

Initiation of an Explosive Charge by Consecutive Projectiles

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ABSTRACT

Test results reported in [1,2] show that when two consecutive projectiles hit an explosive charge, and when their velocity is such that the first projectile is just below the initiation threshold, the second projectile is able to initiate the explosive. We propose here an explanation to this important phenomenon. Our explanation is based on our reactive flow model TDRR for which the explosive reaction rate increases with the reactant temperature. We use our reactive flow code to demonstrate how this works. To simplify the computations, we hit the explosive charge with two consecutive pressure pulses instead of with two projectiles.

INTRODUCTION

In [1,2] they report on a series of tests in which an explosive charge is initiated by two identical consecutive projectiles. The tests show clearly that the explosive charge is initiated much more easily by two consecutive projectiles than by a single identical projectile. In those tests the impact by a single projectile is a little under the initiation threshold, but the impact of a second identical projectile is able to cross the initiation threshold and lead to detonation.

In [1,2] they try to explain their test results by hand waving arguments. They assume (without proof) that the first projectile deforms and damages the explosive on its path in a way that makes it more sensitive to an additional impact. But it's not possible to prove or disprove such an explanation by computer modeling or other means.

The phenomenon reported in [1,2], that when a projectile hits an explosive charge below its initiation threshold, it makes it more sensitive to the impact of an additional projectile, is of practical importance when dealing with the response of explosives to impact by projectiles or fragments. We therefore need to understand this phenomenon thoroughly, and be able to predict it in detail by computer modeling. It seems to us that the explanation given in [1,2] is not the correct one, and in what follows we propose an alternative explanation which we demonstrate through computer simulations. The essence of our explanation is: 1) when a projectile hits an explosive charge, or alternatively, when a pressure pulse acts on an explosive charge, the explosive heats up to some residual temperature which increases with the strength of the impact; 2) an additional projectile or pressure pulse hitting the same explosive charge would heat it up some more and to a higher temperature; 3) as the reaction rate of an impacted explosive increases with its reactant temperature (according to our reactive flow model called TDRR [3-5], which we use later to demonstrate our claim), the explosive charge becomes more sensitive to the consecutive impact.

In what follows we use our reactive flow model TDRR to demonstrate our explanation of the test results reported in [1,2].

DOUBLE IMPACT SIMULATIONS WITH TDRR

To make our computer simulations simple we hit the explosive charge with boundary pressure pulses instead of with projectiles. The application of pressure pulses is much simpler than that of projectiles as there is no need to describe the projectiles and to follow their penetration path and change of shape. Also, instead of looking for the initiation threshold of a single pulse and then decreasing its strength somewhat, we compute and make comparisons of the run distance to detonation of the assumed pressure pulses. We then check whether and by how much the run distance from two consecutive pulses is lower than the run distance from a single pulse.

COMPUTATIONS

We use simple oblong pressure pulses of 10GPa strength and 1 μ s duration. We're changing the time difference between pulses between zero and a few microseconds. When the pulses are without a time difference between them, we get:

- From a single pulse (1 μ s duration), the run distance is larger than 78mm (our charge length).
- From 2 adjacent pulses the run distance is 21.30mm.
- From 3 adjacent pulses: 18.08mm.
- From 4 adjacent pulses: 18.08mm (no change).
- From 2 pulses 1 μ s apart, the run distance goes down to 8.15mm.
- From 2 pulses 2 μ s or 3 μ s apart, the run distance stays the same, 8.15mm.

From these results we see clearly that by introducing a time difference between the two pulses, the run distance to detonation decreases substantially, which means that the first pulse increases the sensitivity (or the reaction rate) considerably.

As stated above, the main feature of the reactive flow model that we're using is that the reaction rate is an increasing function of the reactant temperature. Our computation results therefore support our suggested explanation of the test results in [1,2]. Again, our explanation is that the first pulse heats up the explosive without reacting it. Therefore, as reaction rate increases with temperature of the reactant, the reaction rate from the second pulse is higher.

To demonstrate the higher temperature increase caused by two separate pulses compared to the lower temperature increase caused by connected pulses, we show in Fig. 1 temperature histories from two such computations.

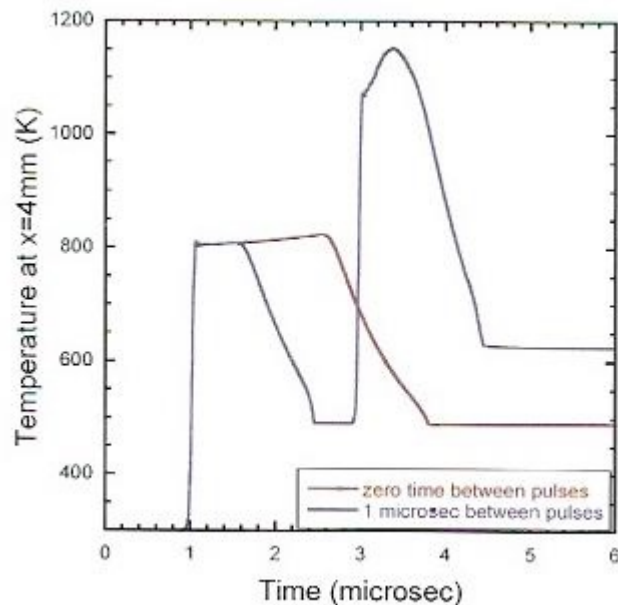


Figure 1. Reactant temperature histories at 4mm into the explosive charge.

Red: two connected pulses.

Blue: two pulses with 1 μ s time separation.

From Fig. 1 we see that the 10GPa pulse increases the reactant temperature by 500K (to 800K). Then as a result of the rarefaction, the reactant temperature decreases back to 500K. When the second pulse arrives, it increases the reactant temperature by 600K (to 1100K), because the reactant temperature is now higher than before. But at such a temperature the reaction rate is already substantial, and the reactant temperature increases even more up to 1150K. The end result is that the run distance to detonation decreases substantially.

SUMMARY

Tests reported in [1,2] show that when two consecutive projectiles hit an explosive charge, they are able to initiate it even when a single such projectile does not. In [1,2] they propose a hand waving explanation to this important phenomenon, but they're not able to provide proof to their explanation.

We propose here our own explanation to the phenomenon observed in [1,2], that the explosive sensitivity to the second projectile (or second pressure pulse) is higher than its sensitivity to the first projectile (or pressure pulse). Our explanation is that the increased sensitivity results from an increase of temperature of the explosive caused by the first pulse. This follows from our reactive flow model TDRR [3-5] for which the reaction rate is an increasing function of the reactant temperature.

We demonstrate how this comes about through our computer modeling code, which is based on our reactive flow model TDRR.

References

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