Effect of the body curvature on aircraft ditching hydrodynamics

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SUMMARY

An experimental investigation on the role played by the curvature of the body surface on the hydrodynamics of water entry with high horizontal velocity component will be presented. The effect of the longitudinal curvature was a part of the investigation done within the FP7-SMAES project. Some preliminary results concerning double curvature effects, which are part of the H2020-SARAH ongoing project, will be presented at the Workshop.

In order to avoid scaling effects which may prevent the development of ventilation/cavitation phenomena, the study is carried out at full scale velocity. Measurements are presented in terms of pressures and loads whereas some underwater visualization are used for the interpretation of the data. Both a convex and concave body surface are considered and comparisons with the flat plate case are established.

In the case of a concave shape a quite complicated flow with large air entrainment develops beneath the plate. The air entrainment causes a general reduction of the pressure at the middle, whereas the pressure peaks recorded at the side probes are about in line with those found in the flat plate case tested in the same conditions. The total hydrodynamic loads acting normal to the plate are more regular but the maximum load is almost comparable to that measured in the flat plate case. For the convex shape the pressure probes located at the middle of the plate get wetted well before the ones at the side and the pressure peaks recorded at the side are much lower than those at the middle which is in line with what happens in the vertical impact of a circular cylinder. The lower pressure at the sides causes a reduction of the total loading in the normal direction compared with both flat and concave plate.

1. INTRODUCTION

In this paper an experimental investigation of the water entry of a concave and convex plate at high speed horizontal velocity is presented. The study follows the activities presented in previous editions of the Workshop (Iafrati and Calcagni, 2013; Iafrati et al., 2014, Iafrati, 2016*a*) where the basic motivations for the specific study on the plate ditching problem as well as some hydrodynamic aspects were discussed. Here attention is focused at understanding the role played by the surface curvature. The curvature of the body surface is expected to affect loads and pressures quite significantly. However, a precise picture can be retrived only by full scale experiments that enables an accurate reproduction of ventilation/cavitation phenomena that may occur. This is particular true for the double curvature shapes characterizing the rear part of the fuselage.

Generally, aircraft manufacturers use computational approaches to simulate the hydrodynamics and the fluid-structure interaction phenomena taking place during the ditching phase. The use of numerical simulations is still at the development stage, but it is becoming technically feasible and sufficiently accurate (Siemann et al. 2014, Guo et al. 2013). In order to reach the reliability level required by design and certification purposes, a careful validation in realistic ditching scenarios is essential.

Most of the experimental analyses done so far on water impact with high horizontal velocity concerned flat plates or wedge shaped bodies, either rigid (Smiley 1950, Smiley 1951, Iafrati et al. 2015, Iafrati 2016*b*) or deformable (Iafrati 2015). However, most of the fuselage has a cylindrical section and there is also a double curvature zone in the rear part where the first contact takes place. The double curvature may induce ventilation/cavitation phenomena and induce negative loading which affects the dynamics of the aircraft in the early stage of impact (Climent et al. 2006). Furthermore, for some aircraft configurations, like those for military transport, the bottom has concave regions and thus it is interesting to achieve a better understanding of the hydrodynamics.

In this paper some results of pressure and loads generated during the water impact of a concave and convex shape are presented and some comparisons with the corresponding measurements for the flat plate are also established. During the workshop some very preliminary results of double curvature specimen will be also presented.

2. EXPERIMENTAL SETUP

The experimental setup and the installed instrumentation for the thick aluminum plates are provided in Iafrati and Calcagni (2013) and in Iafrati, et al. (2015*a*) where the data uncertainty is also assessed. In the following only some details on the instrumentation are illustrated, which are helpful for the discussion.

Plates are 1000 mm long and 500 mm wide and the radius of curvature of the surface that gets in contact with water is 2000 mm. The plates are made of aluminum alloy AL2024-T3 and are 15 mm thick, fully clamped at the sides so that structural deformations, which are negligible, have no effects on the hydrodynamics. Each plate is instrumented by 18 pressure probes, Kulite XTL 123B, full scale range 300 Psi absolute. Strains are also measured by 6 biaxial strain gauges but are not discussed here. The position of the pressure probes is the same for all plates and it is shown in Fig. 1. The loads acting in the direction normal to the plate are measured by four piezoelectric load cells Kistler type 9343, full scale range of 70 kN each.

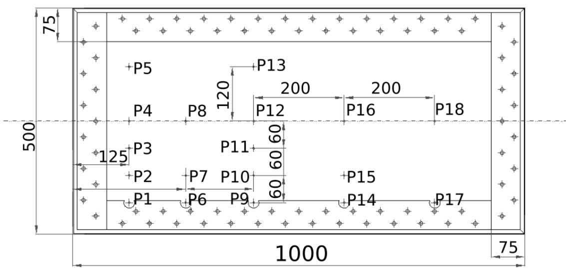

Figure 1: Top view of the convex/concave plates with main dimensions and position of the pressure probes. The distances between the proves are measured along the external surface.

Tests are conducted at a nominal horizontal speed of 40 m/s and a vertical/horizontal velocity ratio of 0.0333 and the pitch angle is 6 degrees.

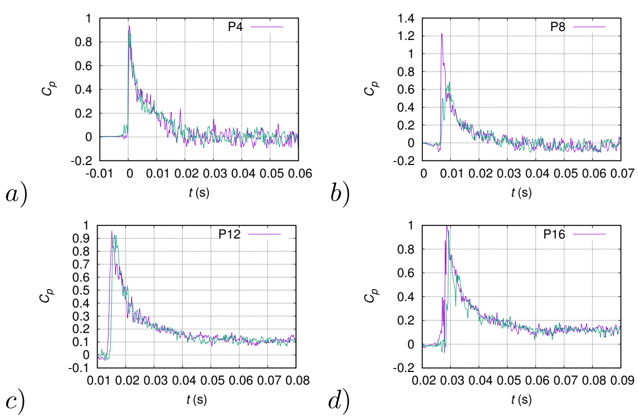

Figure 2: Time histories of the pressure at probes 4(a), 8(b), 12(c), 16(d) in the case of a concave plate

3. ANALYSIS OF THE EXPERIMENTAL DATA

The time histories of the pressure recorded at the probes located along the midline (i.e. 4, 8, 12, 16) for the concave and convex plates are shown in Fig. 2 and 3, respectively. The results show that in the case of concave plate the pressure peak is much lower than for the convex plates. However, for the concave plate the pressure drops after the peak are milder.

The maximum pressures recorded at the probes located at the third sensor rows for the concave and convex plates are shown in Fig. 4. The data indicates that in the case of the concave plate the pressure peak at the sides are much higher than at the middle. In the case of convex plate the incresed possibility for the fluid to escape reduces the pressure at the side compared to that at the middle.

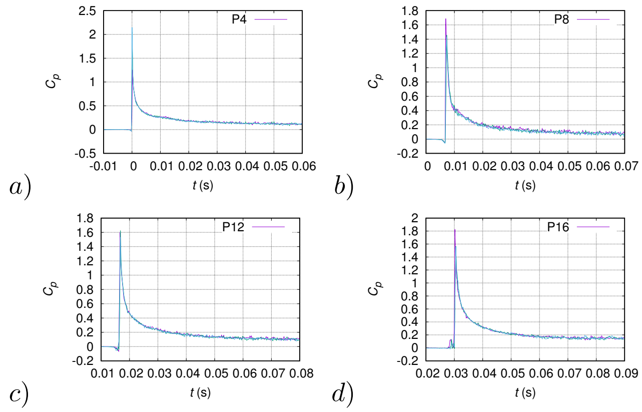

Figure 3: Time histories of the pressure at probes 4(a), 8(b), 12(c), 16(d) in the case of a convex plate

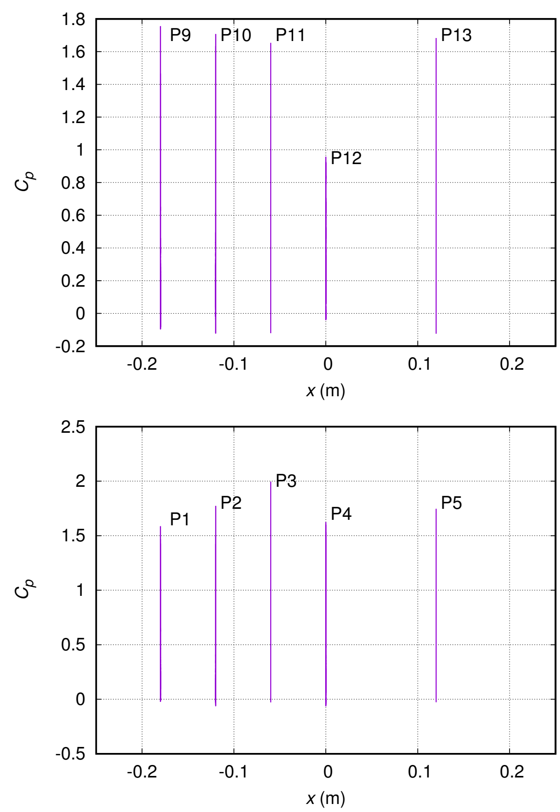

Figure 4: Pressure peaks reached by the probes located at the third sensor row for the concave (top) and convex (bottom) plates

The lower pressure observed in the concave plate case is clearly associated with the air entrainment, and this is indeed confirmed by the underwater images (Fig. 5). It is worth noticing that, differently from what happens for the flat or convex plates, the curvature of the spray root is opposite with respect to that in the flat or convex plates.

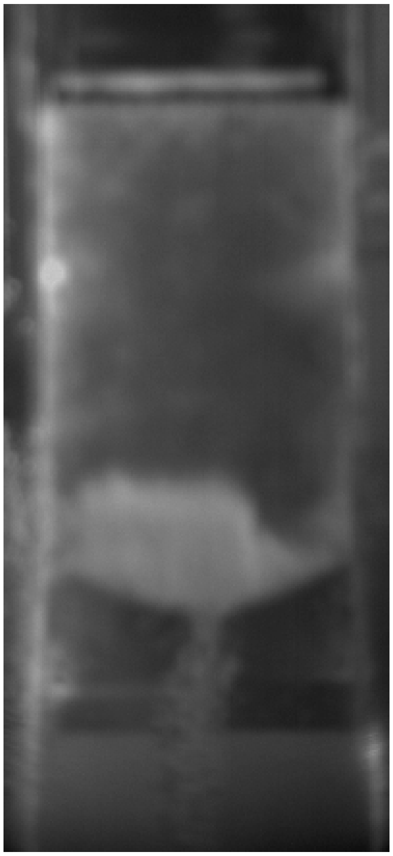

Figure 5: Underwater image of flow generated during the ditching of the concave plate

In spite of the reduced pressure peaks, the total force measured for the concave plate is almost comparable to that measured in the flat plate case, and much higher than that measured for the convex plate (Fig. 6).

4. CONCLUDING REMARKS

A very short and preliminary analysis of the effect of the longitudinal curvature on pressure and loads generated during the water impact with horizontal velocity of rigid plates has been presented here. Additional results will be presented at the Workshop together with some new results of tests on double curvature specimen.

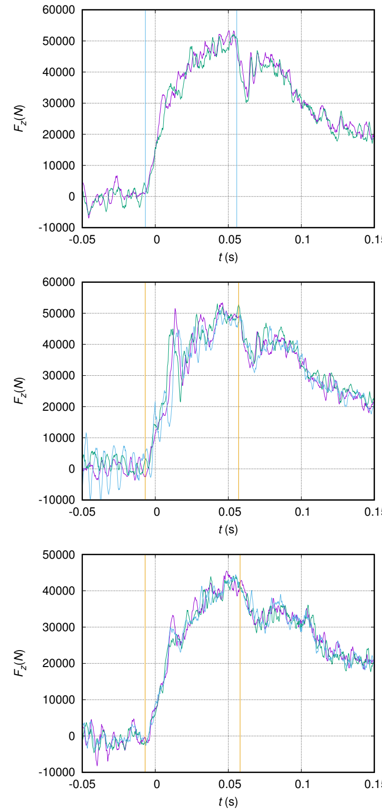

Figure 6: Time histories of the normal force acting on the plate for the concave (top), flat (middle) and convex (bottom) cases.

5. ACKNOWLEDGMENTS

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