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TITLE: PREDICITON OF MATERIAL STRENGTH AND FRACTURE OF BRITTLE MATERIALS USING THE SPHINX SMOOTH PARTIC'LE HYDRODYNAMICS CODE

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PREDICTION OF MATERIAL STRENGTH AND FRACTURE OF BRITTLE MATERIALS USING THE SPHINX SMOOTH PARTICLE HYDRODYNAMICS CODE

by

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Abstract

The design of many devices involves numerical predictions of the material strength and fracture of brittle materials. The materials of interest include ceramics that are used in armor packages; glass that is used in windshields; and rock and concrete that are used in oil wells. As part of a program to develop advanced hydrocode design tools, we have implemented a brittle fracture model for glass into the SPHINX smooth particle hydrodynamics code. We have evaluated this model and the code by predicting data from tungsten rods impacting glass. Since fractured glass properties, which are needed in the model, are not available, we did sensitivity studies of these properties, as well as sensitivity studies to determine the number of particles needed in the calculations. The numerical results are in good agreement with the data.

Introduction

In the current work we use the SPHINX smooth particle hydrodynamics code (Stellingwerf and Wingate, 1993) to predict data from two-dimensional experiments in which a tungsten rod impacted soda lime glass, backed by mild steel (Anderson et al., 1993). A series of experiments was conducted, and the tip and tail positions of the tungsten rod were obtained as a function of time.

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The fracture model used for predictions of impacts into ceramics is critical (Mandell, 1993). A fracture model that is adequate to predict one-dimensional experiments may give very poor results when predicting multi-dimensional experiments. We use the glass fracture model developed by Cagnoux (Cagnoux, 1985) and extended by Glenn and his co-workers (Glenn et al., 1990). Details of the model, comparisons with one-dimensional impacts into glass, and sensitivity studies are presented in a report (Mandell and Wingate, 1994).

Tungsten Rod Impacting Glass

Figure 1 shows a schematic of the geometry, which consists of a tungsten alloy rod impacting glass, backed by mild steel.

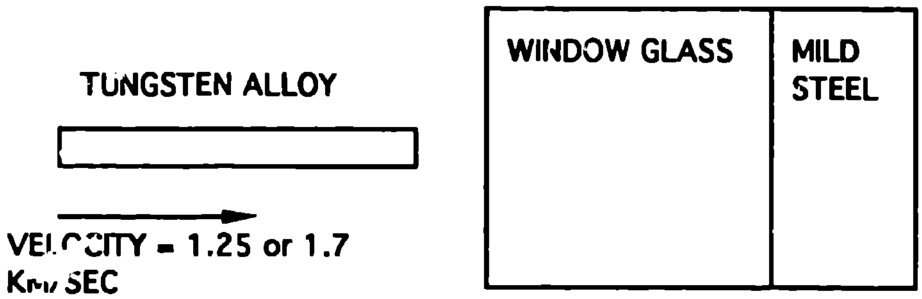

Fig. 1. Geometry for Tungsten Rod Impacting Glass.

The Grueneissen EOS and the elastic plastic strength model were used for the tungsten and mild steel. In these calculations, only the glass was allowed to fracture.

The glass model used in this work requires a knowledge of both the intact and the fractured glass properties - bulk modulus, shear modulus, and yield stress. Intact glass properties are reasonably well known, but the properties of the fractured glass are not available. Therefore we have varied the ratios of the fractured to the intact properties to match the experiments in which the rod velocity was 1.25 km/sec. We then ran the higher velocity experiment, which was at 1.70 km/sec, to determine if the fractured glass properties were valid for conditions other than those for which they were determined.

Figure 2 shows the tungsten rod nose position for the experiments in which the rod was at an initial velocity of 1.25 km/sec. This figure shows the data, a calculation without damage, and a series of calculations with damage in which the ratio of the fractured yield stress to the intact yield stress was varied (YR). For YR = 1.0, only the bulk modulus and shear modulus are decreased after the glass is fractured.

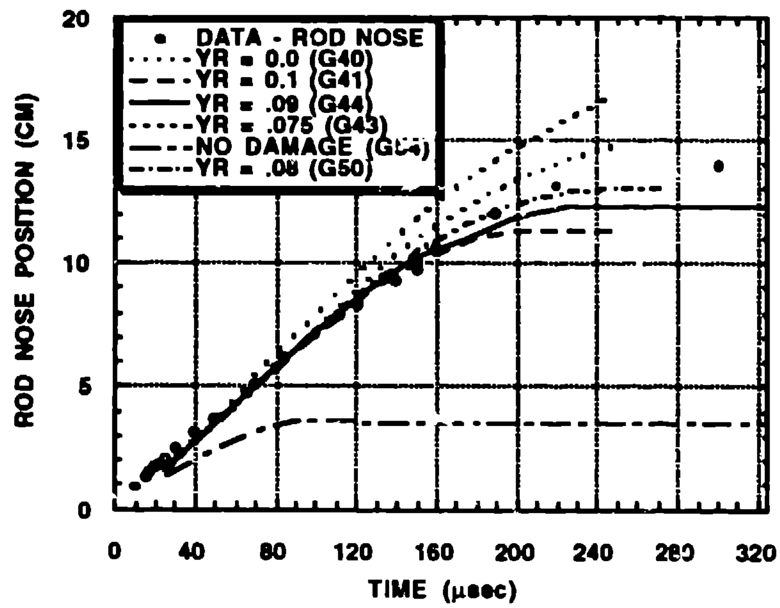

Fig. 2. Predictions of Tungsten Rods Penetrating Glass - Effect of Fractured Glass Yield Stress.

Using the values of the fractured glass properties determined for the experiments in which the rod velocity was 1.25 km/sec, the experiments in which the rod velocity was 1.70 km/sec were predicted. These results are shown in Figure 3. The comparison between the data and the SPHINX predictions is very good.

Conclusions

Two-dimensional experiments in which a tungsten rod impacts soda lime (window) glass were predicted. Fractured glass properties are unknown and had to be estimated. The fractured glass properties estimated for one experiment were used in the predictions of the other experiments, and the data and predictions agree reasonably well.

Several conclusions can be reached from these results. Numerical predictions of glass impacts are greatly in error when no fracture of the glass is allowed. In addition many models let the glass strength go to zero once a cell completely fractures. The model used in this work shows that some glass strength remains after fracture. The results are sensitive to the value of YR, but in all cases the predictions are much better using any nonzero value of YR than assuming that no fracture occurs.

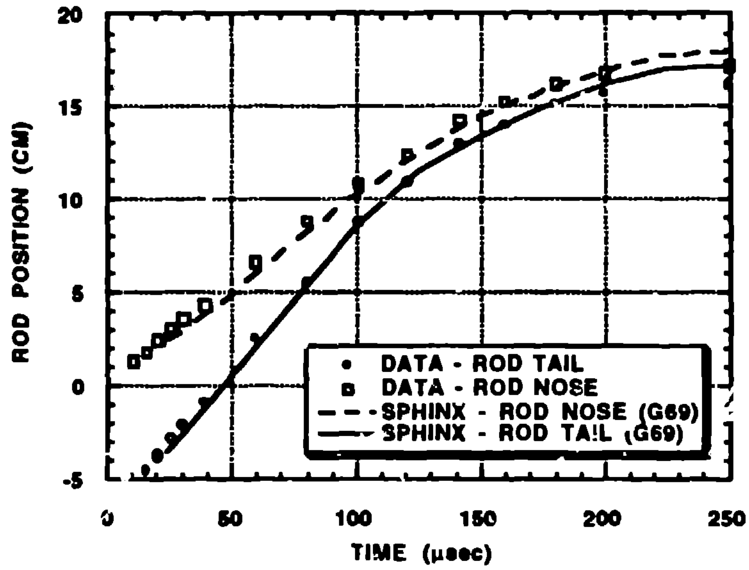

Fig. 3. Predictions of Tungsten Rods Penetrating Glass at 1.7 Km/Sec.

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