Shock To Detonation Transition of Explosives

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***Abstract*—The objective of this work is to improve the knowledge of the shock-to-detonation transition properties variation.The study is based on a different explosives like PETN(pentaerythritol tetranitrate) at initial pressure 1.65 g/cm3 , Nitromethane ,CL-20-based High Explosives , Detonation Transition in Porous Explosives from Rapid Compression Loadings and RDX, HMX and NTO based composite high explosives modelling . Showing the variation in Temperature , Pressure ,Density ,Volume , Pore size in Shock to detonation transition .**

I. Introduction

Any explosive's detonation is said to begin with the production of a shock wave and proceed through its progression to detonation. This argument makes it logical to examine the evolution of impulse-initiated detonations in detail in order to

Identify the physical, chemical, and geometric variables that the growth-to-detonation process appears to be dependent on. This article discusses tests on the shock initiation of cast and pressed explosives. The test explosive sample was set to detonate using plane shocks produced by explosive plane-wave generators and degraded to acceptable peak amplitudes by the employment of intermediary layers of inert materials. Each sample's shock velocity was calculated as a function of both the initial shock amplitude and the distance within the explosion. 28 to 140 kilobars were the range of the first shock pressures. TNT and several cyclotols are mentioned as explosives. Charges were hurled as well as pressed. The shock velocity in cast charges other than TNT largely remained constant for a time, the length of which depended on the initial shock amplitude, before accelerating quickly to the typical, steady state detonation velocity. It was discovered that with pressed charges, during the quick ascent, the shock velocity briefly exceeded the steady detonation value but then fell back to the value of the typical steady detonation. The velocity in cast TNT was observed to increase to a point between the first shock and the final detonation, where it remained for a while before increasing to the regular detonation value. A hydrodynamic model that describes how pressure build-up caused by chemical reactions behind the shock reinforces the shock front as it travels through the charge can explain the overall results. The detailed results, on the other hand, necessitate the idea of hotspot initiation and cannot be explained by thermal processes in homogenous domains. Our research will be contrasted with that of others who have utilised various impact and gap-test settings in the debate. Several of the issues and discrepancies of viewpoint that have developed in the interpretation.

II. Experimental configuration

A. Shock to detonation transition of pentaerythritol tetranitrate (PETN) initially pressed to 1.65 g/cm^3

High energy explosives like pentaerythritol tetranitrate (PETN) are frequently used in detonators1,2, or combined with other explosives and/or binders for main charge applications. The density of the pressing affects the shock to detonation transition of neat PETN significantly3,4. The measured shock to detonation transition sensitivity changes by a factor of 3 for pressings at 1.60 g/cm3 in comparison to charges at 1.72 g/cm3. In comparison to less dense samples, the study discovered that PETN pressed to a high density of 1.65 g/cm3 has a lower threshold shock pressure for the transition from shock to detonation. The findings show that the initial density of PETN significantly affects its shock-to-detonation behaviour and emphasise the need of taking density into account while designing and perfecting high explosive devices. The findings can be utilised to guide future research in the field and offers insightful information about the underlying process of the shock-to-detonation transition of PETN.

S.No	Pressure (GPa)	Specific Volume(cm^3/g)	Density (g/cm^3)
1	60	0.30	3.3
2	15	0.40	2.5
3	3	0.50	2.1
4	0	0.55	0

Fig. 1. Variation in Pressure , Volume and Density.

B. Shock-to-detonation transition of Nitromethane.

The work is based on experiments using plane shock hits on explosive targets at 8.6 GPa and a spectral analysis in the 0.3-0.85 m region with a 28-nm precision. The detonation front,

the reaction products created during the super detonation, and the detonation products are all semi-transparent, according to the time-resolved radiant spectra. Through the use of a mathematical inversion technique based on the equation of radiative transfer with Rayleigh scattering regime, the temperature and absorption coefficient profiles are extracted from the measured spectra. At least 2500 K is reached by shocked nitromethane, demonstrating the presence of local chemical reactions upon shock introduction. Determined are the temperatures of super detonation and steady-state detonation. Determined are the temperatures of super detonation and steady-state detonation. The process in which a shockwave created by an initial spark or impulse is transmitted through nitromethane, resulting in a rapidly growing reaction zone and ultimately a full-scale explosion, is known as the shock-to-detonation transition of nitromethane. The exact mechanisms causing the transition are still not entirely understood, although it is thought to be a result of the interplay between shockwaves and the chemical reactions in nitromethane, which causes a rapid release of energy. In conclusion, the shock-to-detonation transition is a complex process that involves the interplay of physical and chemical events, and it is a significant factor the performance of nitromethane as a high-energy fuel .

Minimum temperature of the different stages of the SDT

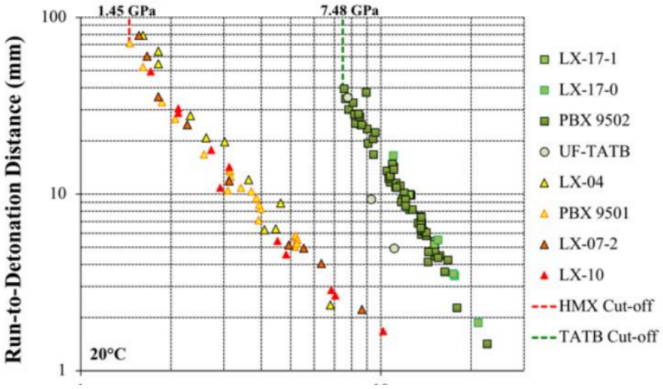
Stage of the SDT	Temperature (K)
After shock entrance	⩾2500
Before the superdetonation formation	⩾2600
Superdetonation	⩾3200
Detonation	⩾3600

S.No	Wavelength (μs)	Transmission (%)
1	0.40	50
2	0.80	100
3	1.15	38
4	1.30	90
5	1.65	0

Fig. 2. Variation in Wavelength and Transmission.

C. Temperature-dependent Shock Initiation of CL-20-based High Explosives.

Hexanitrohexaazaisowurtzitane's shock-initiation properties as a function of temperature (CL-20). An explosive with great energy and extreme sensitivity is called CL-20 [1, 2]. It is commonly known that explosives built on the CL-20 platform are sensitive to a single trigger like shock, collision, or heat.The shock initiation of C-1 at various temperatures was simulated using an ignition and growth reactive flow model. The key findings are listed below. As the temperature rises from 20 °C to 95 °C, C-1 becomes more sensitive. Although the phase transformation induces a volume expansion of the CL-20, which results in additional hot spots under shock compression, the phase transition in CL-20 occurs at 125 °C, and C-1 at 142 °C is less shock sensitive than at 95 °C or 75 °C.



D. Shock-to-detonation transition of RDX, HMX and NTO based composite high explosives modelling.

Cast-cured plastic bounded explosive (PBX), which is based on HMX, RDX, and NTO, is frequently employed in insensitive ammunition. In order to compute shock ignition and detonation propagation inside PBX, strong and trustworthy models are required for designing contemporary warheads. A cast-cured PBX differs from pressed PBX in that it is not porous and has hotspots mostly at the grain-binder interface, which causes a distinct burning behaviour during shock-to-detonation transition.The study discovered that several factors, including the composition, size, and shape of the explosive particles, can affect the shock-to-detonation transition of composite high explosives built from RDX, HMX, and NTO. The detonation behaviour of composite high explosives can be improved by optimising the particle size and shape distribution, according to the consistent results of the experiments and modelling. The study emphasises how crucial it is to take particle size and form distribution into account while designing and perfecting composite high explosive devices.

Overall, the research's conclusion emphasises the significance of taking particle size and shape distribution into account when designing and optimising composite high explosive devices and emphasises the need for additional study to fully comprehend how these complex materials transition from shock to detonation.

S.No	Run up Distance(mm)	Time(μs)	Shock Velocity (mm/μs)
1	2.5	0.5	3.5
2	5	1.0	4.0
3	10	1.8	5.0
4	15	2.6	6.0

Fig. 3. Variation in Run up distance , Time and Shock Velocity.

E. Detonation Transition in Porous Explosives from Rapid Compression Loadings.

The system performs better overall and is more sensitive to the Shock to Detonation Transition when solid rocket propellants have more nitramine in them (SDT). According to the findings, a zone of burning granulated propellant that is constrained and close to a zone of cast propellant occasionally can produce a pressure rise that is quick enough to shock begin the cast material. Any high-energy rocket motor environment has a serious chance of presenting this kind of detonation hazard scenario. The modelling analysis also identifies key areas that require additional investigation. The following are a few of them: relations for determining the volume percent of hot spots based on initial porosity , relations for the dynamic (transient) collapse of the voids or pores , the assessment and expression for the chemical rate of breakdown of the reactive, shocked substance , the evaluation of the equilibrium of a two-phase combination. With regard to limited shock initiation trials, the projected run-to-detonation distance for HMX explosive as a function of porosity compares favourably. A subsequent detonation is unavoidable because the packed

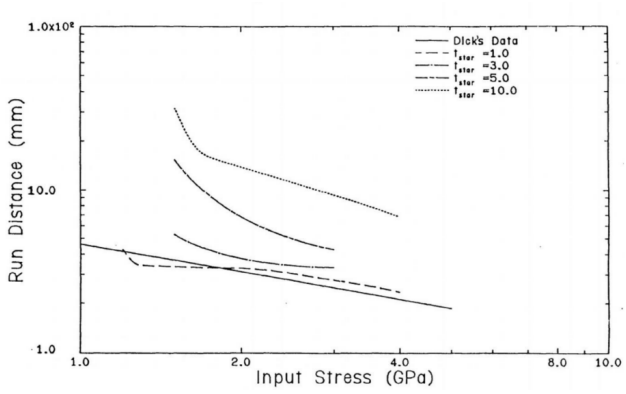


Fig. 4. Variation in Run up distance , Time and Shock Velocity.

bed's length exceeds the critical length required for rapid convective combustion to take place. This graph displays the LSOT time (run-up to detonation distance) for two initial porosity levels. Here, it is seen that the sample with the lower a has a shorter run-up distance than the one with larger porosity. Nonetheless, the hot spot volume is bigger in the material with increased porosity.The low porosity material has a significantly

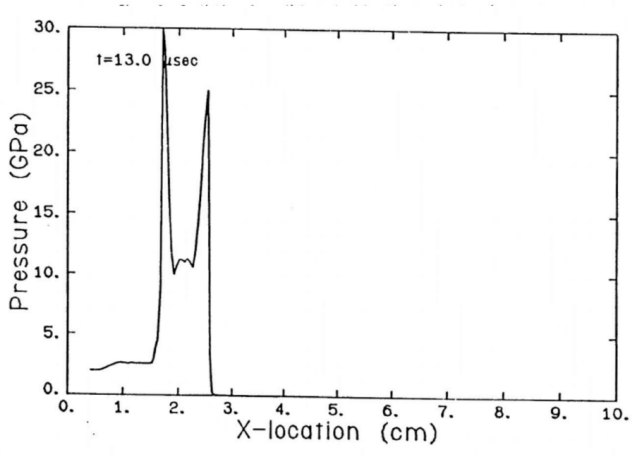


Fig. 5. Variation in Run up distance , Time and Shock Velocity.

higher local density and as a result, when it decomposes, it releases more energy into the shock front.

III. Results and Discussion

The shock-to-detonation transition (SDT) occurs when a shock wave passes through a high explosive substance and changes a subsonic deflagration into a supersonic explosion. The primary factors influencing the SDT are pressure, particle velocity, shock wave temperature, and properties of the explosive material, including its chemical composition, density, and porosity. During the shock-to-detonation transition (SDT), the high explosive substance is compressed by a shock wave, increasing its pressure and density. The initial subsonic deflagration can transform into a supersonic detonation once the pressure and density are critical. Chemical composition of the explosive

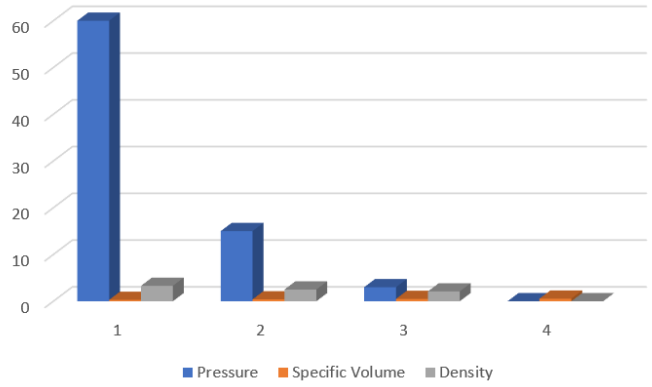
The pressure and density at which the shock-to-detonation transition (SDT) takes place can be influenced by the material, its initial density and porosity, and the shock wave's properties. Keep in mind that the SDT process is very sensitive, and even small changes in pressure or density can have a significant impact on the results of the test. There are many temperatures for the shock to detonation transition (SDT) stages. The run-up distance and shock velocity both grow with the passage of time. The density of the explosives will increase as the pressure on them decreases the Particular Volume.

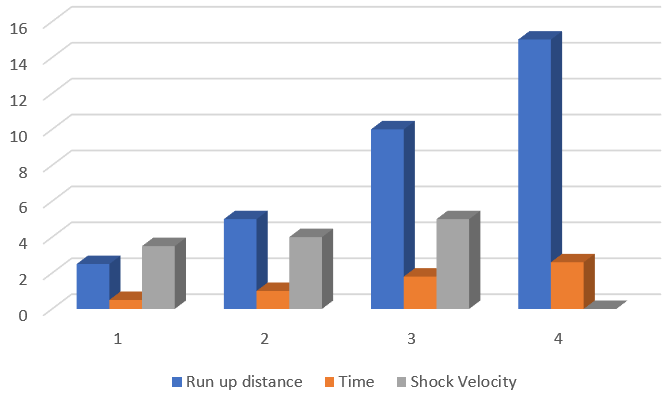
PARTICLE VELOCITY : A key component of the SDT procedure, the particle velocity of the high explosive material affects both the rate of energy transfer and the reaction's overall speed.

TEMPERATURE: The temperature of the high explosive material affects the chemical reaction rate and reactivity of the shock-to-detonation transition (SDT).

CHEMICAL COMPOSITION: The chemical composition of the high explosive material can have an effect on the shock-to-detonation transition (SDT) reaction kinetics, ignition sensitivity, pressure, and density during the transition.

PORE SIZE: The porosity of the high explosive material can have an effect on the initial density, shock wave transmission, and chemical reaction parameters of the shock-to-detonation transition (SDT).
VOLUME: By modifying the pressure and density of the shock wave as well as the overall reaction In addition to energy balance, the volume of the high explosive material can affect the transition from shock to detonation (SDT).
EFFECT OF DENSITY : For the simple reason that a higher loading density assures a greater quantity of explosive per unit volume so that a greater amount of developed energy can sustain the detonation wave, a higher loading density will result in a higher VOD. For describing the density of free-running explosives, the number of pounds of explosives per foot of charge length in a specific borehole size is frequently used. By speaking, denser explosives provide higher detonation pressures and speeds. When selecting an explosive, density is a crucial factor.
EFFECT OF PRESSURE : The starting pressure of the mixture in the acceptor affects the detonation propagation mode. A stable detonation wave may change into a shuttered detonation wave, a galloping detonation wave, or a failure when the initial pressure drops. The density and detonation velocity of an explosive determine the detonation pressure.
EFFECT OF TEMPERATURE : Less heat is lost during the coupling and mutual strengthening of the pressure wave and chemical reaction as the initial temperature rises. As a result, as the initial temperature rises, the tendency of detonation development decreases. Explosive safety will be impacted by a rise in shock sensitivity caused by an explosive's temperature. Thus, it is very important to research how temperature affects the shock initiation of explosives. The findings of the experiments were used to determine the link between the model parameters and temperature. The Pop plot, the reaction degree of the explosives, and the run distance to detonation were all calculated as functions of the initial input pressure at various temperatures. The shock sensitivity diminishes with temperature for temperatures between 25 and 110 °C, primarily due to binder softening. However, for temperatures between 110 and 170 °C, the shock sensitivity rises with temperature, which depends on the RDX's rising sensitivity.





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