Numerical Investigation of pad or air gap between the high explosive and flyer in impelling

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Summary. Numerical simulations of plate impelling by high explosive (named JOB-9003) were carried with two-dimensional Lagrangian code. A pad or air gap was set between the high explosive and flyer. Different influence on the flyer motion induced by the pad or air gap is discussed in one-dimensional detonation and two-dimensional sliding detonation separately. One-dimensional detonation plate push results show that the kinetic energy of the flyer with pad is higher than that of flyer with air gap at the early stage, but it turns to be lower in the following process. Two dimensional results don't show the same trend in the flyers' kinetic energy as that in one dimension. The flyer with pad moves faster than that with air gap all the time since the pad between the flyer and HE enhance the in-going pressure in the flyer and the rarefaction wave draw less effect to the product in the moving direction of the flyer because the detonation wave is almost perpendicular to the flyer in two-dimensional sliding detonation. This conclusion could be the interest of detonation system designers.

Introduction

Plate push and cylinder test are two kinds of classic detonation experiments. Plate push experiment investigates the one-dimensional detonation wave and the flyer, and the cylinder tests were mainly used to obtain the parameters of equation of state of detonation products.
It is hard to keep no air gap between the high explosive and the plate or the cylinder wall in the experiments and detonation devices. In fact, the designers try to or have to keep kind of air gap or pad between the high explosive and the flyers or the containers. Some cylinder tests results show that the air gap between the high explosive and the cylinder wall affect the performance of the wall motion.[2] While the theoretical and numerical explains were few to be found.[1-5]
This paper study one kind of HMX-based plastic bonded high explosive named JOB-9003, which was with plenty of experimental research in detonation and reactive flow parameters. The exact effect of the air gap or the pad on the performance of plate in one-dimensional and two-dimensional case were discussed.

Method

Computational Models

Two typical computational models were chose in this paper. The HE of one-dimensional mode is 30mm length, and detonated by a high speed copper flyer. Another cooper plate with 0.4mm length is set by the left end of the HE. Air gap or pad with 0.5mm length is set between the HE and plate. The length of each cell in HE is 0.01mm. So the Ignition and Growth reactive flow mode is used to solve the 1D detonation under given grid size, because the results are independent of mesh size so the modeling has converged to consistent answers.
Rigid wall condition is set in two-dimensional model on both left and right sides of the model. The detonation wave moves almost perpendicularly to the copper wall. The HE is 30mm length, and the diameter is 60mm. The outside diameter of the copper shell is 69mm, and the inside diameter is 61mm. Air gap or pad with 0.5mm thickness is set between the HE and plate. The grid size of each cell in HE is 0.5mm0.5mm. The grid size is largely decreased comparing to the one-dimensional case since the mesh distortion in two-dimensional modeling is much severe. Hence Coarse mesh and program burn was occupied to modeling the detonation and to study the problem relatively.

Reactive Flow Model

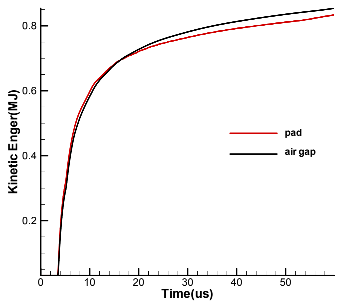
The reaction rate law for the conversion of explosive to products is [6]:

$$\frac{dF}{dt} = \underbrace{I(1-F)^b\left(\frac{\rho}{\rho_0}-1-a\right)^x}_{0<F<F_{Ig\max}} + \underbrace{G_1(1-F)^c F^d P^y}_{0<F<F_{G1\max}} + \underbrace{G_2(1-F)^e G^g P^z}_{F_{G2\min}<F<1}. \qquad (2)$$

where F is the fraction reacted, t is time, (ρ is the current density, ρ_0 is the initial density, and I, G_1, G_2, a, b, c, d, g, x, y, and z are constants. The mixture equations assume pressure and temperature equilibration between the unreacted explosive and its reaction products.

One-dimensional results and discussion

As shown in Figure 1, the energy of the pushed plate in the case with air gap is different as that in the case with pad between the high explosive and the plate. The kinetic energy of the flyer with pad is higher than that of flyer with air gap at the early stage, but it turns to be lower in the following process. Comparing the pressures in the plate and the detonation products, the explanation is highly clear. The in-going pressure to the plate with pad is 8-10GPa higher than that with air gap. So the rarefaction wave reflected from the free surface should also be higher than that with air gap and that results in the lower pressure in the detonation products in the following phases. Higher in-going pressure in the plate leads to the higher kinetic energy in the pad case than that in the air gap case in the early phases, and the lower pressure in the detonation products results in the lower kinetic energy in the pad case than that in the air gap case finally.



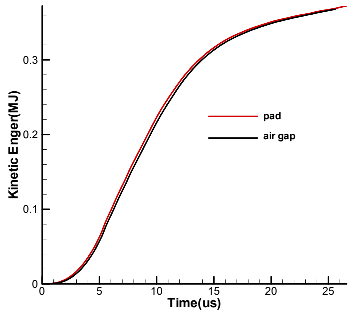
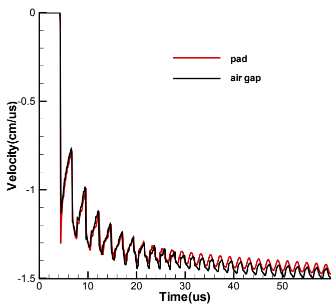


Figure 1. Comparing of the kinetic energy of the plate versus time. Figure 2. Kinetic energy in two-dimensional case.



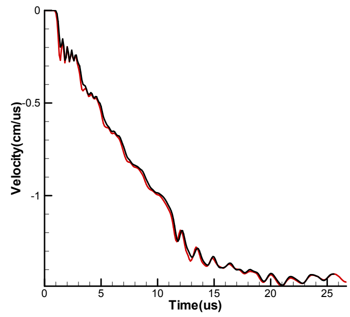


Figure 3. Comparing of the free surface velocity in 1D. Figure 4. Comparing of the free surface velocity in 2D.

Two dimensional results and discussion

Two dimensional results don't show the same trend in the flyers' kinetic energy as that in one dimension. The curves of cylinder wall's kinetic energy, free face location, velocity of free surface versus time in 2D computational model with pad are all higher or larger than that with air gap.The flyer with pad moves faster than that with air gap all the time since the pad between the flyer and HE enhance the in-going pressure in the flyer and the rarefaction wave draw less effect to the product in the moving direction of the flyer because the detonation wave is almost perpendicular to the flyer in two dimensional sliding detonation.

Conclusions

One dimensional-detonation plate push results show that the kinetic energy of the flyer with pad is higher than that of flyer with air gap at the early stage, but it turns to be lower in the following process. The reason is that the case with pad with higher in-going shock wave and higher reflected rarefaction wave into the HE product comparing to the case with air gap, so the HE product pressure in the pad case is lower than that in air gap case. Then that could explain the trend of kinetic energy in one dimension. The 2D cylinder wall with pad moves faster than that with air gap all the time since the pad between the flyer and HE enhance the in-going pressure in the flyer and the rarefaction wave draw less effect to the product in the moving direction of the flyer because the detonation wave is almost perpendicular to the flyer in two-dimensional sliding detonation. Detonation device designers should pay attention to the difference of this effect.

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