Solving a tricky heavy fragment effect : approach and corrective solutions

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ABSTRACT

Heavy Fragment Impact is a French Navy specific requirement for insensitive munitions.

This study aims to present how this requirement has been taken into account for MK82 bombs enhanced design currently on going.

It shows how, after preliminary test results, the heavy Fragment impact was numerically modelled in order to well understand the phenomenon observed.

The model was then correlated with standard tests results, leading to assumptions that allowed to propose some design improvements and to validate them by computer calculation.

At the end those design improvements were implemented and successfully validated by test.

1. BACKGROUND

1.1 Context

In 2015 RWM Italia and EURENCO have been selected by the French Ministry of Defense DGA for a public procurement contract for the development, qualification and production of new generation MK82 General Purpose bombs.

This public procurement contract was following a DGA research and technology program launched in 2009 with Eurenco participation, and aiming to enhance GP bombs performance and IM signature.

In the frame of this contract, RWM Italia is the prime contractor and is responsible of the structure; EURENCO is the subcontractor and is responsible of the explosive loading.

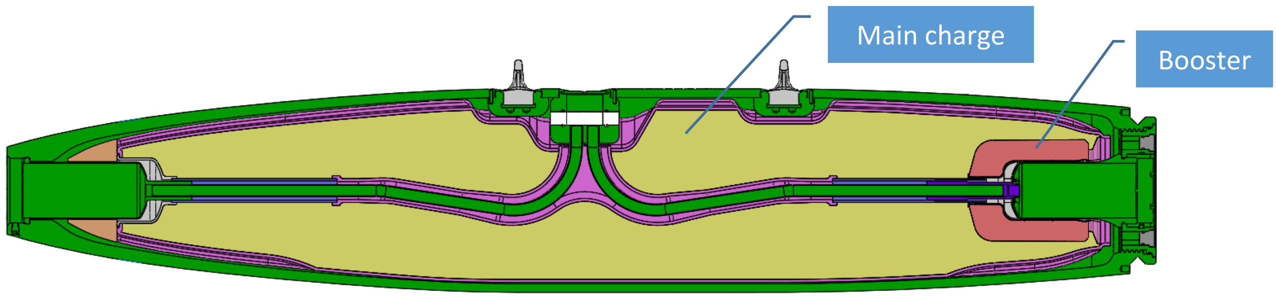
1.2 Bomb description

French Navy specifies specific requirement for insensitive munitions :

- No Sympathetic Detonation (SD)
- No detonation after Heavy Fragment Impact

Those requirements have lead to select NTO based insensitive explosive B2268A for the main charge.

In order to allow the ignition of the main charge by standard fuze, a B2197A (HMX based) booster is embedded into the explosive loading.



1.3 Development test results

During the development phase, a first heavy fragment test was performed by DGA.

The impact was on the B2268A main charge and the response level was judged as a type V (burn).

A second heavy fragment test was performed at Bofors Test Center, the impact point being the most sensitive part of the bomb, ie the B2197A embedded booster.

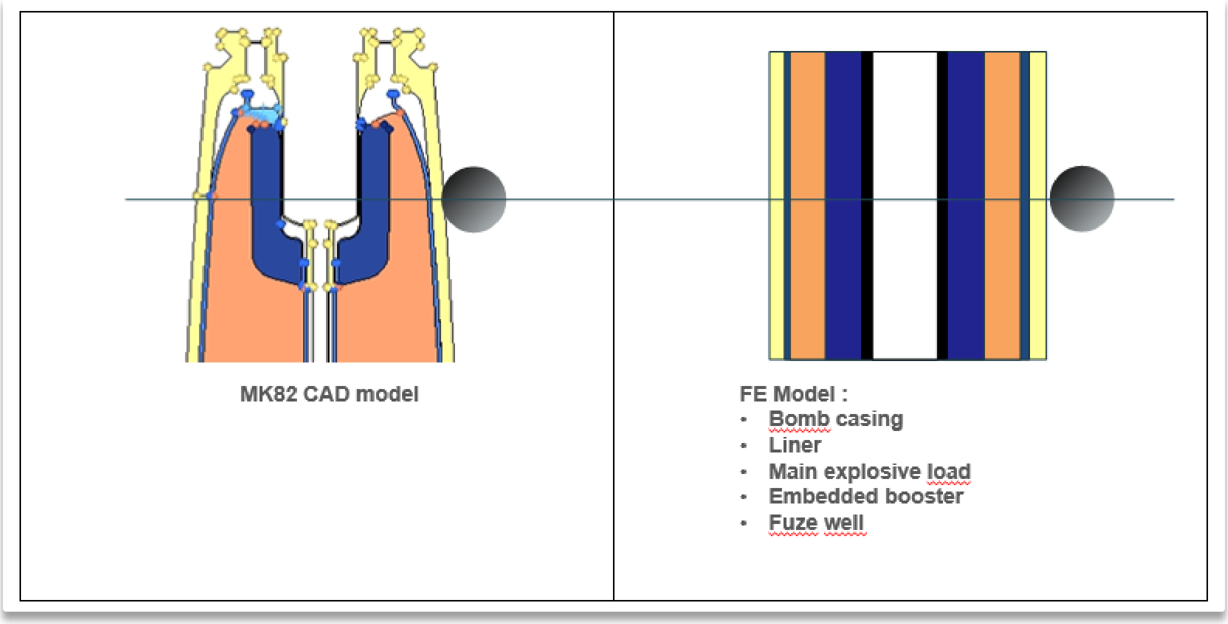
The result was a detonation.

This result was not in line with the expectations, and was not in accordance with test results on similar designs and on explosive samples. In order to understand the phenomenon, it was decided to perform numerical simulations with Ariane Group.

2. NUMERICAL MODELING

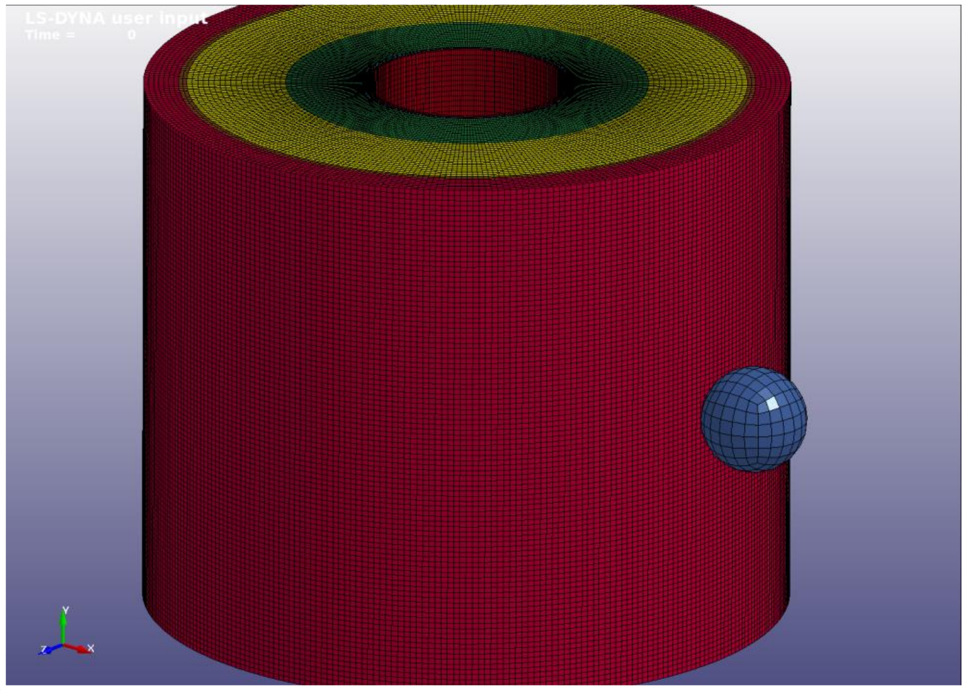
2.1 Model description

The MK82 CAD model was simplified in a cylindrical model with "barriers" representatives thicknesse:



The simulation is run under 3D lagrangian assumptions : the model is a 360° cylinder with a spherical steel « heavy fragment ».

The Finite Element model uses 2 mm meshing.



The table below describes the material stack along the steel ball trajectory.

	Material	Behavior law	Equation of state
Casing	Steel 4340 model	Johnson-Cook	Mie-Gruneisen
Thermal insulator	Rubber PBHT model	Elastic-plastic without hardening	
Main charge	B2268A		
Booster	B2197A (ORA86B)		
Anti-friction sheath	Rubber type PBHT model		
Gap between fuze wall of the well and anti-friction sheath	Void		
Fuze well	Steel 4340 model	Johnson-Cook	Mie-Gruneisen
Inside of the well	Void		

- Johnsonn-Cook behavior law :

$$\boxed{\sigma_y = \left(A + B\varepsilon^{p^n}\right)\left(1 + C ln\dot{\varepsilon}^*\right)\left(1 - T^{*^m}\right)}$$

- Mie-Gruneisen equation of state :

$$\boxed{p = \frac{\rho_0 C^2 \mu \left[1 + \left(1 - \frac{\Gamma}{2}\right)\mu\right]}{\left[1 - (S_1 - 1)\mu\right]^2} + \Gamma e}$$

The FE model includes an erosive algorithm in order to simulate the fragment penetration.

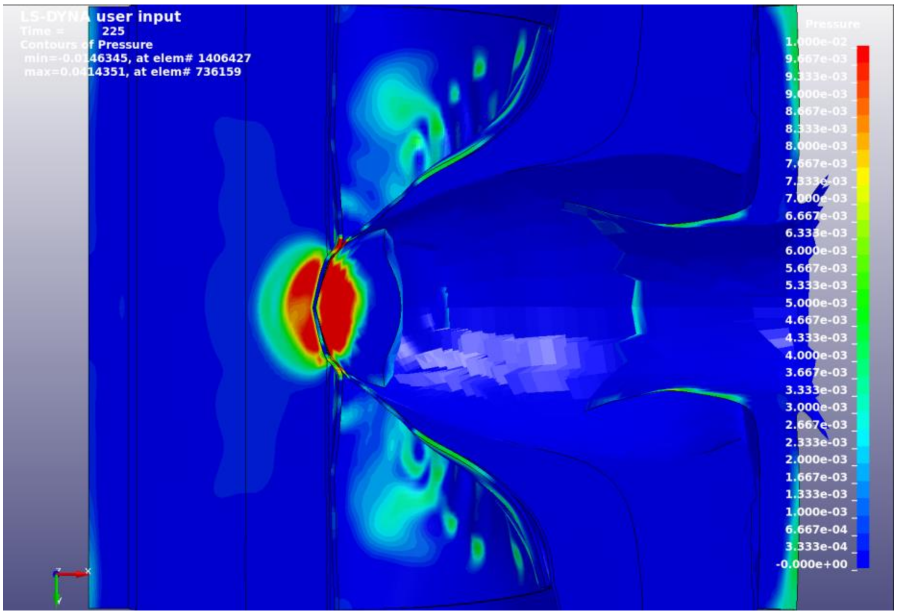
2.2 Explosive characteristics

The Shock to Detonation (SDT) criteria used is the detonation pressure extrapolated from the 40 mm diameter Gap tests according to NF T 70-502 :

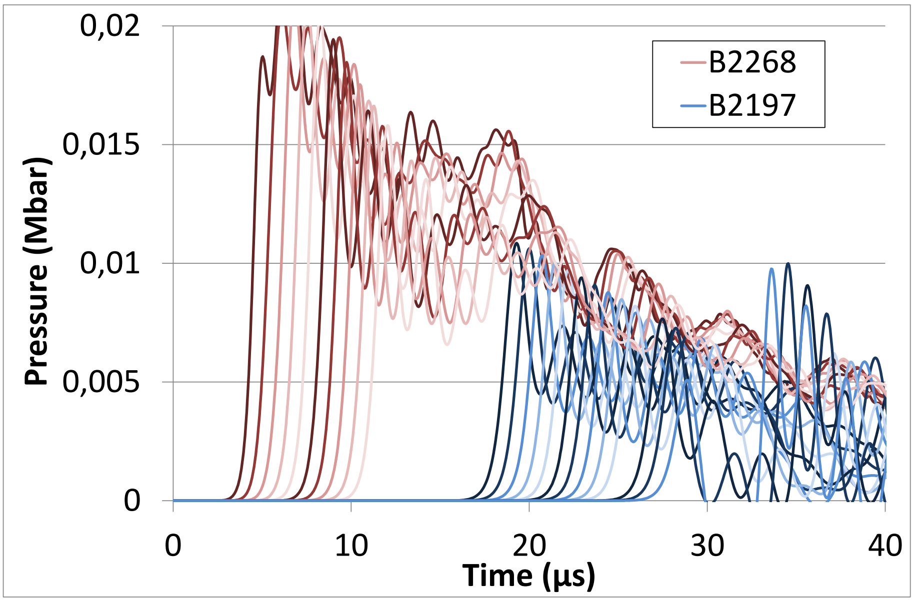
- B2268A : 50 cards / 125 kbar
- B2197A : 160 cards / 45 kbar

2.3 Results

The simulations run show the fragment impacting the body, going through the casing, the explosive main charge and the embedded booster, getting into the fuze well and stopping on the fuze well opposite wall.



The pressure field in the two explosives is post-processed and compared to the SDT criteria:

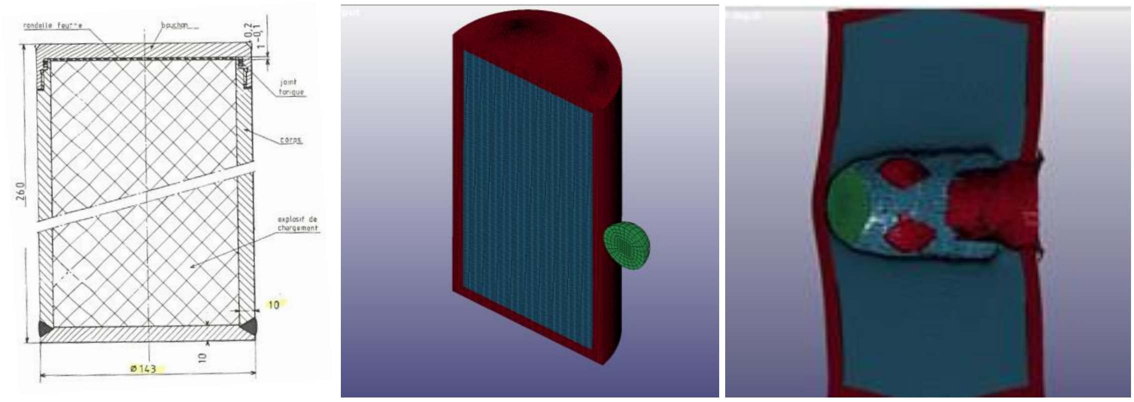


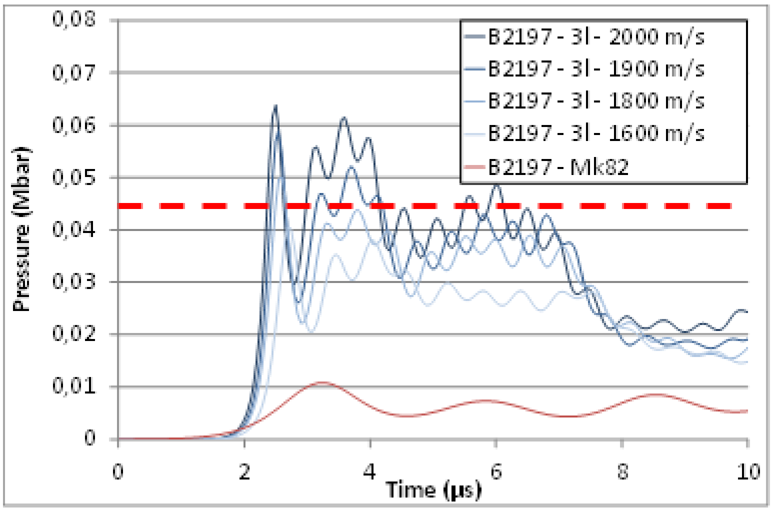
- B2268A ≈ 20 kbar << 125 kbar
- B2197A ≈ 10 kbar << 45 kbar

The preliminary conclusion is that the shock pressure generated by the fragment impact should not lead to a detonation.

3. MODEL VALIDATION

This preliminary conclusion is not consistent with the test results. In order to validate the numerical modeling and the detonation criteria, additional simulations are performed on a 3 liters mock-up used for explosive caracterisation.

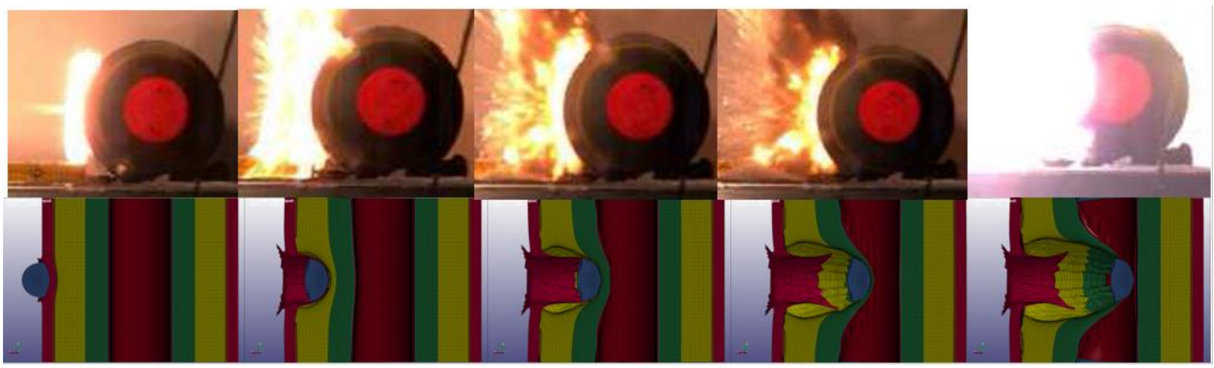




Using the SDT criteria, the model predicts the impact velocity leading to B2197A detonation observed on 3 liters mock-up heavy fragment impact tests, around 1900 m/s.

The intermediate conclusion is that the detonation is likely due to the second shock on the opposite fuze well wall on a damaged B2197A explosive.

This hypotesis seems to be confirmed when comparing the test time sequence with the simulation steps : the detonation occurs after the second shock on the opposite fuze well wall.



4. DESIGN UPGRADE

In order to comply with the heavy fragment impact requirement, a simple design upgrade is to reinforce the fuze well in order to avoid the second shock on the opposite fuze well wall.

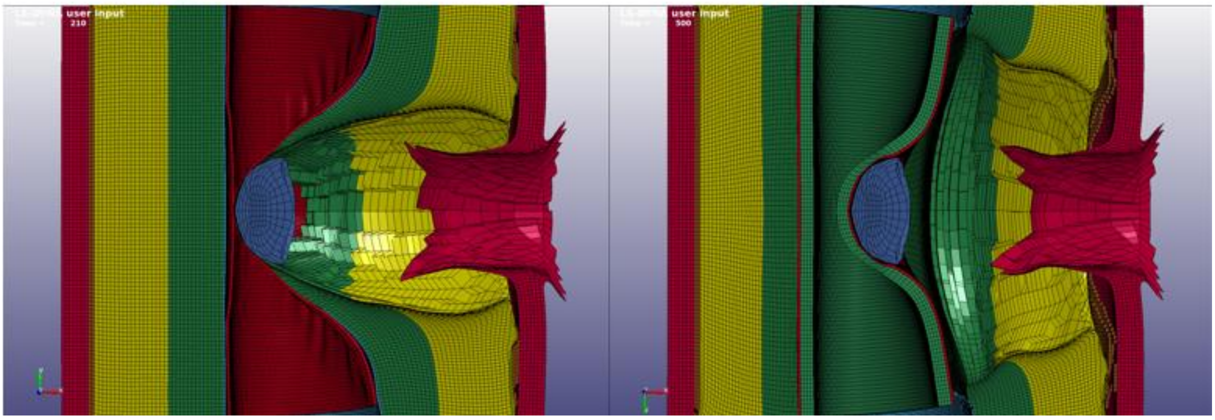
This upgrade can be obtained by different means:

- Steel hollow stiffener
- Full plastic plug

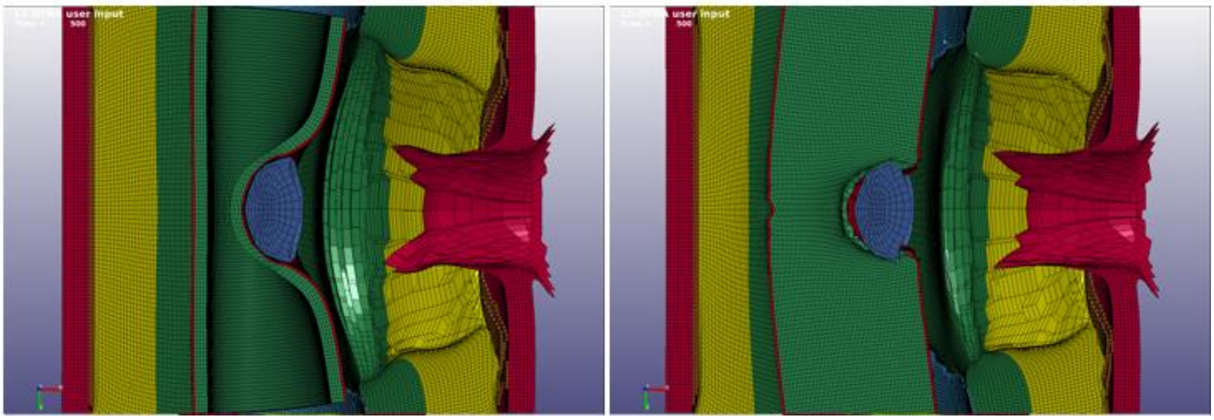
Before testing this design upgrade, a preliminary validation is made by numerical modeling.

The simulations results here under show that a 6,5mm thick steel stiffener or a full polyethylene plug can stop the heavy fragment after hitting the fuze well.

Empty fuze well vs fuze well with steel stiffener



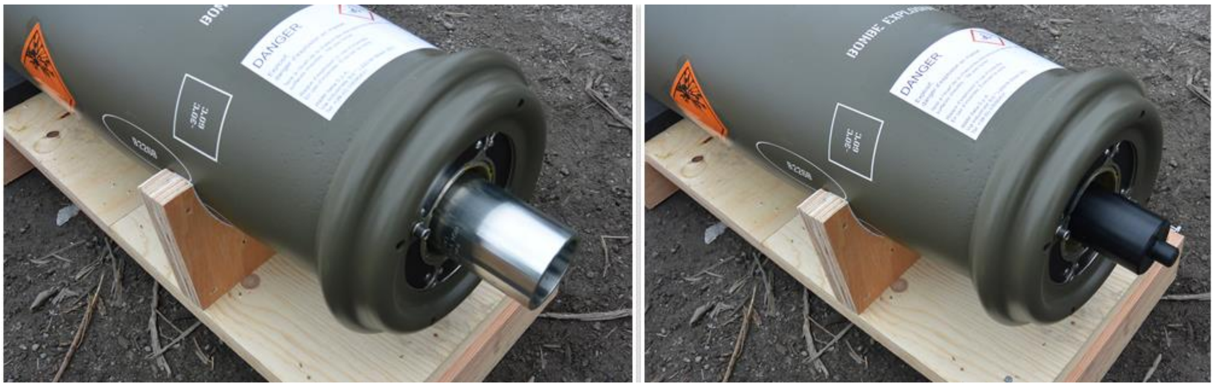
fuze well with steel stiffener vs fuze well with polyethylene plug

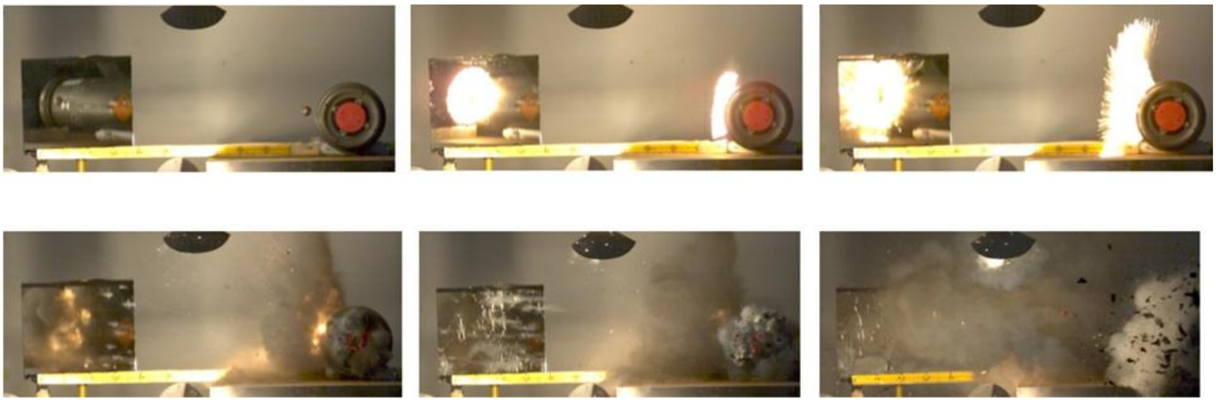


5. TEST VALIDATION

To comply with the heavy fragment impact requirement, the selected design upgrade was a steel hollow stiffener and a polyethylene full plug.

It was validated by a test performed by Bofors Test Center.





After the heavy fragment impact on the embedded booster area, the explosive charge started burning for approximately 20 minutes.
At the end of the test, the bomb body was found with no damage to the structure.
No projection of fragment nor significant overpressure were recorded.
In accordance with AOP-39, the response level is judged as a Type V “Burning” reaction.

6. CONCLUSION

Numerical modeling has permitted to :

- Understand the 1rst test result and identify the root causes
- Validate the Shock to Detonation Transition (SDT) criteria
- Assess the reliability of different solutions for final choice and experimental validation

The final test results have validated the design upgrade solution to comply with the heavy fragment impact threat.

Acknowledgements

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Heavy fragment impact tests performed by Bofors Test Center