Innovative SPH features and Simulation of Aircraft Ditching

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Ditching is an aircraft emergency condition that ends with planned impact of the aircraft on water. The high forward velocity in fixed-wing aircraft ditching affects the aircraft dynamics and its structural response due to complex hydrodynamic effects. Therefore, analysis of ditching impact is particularly relevant to satisfy the airworthiness regulations for modern aircraft. Physical phenomena relevant for ditching include the flow and pressure distribution in the water similar as for vertical water entry, cavitation, suction, ventilation and flight aerodynamics.

Within the EC-FP7 SMAES Project [1] the German Aerospace Center, Airbus Military and ESI-Group teamed up to simulate the hydrodynamic effects with the hybrid SPH-FE code VPS (formerly: PAM-CRASH) from ESI-Group. To this end, the SPH module within VPS has been extended by various features including a model for cavitation [2], damping zones, periodic boundary conditions and particle regularization methods [3]. Recently, a special algorithm for pre-processing has been implemented to fill an arbitrary volume allowing for particles having different sizes in order to obtain particle distributions with a fine resolution where required and coarser elsewhere. The above features allow including many of the complex phenomena during ditching at reduced computational efforts for many cases. In particular, the periodic boundaries allow moving the SPH domain with a velocity that may be linked to the COG motion of the aircraft model. Re-entry of the particles may be done at the same conditions at which they left, but alternative methods that may avoid that the aircraft encounters its own wake are currently being investigated. Using additional code improvements such as the pressure correction [3, 4], the particle distribution and pressure fields are improved which may be expected to provide correct hydrodynamic loads on the aircraft model.

To describe the full aircraft dynamics correctly, it is necessary to also include suction and aerodynamic effects which may be modelled semi-empirically and were found to be important for fuselage and aircraft models [5]. The importance of suction may be demonstrated by comparison of the simulated kinematics of an Airbus Military CN235 rigid subscale model. The results in figure 1 demonstrate that suction causes a huge effect on the pitch angle and spray formation. As discussed in [5], a small suction region located rearwards from the COG can already cause a change of global kinematics due to a much larger lever arm compared to the overpressure region. The heuristic idea that the case with suction included is more realistic is confirmed by the comparison of the pitch angle with the model test as shown in figure 2.

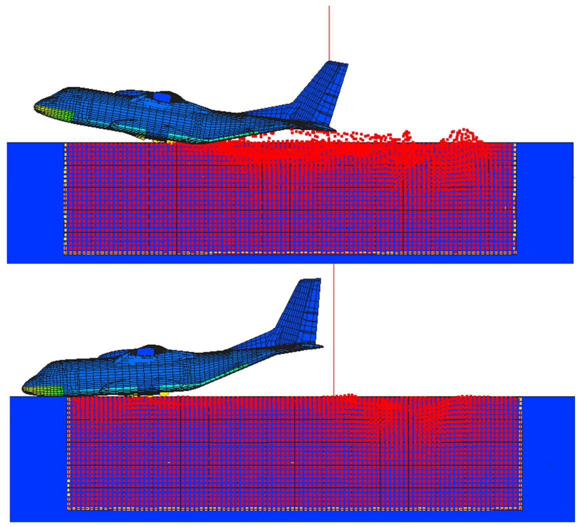

Fig.1 Position of the Airbus Military CN235 model at 200 ms with suction (top) and without suction (bottom)

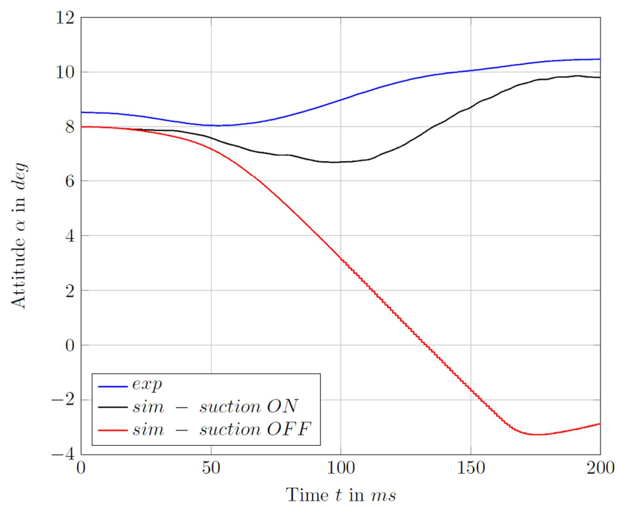

Fig. 2 Attitude time history: Test (blue curve), Simulation with suction (black curve) and without suction (red curve)

In order to investigate the involved hydrodynamic phenomena in greater detail, the correct and reliable pressure evaluation – especially along fast moving structures – is of highest importance. Capturing these pressures has been challenging to date due to their sharp gradients with extremely small time and spatial scales.

Therefore, a simple two-dimensional wedge impact test case at a fixed vertical velocity of 3 m/s was selected for verification of a novel pressure gauge particle technique. In combination with pressure correction methods, the new options allow to reproduce the test results accurately as shown in figure 3. Subsequently, this simple yet effective pressure evaluation method may be applied to aircraft ditching models but also to other numerical models of fluid-structure interaction.

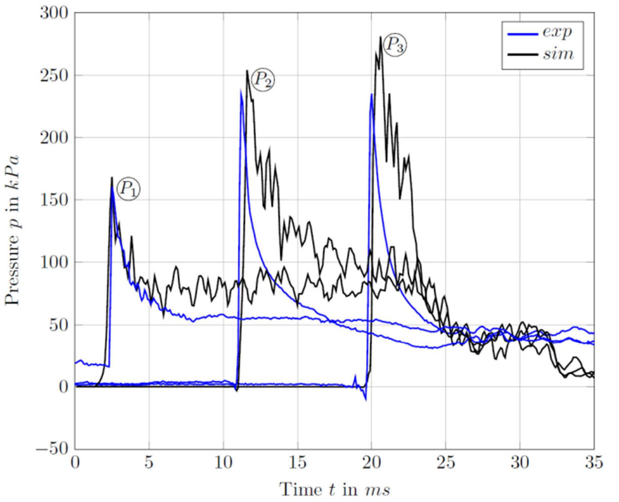

Fig. 3 Pressure time histories at three positions along wedge: Comparison of experimental (blue curves) and simulation (black curves) results

The experimental test campaign of Guided Ditching Tests performed during the SMAES program provides a valuable source of data for comparison with recent features of numerical models. Tests consist of high velocity impacts (between 30 m/s and 50 m/s) of metallic and composite plates with conditions representative of full scale aircraft ditching. The current numerical model, figure 4, include above mentioned features as particle regularization methods, periodic boundary conditions with damping zones and pressure gauges. It allows simulation of rigid and elastic impacts where fluid-structure interaction may play an important role in highly flexible structures like those used in aeronautical industry.

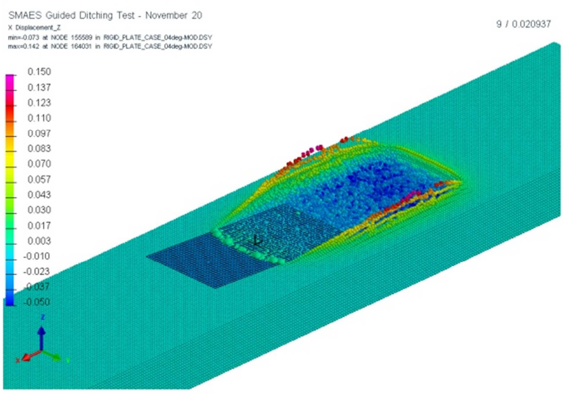

Fig. 4 Guiding Ditching Tests numerical model

Initial comparisons with rigid structures in terms of water pressures acting on the plate show promising results, in particular in non-steady pressure fields, taken into account well known difficulties of weakly compressible SPH methods to match pressure measurements. Figure 5 shows pressure time histories near the plate leading and trailing edge in the axis of symmetry. Numerical results follow experimental tests at maximum values, time delay and spatial distribution. The validated numerical

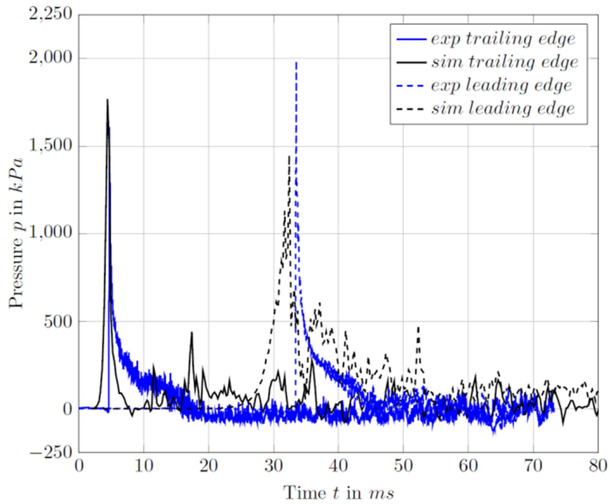

Fig. 5 Pressure time histories: Test (blue curves) and simulation (black curves). Location near plate trailing edge (solid lines) and plate leading edge (dashed lines)

methodology may be applied in the near future to aircraft structural design.

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