Extended Abstract

Model Formulation and Predictions for a Pyrotechnic Combustion Driven Pinpuller[1]

Keith A. Gonthier[2] and Joseph M. Powers[3]

Department of Aerospace and Mechanical Engineering
University of Notre Dame
Notre Dame, Indiana 46556
USA

phone 219-239-5978
fax 219-239-8341
e-mail powers@neumann.ame.nd.edu

submitted

September 15, 1992

to the

Fifth International Conference
of the
Groupe de Travail de Pyrotechnie

June 6-11, 1993
Strasbourg-France

[1]This study is supported by the NASA Lewis Research Center under Contract Number NAG-1335. Dr. Robert M. Stubbs is the contract monitor.

[2]Graduate Assistant.

[3]Assistant Professor, corresponding author.

Abstract

A description of the modeling and predictions of pyrotechnic combustion in the NASA Standard Initiator (NSI) driven pin puller will be given. Included will be 1) a description of the modeling assumptions, 2) a formulation of the model in terms of the mass, momentum, and energy principles supplemented by appropriate geometrical and constitutive relations, 3) a description of the mathematical reductions used to refine this model into a form suitable for numerical processing, 4) pressure-time predictions for the 10 cm^3 closed bomb combustion of 114 mg of $Zr/KClO_4$, 5) pressure-time predictions and piston energy calcuations for typical operation of the NSI driven pin puller, and 6) comparisons with observed system behavior which exhibit reasonable correlation.

The rationale for the modeling effort is to 1) gain fundamental understanding of the operation of pyrotechnic- actuated devices, 2) provide a rational framework for making suggestions for improving the performance of such devices, and 3) suggest useful experiments. One means to these ends is to use the well-documented approach (cf. Powers, et al., 1990) of multiphase continuum mixture theory as applied to a common device for which much experimental data is available such as the NSI driven pin puller, (cf. Bement, et al., 1991).

The NSI driven pin puller is a device which, upon ignition of 114 mg of $Zr/KClO_4$ generates a high pressure gas ($\sim$ 500 bar) in less than 1 ms. The force generated by the high pressure first causes a small shear pin to fail and then accelerates the main pin. This causes the main pin to retract about 1 cm into a kinetic energy absorbing end cap at which time the operation is complete.

The system is modeled as a well-stirred reactor in which all variables are at most time dependent. The system is broken into three subsystems: the unreacted pyrotechnic solid, condensed phase reaction products, and gas phase reaction products. Each subsystem can exchange heat and work with either another subsystem or the environment. The pyrotechnic is assumed to regress linearly with a pressure dependent burning rate. It is assumed that the products of reaction are generated in ratios which are estimated from the NASA Lewis CEC76 equilibrium calculations. The internal energies are determined using the CHEMKIN routines. The model equations, which reduce to a set of ordinary differential equations, are then integrated numerically to predict all variables' time history.

A pressure time prediction which has been correlated with Bement, et al.'s experiments is shown in Figure 1. Examination of the terms in the model equations show that the pressure rise shown for early time is attributable to conversion of unreacted pyrotechnic to product gases and that the pressure drop shown at late time is attributable to heat transfer from the product gas to the surroundings. The predictions of both pressure magnitude, time scale, and pin energy (not shown) agree well with the observations.

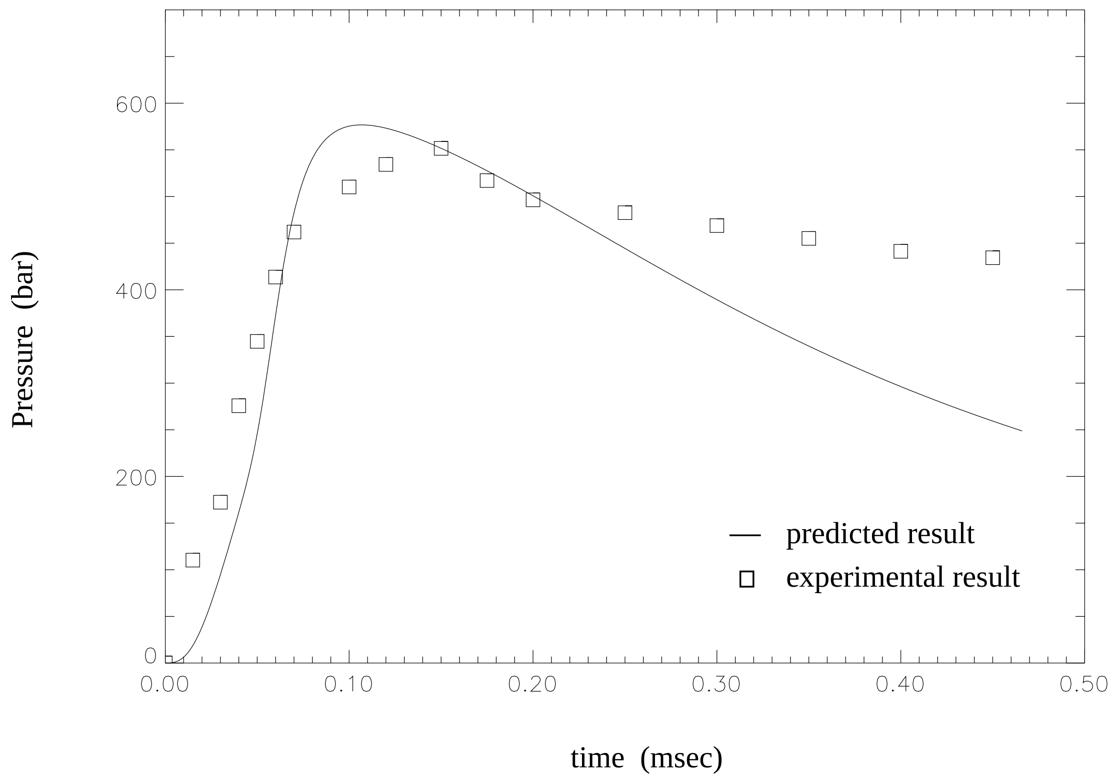

Figure 1: Pressure time predictions and observations for the NSI driven pinpuller.

References

Bement, L. J., Multhaup, H. A., and Schimmel, M. L., 1991, "HALOE Gimbal Pyrotechnic Pin Puller Failure Investigation, Redisign, and Qualification," NASA Langley Technical Report.

Powers, J. M., Stewart, D. S., and Krier, H., "Theory of Two-Phase Detonation– Part I: Modeling," *Combustion and Flame*, Vol. 80, pp. 264-279.