Predict Failure of Thermoplastics Under Monotonic Loading

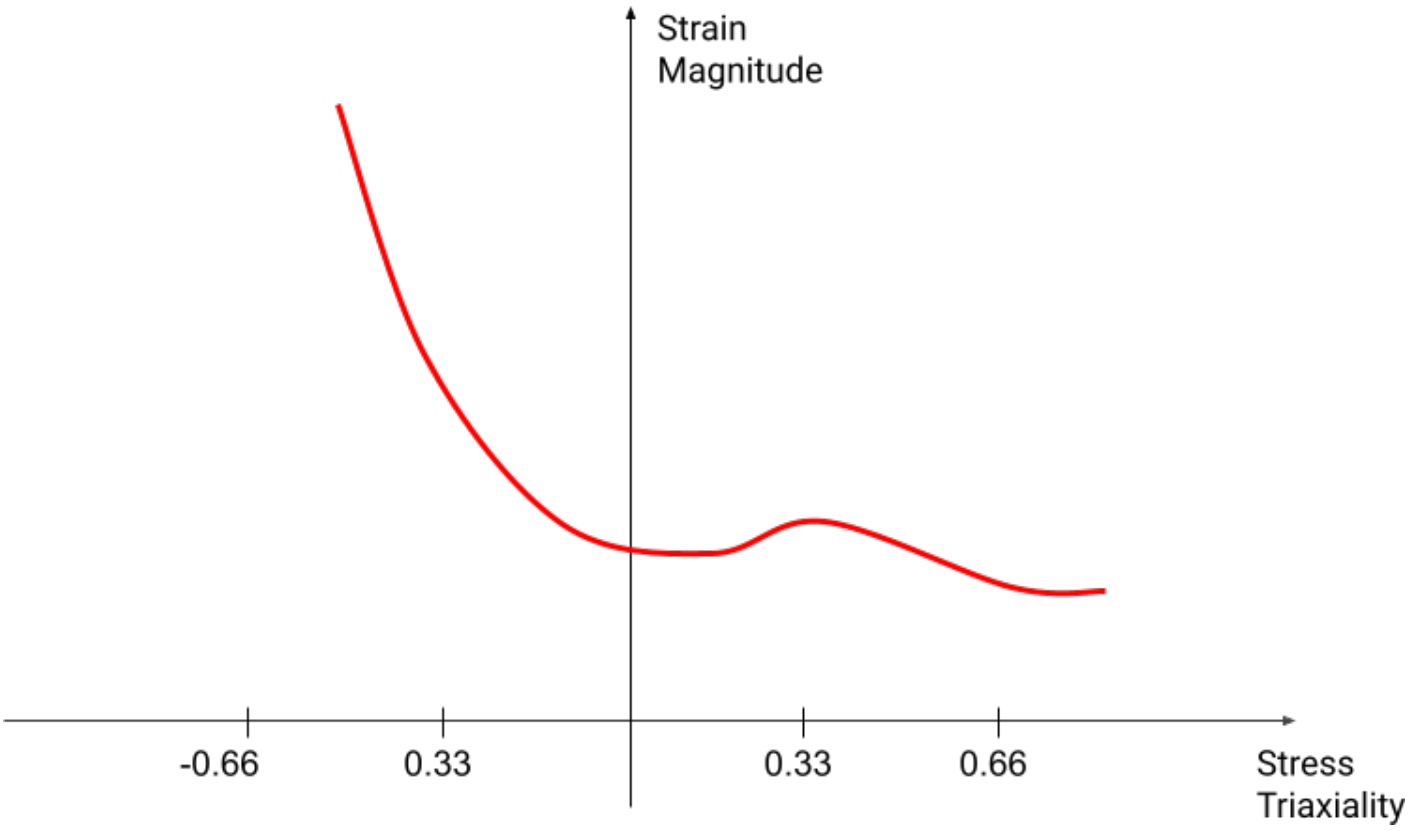
Jorgen May 9, 2023 No Comments

Introduction

The ability to predict when plastic components fail is an important aspect of engineering and industrial processes. Failure of plastic components can result in serious safety hazards, financial losses, and downtime in operations. Despite these important reasons, many engineers still use inaccurate failure conditions. **For example, did you know that the Mises stress is often NOT very accurate when it comes to predicting multiaxial safety factors and failure of thermoplastics**. In this article I will show that a strain-based failure condition with a critical strain that depends on the stress triaxiality can be more accurate. For more info about this topic also see my introductory article on Stress Triaxiality.

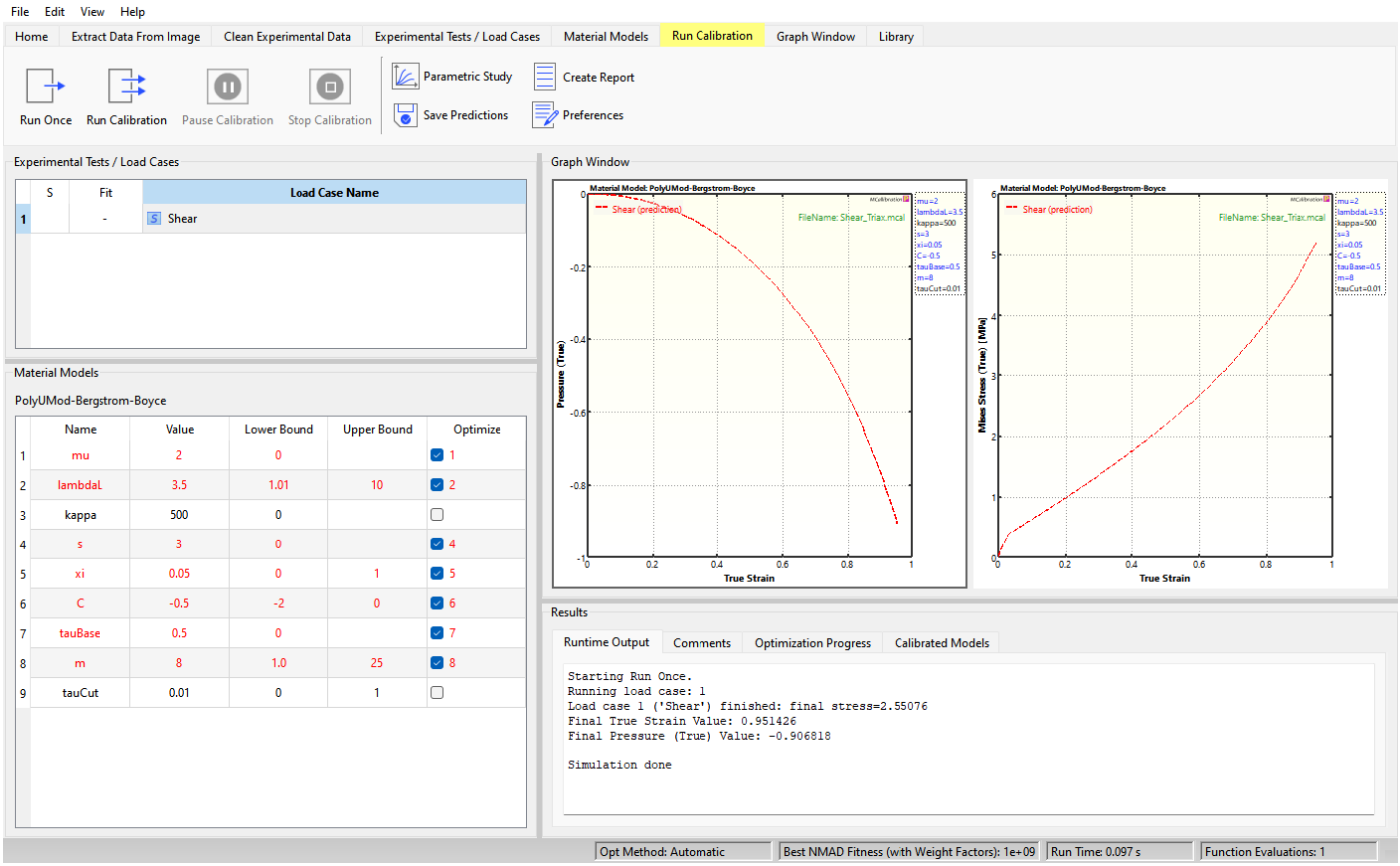
Predicting Failure of Ductile Metals

Predicting failure of ductile metals has been an important topic in the automotive industry for many years now. One of the most successful methods for predicting failure of metals in this application is based on the assumption that failure occurs at a critical strain that depends on the stress triaxiality. Here stress triaxiality is defined by: $T = \sigma_{mean}/\sigma_{mises}$. It is easy to see that T=0 in simple shear, T=0.33 in uniaxial tension, T=0.66 in biaxial tension, etc.



Stress Triaxiality in Large Strain Shear

In small strain simple shear deformation the mean stress is 0, so the stress triaxiality is therefore 0. In large strain simple shear the material starts to develop a tensile stress which leads to a non-zero stress triaxiality. The following MCalibration example shows that for an engineering shear strain of 1.0 (and the specific BB-model), the stress triaxiality becomes 0.18.

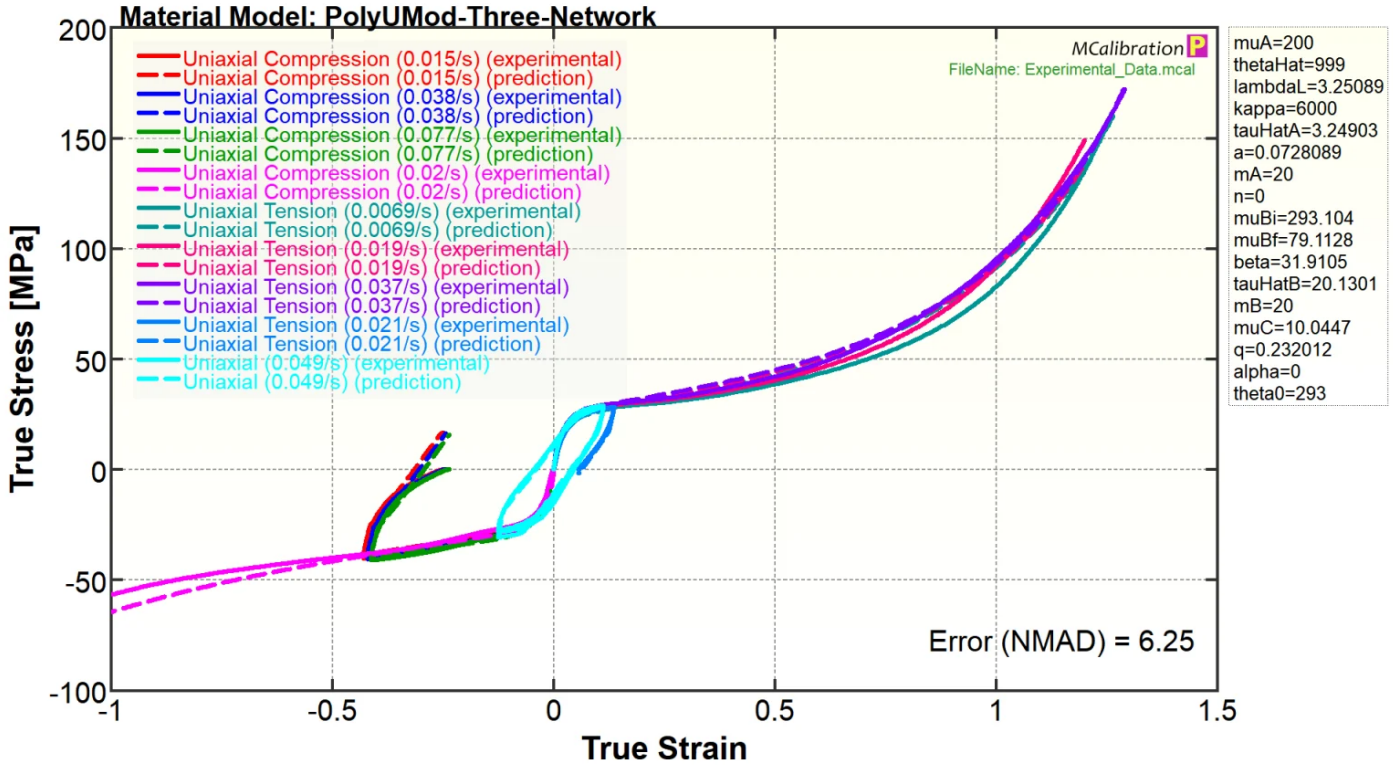


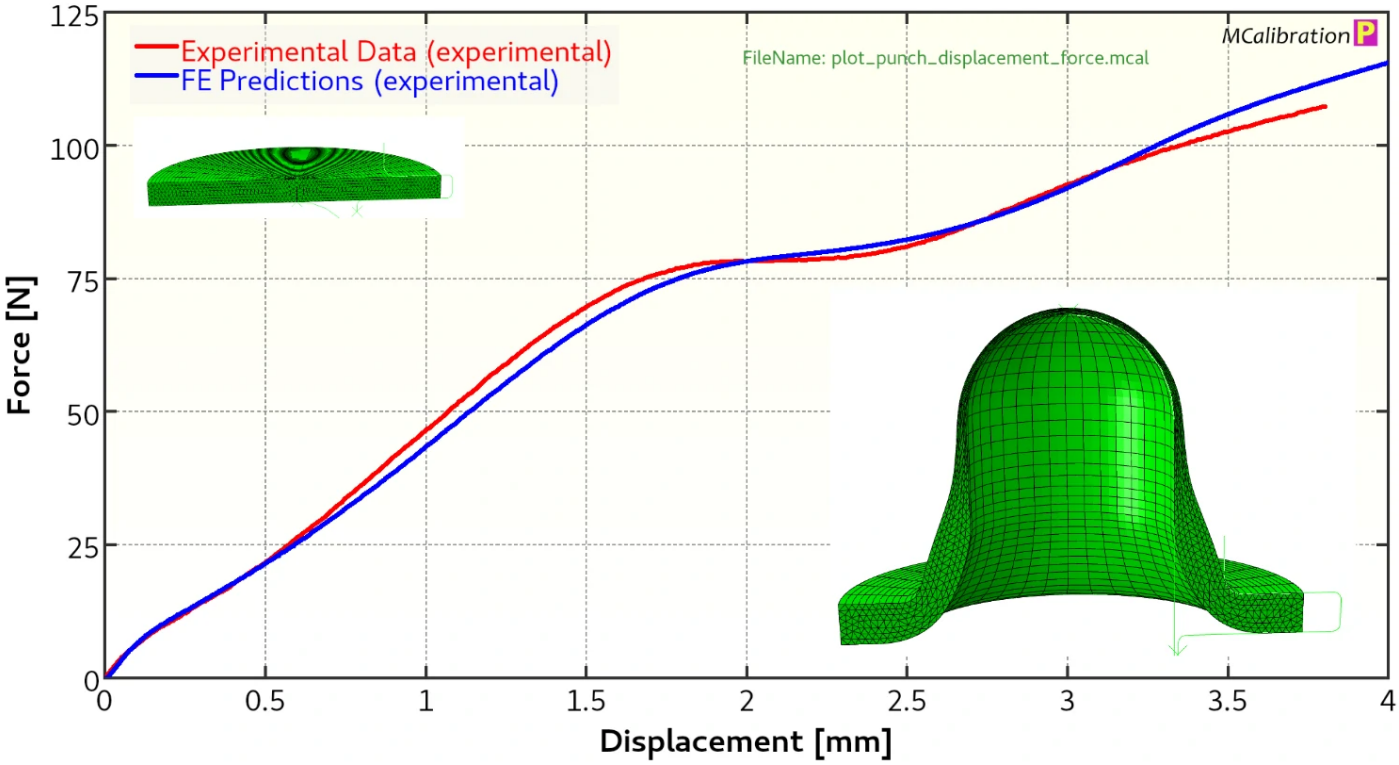
Material Models that Support Stress Triaxiality

There are two main material models that can use triaxiality-based failure models. One is the GISSMA failure model in LS-DYNA, the other is the PolyUMod TNV model.

Failure Prediction Example: UHMWPE

In this example I tested a UHMWPE resin in both uniaxial tension to failure, and in small punch loading to failure, see the next 2 figures.





The results from the experimental failure tests are shown in the table below. The results show that the Mises stress or the max principal stress cannot accurately predict failure in both uniaxial and biaxial loading. This indicates that a simple stress-based failure condition is not suitable for this thermoplastic. The table also shows that a strain-based

failure condition with a critical strain that depends on the stress triaxiality can work well.

Loading Mode	Mises True Stress (MPa)	Max Principal True Stress (MPa)	Max Principal True Strain	Stress Triaxiality
Uniaxial	160	160	1.24	0.33
Punch	233	234	1.07	0.66

strain depends on the stress triaxiality.

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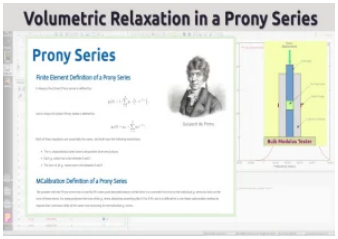
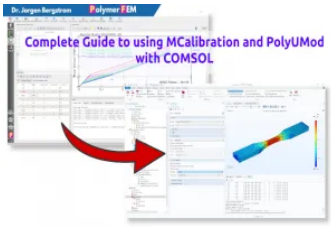


Volumetric Relaxation in a Prony Series

Most people assume that the volumetric relaxation is zero in a Prony series. This article demonstrates a different approach that can be better for some materials.



Complete Guide to Using PolyUMod with COMSOL Multiphysics

Guide to using MCalibration and PolyUMod with COMSOL Multiphysics. A complete start-to-finish tutorial is presented.

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