Validated Material Model with Damage

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Sponsor: PACCAR

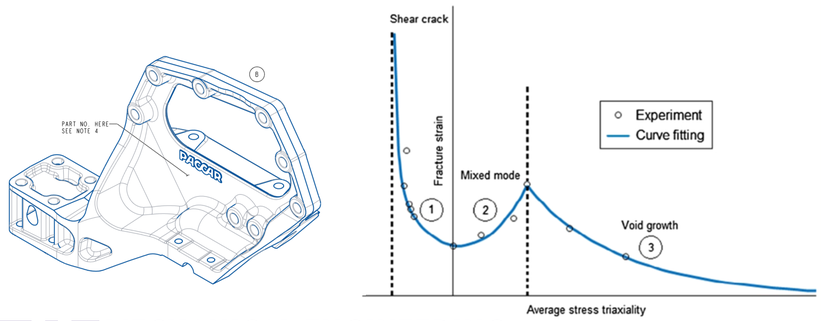
INTRODUCTION

PACCAR Technical Center currently does not have a validated material model with damage. This is because analysis is traditionally more focused towards durability. However, development of battery electric vehicles has more requirements for impact analysis.

Problem Statement: Due to the underlying problems presented, we propose a validated damage material model to simulate crash/impact analysis for battery electric vehicles for PACCAR. The model will assist in accurately defining scope and design for future projects to prevent wasted material and time in unrepeatable electrical car crash tests.

CORE FUNCTIONS

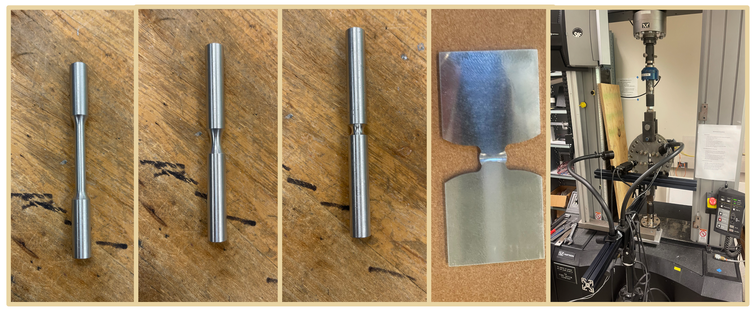
- Create a material model with ABAQUS using parametrized properties of a cast-aluminum truck part provided by PACCAR.
- Predict damage and fracture strain by plotting fracture strains with known stress triaxiality and characterize them with the Johnson-Cook fracture criteria ($\varepsilon_f = D_1 + D_2 \exp(D_3\eta)$).
- Validate results by comparison simulations with 3D DIC-measured physical tests.



DESIGN AND DEVELOPMENT

Material Tests

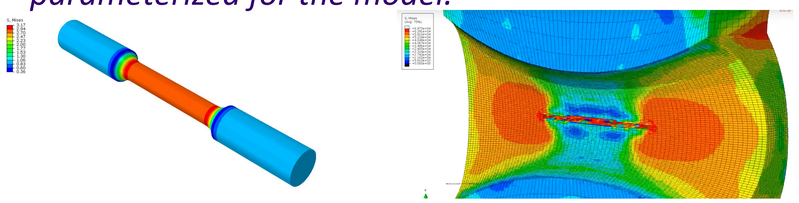
- *4 types of specimens were created to induce different stress triaxiality in the material.*
  - *3 Types of Round Bar specimens*
  - *1 Type of Butterfly Specimen*
- *Specimens were loaded using an Instron and Arcan test fixture, and the strain was measured using 3D DIC.*



Left to right: Long Round Bar, Large Notch Round Bar, Small Notch Round Bar, Butterfly Specimen, Instron and Arcan fixture with 3D DIC

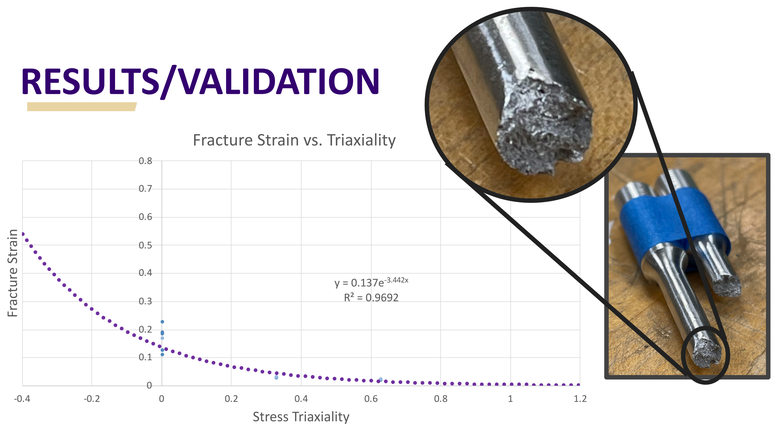
ABAQUS Models

- *Modeled all material tests with proper boundary conditions and loading to determine stress triaxiality.*
- *The true-stress strain curve for the material was determined with load data from the long round bar.*
- *With collected fracture strains and stress triaxiality, the coefficients for the fracture criteria were determined through the least squared method and parameterized for the model.*

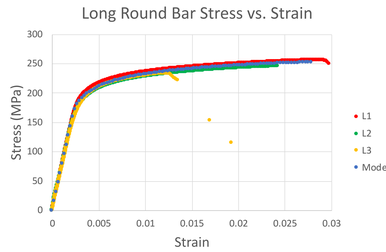


ABAQUS Models of Round Bar (right) and Butterfly Specimen (left)

RESULTS/VALIDATION



- *Specimens exhibited brittle-like properties, including no necking and rough fracture surfaces.*
- *The calculated coefficients of the Johnson-Cook fracture criteria were $D_1 = 0.0$, $D_2 = 0.137$, and $D_3 = -3.442$.*



CONCLUSION & FUTURE WORK

- *Assumptions about the behavior of the material under compression were made. In the future, more tests should be done for total validation.*
- *Pits in casted parts can lead to inconsistencies in data therefore a larger sample pool is suggested.*
- *Determine a high energy impact test for PACCAR part for future validation.*
- *Test for the effects of strain rate dependencies to determine the scope our model can be used in.*

Acknowledgements

Aisha Gautam, Ben Speirs, Per Reinhall, Bob from the Physics Machine Shop

Mechanical Engineering Capstone Exposition

May 30st 2023, Husky Union Building, University of Washington, Seattle

MECHANICAL ENGINEERING
UNIVERSITY of WASHINGTON