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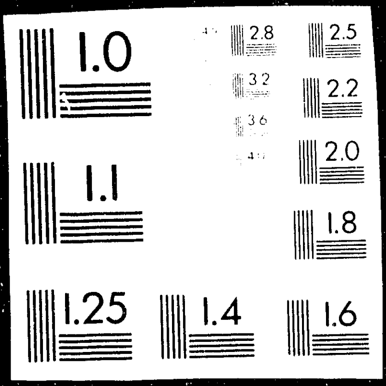

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Computer Modeling of Gas Flow and Gas Loading of Rock in a Bench Blasting Environment

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Introduction

Detonation of the explosive in a blastwell results in a transient stress wave that fragments the rock and a high pressure, high temperature gas pocket that expands pushing the rock in front of it. Events that occur during a blast have been difficult to understand because the short time scale and the severe environment make measurements difficult. Numerical modeling can contribute greatly to an understanding of the physics involved in the blasting process. This paper will describe the latest enhancements to the blast modeling code DMC (Distinct Motion Code) [Taylor and Preece,1989] and will demonstrate the ability of DMC to model gas flow and rock motion in a bench blasting environment.

DMC has been used previously to model rock motion associated with blasting in a cratering environment [Preece and Taylor, 1990] and in confined volume blasting associated with in-situ oil shale retorting [Preece, 1990 a&b]. These applications of DMC treated the explosive loading as force versus time functions on specific spheres which were adjusted to obtain correct face velocities. It was recognized that a great need in explosives modeling was the coupling of an ability to simulate gas flow with the rock motion simulation capability of DMC. This was accomplished by executing a finite difference code that computes gas flow through a porous media [Baer and Gross, 1989] in conjunction with DMC. The marriage of these two capabilities has been documented by Preece and Knudsen, 1991.

The capabilities that have been added recently to DMC and which will be documented in this paper include: 1) addition of a new equation of state for the explosive gases, 2) modeling of gas

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flow and sphere loading in a bench environment.

Equation of State

DMC has utilized the JWL equation of state [Lee et al, 1973} to describe the pressure-volume relationship of the explosive gases. A new equation of state, in addition to JWL, has been added to DMC. It is called the ICI equation of state [Kirby and Leiper, 1985] because it is used by the ICI Explosives Group Technical Centers for modeling ideal and non-ideal detonations. The ICI equation of state has the following form

$$E = \frac{P}{\rho(g-1)}$$

$$g = g_0 + g_1\rho + g_2\rho^2$$

Where P = pressure, ρ = density, E = specific internal energy and g_0, g_1 and g_2 are constants for a particular explosive. The advantage of incorporating this equation of state is that parameters are available in this form for many different explosives. Costly time-consuming conversions to JWL parameters is thus avoided. This makes it possible to study the influence of different explosive types on rock motion.

Gas Flow in a Bench Environment

The gas flow calculation assumes the rock is a porous media and computes the gas flow through the porous field taking all the significant properties of the rock and gas into account including gas viscosity, specific heat, Prandtl number, and thermal conductivity. The properties of the rock that are utilized in the gas flow calculation includes the temperature, initial porosity, specific heat and mean particle size. The mean particle size is the size of the close-packed spheres assumed to represent the matrix of the rock.

A blastwell from a typical bench blast has a very large aspect ratio which makes it difficult to model the gas flow from the entire blastwell. This difficulty has been overcome by setting the gas flow calculation grid to be a slice through the center of the blastwell as shown in Figure 1. This greatly reduces the number of gas computation cells which makes the calculation tractable on a SUN SPARCstation 2 computer workstation. The spheres along the length of the blastwell are mapped onto the gas grid to determine the gas loading of the spheres. Two mechanisms for transferring momentum from the gas to the spheres have been used, viscous drag and pressure gradient [Preece and Knudsen,1991]

Example Problem

Figure 2 shows an example bench blast consisting of only a single row of blastwells. Figure 3 shows the spherical element model of this bench blast configuration at 50 ms after detonation. The arrows on the spheres represent the velocities of the spheres. At this point in time the face velocities are approximately 8 m/s. The blastwell is not shown explicitly in Figure 3 but it is evident in the split between the spheres. Figures 4 and 5 show the motion of the material in the bench at 200 ms and at 6.0 s, when motion has stopped and the muck pile has been formed. Observed bench blast behavior, such as vertical lift of the material due to dilation, is evident in this calculation.

Conclusions

The spherical element computer program DMC has been enhanced to perform coupled gas flow and rock motion simulations in a bench blasting environment. The ICI equation of state for the explosive gases has been added to the program which will allow modeling many different explosives including those that exhibit non-ideal detonation behavior. Using a gas computation grid that is only a few cells wide is much more efficient than modeling the entire blastwell. The enhancements discussed here will make numerical modeling of bench blasting a useful tool for designing bench blasts.

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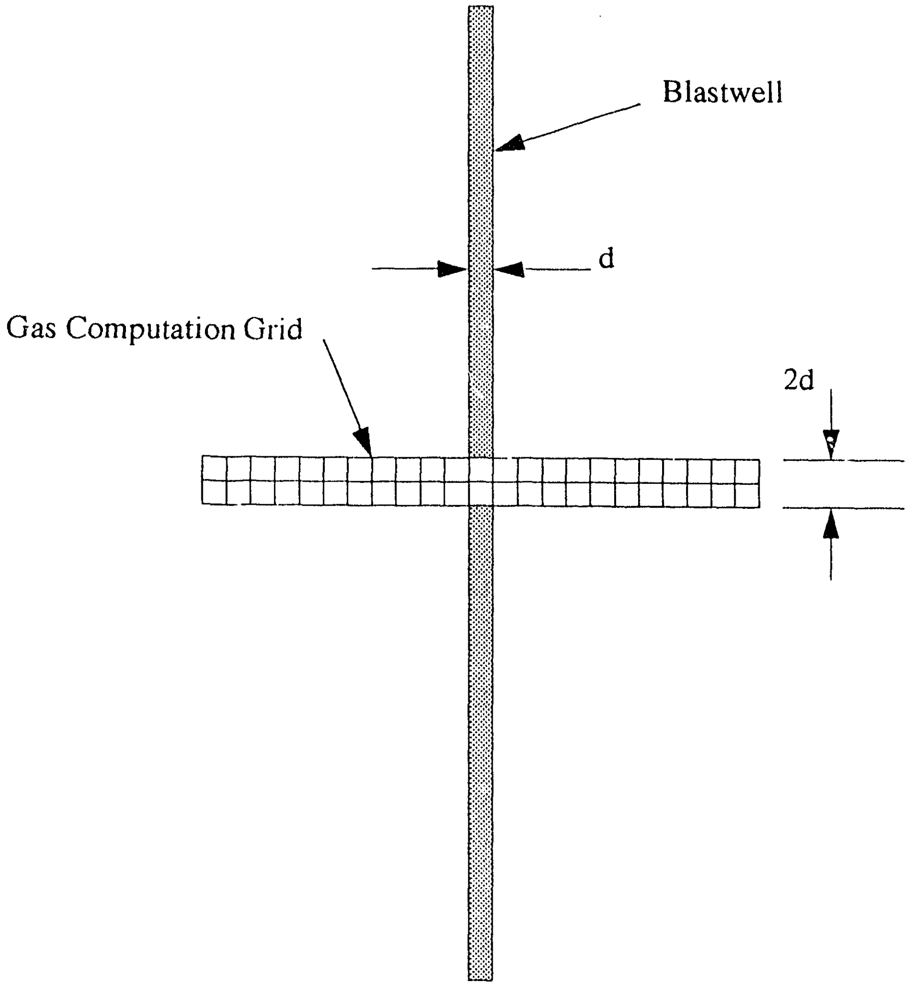

Figure 1: Blastwell and Gas Computation Grid

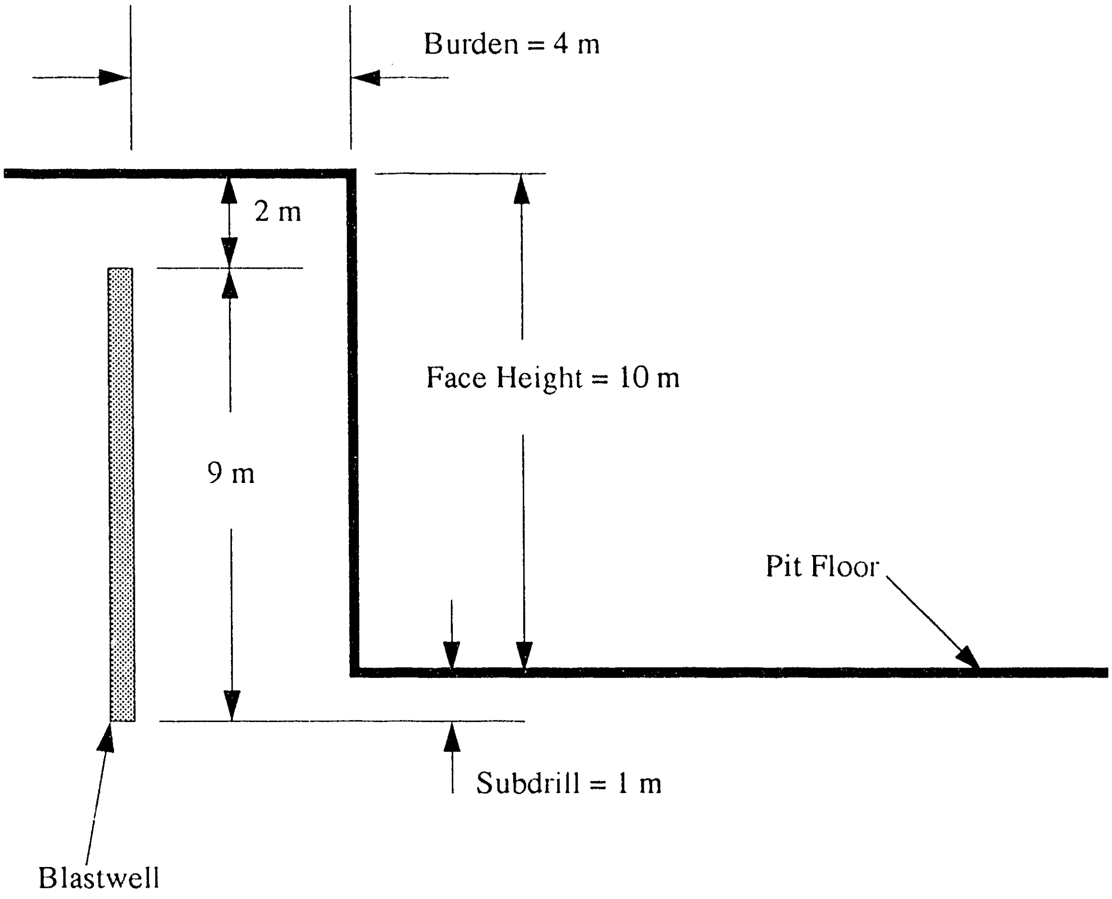

Figure 2: Single Row Bench Blast Configuration

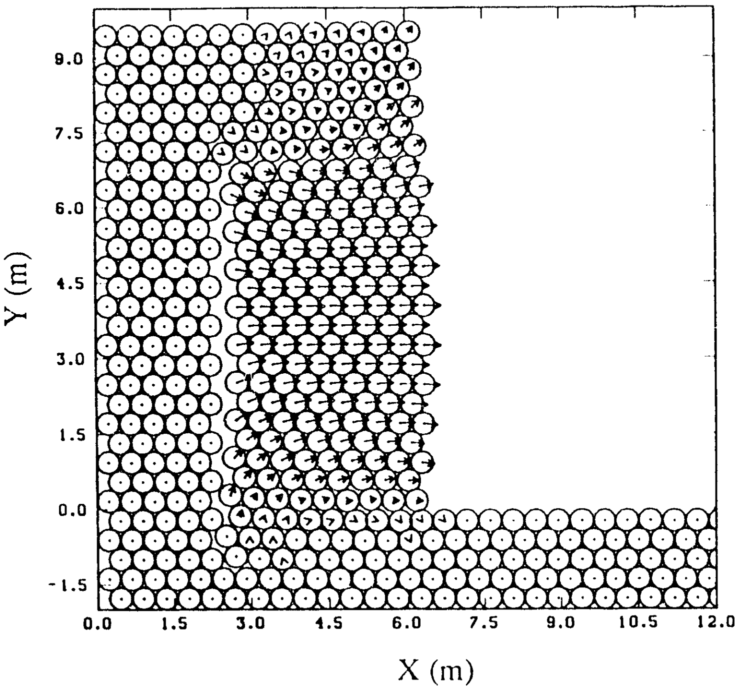

Figure 3: Bench Blast Simulation at 50 ms Showing Initial Velocities.

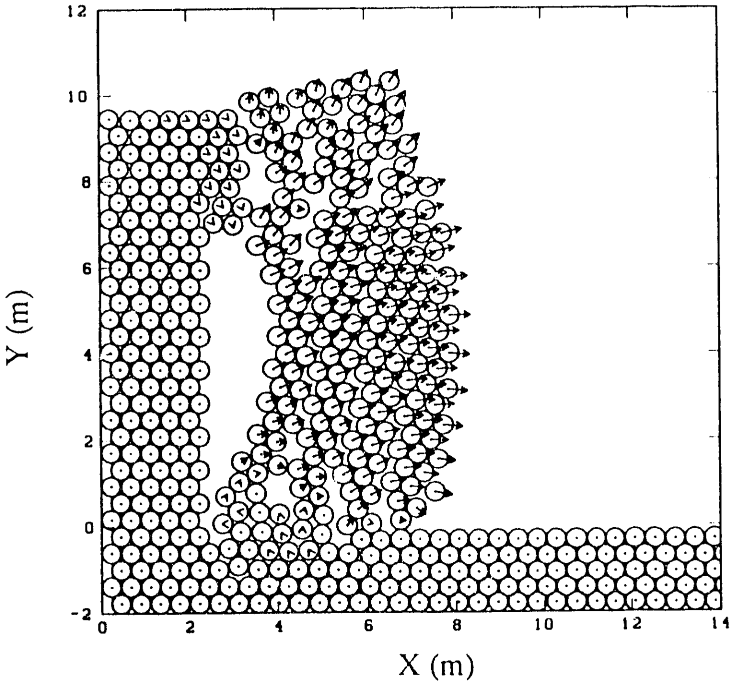

Figure 4: Bench Blast Simulation at 200 ms

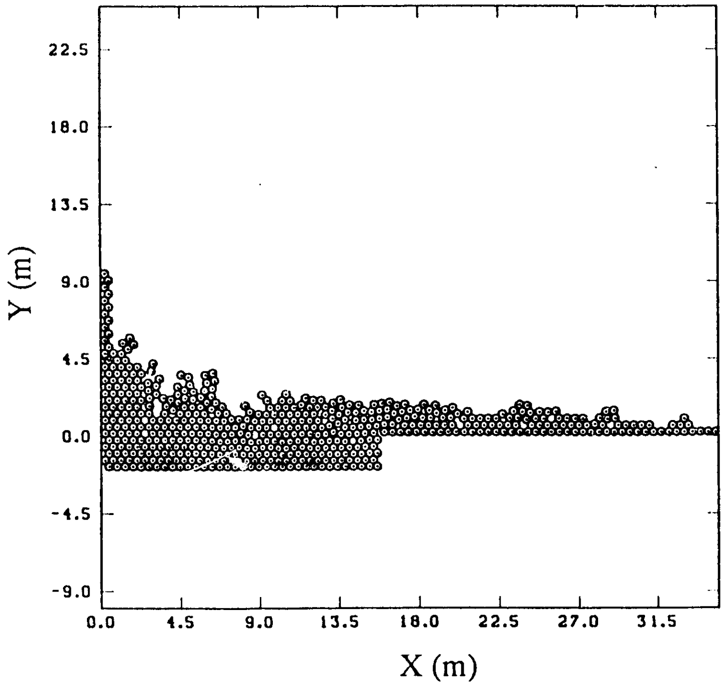

Figure 5: Bench Blast Simulation at 6.0 s

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