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SHOCK DESENSITIZATION EFFECT IN THE STANAG 4363 CONFINED EXPLOSIVE COMPONENT WATER GAP TEST

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Abstract. The Explosive Component Water Gap Test (ECWGT) in the Stanag 4363 has been recently investigated to assess the shock sensitivity of lead and booster components having a diameter less than 5 mm. For that purpose, Pentaerythritol Tetranitrate (PETN) based pellets having a height and diameter of 3 mm have been confined by a steel annulus of wall thickness 1-3.5 mm and with the same height as the pellet.
1-mm wall thickness makes the component more sensitive (larger gap). As the wall thickness is increased to 2-mm, the gap increases a lesser amount, but when the wall thickness is increased to 3.5-mm a decrease in sensitivity is observed (smaller gap). This decrease of the water gap has been reproduced experimentally by many nations.
Numerical simulations using Ignition and Growth model have been performed in this paper and have reproduced the experimental results for the steel confinement up to 2 mm thick and aluminum confinement. A stronger re-shock following the first input shock from the water is focusing on the axis due to the confinement. The double shock configuration is well – known to lead in some cases to shock desensitization.

INTRODUCTION

The shock sensitivity of initiation devices is difficult to assess because of many parameters involved : the size, many materials with different impedance, several possible shock scenario … Different kinds of tests have been used to identify a go/no go threshold for the explosive components : PMMA gap test[1], water gap test[2], bullet impact ... The effect of the confinement seems to play a major role.

Through the Stanag 4363 efforts, several countries have investigated the shock sensitiveness of lead and booster explosive components using the water gap test[34567]. The sensitivity usually increases with the steel confinement. Recent experimental results show a desensitization phenomenon for explosive components having a diameter less than 5 mm[8].

An experimental set-up of the Explosive Component Water Gap Test is proposed in the Stanag 4363 and presented Figure 1, but has not been validated yet for confined lead and booster having a diameter less than 5 mm. The water column is confined with 2 mm thick PMMA cylinder with a inner diameter of 21 mm. A reference has been chosen for the explosive component : the Pentaerythritol Tetranitrate (PETN) based pellet has a height and diameter of 3 mm and is confined by a steel or aluminum annulus of wall thickness 1 - 3.5 mm and with the same height as the pellet. The unusual desensitization behavior has been identified for a 3.5 mm thick steel annulus.

Numerical simulations are performed using an ignition and growth reactive flow model for the PETN based pellet. The initiation of the donor charge and the influence of the half height donor charge on the go / no go threshold is investigated. The effect of the aluminum and steel confinement is evaluated and compared with the experiments.

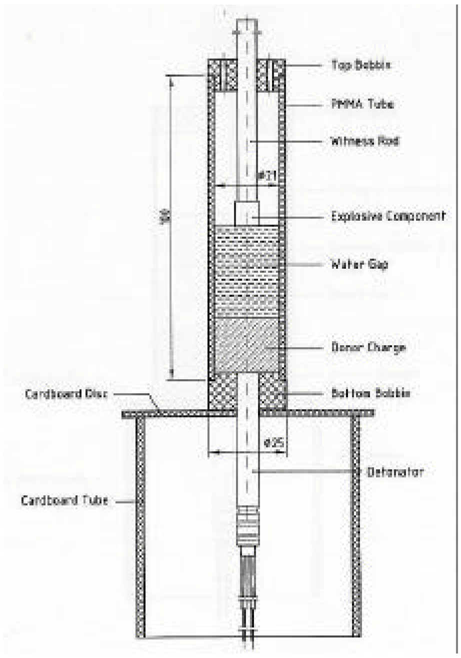

Figure 1 : Explosive Component Water Gap Test set-up (Stanag 4363)

CONFIGURATION OF THE NUMERICAL SIMULATIONS

2D axi-symmetrical configurations have been studied, respectively with a Lagrangian description in LS-DYNA. A resolution of 10 elements/mm is used in this paper. Some attempts have been performed with lower and higher resolutions. The mesh then reaches approximately 100,000 elements, depending on the confinement thicknesses and water gaps.

The parameters of the ignition and growth reactive flow model[9] have been recently identified to assess the shock initiation of the LX16 pellet[10]. These parameters have been used here as a first attempt. Additional small scale shock initiation experiments using run distance to detonation transition such as a small scale wedge test, shock time arrival for different HE thicknesses and foil velocities are required to build a more complete Ignition and Growth reactive flow model for a very small critical diameter composition like LX-16.

A Jones-Wilkins-Lee (JWL) equation of state has been used for the reaction products of the donor composition 9407 (RDX/ Exon 461 94/6), instead of the experimental composition RDX/wax 95/5. The donor charge is point-initiated at the bottom axis or flat initiated within the inner diameter of the detonator.

For water, PMMA, aluminum and steel, classical Gruneisen equations of state have been applied.

RESULTS AND COMPARISON WITH EXPERIMENTS

Influence of The Donor Charge

The Stanag 4363 rev.4 final draft allows one of the two following specifications for the donor pellet set-up:

- a plain pellet ∅ 21 mm h 18 mm initiated at the back,
- or a cavity pellet ∅ 21 mm h 20.3 mm with a cavity for the detonator.

The chosen reference for the numerical simulation is the plain donor pellet ∅ 21 mm h 18 mm point initiated at the back. A point or a flat initiation of the same donor (diameter 21 mm and length 18 mm) have been calculated and give the same go-no go threshold, Table I. The diameter of the flat initiation corresponds to the entire inner diameter of the detonator.

The influence of the cavity pellet filled with the detonator is also investigated. The cavity pellet is modeled as a plain pellet (∅ 21 mm h 20.3 mm, point initiated at the back) and gives the same go / no - go threshold as the reference.

Table I. Influence of the donor charge, Lx16 ∅ 3 mm, h 3 mm no confinement, numerical simulations

Initiation / donor charge (mm)	Go, water gap (mm)	No Go, water gap (mm)
Point / ∅ 21 h 20.3	-	16.7
Point / ∅ 21 h 20.3	-	20.7
Point / ∅ 21 h 18 (reference)	15	17
Flat / ∅ 21 h 18	15	17

The interest is also to small scale the donor charge. Half height of the donor charge is calculated and presented Table II. This configuration seems to give the same go / no go threshold than the reference set-up.

The peak pressure in water versus the distance is presented figure 2 for the half donor configuration and compared with the standard height (experiments, point and flat initiated). The pressure is lower for shorter distances. This could perhaps influence the go / no go threshold with no confinement. Nevertheless, the go / no go results with confined target are obtained for water gaps greater than 25 mm. For water gaps greater than 18 mm, the half donor configuration seems to match the experiment and the numerical results with the point initiated plain pellet donor. The curvature in water could be slightly different.

Table II. Influence of the half height donor charge, Lx16 ∅ 3 mm, h 3 mm, 1 mm steel confinement, numerical simulations

Donor charge	Go, water gap (mm)	No Go, water gap
Half height	26	28
Standard height	27	29

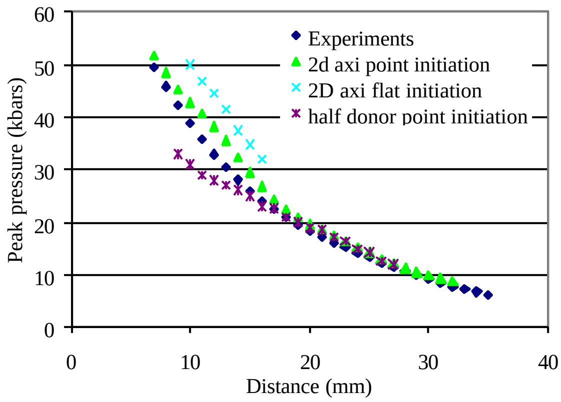

Figure 2. Peak pressure of the shock front versus tracer distance in water, half height donor compared to experiment and the plain donor numerical simulations.

Influence of the Aluminum Confinement

The diameter and length of PETN based pellets are 3 mm in diameter and 3 mm long. The aluminum annulus confinement has the same height and a 1 mm, 2 mm or 3.5 mm thick.

The numerical results are presented figure 3 and reproduce the experiments performed at WIWEB Germany[11] with a good accuracy.

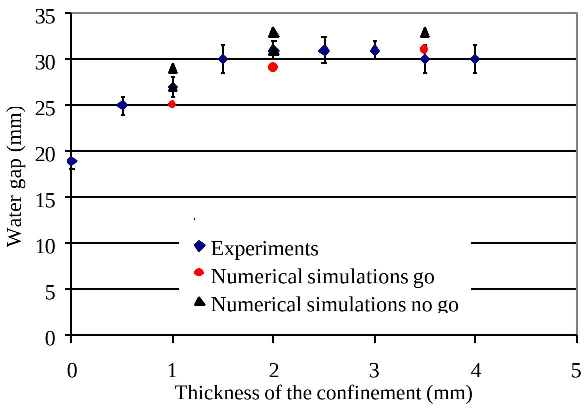

Figure 3. Go / no go thresholds for different aluminum confinement thickness, PETN based HE 3 mm in diameter 3 mm height.

Influence of the Steel Confinement

The water gap versus the steel confinement thickness is presented figure 4. The experimental go/no go threshold is reproduced with a very good accuracy for 1 mm steel confinement, and about 10 % accuracy for the no steel confinement and the 2 mm steel confinement.

The Lagrangian pressures for the 2 mm thick steel annulus is presented in figure 5. In this case as for the 1 mm steel annulus, the first shock in the pellet is followed by a re-shock coming from the side due to the steel confinement and focusing on the axis. The SDT process is related to the level and duration of the re-shock on the axis.

Without any confinement, there is no re-shock on the axis. An entry shock of 38 kbars at the bottom of the pellet is required for the go – no go threshold.

The numerical simulations predict a slight sensitiveness increase for the 3.5 mm steel confinement, which is not in agreement with the experimental desensitization. Nevertheless, the first shock and re-shock pattern lead us to the conclusion that the experimental results are indeed related to shock desensitization. The ignition and growth model does not easily treat the double shock desensitization process[1213], although it reproduces most of the main features of the reactive flows.

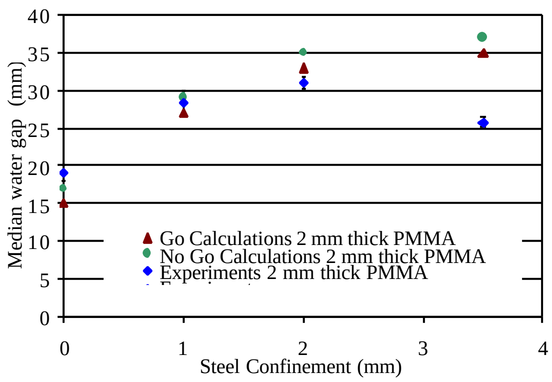

Figure 4. Go / no go thresholds versus the steel confinement thicknesses.

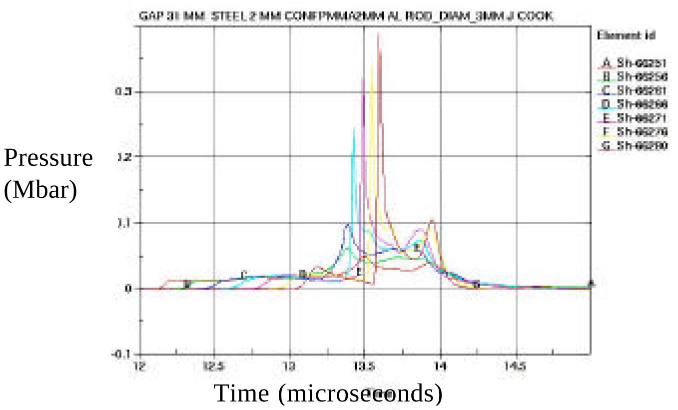

Figure 5. Lagrangian pressures in 0.5 mm increments on the pellet axis versus time for 2 mm thick steel confinement and a water gap of 31 mm

Influence of the height of the HE receptor

The diameter and length of the LX16 pellets are 3 mm in diameter and 6 mm long. The steel annulus confinement has the same height and different thicknesses.

The experimental results from WIWEB Germany are presented Figure 6. The numerical simulations are presented Table III and Figure 5.

The experiments show no decrease of sensitivity with thicker confinement walls. The numerical simulations reproduce the increase of sensitivity due to a longer PETN – pellet. The SDT process has more time to complete.

Table III. Influence of the 6 mm height PETN pellet, Lx16 ∅ 3 mm, h 6 mm, 1 mm steel confinement, numerical simulations

Donor charge	Go, water gap (mm)	No Go, water gap
6 mm height	-	33
3 mm height (reference)	27	29

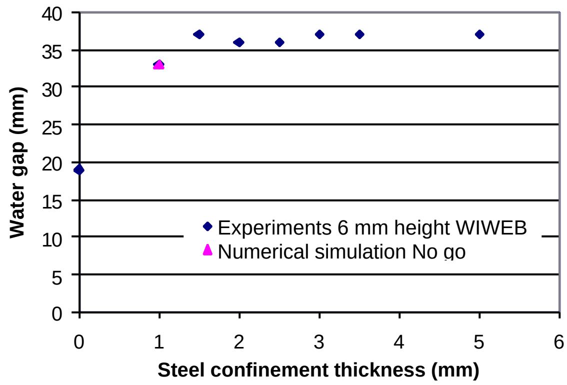

Figure 6. Go / no go thresholds for 6 mm height pellet versus the steel confinement thicknesses.

CONCLUSION

The shock sensitivity of a confined PETN-explosive component having 3 mm in diameter and height has been investigated using the water gap test by numerical simulations in order to understand the desensitization phenomenon observed by several countries through the Stanag 4363 efforts with the 3.5 mm thick steel confinement.

The numerical simulations have been possible thanks to the recent identification of the ignition and growth model parameters for the LX16 shock to detonation processes.

The initiation of the given donor charges has shown no significant influence on the go/no go threshold : the half height donor charge compared to the standard donor charge, the point initiated cavity pellet compared to the plain pellet, the flat initiation compared to the point initiation of the plain pellet donor charge.

The effect of the aluminum confinement is reproduced, and shows an increase of the shock sensitivity with thicker confinement walls.

The effect of the steel confinement is reproduced up to 2 mm thick wall. The presence of a stronger re-shock following the first input shock from the water and focusing on the axis have been identified in the PETN-pellet. This double shock feature could explain the experimental desensitization, even if it has not been reproduced numerically.

The effect of a longer PETN pellet with steel confinement show an increase of sensitivity, and no decrease of sensitivity versus thicker steel confinement walls.

Further investigations are needed to study the influence of the experimental set-up it-self on the go / no go threshold, such as the thickness of the PMMA cylinder column, the possible spall of the confinement and witness rod, the off - axis configuration of the confined pellet… The characterization of the shock sensitivity of even smaller devices remains a challenge.

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