COMPARISON OF NUMERICAL MODELS FOR THE PREDICTION OF BLADDER TANK CRASHWORTHINESS

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ABSTRACT

Nowadays helicopters, thanks to its unique vertical take-off and landing properties, play significant roles in transportation, medical rescue, aerial detection, and so on. However, the possibility of an accident must be taken into account from the first design phases, trying to adopt all possible solutions to minimize the consequences due to possible crashes. In particular, approximately 15 % of the injuries and deaths in helicopter accidents are caused by fuel ignition on account of the fuel tank failure. In this context, a methodology to predict the tank behaviour during the crash, can be conceived. This paper provides a comparison between two numerical models, developed by means of different software: Abaqus and Ls-Dyna, and experimental test came from literature, in order to assets the capability in simulating this kind of events.

1 INTRODUCTION

Nowadays, helicopters are widely used in military and civil fields owing to its unique vertical take-off and landing properties, excellent hover performance and low-speed characteristics. It is becoming increasingly obvious that helicopters play significant roles in transportation, medical rescue, aerial detection, and so on. During the operative life of a generic aircraft, and therefore also of a helicopter, it is possible that it could incur into dangerous situations such like an emergency landing or worse scenarios. Even if several attempts have been made to improve helicopter crashworthiness and passenger safety level during the critical events, the crashes could generate serious injuries and even the death of occupants. According to the statistics, approximately 15 % of the injuries and deaths in army and civilian helicopter accidents are caused by fuel ignition on account of the fuel tank failure [1]. Consequently, the crashworthiness is the crucial concern in the design of a helicopter fuel tank to improve the survivability of aircraft occupants and structures under crash situations [2]. Since the 1960s, the US army has issued the first military regulations (MILDTL-27422) that defines the performance requirements for helicopter fuel tanks to eliminate post-crash fire after an emergency landing [3]. As described in the MIL-DTL-27422, the drop impact test must be conducted to check the dynamic response of the fuel tank. Numerical models for the analysis of water sloshing in a fuel tank during crash was developed and verified by experimental results, which generates four different models to simulate the water inside the tank [4]. Luo et al. [5] analysed the crashworthiness of fuel tank for helicopter by utilizing the finite element method (FEM) for the purpose of validating energy-absorption capabilities of the textile layer and protection frame. Kim and Kim [6] numerically simulated crash behaviour of fuel cell group of rotorcraft based on the smoothed particle hydrodynamics (SPH) method by utilizing the commercial software LS-DYNA. In this paper two numerical models for the prediction of fuel tank crash was developed and verified by experimental results find in literature. Numerically the behaviour of fuel have been simulated by means of algorithm based on the smoothed particle hydrodynamics (SPH) method by utilizing two commercial software LS-DYNA and Abaqus.

2 EXPERIMENTAL TEST

In order to validate the numerical model, experimental data find in literature was used. A soft tank realized with one layer of nylon woven fabric composite material and 760 mm long, 760mm wide and 600 mm high and full of water (350 kg) was used as reference in this work [7]. In the drop test the tank falls freely and drops on a rigid surface, on which four pressure sensors are installed in order to record the time-history reaction force. The reference [7] reports two different experimental test which are performed with two different set of impact parameters: drop height equal to 15.2 and 19.8 m that correspond to an impact velocities equal to 17.3 and 19.7 m/s, respectively.

3 NUMERICAL MODEL

3.1 Finite element model

The experimental test is simulated by means of a FE model composed by three parts: the fuel tank, the ground and the fluid inside the fuel tank. In particular, the fuel tank is realized by using shell elements with a thickness of 2 mm, the ground is treated as a rigid body and hexahedral elements is used for the fluid.

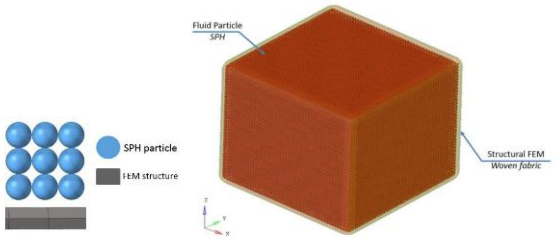

Figure 1 FE Model

3.2 Smooth Particle Hydrodynamics method (SPH)

The Smoothed Particle Hydrodynamics (SPH) are represented by three-dimensional elements with three degree of freedom and defined by their centre of mass. These elements have their own shape functions that depends on the connectivity of the particles. The interpolation distance between the particles, called smoothing length, furnish the location and gave information about the transmission among the different particles. In the SPH approach the water is simulated as particles with the same dimensions and distances without mass.

3.3 Water material model

The behaviour of the fluid material inside the fuel tank is regulated by the equation of state (EOS) relates pressure to a specific change rate of the material volume at a physical state. The Us-Up equation is chosen for the water formulation.

3.4 Tank material model

The fuel tank is composed by a crash-resistant layer made of textile. The mechanical characteristics of this material is find out by a uniaxial tensile tests of the woven material. It is tested that the density of the woven material is 1150 kg/m^3. The average thickness of the woven material is 2 mm. Stress–strain curves of the woven material is reported in Figure 2.

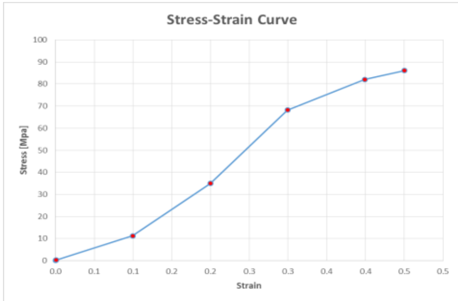

Figure 2 Stress–strain curves of the woven material

4 NUMERICAL RESULTS

The comparison, between Ls-Dyna and Abaqus, of deformation modes of the fuel tank is shown in Figure 3. The figure shows the deformation of the tank in six different time step. The images seems to put in evidence that the model realized with Ls-Dyna is more rigid than Abaqus model. In particular the frames at time step 4 and 5 show that tank made up with Abaqus is more sagged than the other.

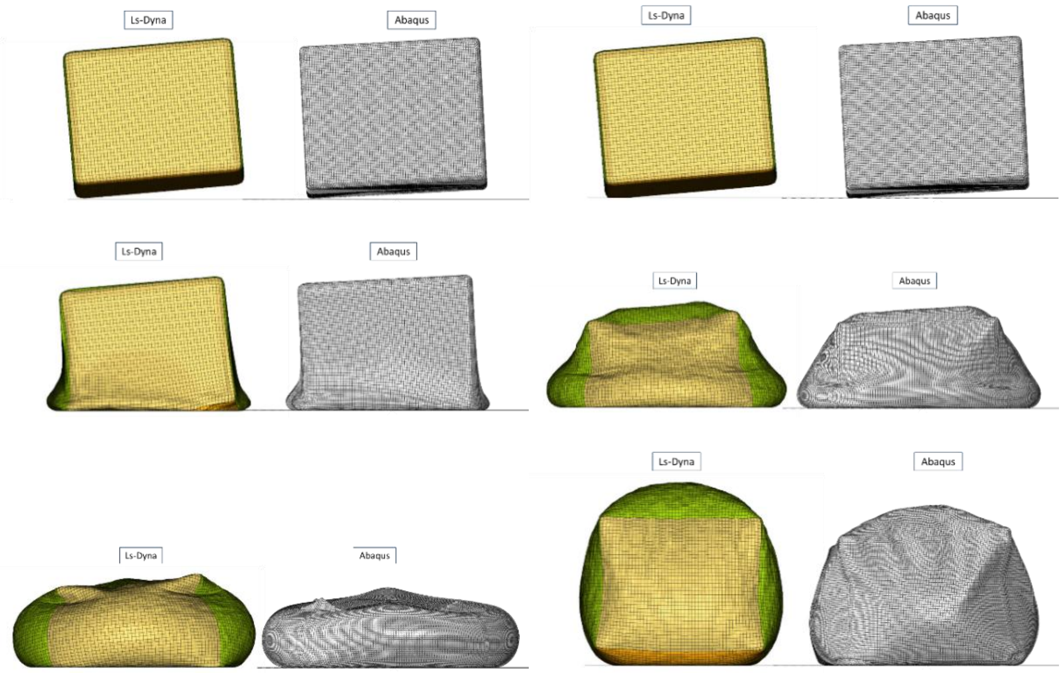

Figure 3 Comparison of deformation modes of the fuel tank between Ls-Dyna (on the left) and Abaqus (on the right)

Figure 4 shows the time histories of the reaction force on the rigid impact surface. It is possible to note that both codes are able to reproduce, with a good accuracy, the general trend of the dynamic event. The first two peaks represent the total tank sag on the soil, which lasts about 20 ms. After that in the numerical simulations the tank starts to rebound and therefore the reaction force goes to zero within 20-30 ms. The figure shows that the peak of the resultant force at the impact instant is similar between the numerical and the reference values.

In particular, the experimental value is about 622 kN, instead the maximum force evaluated by Abaqus is 637 kN (+2.4 % respect experimental value), and the value obtained with Ls-Dyna is 607 kN (-2.4% respect experimental value). Furthermore, the second peak of force underline, how previously observed, that the Ls-Dyna model is more rigid than Abaqus one.

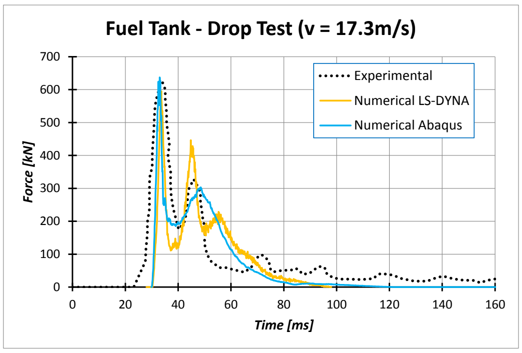

Figure 4: Impact force: Numerical and reference data

5 CONCLUSION

The present work provides a numerical investigation on the crashworthiness of bladder tank for aeronautical application. The test case assumed as reference represent the standard tank in according to the MIL-DTL-27422. In particular, two different commercial code was used to simulate the experimental test came from literature. For both code the same geometrical and FE models and the same material models were adopted. The obtained results highlighted that both code are able to simulate with a good accuracy the first parts of the experimental test. Actually the error, in terms of maximum reaction force is small that 3%. After the first peak, that both codes replicate very well, the results diverges a little bit. Ls-Dyna model seems to be stiffer than the Abaqus one, since the Ls-Dyna second peak is higher than the Abaqus one. Further, the response time are different and this aspect lead to suppose a slight stiffness in the Ls-Dyna model. Despite that, the numerical results are very good, especially considering the complexity of the analysed problem.

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