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Detonation Wave's Corner Effects

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Abstract: Wave shaping with different contours, such as sharp or smooth corners, seems to give the same shock or detonation velocities, but different pressure profiles, which is demonstrated by different emitted light intensities. The detonation wave created less light output after running around a sharp corner compared to a smooth corner, which was obviously caused by different pressure profiles.

Key words: detonation wave; corner effect; explosive

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1　Introduction

A number of papers have been published with regard to the change of the detonation directions around corners or obstacles[1~3]. This papers should describe the observation of the author by simultaneously testing the detonation profile around a wave shaper with a sharp corner on one side and with a smooth radius on the other side.

2　Test set up

A squeeze cast TND/RDX charge with 15/85 percen-tage by weight was used. The charge's outer diameter was 96 mm and a rotational symmetric internal cavity was machined for wave shaping which had on the left side a rectangular shape with a radius (R_L) of 32 mm and a height H of 40 mm with relatively sharp corners on the edges and on the right side a hemispherical shape with a larger maximum ra-dius R_R of 40.6 mm, but with a hemispherical profile with a radius $r = H/2 = 20$ mm. Both cavities were filled with silicon rubber (Fig. 1).

The two internal semicircles—left and right side are separately machined from the same cast high explosive cylinder. Both half circle sections are put together. For a direct, well comparable observation they are held together by a plastic support, in which was also fixed a precision initiation coupler (PIC)[4], aligned in the charge symmetry axis (see Fig. 1).

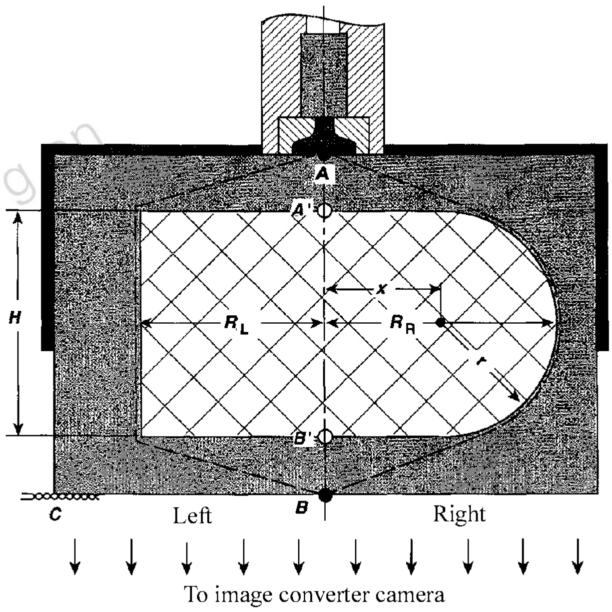

Fig. 1　Test set-up of a wave shaping system with sharp corners on the left side and a hemispherical smooth radius on the right side with constant distances from the central initiation point A to the point B on the other side of the wave shaper

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Biography: Dr. Manfred Held (1933 –), Professor of Military University of München, Germany. He is a world-famous expert in research, design, development and test of different advanced missile warheads and the related science and technology. He is also an internationally recognized authority in the field of dynamic response of materials as well as advanced armor and anti-armor.

3 Defining the radii R_L and R_R

The requirement was, that the detonation distances from the axial initiation point A should be equal behind the wave shapers of the left and right side, i. e. the sharp corner and the smooth hemispherical radius to point B (see Fig. 1). For the tests the radii R_L and R_R were exactly calculated for these two points.

For simplification it should be assumed that the detonation wave is running along the contour of the wave shaper without any high explosive charge layers from point A', and behind the wave shaper to point B'. In this simplified consi-deration it is assumed, that the rectangular wave shaper on the left side has the radius R_L and the height H, while on the right side the maximum radius R_R in the symmetry plane is given by the sum of $x+r$. where r is equal to $H/2$. If the distance from the symmetry axis around the two different shapes of the wave shapers should be equal, it can be written.

$$2R_L + H = 2x + \pi r \tag{1}$$

This equation (1) can be solved according to x:

$$x = (2R_L + H - \pi r)/2 \tag{2}$$

r should be equal to H/2, therefore

$$R_R = x + H/2 \tag{3}$$

Taking x from equation (2) in equation (3)

$$R_R = R_L + H/2 - \pi H/4 + H/2 \tag{4}$$

$$R_R = R_L + H(1 - \pi/4) \tag{5}$$

The right radius R_R is linearly increasing with the height H of the wave shaper. The ratio R_R/R_L is given with the equation (6) and is shown in Fig. 2.

$$R_R/R_L = 1 + 0.215\ H/R_L \tag{6}$$

In the example used, the left radius R_L was 32 mm and the height H 40 mm. This gives a ratio of H/R_L to 1.25. By using the equation (6) or reading Fig. 2 the ratio R_R/R_L gives 1.27 or multiplied with the used radius R_L of 32 mm on the left side a maximum radius R_R of 40.6 mm is obtained on the right side. In this example the right side has then a 27% larger maximum radius than the left side.

4 Diagnostic

The circular cross section opposite the axial initiation coupler was observed by Beckman and Whitely image con-verter shutters or cameras with 10 ns exposure times with a beam splitting system[5]. Therefore two pictures could be gained with the same objective lens at two different times (Fig. 3).

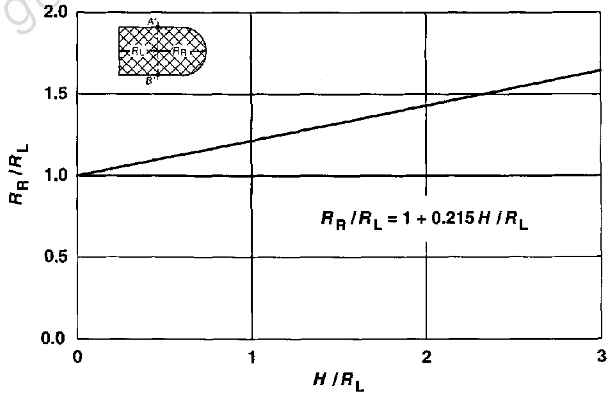

Fig. 2 Ratio R_R/R_L as a function of the height H of a wave shaper with rectangular cross section on one side and a hemispherical end on the other side

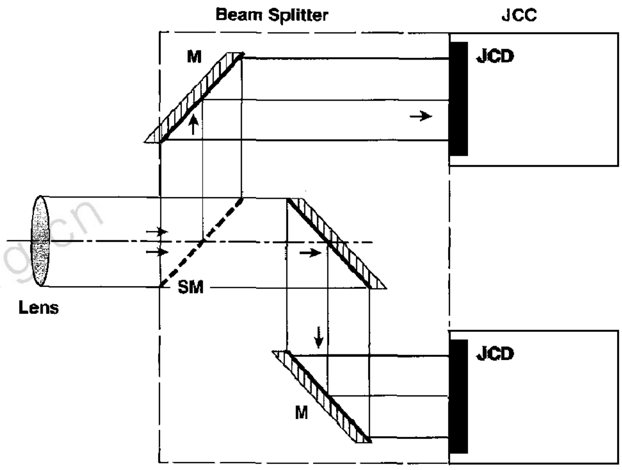

Fig. 3 Beam splitter in front of two image converer diodes M—mirror, SM—semi mirror, JCD—image converter diode, JCC—image converter camera

The camera was triggered by an ionisation probe at the arrival time of the detonation wave on the edge of the observed surface. The four frames gained from two firings with the time delays of 0 μs and 1.5 μs for the first firing, and of 5.0 μs and 15 μs for the second firing are shown in Fig. 4.

5 Analysis

The first frame shows clearly the expected picture. The radius R_L is smaller compared to the radius R_R. Therefore the distance to the observed plane of the charge is shorter on the left side than to the right side at the very early time of 0.0 μs after the trigger signal at the outer edge C of the high explosive charge.

The pictures show also the radially expanding products of the high explosive charge upper portion with the expanding ring of the thin plastic casing.

Definitely surprising is the result of the second frame after 1.5 μs delay time upon arrival of the detonation wave on the outer edge of the charge. With the higher phase velocity of the detonation wave on the right side. the converging detonation front had reached nearly the same distance on the observed bottom to the axis as the left side. This means a more or less regular detonation wave ring from both sides is given, as calculated and desired.

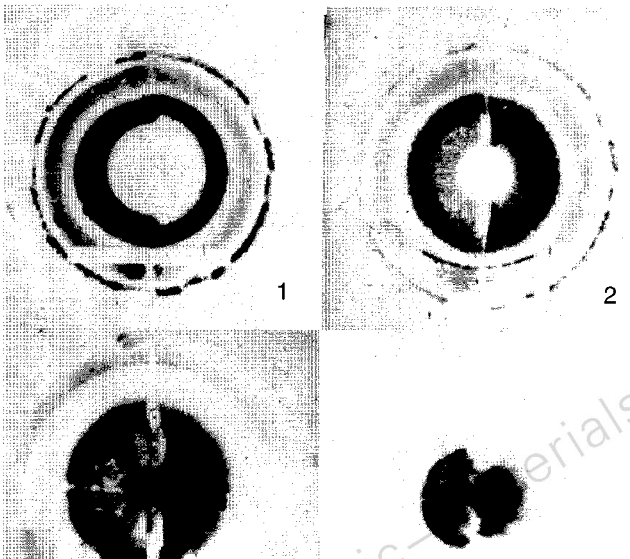

Fig. 4 Four frames of two firings with the wave shaping arrangement according to Fig. 1 with 4 different time delays of 0.0 μs, 1.5 μs, 5.0 μs and 15 μs

But the light intensity is drastically reduced just beneath the wave shaper on the left side, where the detonation wave is going around the corner with a 90 degree change of the direction. The light on the right side is much brighter where the detonation wave is running around the semicircle of 20 mm radius. This second picture demonstrates that the sharp corner on the left side does not, or at least not noticeably reduce the shock or the detonation velocity, but does reduce the pressure profile which causes the reduction of the light output.

The plastic ring has still the same velocities on both sides, which was mostly accelerated by the high explosive layer in front of the wave shaper.

The further two pictures after 5.0 μs and 15 μs show some small asymmetries from these two different wave shaping contours to the left and right side which can not be very well explained in all details at the moment. It looks as if the forces on the left side are a little bit stronger because it seems that the left side is slightly pushing the right side over the separation line. Brighter light is emitted at the right side. Bright light is also emitted at the charge axis where the detonation waves are collapsing.

6 Conclusion

These pictures demonstrate that a change of detonation wave is not at all very simple. The observation of the detonation front is one thing and the power behind the detonation front with the pressure profile can be different which in this example is expressed and demonstrated by the light intensities.

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爆轰波的拐角效应

摘要: 爆轰波绕过急拐角或弧形拐角会产生不同的波形,其冲击波速度或爆速是相同的,但爆压却不同,这可以从不同的发光强度看出,爆轰波绕过急拐角后的光输出弱于绕过弧形拐角的发射光强度,显然这也是由于压力不同引起的。

关键词: 爆轰波; 拐角效应; 炸药