Effect of Explosive Charge Geometry on Boundary Surface Peak Pressure with Regard to Standoff Distance

Joseph Hamilton[1,a], Daniel Coleman[1,b]
[1]Karagozian & Case, Inc., 700 N. Brand Blvd., Suite 700, Glendale, CA 91203

[a]hamilton@kcse.com
[b]coleman@kcse.com

Abstract

In an effort to better understand the effect of explosive charge geometry on blast effects, in particular with regard to standoff distance, this paper presents a study of three different geometries at varying standoffs. The geometries reviewed in this study were: cylinder, sphere, and rectangular cuboid. The explosive mass was held constant between all geometries, and the system was modeled with the LS-DYNA® structured Arbitrary Lagrangian-Euler (ALE) solver. The peak pressure on a reflective boundary surface was measured and recorded in order to quantitatively categorize the blast effects of each case.

Introduction

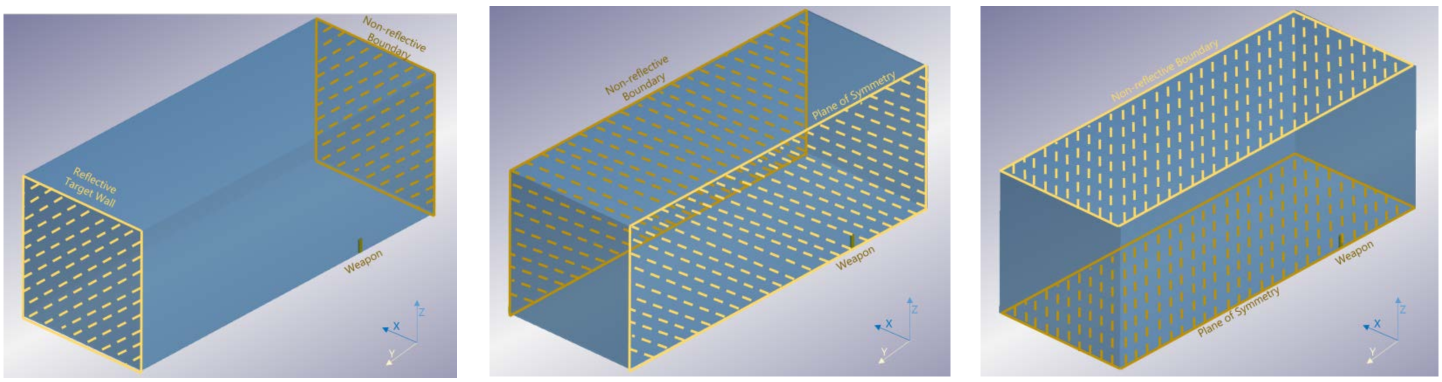
In response to an increase in the threat of terrorism in nearly every region of the world, protective design has emerged as a specialty sub-discipline within the broader field of structural engineering. As a product of this growth, numerous tools have been developed to aid engineers in studying structural component response to a wide range of weapons effects scenarios. Many of these tools fall into the category of simplified engineering models and work off the common assumption that explosives are constructed using a spherical geometry. While spherical explosives may exist, a quick survey of the market for civilian and military explosives shows that cylindrical or rectangular geometries are much more prevalent [1]. Pervious research has shown that these geometric effects are only significant within near field detonations [1]; however, a quantifiable limit for what constitutes near field has yet to be defined. The purpose of this paper is to study the influence explosive geometry has on blast profile and determine a range at which these effects are significant. The study is based on a series of numerical simulations solved using LS-DYNA multi-material arbitrary Lagrangian-Eulerian (MM-ALE) formulation.

Background

The effects of explosive geometry on near field blast profiles has been an emerging topic of study over the past decade. To date, a series of small scale explosive simulations, and follow-up numerical study using LS-DYNA MM-ALE formulation, have been conducted to analyze the difference in near field blast profile of hemispherical and thin plate charges [2]. Additionally, an independent study was conducted to numerically investigate the difference in pressure fields originating from spherical and cylindrical charges [1]. These studies showed that, at general level, spherical explosive geometry yielded symmetric pressure fields while elongated charges produced asymmetric pressure fields. Specifically, explosive plates, as compared to hemispherical charges, were shown to generate additional blast load directly above the plate while lateral blast load was reduced. Cylindrical geometries were shown to have a similar effect where higher blast loads were observed in the direction normal to the elongated dimension [1,2]. Both studies note future investigation of rectangular geometries as a useful next step in research of this topic. Additionally, the spatial bounds defining when these effects can be considered important have not yet been defined.

Model Description

Three different shapes, a sphere, a rectangular block, and a cylinder of explosive material were modeled at increasing standoff to a reflective boundary target wall using LS-DYNA structured ALE solver. An array of tracers was placed at the target wall and used to record the pressure values during the simulation. The ALE domain was modeled with symmetry about the X-Y plane and Z-Y plane, and non-reflective conditions were set on the outer boundaries, as shown in Figure 1 below.



a) Target wall, and non-reflective boundary

b) Plane of symmetry and non-reflective boundary

c) Plane of symmetry and non-reflective boundary

Figure 1. Model setup showing ALE domain, weapon location, planes of symmetry, and target wall locations.

The explosive charge was modeled using a TNT material model with the *MAT_HIGH_EXPLOSIVE_BURN card. Approximately 0.76 kg of explosive was modeled for each shape. The rectangular block dimensions were 280 mm x 40 mm x 40 mm, the sphere had a radius of 47.47mm, and the cylinder had a radius of 40 mm and a height of 89 mm. For each case the detonation was initiated at the explosive center of mass. Weapon standoff was varied between 0.5 m, 1 m, 2 m, 3 m, and 6 m for each shape, and in each case the target wall with tracer array was held constant at 3 m height and 3 m width.

Results

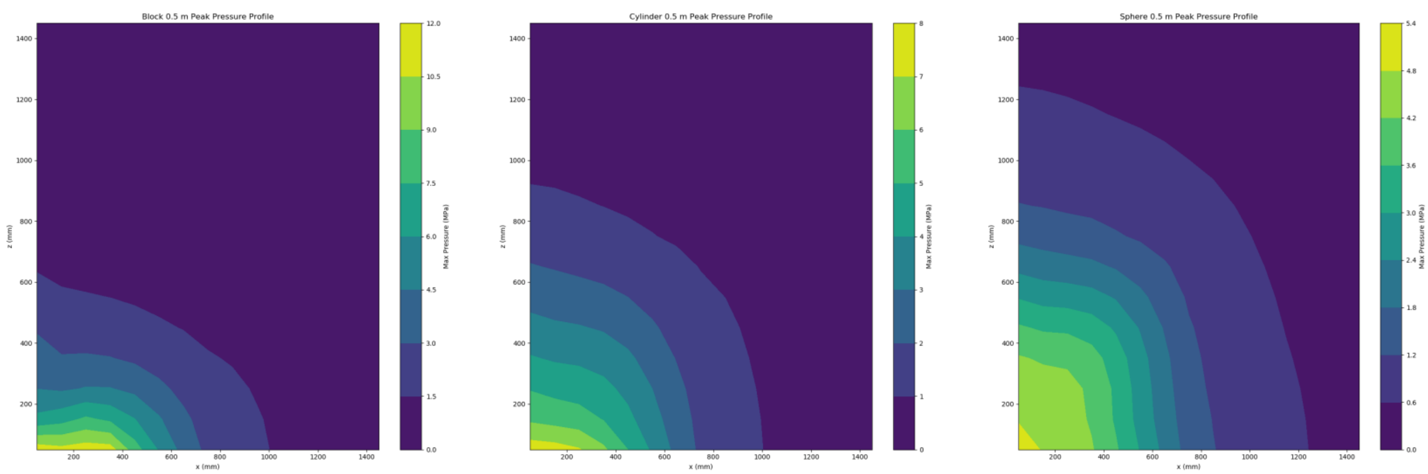
Pressure history was saved in each simulation using tracers located at the reflective target wall of the model. These tracers were spaced 100 mm from one another in both the X and Z directions. In order to process the pressure output from the tracer files a python script was written to generate a peak pressure profile contour plot from the binout tracer history data generated by the LS-DYNA solver. This contour plot used the dimensions of the target wall and the peak pressure value with coordinates from each tracer. Additionally, the maximum pressure value from all tracers was recorded and collected in Table 1.

Table 1. Max pressure recorded at target wall.

	Max Pressure (MPa)		
	Block	Cylinder	Sphere
0.5 m	11.35	7.54	5.01
1 m	1.97	1.59	1.58
2 m	0.43	0.40	0.40
3 m	0.23	0.23	0.23
6 m	0.14	0.14	0.14

At the minimum distance studied, 0.5 m, the block geometry showed a maximum pressure of 11.35 MPa while the sphere showed only 5.01 MPa, and the cylinder was between both with 7.54 MPa. The maximum pressure at the target wall showed less difference between geometry as the standoff distance was increased. By 2 m of standoff the max pressure was nearly equal between all geometry, and at 3 m and 6 m there was practically no observable difference in max pressure at the target wall regardless of the geometry shape in this study.

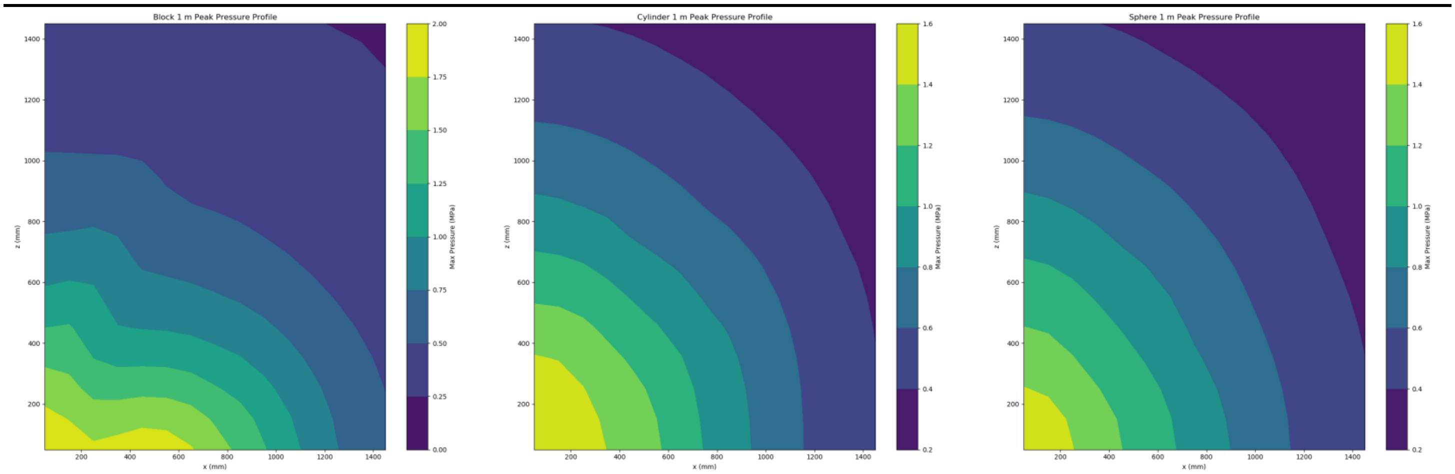
With regards to the peak pressure profile contour plots a similar trend was observed. Figure 2 shows the peak pressure profile at 0.5 m of standoff. At this standoff distance the most asymmetry was observed with the rectangular and cylinder shapes, whereas the sphere showed a more symmetrical pressure distribution.



a) Rectangular Block b) Cylinder c) Sphere

Figure 2. Peak pressure profile at 0.5 m standoff.

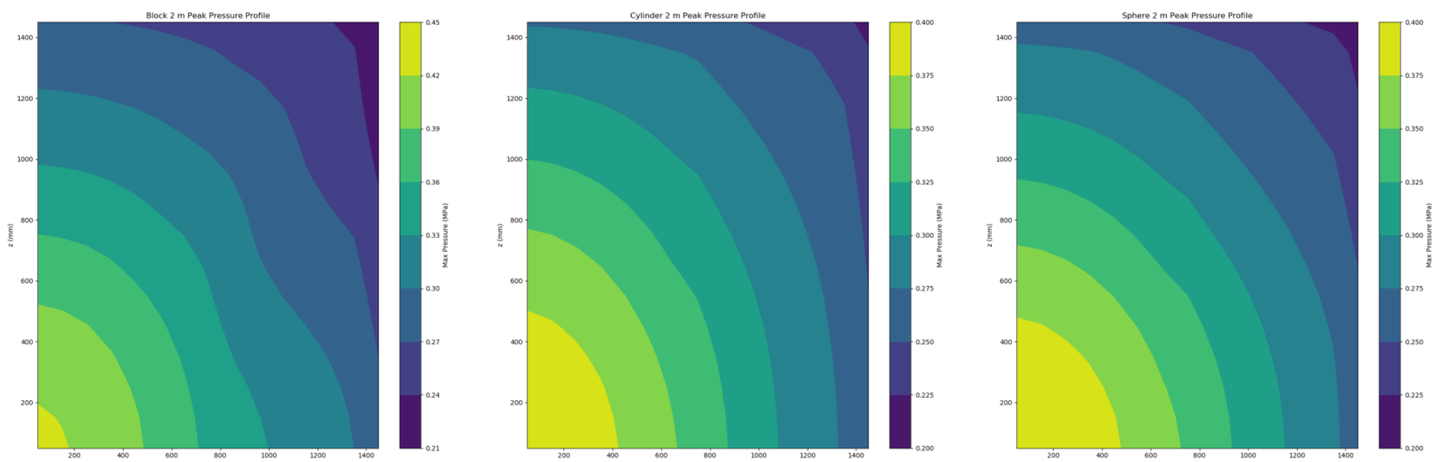
At 1 m of standoff, shown in Figure 3 below, the pressure profile remained asymmetric for the rectangular block while the cylinder pressure profile became more symmetric. The sphere also generated a more symmetrical pressure profile compared to the closer standoff distance case, and the maximum pressure of both the cylinder and sphere were nearly identical at 1.59 MPa and 1.58 MPa respectively. With 1.97 MPa the maximum pressure of the rectangular block remained slightly higher than the other shapes.



a) Rectangular Block b) Cylinder c) Sphere

Figure 3. Peak pressure profile at 1 m standoff.

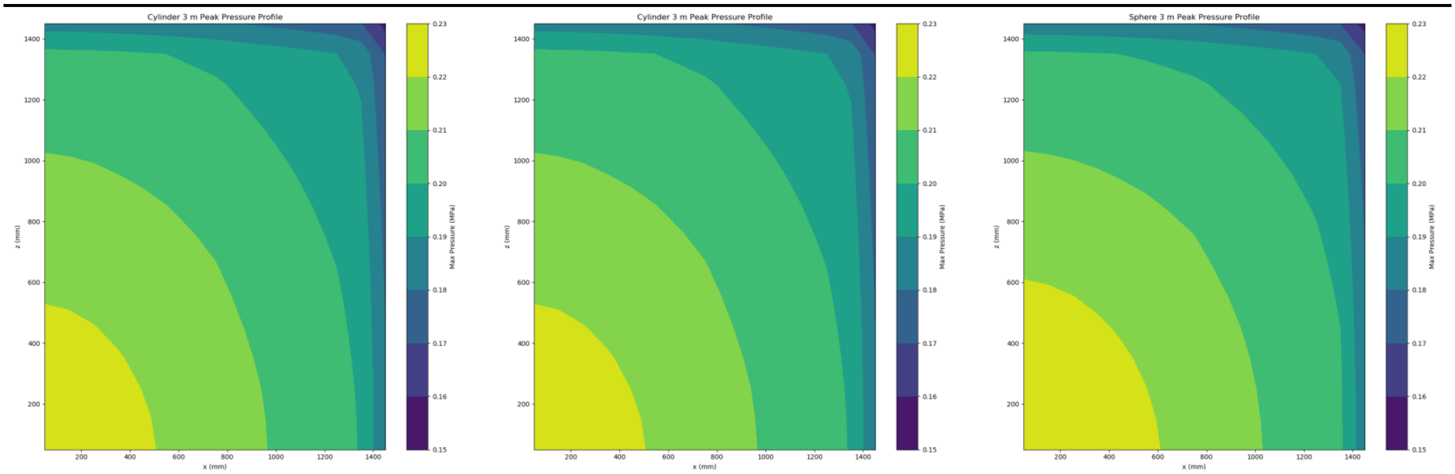
The pressure profile for the rectangular block case started to show similar symmetry and distribution as the cylinder and sphere cases when the standoff was increased to 2 m, shown in Figure 4. At this distance the max pressure also remained slightly higher for the block with 0.43 MPa compared to the cylinder and sphere max pressure of 0.40 MPa.



a) Rectangular Block b) Cylinder c) Sphere

Figure 4. Peak pressure profile at 2 m standoff.

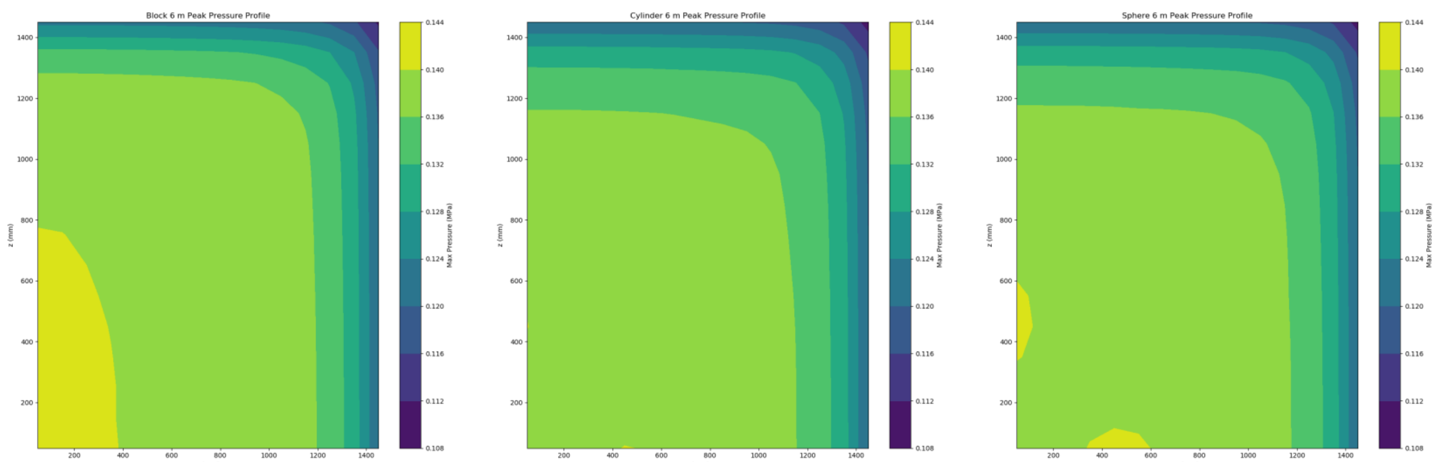
With a 3 m standoff distance the pressure profile was nearly identical for all three geometries and the maximum pressure for each was an identical 0.23 MPa. At this distance the geometry had no discernable effect on the pressure profile or max pressure at the target wall with regards to pressure.



a) Rectangular Block b) Cylinder c) Sphere

Figure 5. Peak pressure profile at 3 m standoff.

When the standoff distance was increased to 6 m the symmetry of pressure distribution remained similar among all geometry shapes, and the maximum pressure for each was equal at 0.144 MPa. However, the location of the maximum pressure did vary between each case. This is shown in Figure 6 below.



a) Rectangular Block b) Cylinder c) Sphere

Figure 6. Peak pressure profile at 6 m standoff.

Conclusions

In this study LS-DYNA structured ALE solver was used to study the effects of varying standoff distance with three different explosive charge geometries. While the mass was held constant the shape was varied between a rectangular block, cylinder, and sphere. The standoff distance varied between 0.5 m and 6 m while the pressure at a reflective target wall was studied. The results suggest that when standoff distance was minimal the geometry had the greatest effect on the pressure profile at the target, and by 2 m the pressure profile and maximum pressures observed were all nearly identical. Also, at the minimum standoff distance considered in this study, 0.5 m, the pressure profile of the rectangular block case was not as symmetrical as the sphere, but the peak pressure was significantly higher, over twice as much with 11.35 MPa for the block and 5.01 MPa for the sphere. This indicated that varying the geometry at closer standoff could have significant effects on localized blast pressures.

References

[1] Hryciów, Zdzisław, et al. "Influence Of The Shape Of The Explosive Charge On Blast Profile." Journal of KONES. Powertrain and Transport, vol. 21, no. 4, 2014, pp. 169–176., doi:10.5604/12314005.1130466.
[2] Mespoulet, J., Plassard, F., Hereil, P., Lefrançois, A., Influence of HE shape on blast profile, 8th European LS-DYNA Users Conference, Strasbourg 2011.