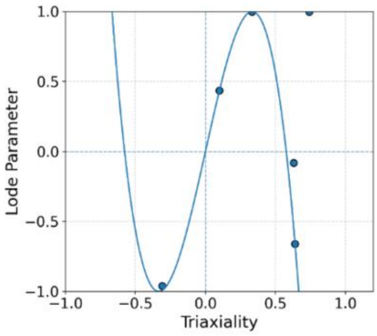

Fig. 2: Pareto-optimal specimen combination with a fixed number of six specimens