第 13 卷　第 6 期
2005 年 12 月

含　能　材　料
ENERGETIC MATERIALS

Vol. 13, No. 6
December, 2005

文章编号:1006-9941(2005)06-0355-04

Expansion of the Reaction Products of Detonating Explosives

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Abstract: The expansion of the reaction products of detonating cylindrical charges is presented and analyzed with regard to the radial and axial mean velocities and the real expansion velocities as a function of time and distance.

Key words: explosion mechanics; expansion; detonation product; explosive; cyclinder test; detonation mechanics

CLC number: TJ55; O389　　**Document code**: A

1 Introduction

At the measurements of momenta as a function of polar angles of detonating cylindrical high explosive charges large differences of the impulse density values are found between the axial and radial to the bridge-wave directions[1]. This fact was also found on frames of the expansion of reaction products, obtained with an ultra-short camera. For this reason a few tests with different time delays between detonation and exposures were performed.

2 Test set-up

The 1 kg heavy cylindrical test charge, containing 87% PETN and 13% binder-system, had a ratio of length to diameter 2/1 with 150 mm length and 75 mm diameter. The charge was initiated at the axis on one end surface by a number 8 detonator.

A still picture before every firing was made from the charge with surrounding a mask, to get the exact wanted field of view and the magnification factors (Fig. 1). The charge was exactly arranged in the centre of the ring mask. The time delays between detonation and exposure were selected as 50 μs, 100 μs, 200 μs, 400 μs and 600 μs, respectively. It was used an exposure time of 0.1 μs until 600 μs time delay, where 0.2 μs was used for a little more light input. It was expected a reduced light intensity by the larger expansion of the reaction products.

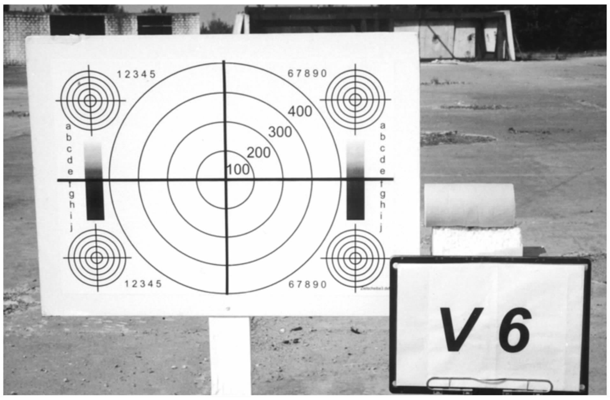

Fig. 1　Still picture of the cylindrical HE charge on the right with the background mask on the left side

3 Analysis

The obtained frames with the five different delay times are shown in Fig. 2 – 6 in a format in which they fill out the available space in a good way.

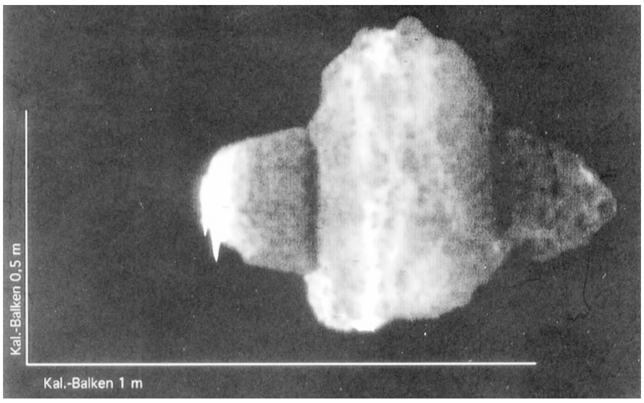

Fig. 2　Expansion of 1 kg detonating Seismoplast (PETN/binder-system 87/13) in cylindrical form of 150 mm length and 75 mm diameter, initiated in the axis from the right sight. The picture was taken after 50 μs delay time with 0.1 μs exposure time

Received Date: 2005-04-20

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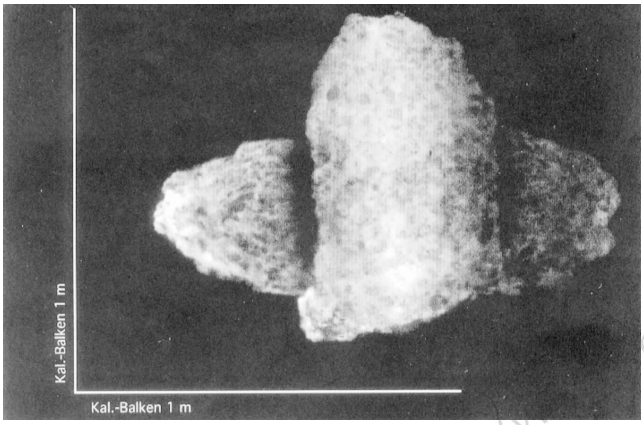

Fig. 3 Expansion of the reaction products of the same charge after 100 μs delay time

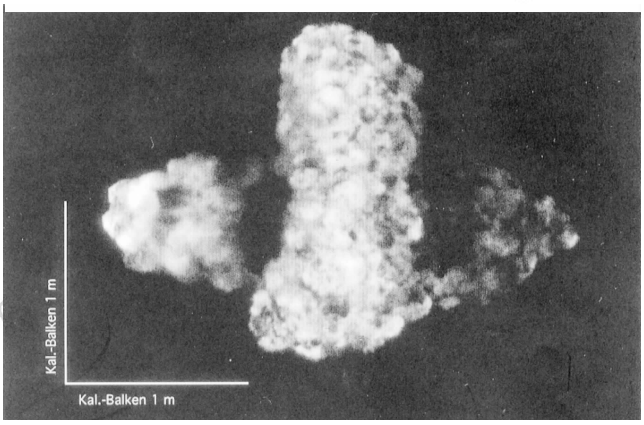

Fig. 5 Expansion of the reaction products of the same charge after 400 μs delay time

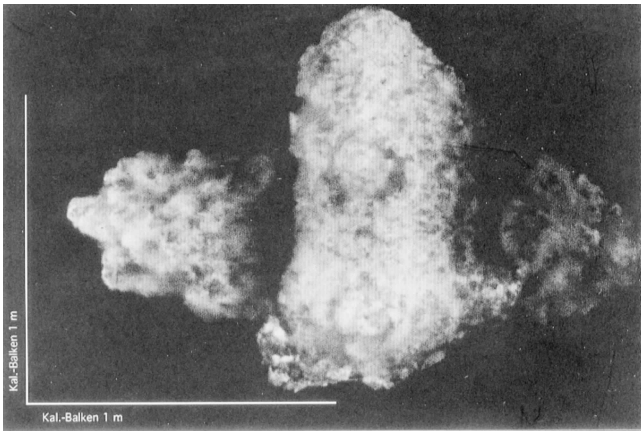

Fig. 4 Expansion of the reaction products of the same charge after 200 μs delay time

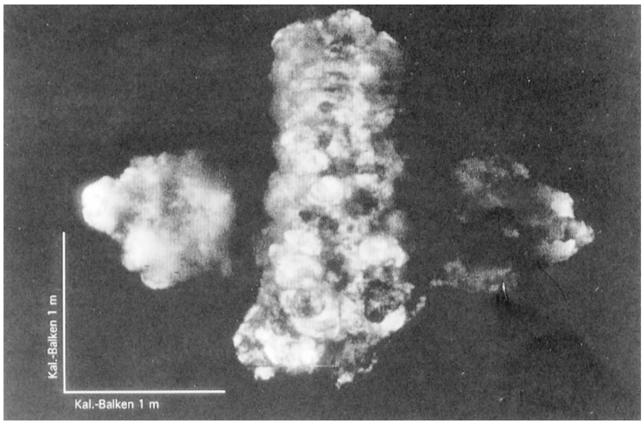

Fig. 6 Expansion of the reaction products of the same charge after 600 μs delay time, but with 0.2 μs exposure time

All of the frames show clearly an axial bright stream from the end-surface in the direction of the detonation wave and a radial expansion wave, and nearly no light from reaction products in the bridge-wave areas.

Surprisingly, some expansions in the rearward direction can also be found, where the impulse density values are generally very low.

Neither the axial blast wave nor the radial expansion shows smooth surfaces in all investigated delay times. The clouds are structured with dimples which are the reasons of scatter in electronic and also mechanic diagnostic results. These structured expansions are clearly visualised in these optical frames.

The magnifications for the first five frames are different, because the axial and radial expansions have travelled different distances. Figure 7 gives a direct comparison of these five frames, using the same magnification factor for all the five exposures. It is clearly visible that the expansion of the reaction products drastically increases as the time difference increases.

More interesting thing are the axial forward and radial expansion behaviours of the 1 kg heavy cylindrical charge with the L/D ratio of 2/1. The distances of the front surface of the clouds in the axial and radial directions of the five frames are summarized in Fig. 8. Compared with the radial direction for this charge type and charge geometry, the axial displacement is large in these near field.

The displacements can be divided by the delay times which gives the mean expansion velocities as a function of time (Fig. 9). After 50 μs the axial mean expansion velocity has achieved around 6.5 km/s and the radial mean velocity around 6.0 km/s. Their mean velocities fast reduce to values of 2.6 km/s for the axial and 2.0 km/s for the radial velocity at 600 μs time delay (Fig. 10).

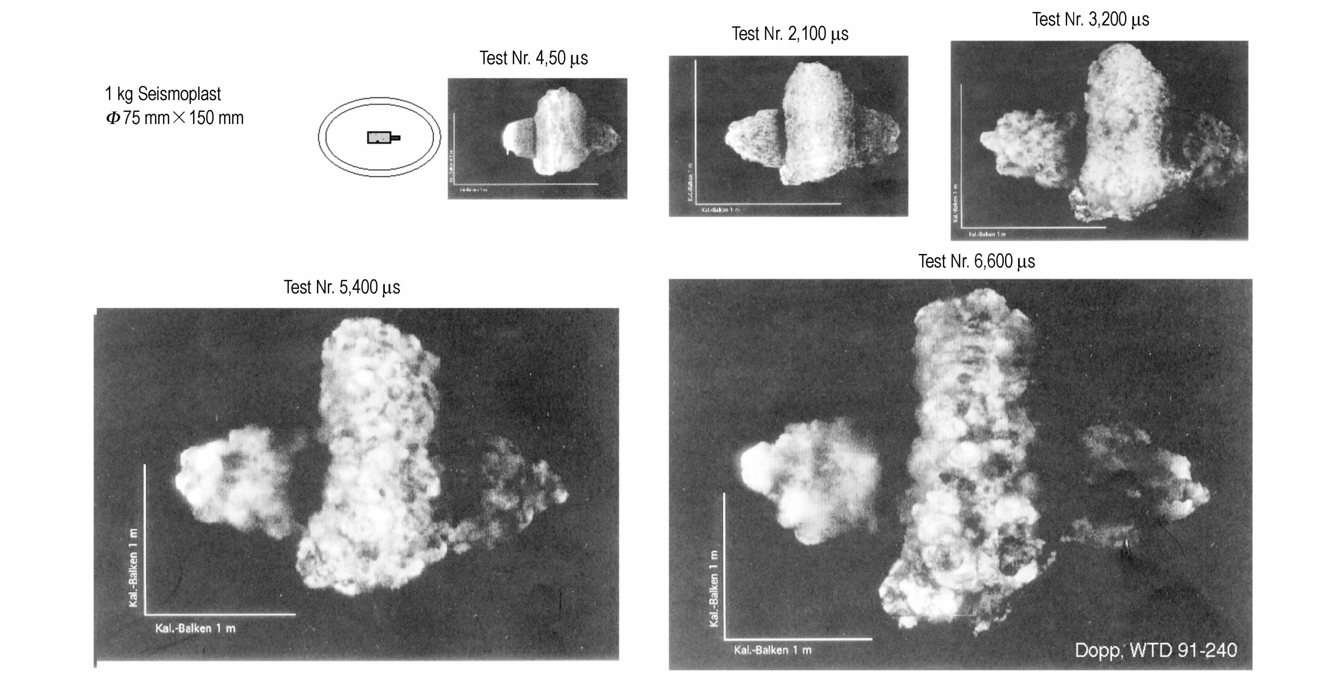

Fig. 7　The calibration bars have 1 m length. The five frames are now compared with the same magnification. The charge in the same scale to this frames are given in the upper line on the left in the circle

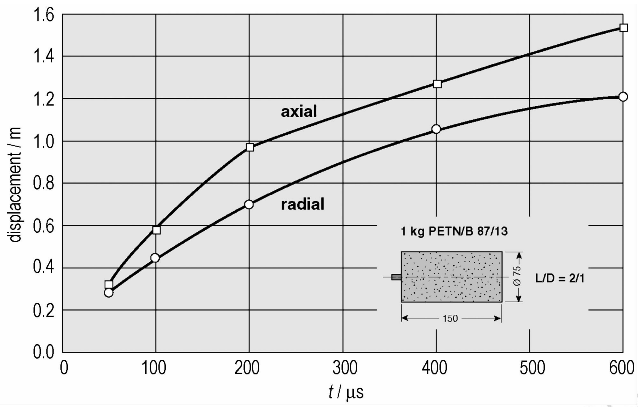

Fig. 8　Axial and radial expansion distance as a function of the delay times

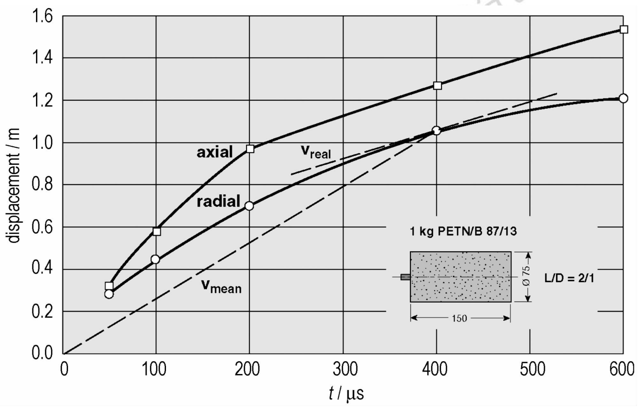

Fig. 9　Definitions of the mean velocities defined as a displacement divided by the delay time and the real velocity which is an tangent to the curves

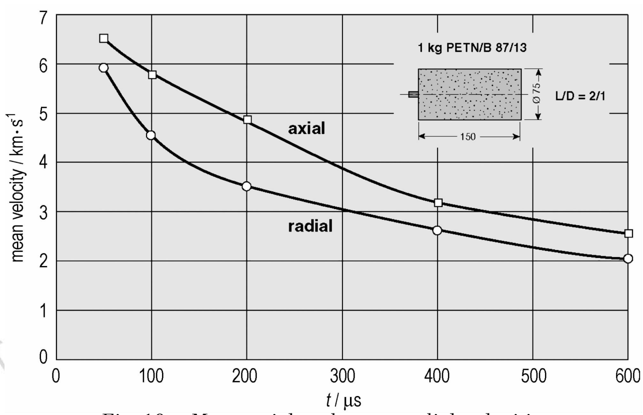

Fig. 10　Mean axial and mean radial velocities as a function of time delay

But it can also be analyzed the real expansion velocity at the measured time differences by tangent lines on the displacement diagram of Fig. 9. This is not too accurate because for this only five points are available and not more to smoothen the curve. Nevertheless, this gives some rough ideas of the magnitudes of the real velocities of the expanding reaction products which corresponds in the near field to the blast wave. For doing this, we get the Fig. 11 with the axial and radial real or tangent expansion velocities of the explosive reaction products. The axial expansion velocity starts with 6.5 km/s, whereas the radial begins with 4 km/s. Both of them fast decrease to about 1.5 km/s at 400 μs. At 600 μs these actual velocities are around 1 km/s for the real axial and 0.5 km/s for the real radial expansion velocity.

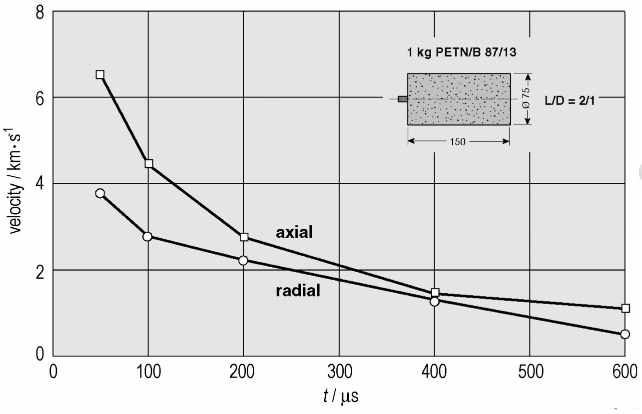

Fig. 11 Real axial and real radial velocities as a function of time delays

But more is wanted to get the velocities at different expansion distances. This point can be found by multiplying the mean velocity with the time delays and using the same real or tangent velocities as used in Fig. 10. Between around 0.3 m and 1.2 m distance the real axial and radial expansion velocities are nearly linear decreasing, beginning at 6.5 km/s for the real axial and 3.95 km/s for the real radial velocity (Fig. 12).

4 Conclusions

With ultra-high-speed camera frames the fact is optically confirmed that a strong axial blast fan is formed by the detonation of a flat ended cylindrical charge and a relative narrow radial blast wave . Between around 10° to 80° and 100° to 170°, in the bridgewave zones, no reaction products are visible. In the impulse density polar diagrams more than one magnitude reduced impulse densities values are measured in these angles.

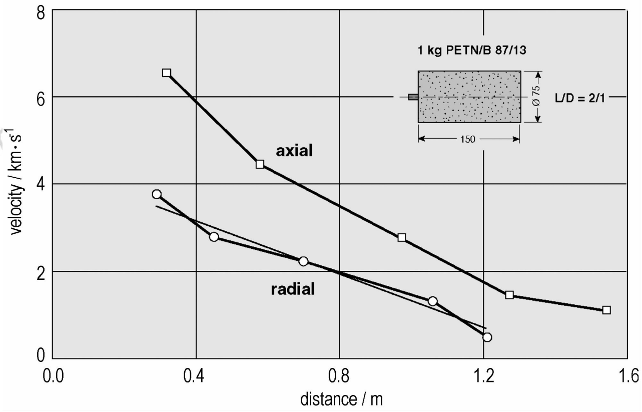

Fig. 12 Real axial and real radial velocities as a function of distance to the detonating cylindrical charge

From the frames at different time delays the displacements as a function of time, the mean velocities and the real velocities as functions of time difference and, what is more important, as functions of the distance can be defined.

The frames also clearly show wavy turbulent fronts on the axial and radial expansions. Such irregularities happen in all diagnostic techniques of pressure time history records in discrete directions, but also on the Heldschen Momentum Method with the high angle resolutions in the nearfield.

Reference:

[1] M Held. Blast Contour[A]. 18th Military Applications of Blast Simulations (18. MABS) in Bad Reichenhall[C], Germany, on CD, 2004.

炸药爆轰过程中反应生成物的传播研究

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摘要: 对圆筒型装药发生爆轰后的反应物的传播过程进行了研究,分析了轴向平均速度、径向平均速度和实际传播速度与时间和距离的函数关系。

关键词: 爆炸力学; 传播; 爆轰产物; 炸药; 圆筒试验; 爆轰机理

中图分类号: TJ55; O389 **文献标识码**: A