Instabilities in granular medium due to explosions

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1. INTRODUCTION

When two fluids of different densities are placed over each other and subjected to gravity, the perturbations on the interface grow unboundedly when gravity acts in a direction opposite to the density gradient. This kind of instability is called as Rayleigh-Taylor instability. Such instabilities also occur in solids that are subjected to very high pressure. An example of this phenomenon can be found during explosions in granular media such as sand. Consider a spherical shell of sand with an explosive embedded inside the shell. On detonation, the outer surface of the sand expands. This expansion leads to shock waves in ambient air. The sand shell accelerates in this shocked air. When, this pressure ahead of the moving sand shell is large enough, the perturbations on the surface of the sand shell grow in an unstable manner. The sand shell disintegrates. This is usually observed as sand ejecta, see Fig. 1.

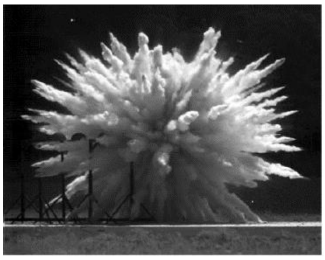

Figure 1: Jet formation after explosion in sand (Frost et al. 2012).

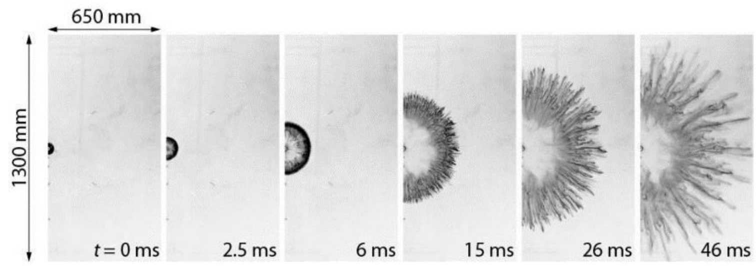

Figure 2: Sequences of high speed photograph showing the cylindrical explosive dispersion of granular medium (Rodriguez et al. 2014).

Recently, it has been shown that this instability starts from the inner surface of the sand shell, and then propagates to the outer surface, see Fig. 2. In this work we investigate the conditions under which the inner surface of the sand shell becomes unstable.

2. MODEL DESCRIPTION

We analyze the stability of cylindrical sand shells when subjected to an internal pressure in an Eulerian frame work. The computational domain is shown in Fig. 3. To reduce the computational cost, we model only a sector of the computational domain. It consists of three components: explosive, sand shell and ambient air. At time t = 0, we assume that detonation process is completed and the explosive is converted to a high pressure gas. The explosive and ambient air are modelled as ideal gas, while the sand is modelled as an elastic, perfectly-plastic solid that obeys the Drucker-Prager yield criterion. The properties of these components are listed in the Table 1. The simulations are

	Gas constant (J $Kg^{-1}K^{-1}$)	Ambient pressure (Pa)	Specific Heat (J $Kg^{-1}K^{-1}$)	Viscosity (Pa-sec)	Density (Kgm^{-3})
High press.	36	0	1062	1e-08	1000
Ambi-ent	287	0	1005	1e-08	1
Sand	N.A	N.A	N.A	N.A	1650

Table 1

performed using the commercial software ABAQUS. In order to trigger the instability, we give a small perturbation to the inner surface of the sand shell.

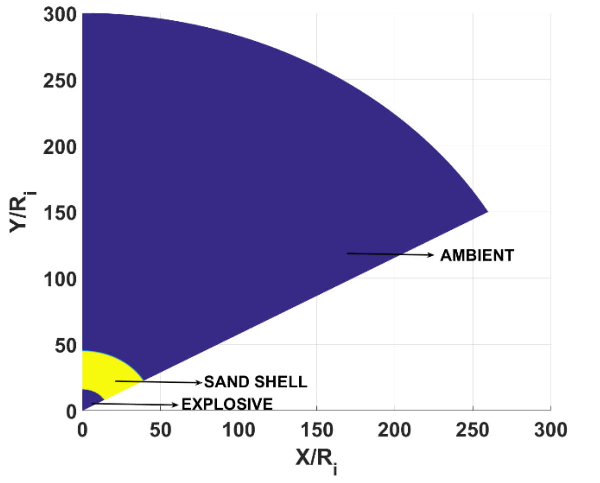

Figure 3: Numerical model used to investigate the stability of cylindrical sand shells

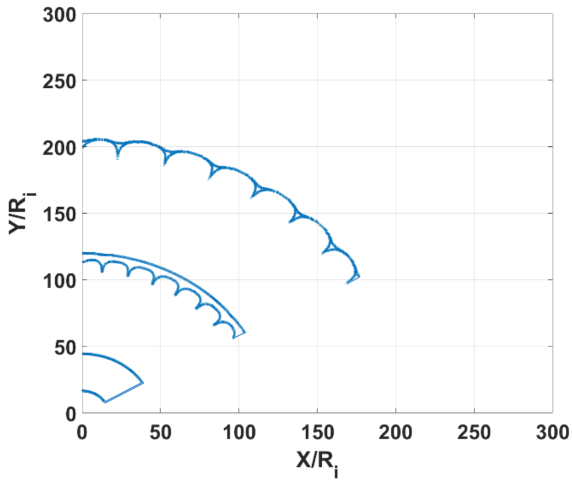

Figure 4: Growth of imperfection on the inner surface of cylindrical sand shells at various times.

3. RESULTS

The position of the sand shell at three different time instants are shown in Fig. 4. The growth of the perturbations on the inner surface of the sand shell can be easily seen. We then carry-out a parametric analysis in which the effect of the explosive pressure (P_i), yield strength (Y) and the pressure dependency parameter on the stability are investigated. Consider the line corresponding to $\frac{P_i}{E} = 0.5$ in Fig. 5. The sand shells are unstable (or stable) when the combination of yield strength and friction parameter μ are below (or above) this line. Thus, this line marks the stability limit for $\frac{P_i}{E} = 0.5$. We also plot the stability limits for $\frac{P_i}{E} = 0.5$, 1 and 1.5. It can be seen that as the pressure of the explosive is increased, a higher value of yield strength and friction parameter are needed to prevent instability. The present study will be extended to find the effect of amplitude and wavelength of perturbation on the stability of sand shells.

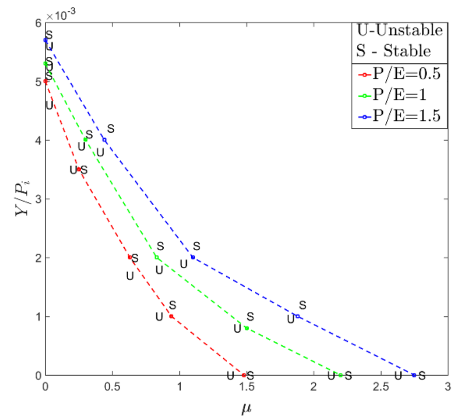

Figure 5: Stability chart for cylindrical sand shell.

REFERENCES

1. David L. Frost, Y. G. (2012). Particle jet formation during explosive dispersal of solid particle. *Jornal of Applied Physics*, 3.

2. V.Rodriguez, R. G. (2014). External front instabilites induced by shocked particle ring. *American Physical Society*, 5.