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STUDY OF THE EFFECTS OF A PARTICULAR FUEL TANK FILLER IN CRASH ENVIRONMENT

C.CAPRILE, G.JANSZEN, M.MORANDINI

Dipartimento di Ingegneria Aerospaziale, Politecnico di Milano, Milano

ABSTRACT

This paper describes an experimental work carried out in the crash test laboratory of the Aerospace Department of the Politecnico di Milano. Several crash tests have been performed to analyse the behaviour of helicopter fuel tanks when filled with water and expanded aluminium foils. Accelerations and pressures have been measured to compare the behaviour of the tanks with and without this particular filler. Results of the work show how the expanded aluminium foils (already known as efficient passive explosion suppression media for aeroplanes fuel tanks) greatly reduce the leakage of the fluid in case of impact and subsequent failure of the tanks; a reduction of the pressure increment, caused by the movement of the fluid towards the impact area, has been noticed too. The experimental data are being used to validate a numerical model of the tank with the filler, to simulate different impact scenarios and further study the dynamic of both the fuel tanks and the filler when subjected to high decelerations or crashes.

1. INTRODUCTION

Fuel tank explosion resulting from ignition of vapours by various means is a major cause of aircraft loss. Over the years, many concepts which seek to prevent or suppress such explosions have been explored. Among these a particular expanded aluminium foil has been investigated for several years by a performance and qualification test program to meet the Military Standard MIL-B-87162A (USAF).

The purpose of this research was to study the effect of the filler on the fuel tank in case of a crash event. Failure of the tank or leakage of the fuel resulting in explosion of an aircraft would vanish the great efforts that have been made, in recent years, in the design of more crashworthy aircraft systems, with an eye to reduction of fatalities and serious injuries in survivable accidents.

2. EXPERIMENTAL TESTS

In the first phase of the research, two dropping tests on a small box filled with water were carried out, in accordance to the Aviation Regulations, using a dropping tower. These tests provided first information on the effectiveness of the filler showing less leakage when the box was filled with the expanded aluminium foil.
The next step was to perform crash tests on a real fuel helicopter tank. These tests were carried out using a *deceleration sled facility* (see Fig. 1).

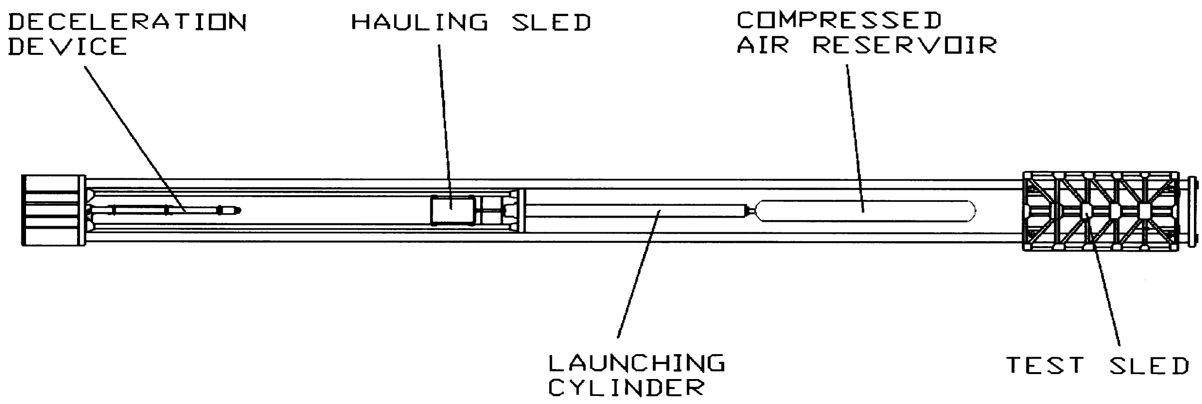

Fig. 1 - Deceleration sled facility

In this facility the items to be tested are mounted on a sled running on two horizontal rails. The initial velocity is reached by means of a compressed air piston that pushes the hauling sled which is connected to the test sled with a steel cable running over a series of pulleys. A rod under the test sled provides a mean for the braking phase by engaging an hydro-pneumatic deceleration device at the end of the sled run. The coasting space is about 10 m and the initial acceleration is less than unity (in g's).
Fuel tanks were sent against an anvil at the end of the test sled run. To perform the tests two wooden plates were mounted, one on the sled and one at the anvil impact area. Fuel tanks were put on the sled wooden plate, and left free to move forward during the sled braking phase (see figures 2, 3 and 4). When the sled was at its final stop position the distance between the two plates was less than 1 cm, allowing a soft sliding of the tank from the first to the second plate. Two L shaped profiles were installed on both the plates to maintain the direction of the tank motion within a small angle.
Three mutually perpendicular piezoresistive accelerometers on the top of the tank and two piezoresistive pressure transducers on the front left side and the back side of the tank were mounted (see figures 5,6 and 7)

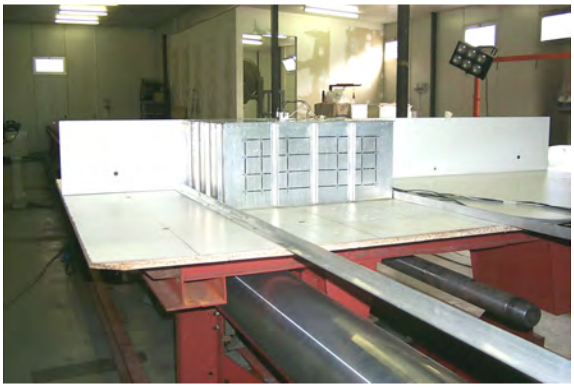

Fig. 2 - Test equipment: sled view.

Fig. 3 - Test equipment: sliding and impact surface view.

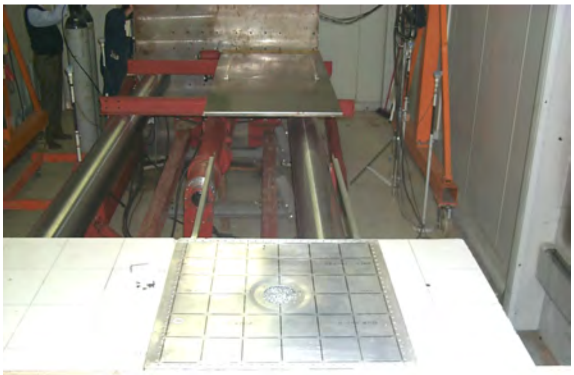

Fig. 4 - Test equipment: global view.

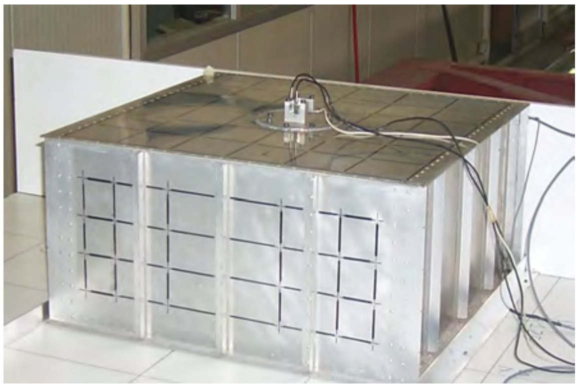

Fig. 5 - Test equipment: top side acceleration transducer.

Fig. 6 - Test equipment: right side pressure transducer.

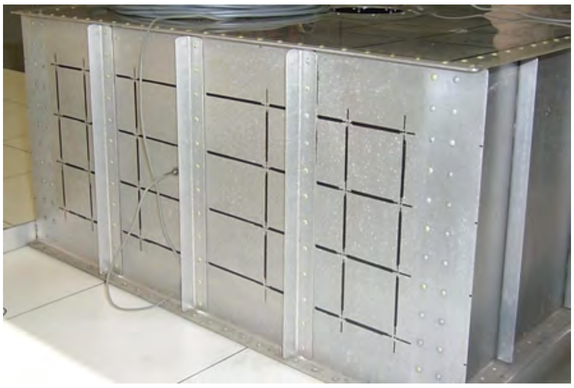

Fig. 7 - Test equipment: back side pressure transducer.

During the impact phase data acquisition systems and a STALEX high speed camera were running. The data, sampled at 12500 Hz and filtered during the test, were:

- sled position;
- sled velocity;

- sled acceleration;
- fuel tank accelerations;
- water pressure.

Data was digitally filtered after the test at the prescribed filter class. Fuel tank velocity at impact was measured using two photocells.

3. RESULTS

The following figures show the comparison of the accelerations curves of the fuel tank and the pressures curves of the water measured during two tests with and without the filler.

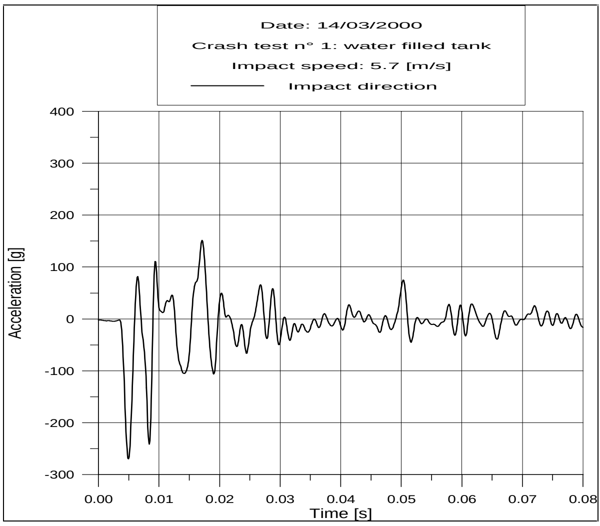

Fig. 8

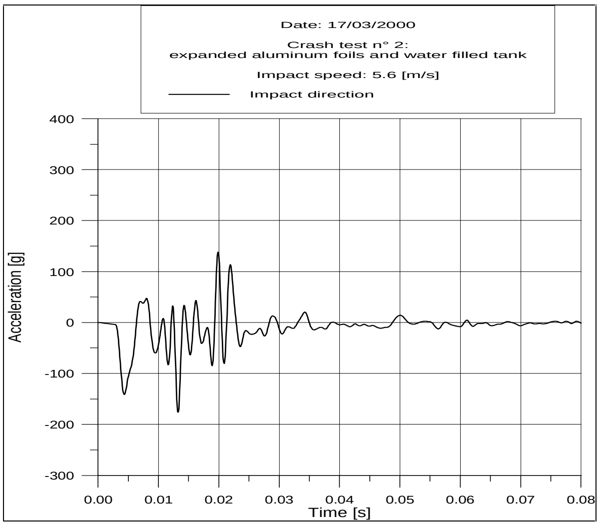

Fig. 9

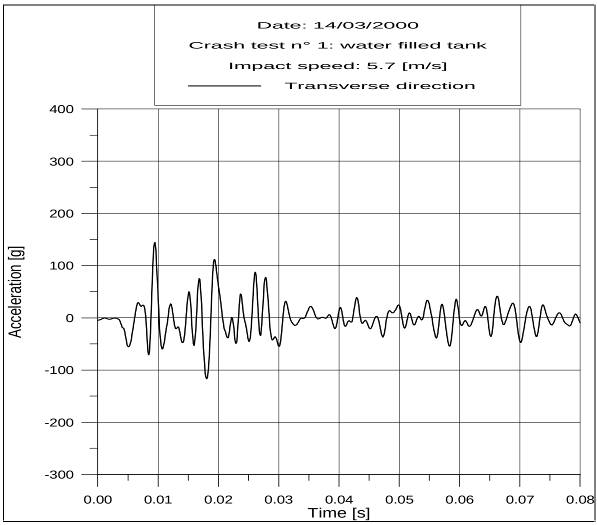

Fig. 10

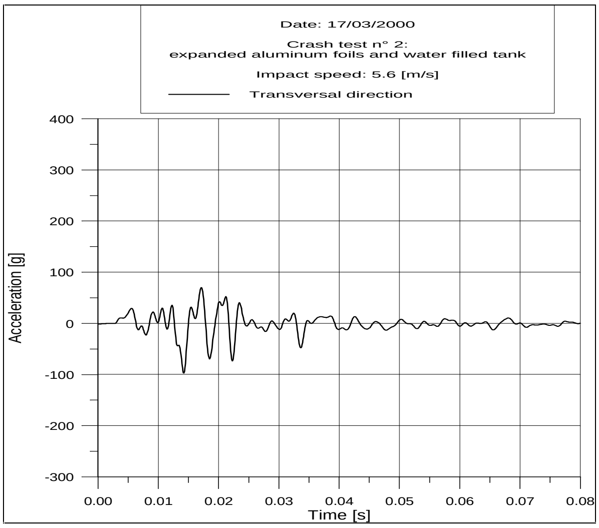

Fig. 11

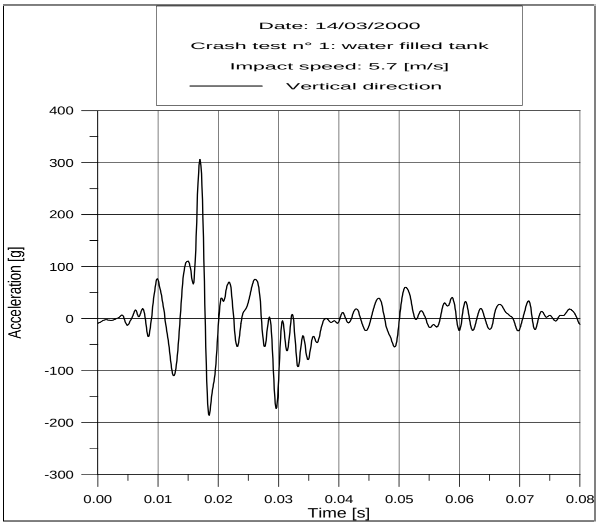

Fig. 12

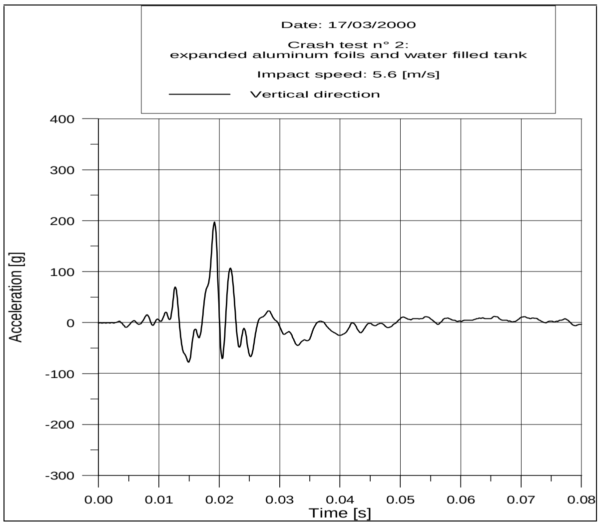

Fig. 13

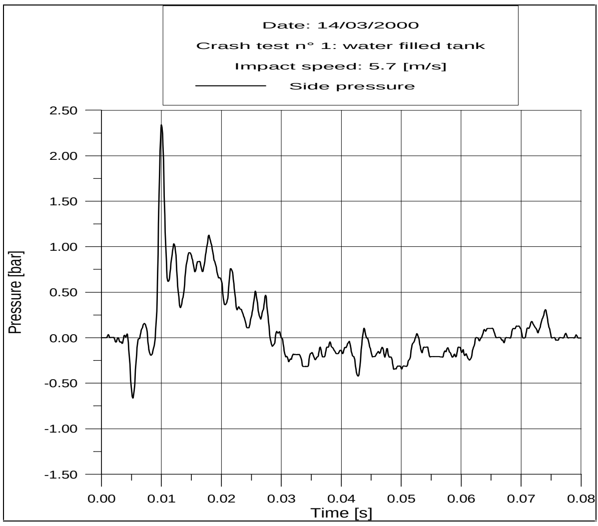

Fig. 14

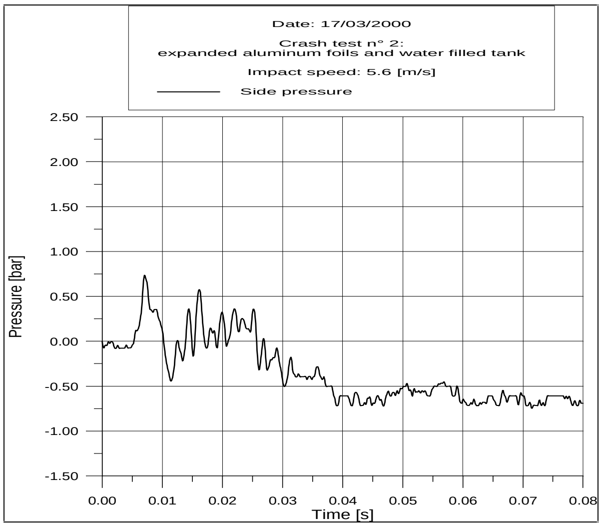

Fig. 15

Comparison of accelerations as well as pressure time histories clearly shows how the presence of the filler help reducing peaks and loads on the structure. For example, in Figs. 16 and 17 the pressure measured at the rear of the tank reach the cut-off value of -1 bar of relative pressure for a significant amount of time without the filler, while if kept limited to –0.75 bar with the filler.
After the test residual deformations of tanks were measured by means of a laser distance transducer at different locations of the upper, lower and rear surface. Deformed surface are reported in the following figures. Comparison of deformed configuration shows that the tank with the filler has a lower final plastic deformation.

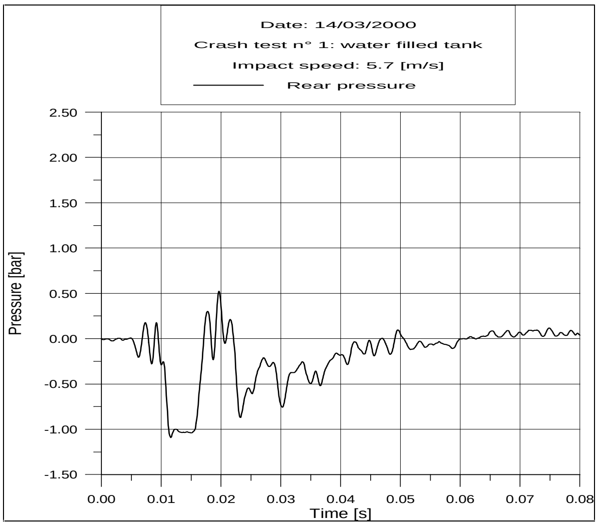

Fig. 16

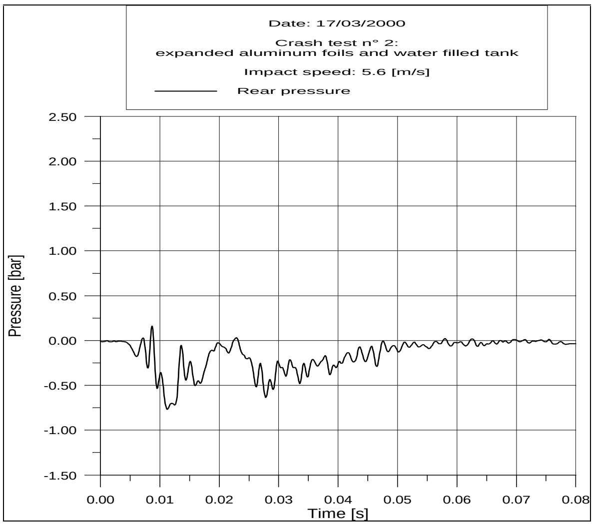

Fig. 17

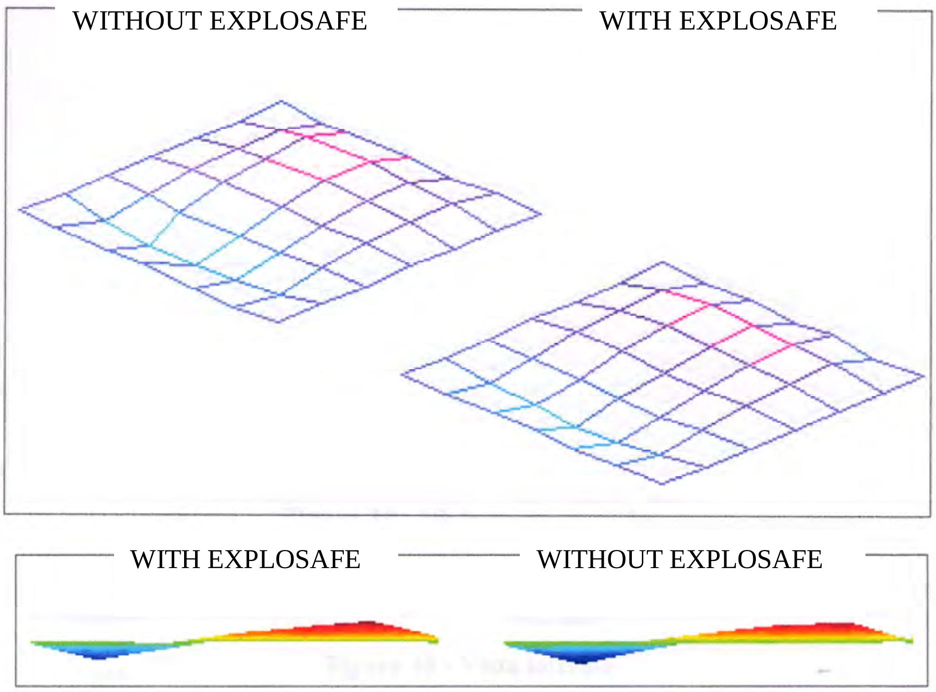

Fig. 18 – Upper surface final configuration, axonometric and lateral view.

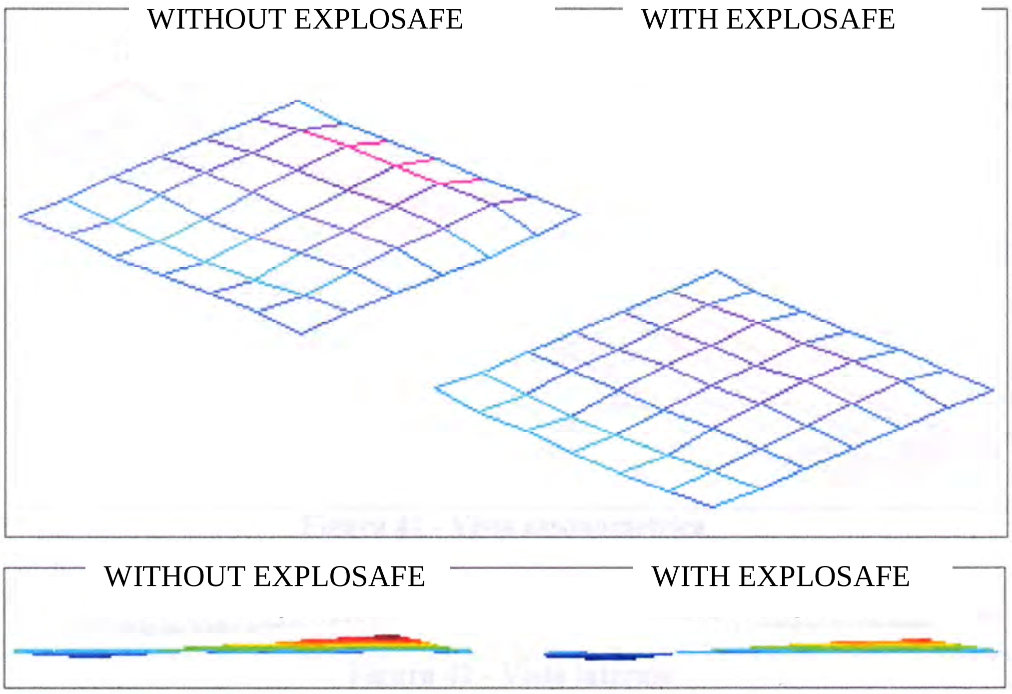

Fig. 19 – Lower surface final configuration, axonometric and lateral view.

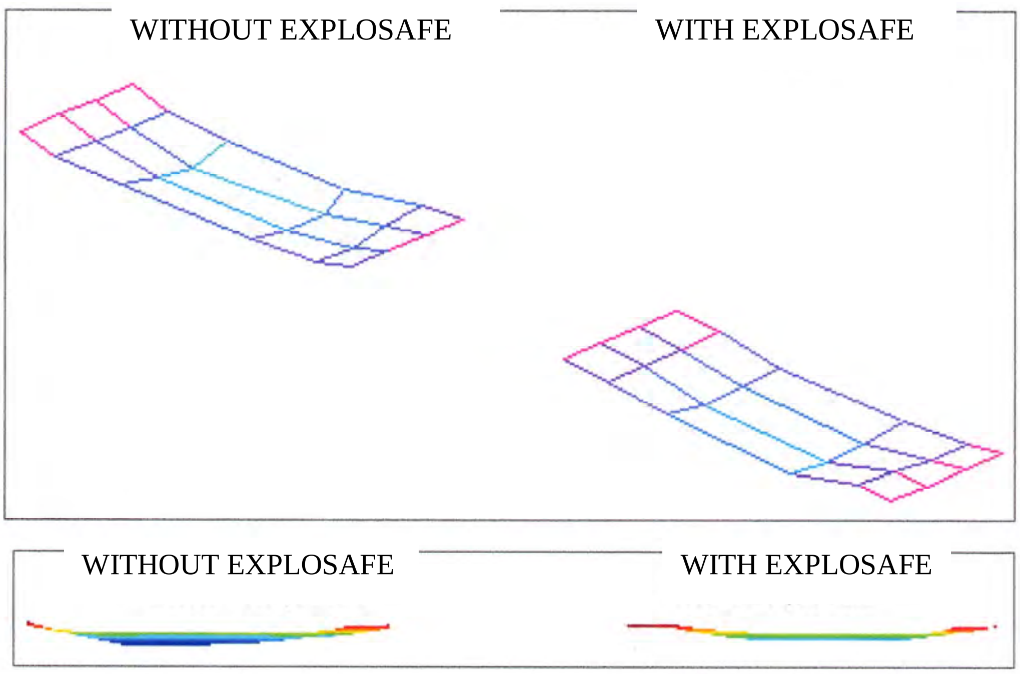

Fig. 20 – Rear surface final configuration, axonometric and lateral view.

The following pictures show the items after the tests.

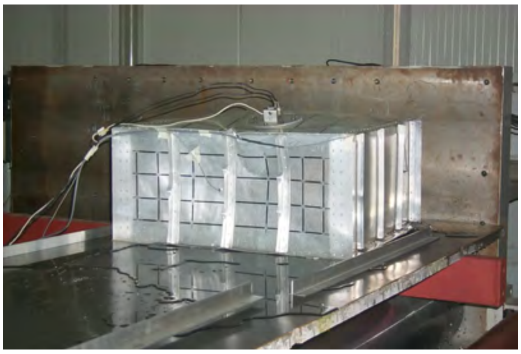

Fig. 21 - Without filler rear view.

Fig. 22 - With filler rear view.

Fig. 23 - Without filler top view.

Fig. 24 - With filler top view.

5. NUMERICAL SIMULATIONS

Experimental pressure time histories and final deformations were compared with results obtained with an explicit FEM simulation of the impact. To this end, a FEM model of the tank, of the horizontal wooden plate and of the water was made. The impact simulation was performed with the DYTRAN code. Experimental initial impact condition, obtained from analysis of high speed camera films, were imposed. Comparison of the final deformed configuration shows good agreement between experimental and numerical results (Fig. 25). Comparison of pressure time histories on the tank rear shows a good initial agreement, in particular for the 0 bar absolute pressure cut-off, but shows also a quick loss of correlation between experimental and numerical data (Fig. 26). It was not possible to perform the simulation of the tank with the filler as the model to be used for the filler/water interaction is still under development.

4. CONCLUSIONS

An extensive experimental investigation on the effect of expanded aluminium foils in case of fuel tank crash was performed. Results clearly show a reduction in acceleration peaks, pressure peaks, deformations of all the faces of the tank and leakage of the fuel levels when the expanded aluminium foils were used.

In the future, dynamic (high decelerations) and crash tests will be carried out on different tanks. Different fillers should also be used to have a better comparison between them. All the data from the tests will be used to get better results from the numerical model of the tank without the filler and to study a suitable model for the tank with the filler. After that, models will be used to better analyse tanks behaviour in different impact scenarios.

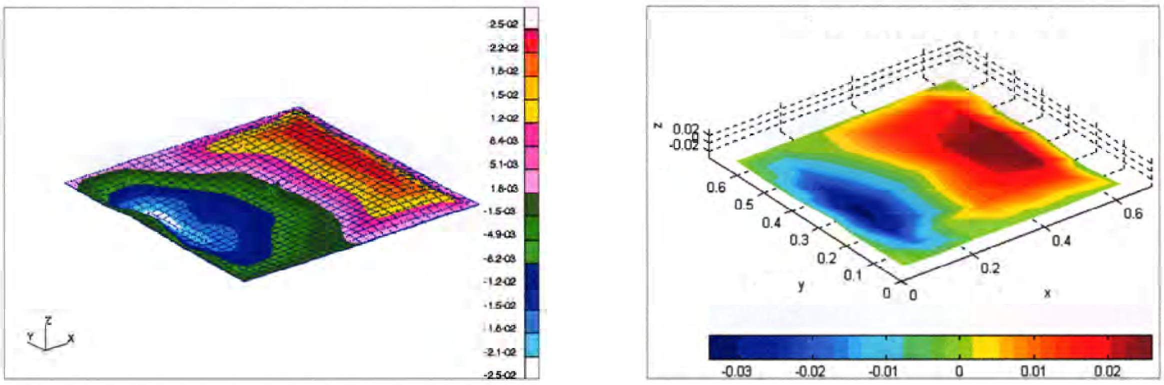

Fig. 25 – Numerical (left) and experimental (right) upper surface final deformation.

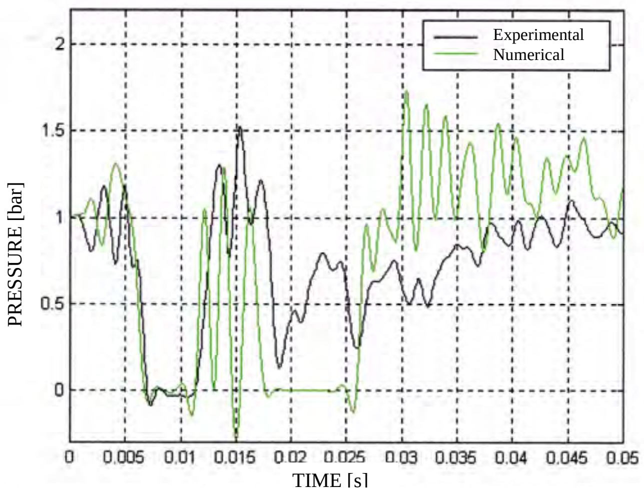

Fig. 26 – Numerical and experimental absolute pressure time histories.

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