# Advances in the Measurement and Modeling of Plastics for Impact Simulations

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## Abstract

*High strain-rate properties have many applications in the simulation of automotive crash and product drop testing. These properties are difficult to measure. Previously, we described a novel inferential technique for the measurement of the properties of polycarbonate. In this paper, we demonstrate that the technique appears to work for a variety of polymers. We also show that plastics exhibit different kinds of high-strain rate behaviors. It is important to use an appropriate LS-DYNA material model for valid simulation results.*

## Summary

High strain rate tensile data have many uses in industry but it is often difficult to obtain accurate data at high strain rates. These tests are usually performed on a Universal Testing Machine (UTM) with an extensometer attached to a small specimen to measure strain. The extensometer most often is the cause of inaccurate strain readings when testing at high strain rates. These errors can result from slipping, inertial effects from the mass of the extensometer, and also from background noise at the start of the test. Non-contact devices such as laser or video extensometers have been used but these are also limited by vibration and noise. In a previous paper, we showed that strain should be measured by crosshead displacement rather than by an extensometer at high strain rates to avoid these errors. The relationship between crosshead displacement and strain was shown to be independent of strain rate. A correlation between displacement and strain was accurately established using extensometry at low strain rates. This correlation could then be used to convert displacement to strain at high rates. The resulting data was shown to be clean and self-consistent lending itself to the creation of robust material models for impact simulation.

In the current study, tests were conducted on a variety of polymers. The resulting data showed distinct behaviors for different classes of polymers. In describing the behavior of a polymer up to yield, we noted that certain plastics exhibited significant rate-dependency of modulus while others did not. This is in distinct contrast to metal behavior where the expected behavioral trend is toward no dependency of modulus with strain rate. A consequence of this finding is that polymers exhibiting rate dependency of modulus cannot be described by a MAT24 type model. The use of MAT24 for such materials will result in significant error in stiffness predictions. In contrast, MAT 19, even though it suffers from the deficiency of being a bi-linear model, is better suited and yields results of higher accuracy. Another deficiency in the MAT24 model was in its ability to handle some kinds of post-yield behavior. Some polymers such as polycarbonate, polyethylene and polypropylene exhibit long tails of post-yield strain and are capable of absorbing significant energy in this phase of their deformation. For such situations, MAT123 was found to be appropriate for describing the post-yield behavior. The nature of the failure changed when fillers were added. In extreme cases, such as highly glass filled plastics, the failure

changed from ductile to brittle. Interestingly, with intermediate fiber loadings, there was a gradual change from ductile to brittle failure with the increase in strain rate. This variation in post-yield behavior with strain rate is not easily captured in available material models today.

Lastly we noted a predominant trend toward agreement with the Eyring model in correlating yield stress and strain rate. This remarkable effect is most clearly observed as a linearly increasing relationship between yield stress vs. log strain rate. The obvious exception was the case of plastics exhibiting brittle failure where the result is noisier.

## References

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