

Miniaturized Detonation Velocity Measurement

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Abstract

Small high explosive charges < 500 mg are commonly used for components within ignition chains, igniters for secondary high explosives or high speed actuators. Reaction velocity and stability of the used high explosive configuration strongly affects correct and sure functioning of these mini charges. Measurement of this reaction velocity under application conditions represents a tool for optimization purposes, e.g. minimal necessary high explosive mass or charge geometry.

1. Introduction

The aim of usual detonation velocity measurement is to identify the detonation velocity of a specific high explosive formulation in order to optimize the high explosive material itself. Setups for this kind of measurements use typically cylindrical high explosive charges with diameters between 20 mm and 50 mm at charge lengths between 200 mm and 500 mm. The charges are ignited at one end via detonator and booster charge. Detonation velocity is measured by using time-of-arrival probes applied to equidistant drilled holes along the high explosive. Detonation velocity is derived from measured time delay and known geometrical distance between the probes. Usual time-of-arrival probes are wrapped copper wire loops, piezoelectric pin probes or ionisation pins. 20 to 30 mm are typical distances between the probes.

This setup size is not applicable to charges in the mass range between 50 mg and 500 mg used for e.g. detonators, ignition transfer devices and high speed actuators. A downsized setup for this special kind of charges is presented.

2. Experimental Setup

In order to realize a compact setup, thin ionisation pins are selected with an outer diameter of 1mm.

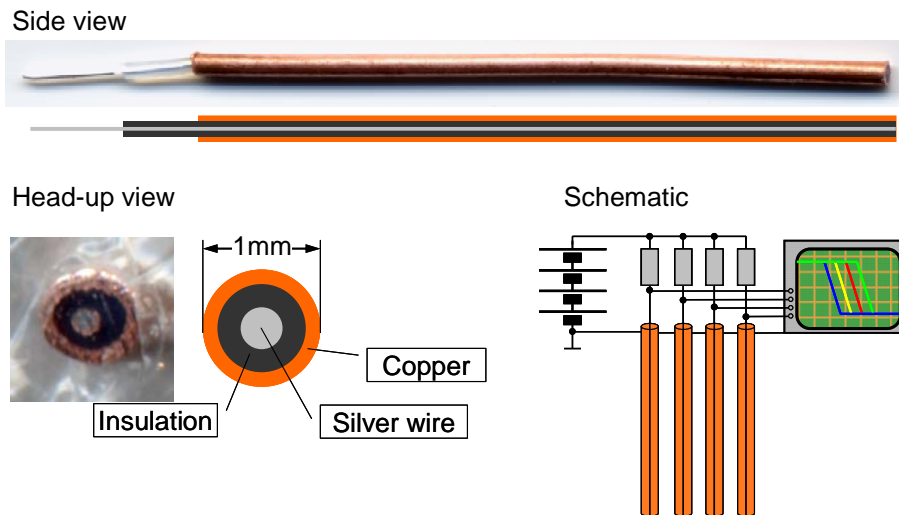


Fig. 1 Ionisation pins: side view, cross section and electrical connection

This pin type allows 1.1 mm drill hole diameter which ensures ± 0.05 mm maximum geometrical uncertainty. Additional ± 0.1 mm uncertainty is caused by 0.2 mm diameter of the axial silver wire and leads to ± 0.15 mm total geometrical uncertainty of the applied probe. Related to 3 mm distance between each probe <5% maximum error occur for calculated probe to probe velocities. Errors caused by the data acquisition are negligible.

To ensure lowest possible disturbance of the detonation front, ionisation probes are positioned in a depth of only 0.1 mm just below the charge surface.

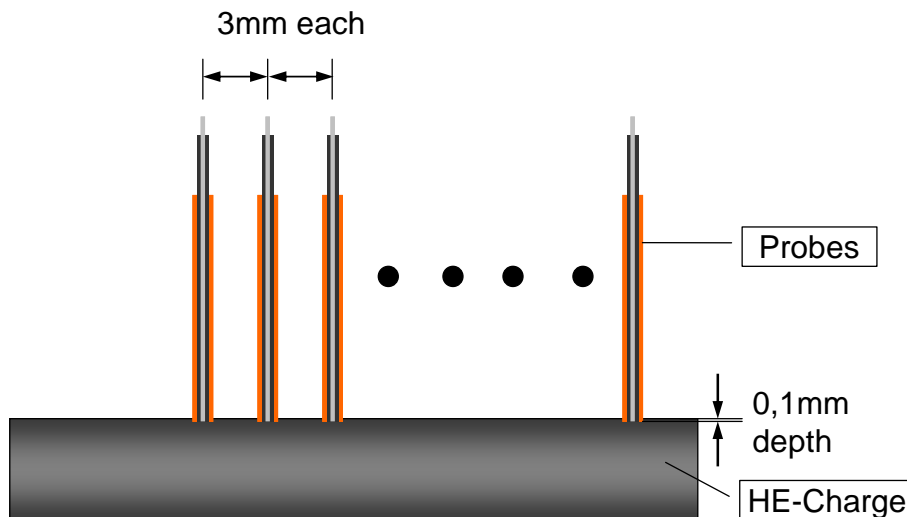


Fig. 2 position of ionisation pins on HE-Charge

Charge and probes are applied to a special setup, which ensures exact positioning of the charge and geometrical guidance of all applied ionisation pins on the charge.

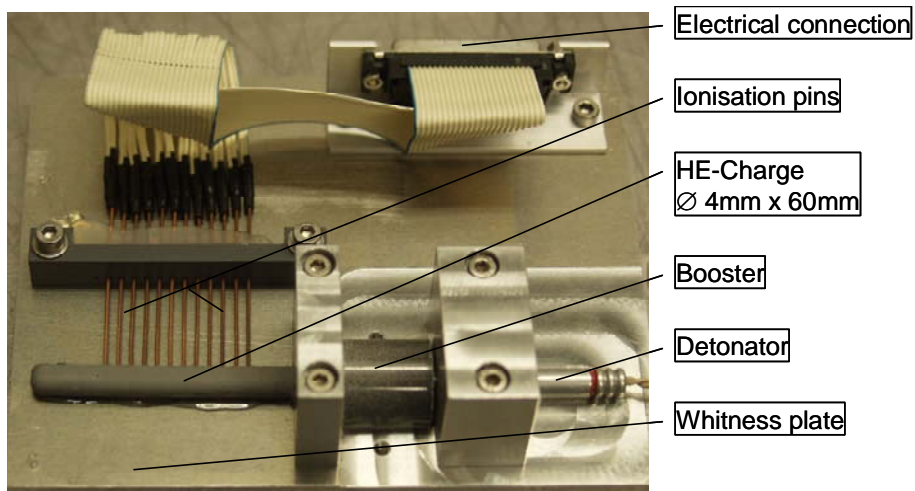


Fig. 3 miniaturized detonation velocity setup

12 Probe signals are conducted simultaneously on a PC-based 8-bit data acquisition system with 0.5 ns time resolution (2GS/s). The presented setup leads to very precipitous pin probe signals caused by the passing reaction front. The falling flank of the specific probe signal is passed in less than 20 ns.

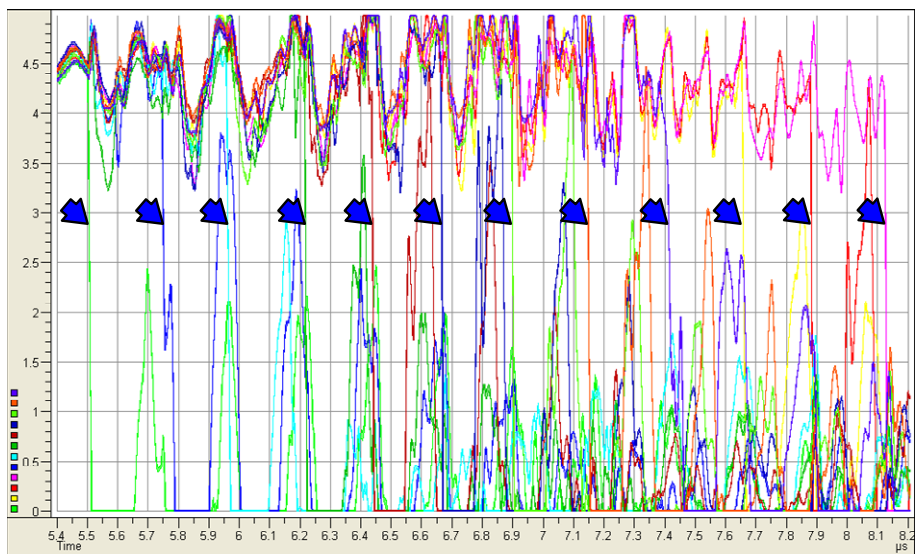


Fig. 4 typical ionisation pin signals: Precipitous falling signal flanks, here marked with arrows

The presented example shows results for a plastic bonded RDX system at charge diameters of 3 mm, 4 mm, 5 mm and 6 mm with identical formulation.

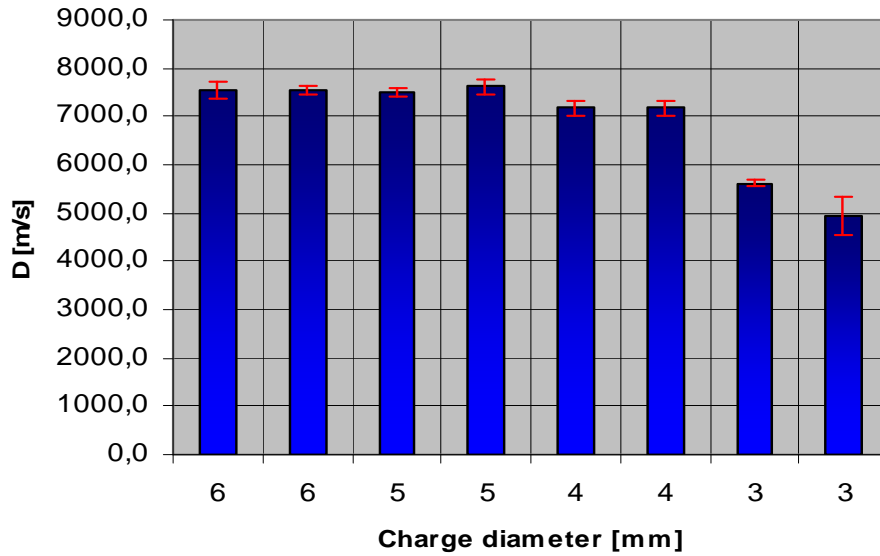


Fig. 5 miniaturized detonation velocity measurement results

The results show stable detonation for 6mm and 5 mm charge diameter and with slightly reduced detonation velocity also for 4 mm diameter. Increasing instability and clearly reduced detonation velocity for 3 mm charges indicates the undershoot of the critical diameter.

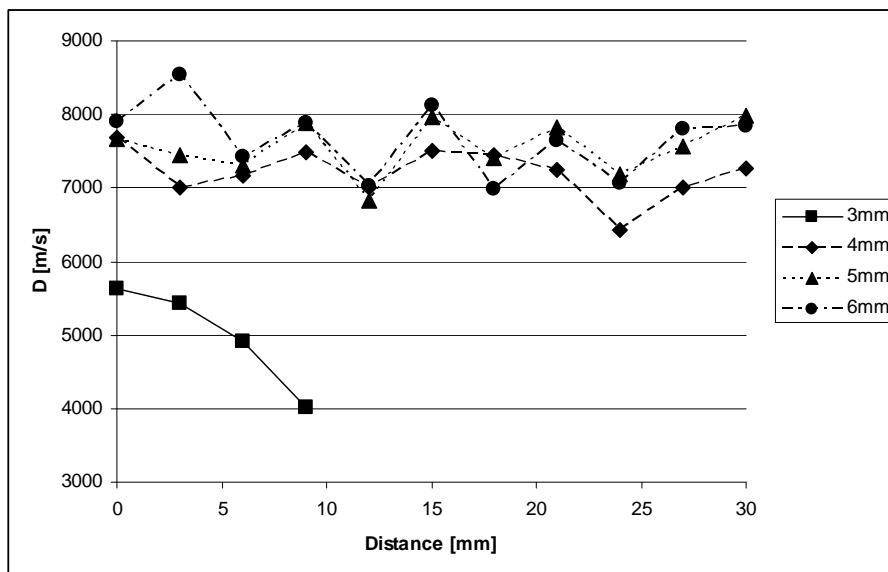


Fig. 6 Detonation velocity progress along the charge length for different charge diameters

The curve of the 3mm charge shows a reduced detonation velocity at the beginning and a quick decay afterwards which led to a broken off reaction after the 4th probe.



Fig. 7 Witness plate results for full (1) and for interrupted (2) detonation

Witness plate results with continuous detonation imprints as shown in case 1 occurred for 6 mm, 5 mm and even for 4 mm charge diameter, whereas 3 mm charge diameter led to interrupted detonation imprints, unreacted charge fragments and finally to breaking-off probe signals.

Nevertheless, miniaturized detonation velocity measurement is not necessary for the localisation of the critical charge diameter where detonation breaks down. This result can easier be achieved by evaluating witness plates. Miniaturized detonation velocity measurement is especially suited for a precise identification of the point, when detonation velocity and therewith performance and reliability starts to sink. For the presented example of charges without enclosure, this occurred at a charge diameter between 5 mm and 4 mm. The benefit of the presented setup is the ability to measure reaction velocities within small applications. A natural limitation of the method is given by the measurement principle of ionisation probes: low reaction velocities below ~ 1000 m/s in the deflagration or even the burning range result in worse or missing probe signals.

3. Conclusion

The presented setup for a miniaturized detonation velocity measurement was successfully applied to small high explosive charges and passed several practical tests at real small scale high explosive applications like igniters, ignition chain components and high speed actuators.