Modelling of Polypropylene Subjected to Impact Loading at Low Temperatures

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1 Summary

The use of thermoplastics in structural applications requires that engineers can reliably predict their mechanical behaviour. Depending on the intended use, a component must withstand various load cases and environmental factors. This paper seeks to investigate the capabilities of a phenomenological material model to represent polypropylene (PP) plates subjected to a dropped weight impact at low temperatures.

The dropped weight tests were performed with an *Instron CEAST 9350 Drop Tower Impact System,* shown in Figure 1. An incorporated environmental chamber injected with liquid nitrogen enabled sub-room temperature conditions. A total of 11 drop tests were made at five different impact velocities.
The material was found to experience moderate plastic deformations until failure through plugging. By comparison of force displacement curves, the tests are found to show good repeatability. Some variations are found with respect to initiation of failure, possibly caused by small variations between the plates or misalignments during tests.

Numerical simulations were carried out with the *SIMLab Polymer Model*, which is implemented in LS-DYNA as a user defined material model. Inspired by a hyperelastic-viscoplastic model proposed by Polanco-Loria et al. [1], a hypoelastic formulation was adopted for the present study [2]. The model can be calibrated to account for typical characteristics of ductile thermoplastics with as few as three uniaxial tests; two different rates in tension and one in compression. Notable features include; pressure dependent flow, viscoplasticity, plastic dilation and coupled damage evolution. The low number of tests makes the model suitable for industrial applications. One important feature that is not included in the model is thermal softening due to adiabatic heating. As droped weight tests are generally considered adiabatic impact cases, an attempt to remedy the lack of thermal softening is made through the calibration of the model.

In this paper, the material model was calibrated through five unique tests including one uniaxial compression test and four tension tests at different strain rates. Each test was replicated to ensure repeatability. To compensate for the lack of thermal softening in the material model, the hardening law was calibrated from tensions tests at an intermediate strain rate of $10^{-0.5}\ \frac{1}{s}$. Assuming that the material experiences close to adiabatic conditions at said rate, the hardening incorporates the thermal softening caused by the heat accumulated from plastic dissipation. This becomes an effective, but slightly low, estimate of the thermal effects present in a dropped weight test where rates and thus dissipation of heat are expected to be somewhat higher.

Simulations of the dropped weight test were performed by modelling the impactor and supports as rigid bodies as sketched in Figure 2. The PP target plate was modelled with both shell and solid elements. An auxiliary goal was to investigate the proficiency of shell elements in combination with the material model, as shells are more widely used in industrial applications due to low computational cost. The numerical results showed good agreement with experiments throughout the perforation of the plate. Some discrepancies however, are found close to failure. This is most likely due to underestimation of the thermal softening. The results nevertheless indicate that the model is well able to reproduce the high rate bi-axial response experienced during an impact.

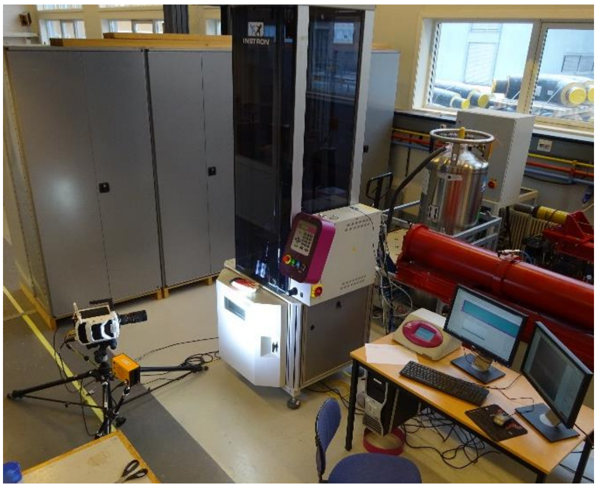

Fig. 1: Instron drop tower impact system.

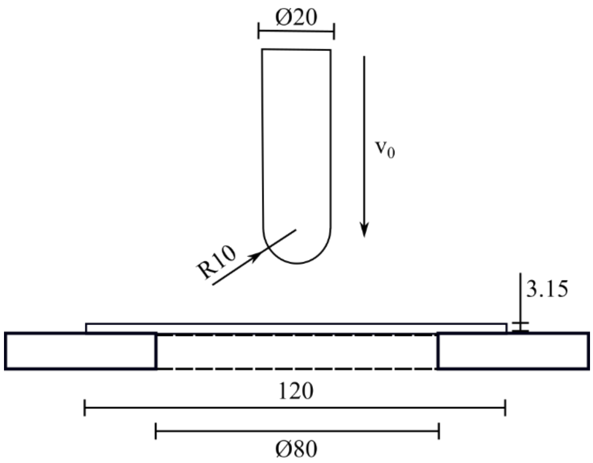

Fig. 2: Test setup geometry.

2 Literature

[1] Polanco-Loria, M., Clausen, A. H., Berstad, T., and Hopperstad, O. S.: *International Journal of Impact Engineering*, *37*(12), 2010, 1207-1219.

[2] Morin, D., Berstad, T., Clausen, A. H., Hopperstad, S. H.: 10th European LS-DYNA conference, 2015