Strong fluid-Structure interaction during the inclined water entry of a fuselage-like aluminum specimen

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1 INTRODUCTION

The fluid-structure interaction taking place during the water impact at high horizontal speed of an aluminum specimen mimiking a fuselage component is investigated experimentally to achieve a better comprehension of the physical phenomena taking place in the aircraft ditching.

A review of the studies done in the context of water entry with application to the aerospace structures is provided in [1] but many other studies have been done since then. Numerical simulations of the water impact of a helicopter structure have been presented by [2] and, more recently, by [3]. Different computational models are used in [4] to simulated the water entry of a sphere and the ditching of a small scale airplane. In the latter case, the relevance of the suction forces developing at the rear are highlighted as well. Highly accurate simulations of the aircraft ditching are provided in [5] who used a tightly coupled SPH solver with a FEM solver, enabling accurate prediction of the structural deformation and their effect on the aircraft dynamics. In [6] the aicraft landing phase, i.e. the phase after the early impact, is simulated numerically by RANS solver and the role played by the longitudinal and transverse curvatures on the hydrodynamic loads is highlighted.

In spite of the significant development, the use of high-fidelity computational tool for design and certification of the aicraft at ditching remains challenging. The strong nonlinearities of the phenomenon is such that a careful validation of the computational tools versus reliable and accurate experimental data is essential.

Based on the above consideration, experimental tests at nearly full-scale conditions, with horizontal speed U = 48 m/s and vertical speed V = 1.6 m/s, have been conducted by using the High-Speed Ditching Facility (HSDF) available at INM-CNR [7]. The use of nearly full-scale conditions overcome the limits of scaling of both hydrodynamics and structure, yielding a highly reliable dataset enabling an accurate analysis of the problem as well as an accurate validation of the computational models using in the design and certification phases. Strains and total loads acting on the specimen are measured. The interpretation of the data is supported by synchronized underwater movies. Large deformations exceeding the yielding limits are observed and the residual, plastic, deformation at the end of the test is also provided. By comparing the forces measured during the impact of specimen with different skin thickness it is observed that the highest loads occurs in the thinner skin case, in line with previous studies [8].

2 EXPERIMENTAL SETUP

The HSDF has been described in detail in [7] and in previous editions of this Workshop (e.g. [9]). The specimen to be tested is installed on a trolley that carries the acquisition box on top. The trolley runs along a guide, 64 m long, installed over the water basin at an inclination that can be varied to achieve a vertical to horizontal velocity ratio in the range $0.03 \div 0.05$.

The specimen is a caisson closely resembling an actual aircraft structure. It was 1204 mm long and 596.5 mm wide, with a single curvature surface, with a curvature radius of 2019 mm. All components were made in aluminium alloy AL2024-T3. The bottom skin was internally reinforced by four stringers and two frames, whereas a thick frame closed the caisson at the four sides and connected the external skin to the acquisition box (Figure 1). In addition to the skin with uniform thickness of 1.6 mm, a specimen was made by using a skin milled to a reduced thickness of 1.2 mm in the empty regions between frames and stringers, thus making the tests even more representative of the real scenario. The structural design was guided by FEM simulations done by Airbus Defence and Space in Madrid, assuming a horizontal speed of 45 m/s, a vertical speed of 1.5 m/s and a pitch angle of 6 degrees. The FEM simulations were also exploited to locate the strain gauges in the points of maximum strain. Seven biaxial gauges are located on the internal side of the skin, four single-axis gaues are located on the stringers, and six biaxial gauges are located on the frames (Figure 2). Besides the strains, the loads in the longitudinal and normal directions are measured, the latter being measured at the front and at the rear of the specimen.

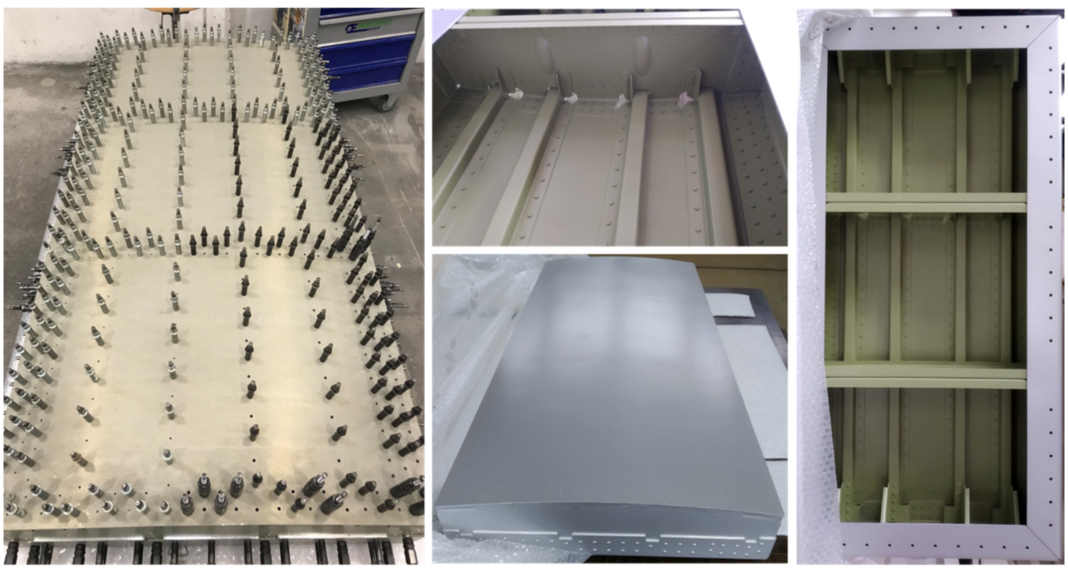

Figure 1: Picture of the specimen. The assembly phase and the final realization are shown.

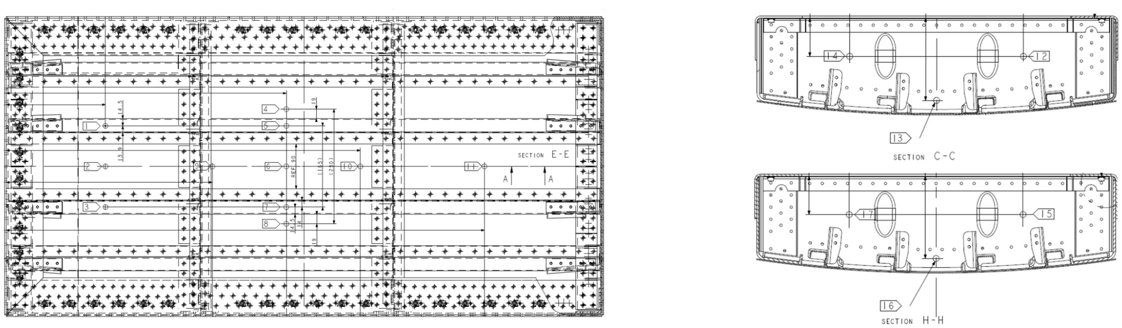

Figure 2: Positions of the strain gauges: measures were taken on a total of 16 points with single or multiple directions. Most of the gauges are located about the middle bay, which is the one less influenced by the boundary conditions.

3 EXPERIMENTAL RESULTS

The time histories of the strains measured in the longitudinal and transverse directions by the gauges located along the midline of the plate are shown in Figures 3 and 4 for the uniform and milled skins, respectively. It is worth noting that for the milled skin case the strain gauges $6y$ is not shown as it gave some irrealistic results.

In Figure 5 the normal load acting at the rear and at the front of the specimen are provided together with the total load. Data are provided for the uniform and milled skins and it can be noticed that, in spite of the not too significant differences in the strains, an increase of about 10% of the total load is observed for the milled skin. Further results and test repeatability checks will be presented at the workshop.

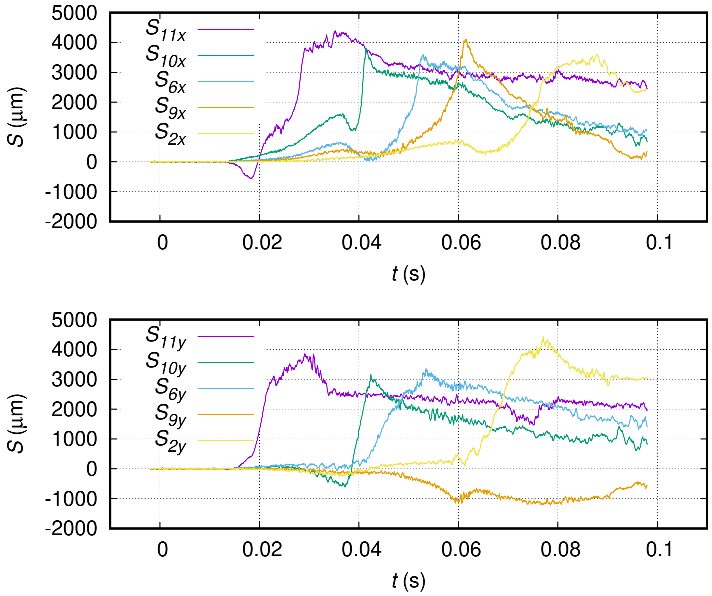

Figure 3: Time histories of the strains measured in the longitudinal (x) and transverse (y) directions by the probes located along the midline of the specimens for the skin with uniform thickness.

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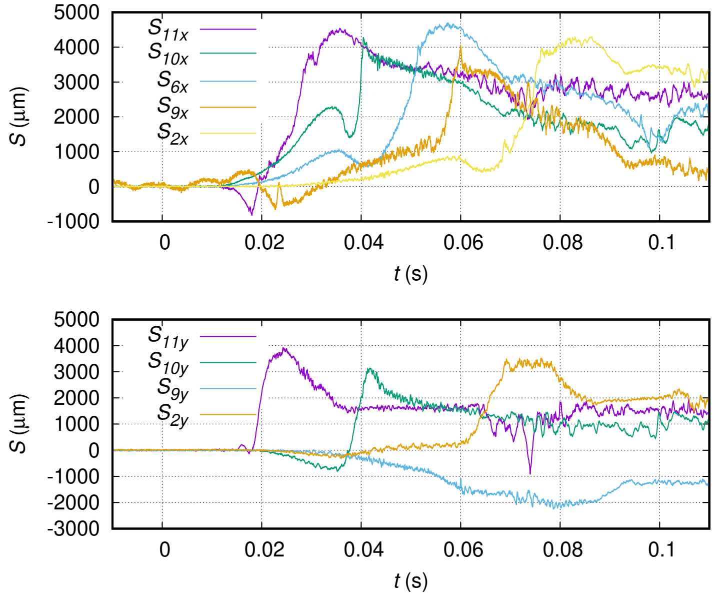

Figure 4: Time histories of the strains measured in the longitudinal, x, and transverse (y) directions by the probes located along the midline of the specimens for the milled skin.

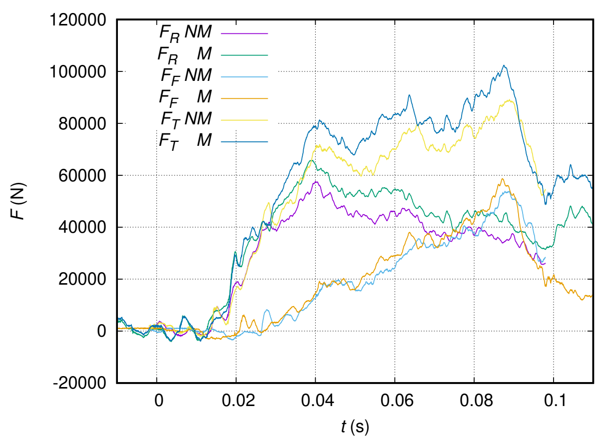

Figure 5: Time histories of the total load measured at the rear, R, at the front, F, and the total load, T, measured for the tests with the uniform skin, NM, and with the milled plate, M.

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