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D5.1: Definition of the conditions for guided aircraft ditching tests

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Glossary

Acronym	Full title

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Abstract – Publishable Summary

In this report the conditions that will be used for the aircraft ditching tests to be performed at CNR-INSEAN are presented. According to what planned in the original proposal and subsequent discussions within the consortium, four different test typologies will be considered, which correspond to the four tasks of the WP5. Namely they will be conducted on: double curvature rigid specimen, single curvature aircraft-like structure, thin flat plates and scaled fuselage with dynamic pitch. The main features of the shapes and of the structures to be used in the test campaign as well as some aspects concerning with the instrumentation are provided together with the test matrix.

1. Introduction

In this document the conditions that will be used to perform the aircraft ditching tests in Task 2 of WP5 are presented. Some aspects concerning the shapes, dimensions and main structural characteristics of the specimen are also provided. All the main aspects of the test conditions have been discussed and agreed with other partners, mainly TUHH, ADS, DAv and TUBS, within the technical limits allowed by the testing facilities. For each test typology, the instrumentation adopted and the quantities that will be measured are briefly discussed.

An identification code for the tests has been proposed which will be used in future to recognize the test type and conditions. The proposed ID is composed by a combination of digits and letters. They are: Task, Facility, Shape, Horizontal velocity, Horizontal/Vertical velocity ratio, Pitch angle/Pitch angle dynamics, Other condition. The digits/letters are defined as follows:

- **Task**: T 5.2.1 (**1**), T 5.2.2 (**2**), T 5.2.3 (**3**) T 5.2.4 (**4**)
- **Facility**: High speed ditching facility (**H**), Towing Tank (**T**), Wave Tank (**W**)
- **Shape**: S1 (**1**), S2 (**2**), S3 (**3**), aircraft-like structure (**4**), flat plate (**5**)
- **Horizontal velocity** (m/s): 35 (**1**), 40 (**2**), 45 (**3**), 12 (**4**), 5 (**5**), -5 (**6**)
- **Horizontal/vertical velocity ratio**: 0.0333 (**1**), 0.0375 (**2**), 0.05 (**3**)
- **Pitch angle/Pitch angle dynamics** (degrees): 4 (**1**), 6 (**2**), 8 (**3**), 6→8 (**4**), 6→4 (**5**), TUHH specified (**6**), 10 (**7**), 13 (**8**), 16 (**9**)

The “**Other condition**” element is different for the different tasks. For task T 5.2.1 and only for the tests on shapes S1 at 6 degrees it indicates which specimen is used (options **D/E**); for T 5.2.3 it indicates the plate thickness (options **H/I/J/L**); for task T 5.2.4 the “Other condition” indicates the relative position between the wave and the fuselage (options **F/C/B**). For all tests which do not have any further condition to be specified, the “Other condition” is set to null (**N**). Only for T 5.2.3 an additional parameter denoting the size of the window in the reinforcement will be used (options **W**/**R**). Detailed explanations of the meaning of the different codes/letters adopted for the definition of the “Other conditions” are provided in the following.

For the sake of the clarity, the fuselage shapes to be adopted in T 5.2.4 are introduced first as they represent the basis for the definition of the larger scale specimen to be used in T 5.2.1, which is discussed next. Hence, the test conditions used in the tests on the aircraft-like structure (T 5.2.2) and on the flat aluminium plates (T 5.2.3) are presented.

2. Tests on Scaled Fuselages with Dynamic Pitch

2.1 Parametric representation of the fuselage shape

A parametric description of the fuselage shapes has been proposed by TUHH. By varying the different parameters, it allows to generate fuselage shapes which are representative of a wide class of commercial aircrafts. Being based on analytic expressions, it can be easily shared and distributed without any confidentiality issue. The parametric description provided by TUHH has been successively refined by CNR to match the characteristic shape of transport aircraft, which are the ones ADS is more interested in.

The main parameter is the fuselage breadth *B*. Other main geometrical parameters are the non-dimensional values of the total length *LB* and of the length of the fore and rear portions, which are denoted by *FB* and *RB*, respectively (Figure 1).

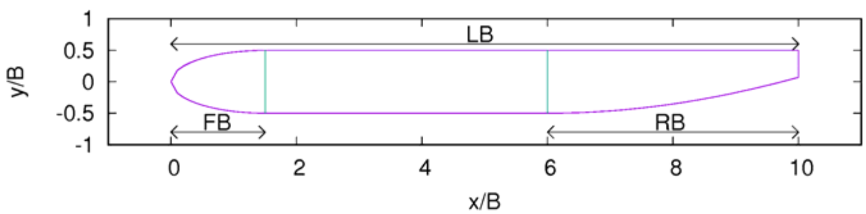

Figure 1 Parameterization of the fuselage shapes

In the fore part, i.e. for $x/L \in (0,FB)$, the fuselage profile is assumed to be of elliptical shape, as in the NACA 2929 report, and the local fuselage radius is given by the equation

$$r = 0.5B\sqrt{1-\left(\frac{x/B-FB}{FB}\right)^2}$$

The fuselage radius is constant with r=0.5B for $x/B \in (FB, LB-RB)$ and for $x/B > (LB-RB)$ the radius progressively diminishes as

$$r = 0.5B + Sweep \qquad (1)$$

where

$$Sweep = -0.5B \cdot \sin\left(\frac{x-x_H}{K \cdot RB \cdot B}\right) \cdot \left[\frac{x-x_H}{\sin\left(\frac{1}{i}\right) \cdot RB \cdot B}\right]^{\frac{1}{i}} \qquad (2)$$

In equation (2) x_H=B·(LB-RB) whereas K and i are additional parameters which governs the fuselage shape at the rear. Besides being used for the reduction of the radius, the *Sweep* function also represents the *y*-coordinate of the center of the circular section.

2.1.1 Passenger aircraft – S1

For the first fuselage shape parameters are chosen to be representative of a medium size passenger aircraft:

LB	10
FB	1.5
RB	4
i	1
K	2

The resulting shape is shown in Figure 2 where the side and back views are provided.

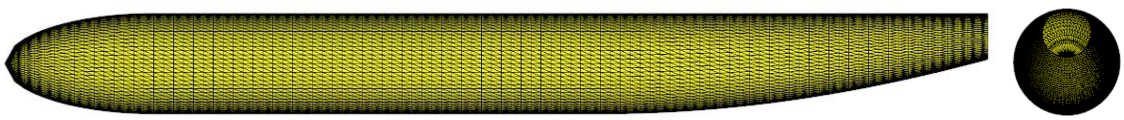

Figure 2 Aircraft transport fuselage (S1): side and back views

2.1.2 Transport aircraft with circular cross section – S2

Military transport aircrafts are usually characterized by a much sharper kink at the rear and the bottom is much flatter than a typical passenger aircraft to allow the installation of the ramp. In order to distinguish the effects of the longitudinal and transverse curvatures on the hydrodynamic phenomena, a first fuselage shape is chosen to have a bottom profile resembling that of a typical transport aircraft but a circular cross section. The parameters for such a shape are

LB	7.5
FB	1.5
RB	2.5
i	2.6
K	1.55

The resulting shape is shown in Figure 3.

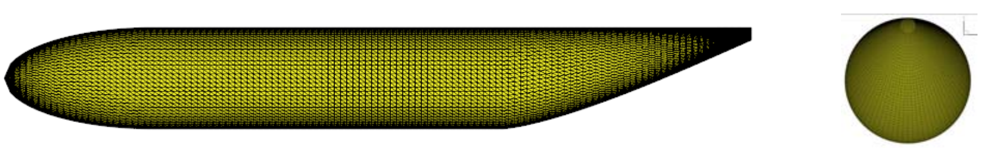

Figure 3 Transport Aircraft with circular cross section (S2)

2.1.3 Transport aircraft with circular-elliptical cross section – S3

In order to achieve a better representation of the flow about military transport aircrafts, a mixed circular-elliptical cross section is introduced. The section is derived by matching a circular and elliptical sections enforcing the continuity of the slope at the contact points. The section itself is based on its own parameterization which is referred to a circular section of unit radius. The two main parameters are the angle of the contact points Θ and the ratio *C/D* between the shorter semi axis *C* and the offset *D* (Figure 4).

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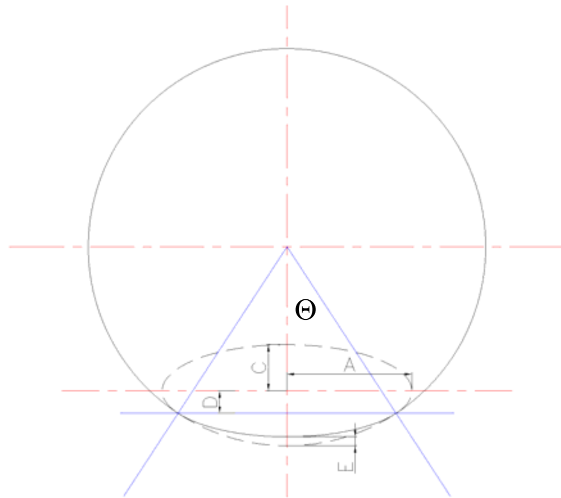


Figure 4 Sketch defining the circular-elliptical cross section

Once the two parameters are assigned, the semi axis *A* is derived by enforcing the contact of the ellipse and the circle at the angle Θ, which provides:

$$A = \frac{C}{D}\frac{\sin\theta}{\sqrt{\left(\frac{C}{D}\right)^2 - 1}}$$

The semi axis *C* is derived from the continuity of the tangent at the contact points

$$C = \frac{A\sin\theta}{\sqrt{\left(\frac{C}{D}\right)^2 - 1}}$$

and then the offset *D* is obtained as

$$D = C - (1 - E) + \cos\theta$$

where

$$E = 1 - \cos\theta - \frac{\left(\frac{C}{D} - 1\right)}{C/D}C$$

The horizontal semi axis of the ellipse is located at $z = -1 + E + C$ and then the equation of the ellipse in the *y,z* coordinates is given by

$$\left(\frac{y}{A}\right)^2 + \left(\frac{z + 1 - (E + C)}{C}\right)^2 = 1$$

For the specific shape, it is assumed $\theta = 50°$ and $C/D = 5$ which provide $E = 0.2$. The comparison between the circular and the circular-elliptical shapes is provided in Figure 5.

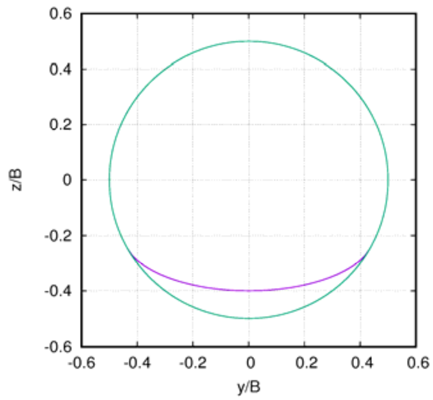


Figure 5 Comparison between circular (green) and circular-elliptical (magenta) shapes

For the definition of the fuselage shape, it is assumed that the cross section is always the mixed circular-elliptical one which is scaled by using the local radius defined by the same equations used for shape S2. In order to have the same bottom profile of shape S2 at the rear, a correction factor *G* has to be applied to the *Sweep* function when used for fuselage shape S3:

$$Sweep^{S3} = -0.5B \cdot G \cdot \sin\left(\frac{x - x_H}{K \cdot RB \cdot B}\right) \cdot \left[\frac{x - x_H}{\sin\left(\frac{1}{i}\right) \cdot RB \cdot B}\right]^{\frac{1}{i}}$$

where *G*=2/*E*. All other parameters are the same used for the definition of shape S2. The resulting shape is shown in Figure 6 where the side and back views are provided.

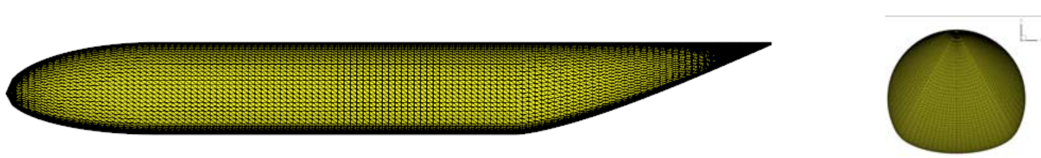


Figure 6 Transport aircraft with circular-elliptical cross section (S3)

2.2 Test conditions

Ditching tests on scaled fuselages with assigned dynamic pitch motion will be performed at both Towing Tank, i.e. still water basin, and Wave Tank. The size of the fuselage will be mainly limited by the maximum length that can be hosted in the wave tank carriage, as well as by some possible constraints associated to the actuator system. Even though the limits will become clearer once the experimental design will be completed, at present it seems that fuselages with breadth B=0.40 m can be used for all three shapes S1, S2, S3.

The attitude will be controlled by two linear actuators at the rear and fore part of the fuselage. Load cells will be used to connect the actuators to the fuselages and will be used to derive the total loads in the horizontal and vertical directions. Appropriate solutions will be adopted to prevent the occurrence of yaw and roll motions.

Tests at the towing tank will be performed at a horizontal velocity U=12 m/s, unless some unforeseen limits related to the actuation system will be found when the experimental setup will be designed. After the acceleration of the carriage, once the final speed is reached, the fuselage will be moved vertically with a constant attitude and will touch the free surface at $t=t_0$ with a given velocity V_0 and a pitch angle α_0. The vertical velocity at the rear will be gradually (sinusoidally) reduced until the vertical motion at the rear stops at $t=t_1$ when the lowest point of the fuselage reaches a maximum depth of one fourth the fuselage diameter (i.e. 0.10 m for the 0.40 m fuselage breadth).

The two actuators will be synchronized and starting from $t=t_0$ the pitch angle will be varied, in both positive and negative directions. Due to limits in the maximum accelerations and loads that can be exerted by the actuators, the variation will be necessarily smooth. At present, it is assumed that a time interval of 0.5 s, i.e. $t_1= t_0$+0.5 s, should allow sufficiently low acceleration and loads. Three test conditions will be considered for the towing tank tests:

- V_0=0.45 m/s, which corresponds to V/U=1.5/40, pitch angle varies from α_0=6 deg at $t=t_0$ to α=8 deg at $t=t_1$
- V_0=0.45 m/s, which corresponds to V/U=1.5/40, pitch angle varies from α_0=6 deg at $t=t_0$ to α=4 deg at $t=t_1$
- V_0=0.40 m/s, which corresponds to V/U=1.5/45, pitch angle varies from α_0=6 deg at $t=t_0$ to α=4 deg at $t=t_1$

Only for the towing tank tests on fuselage shape S1, a fourth dynamic pitch condition based on the pitch history computed by TUHH will be used, with some corrections in case the computed time history will exceed the limits of the actuators in acceleration and load.

For each test condition, three different repeats will be performed to have an estimate to the uncertainty. Considering 3 shapes, 3 pitch histories and 3 repeats plus additional 3 repeats on S1 for the TUHH pitch history, a total of 30 tests will be performed at the towing tank.

For fuselage shapes S1 and S3 tests will be repeated at the wave tank. The size of the basin and the maximum speed are lower and the maximum speed in the following wave condition is even lower. It is worth noticing that at present the experimental setup for this tests has to be designed yet and it is not clear if the tests in the following wave conditions can be actually made. Assuming that tests in the following wave configuration can be made, the horizontal speed is assumed to be U=±5 m/s depending on the wave propagation direction. Correspondingly, a vertical velocity V_0=0.1875 m/s, which corresponds to V/U=1.5/40, is used. In order to isolate the effect of the wave on the hydrodynamics, tests will be performed in the fixed pitch angle condition. This is further motivated by the difficulty in achieving a perfect synchronization between the fuselage motion and the wave crest.

Both head and following sea conditions will be considered, unless unforeseen limitations will appear at the design stage of the setup. In both cases and for the two fuselages, tests will be performed at 6 degrees pitch angle, with *U*=5 m/s and *U*=-5 m/s, respectively. In order to isolate the effect of the wave on the hydrodynamics, a first test for the two fuselage shapes will be performed with no waves. Hence, tests in presence of waves will be considered. A monochromatic wave, with wavelength λ=6 m and wave amplitude *a*=0.05 m will be used for the tests. At each test condition three repeats will be performed in order to achieve different impact conditions with respect to the wave profile and two repeats will be performed to have a rough estimate of the inherent uncertainty. A total of 30 tests will be performed on the wave tank.

The full test matrix for the tests on scaled fuselages with dynamic pitch are summarized in Table 1.

Table 1 Conditions to be used for the ditching tests with dynamic pitch (Task 5.2.4)

Facility	Shape	U,V (m/s)	α_0 (deg)	α_1 (deg)	t_1-t_0 (s)	λ (m)	a (m)	Wave-fuselage positions	Rep	**ID**
TT	**S1**	12,0.45	6	8	0.5	-	-	N	3	4T1424N
		12,0.45	6	4	0.5	-	-	N	3	4T1425N
		12,0.40	6	4	0.5	-	-	N	3	4T1425N
		12,0.45	TUHH	TUHH	TUHH	-	-	N	3	4T1426N
	S2	12,0.45	6	8	0.5	-	-	N	3	4T2424N
		12,0.45	6	4	0.5	-	-	N	3	4T2425N
		12,0.40	6	4	0.5	-	-	N	3	4T2425N
	S3	12,0.45	6	8	0.5	-	-	N	3	4T3424N
		12,0.45	6	4	0.5	-	-	N	3	4T3425N
		12,0.40	6	4	0.5	-	-	N	3	4T3425N
WT	**S1**	5,0.1875	6	-	-	-	-	N	3	4W1522N
		5,0.1875	6	-	-	6	0.05	Front (F), Crest (C), Back (B)	2	4W1522-F/C/B
		-5,0.1875	6	-	-	6	0.05	Front (F), Crest (C), Back (B)	2	4W1622-F/C/B
	S3	5,0.1875	6	-	-	-	-	N	3	4W3522N
		5,0.1875	6	-	-	6	0.05	Front (F), Crest (C), Back (B)	2	4W3522-F/C/B
		-5,0.1875	6	-	-	6	0.05	Front (F), Crest (C), Back (B)	2	4W3622-F/C/B

2.3 Instrumentation and measurements

In the test of scaled fuselages with dynamic pitch, measurements will be provided in terms of: total load in horizontal direction, normal loads at fore and aft actuators, actuators inclinations, pressure (8-10 probes), fuselage attitude via IMU and accelerations (including static component). For the tests on waves, the free surface elevation measured nearby the wave maker and in a frame of reference moving with the fuselage will be also provided.

3. Tests on Double Curvature Rigid specimen

3.1 Definition of the shapes

The tests on double curvature specimen of Task 5.2.1 are aimed at investigating some of the hydrodynamic phenomena occurring in full scale conditions such as ventilation, separation and possibly cavitation which do not appear in the tests on scaled fuselage because of the too low velocity values.

The tests will be performed at the High Speed Ditching facility (HSD), allowing a horizontal velocity in the range 30-45 m/s. Higher velocity values should be also possible but such possibility will be explored during the test campaign. The vertical velocity depends on the horizontal velocity and on the inclination of the guide. The guide can be rotated so that the vertical/horizontal velocity ratio is in the range $V/U \in (0.03, 0.05)$.

The idea is to use a portion of the fuselage shape tested at low speed to define the shapes of the double curvature specimen, so that the effect of the scaling on the hydrodynamic aspects can be easily identified. There are however some limits in the minimum and maximum size of the specimen which can be accommodated beneath the trolley. The specimen have to be connected to the lower frame of the trolley which is 0.596 m wide and 1.20 m long. The main limitation concerns the longitudinal dimension: in the following it is assumed that the longitudinal dimension of the specimen will be 1.24 m but during the final design stage the possibility of using longer specimen will be considered.

At the same time, the breadth at the upper side has to be equal to that of the frame not only for the mechanical connection but also to avoid that the hydrodynamics is affected by the interaction of the water with the portion of the frame outside the fuselage specimen. For this reason, the *z*-coordinate of the cut is moved up until the local breadth of the fuselage is always larger than the frame. However, this introduces another problem related to the maximum thickness of the specimen. In the HSD facility the water impact has to occur in a specific portion of the guide which is properly reinforced to limit the bending caused by the hydrodynamic loading, thus keeping the deviations in terms of the V/U within acceptable limits [1]. If the thickness is too high, the initial contact point is anticipated in a region where larger oscillations are expected, and data are much less reliable.

Bearing in mind the above constraints, several attempts have been made in order to achieve the best compromise among technical feasibility and usefulness of the data. Preliminary hypotheses for the specimen shapes are formulated in the following, but some changes might occur during the final design stage. Three shapes are defined, one per each fuselage. The most problematic is that for the passenger aircraft, referred to as S1, as the curvature at the rear is quite smooth and a rather long specimen would be necessary to cover the different pitch angles of 4, 6 and 8 degrees considered in the test conditions. A solution is to use a fuselage breadth B=1.0 m and two different specimen: a first specimen (S1D) will cover the region about the contact points for 4 and 6 degrees and a second one (S1E) will cover the region about 6 and 8 degrees. The position of the two cuts on the central longitudinal/vertical plane are shown in Figure 7 where the positions of the contact points at 4, 6 and 8 degrees are drawn. The *z* coordinate of the two cuts is different as a higher fuselage portion is needed for S1E because of the smaller radius of the cross section at the rear. It has been verified that the above solutions allow to have the first impact always within the reinforced portion of the guide. At the final design stage the possibility of installing longer specimen (up to 0.20 m longer anyhow) will be considered.

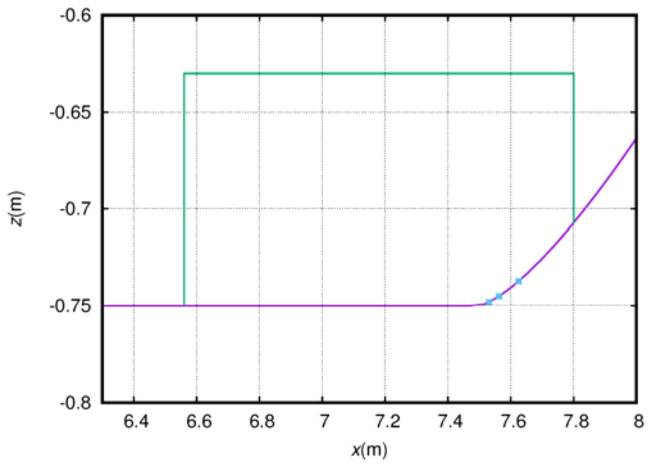


Figure 8 Position of the cut for the transport aircraft with circular cross section (S2): note that different scales are used for the vertical and horizontal axes

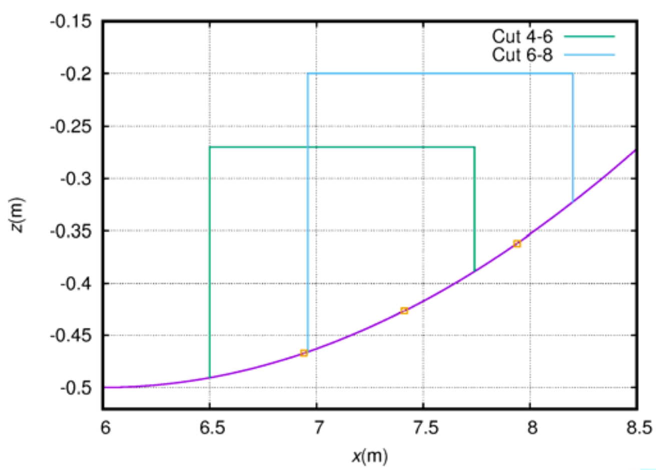


Figure 7 Position of the two cuts for the passenger aircraft fuselage (S1D, green; S1E, cyan) on the middle *x-z* plane. Note that different scales are used for the vertical and horizontal axes

For the transport aircraft with circular cross section, i.e. S2, a fuselage breadth *B*=1.5 m has been chosen. In this case the sweep function varies more rapidly and the three contact points for 4, 6 and 8 degrees pitch angle can be inside one single specimen. The position of the cut is shown in Figure 9. As the transport aircraft with the circular-elliptical cross section, i.e. S3, has exactly the same bottom profile, the longitudinal cut, shown in Figure 9, is essentially the same, but for the *z*-coordinate.

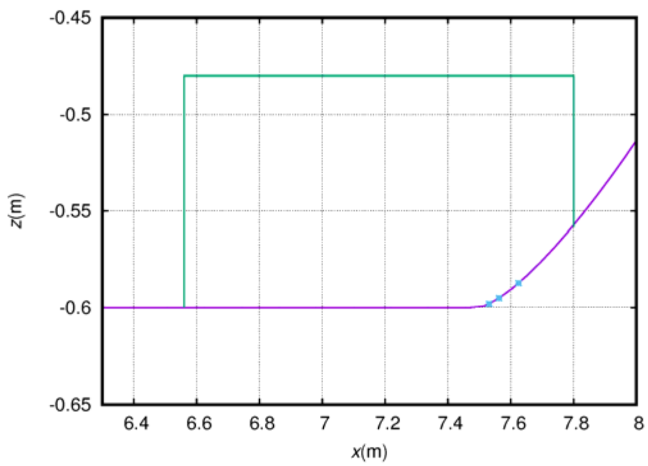


Figure 9 Position of the cut for the transport aircraft with circular-elliptical cross section (S3)

3.2 Test conditions

The test conditions for Task 5.2.1 will be the same for all three specimen. For shape S1, the specimen S1D or S1E will be used for the tests at 4 and 8 degrees pitch angles, respectively. For the 6 degrees condition some of the tests will be performed using both specimen, thus allowing how the hydrodynamic aspects change because of the different fuselage portion considered.

The test conditions are chosen to isolate the role played by the different parameters. Aside from the shape, the main parameters are: horizontal velocity, pitch angle and V/U velocity ratio. The test conditions are summarized in Table 2. A total of 50 tests are considered with 2 repeats per test condition. In the course of the project additional tests for some specific conditions will be considered if necessary to provide a better visualization by the underwater camera.

3.3 Instrumentation and measurements

For the test of double curvature specimen, the interest is mainly on the peculiarities of the high speed hydrodynamics and on the role played by the longitudinal curvature. For this reason 30 pressure probes will be installed on the specimen, flush-mounted to the surface. Besides the pressure, the loads acting in the longitudinal and normal directions will be measured. It order to support the interpretation of the measurements, the tests will be recorded by submerged high-speed camera. The velocity and the impact will be also measured by high-speed camera installed on the side as well as by a non-contact optical sensor.

Table 2 Test conditions to be used for the tests on double curvature specimen (T5.2.1)

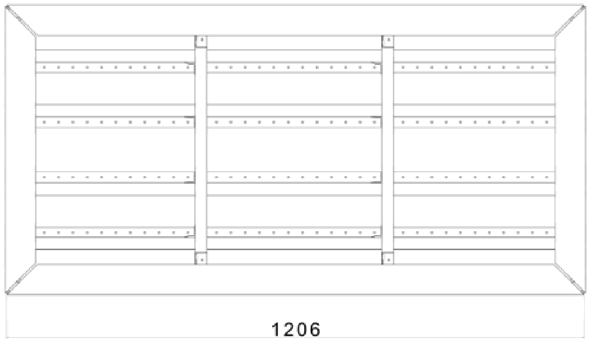
Facility	Shape	U (m/s)	V (m/s)	V/U	α (deg)	Specimen	Rep	**ID**
HSD	S1	40	1.5	0.0375	4	1D	2	1H1221-D
		40	1.5	0.0375	6	1D,1E	2+2	1H1222-D/E
		40	1.5	0.0375	8	1E	2	1H1223-E
		35	1.3125	0.0375	6	1D/1E	2	1H1122-D/E
		45	1.6875	0.0375	6	1D/1E	2	1H1322-D/E
		35	1.1667	0.0333	6	1D/1E	2	1H1112-D/E
		40	1.333	0.0333	6	1D/1E	2	1H1212-D/E
		45	1.5	0.0333	6	1D/1E	2	1H1312-D/E
	S2	40	1.5	0.0375	4	2	2	1H2221N
		40	1.5	0.0375	6	2	2	1H2222N
		40	1.5	0.0375	8	2	2	1H2223N
		35	1.3125	0.0375	6	2	2	1H2122N
		45	1.6875	0.0375	6	2	2	1H2322N
		35	1.1667	0.0333	6	2	2	1H2112N
		40	1.333	0.0333	6	2	2	1H2212N
		45	1.5	0.0333	6	2	2	1H2312N
	S3	40	1.5	0.0375	4	3	2	1H3221N
		40	1.5	0.0375	6	3	2	1H3222N
		40	1.5	0.0375	8	3	2	1H3223N
		35	1.3125	0.0375	6	3	2	1H3122N
		45	1.6875	0.0375	6	3	2	1H3322N
		35	1.1667	0.0333	6	3	2	1H3112N
		40	1.333	0.0333	6	3	2	1H3212N
		45	1.5	0.0333	6	3	2	1H3312N

4. Tests on Aircraft-like Structure

4.1 Preliminary design of the structure

Tests to be performed in Task 5.2.2 are aimed at building a dataset for the deformations undergone by an aircraft-like structure during a ditching event. The structure will be composed by a single curvature plate at the bottom reinforced by four stringers and two frames on the internal side. In order to have more realistic loading and boundary conditions, the plate will be connected to the trolley by an intermediate structure which will be closed all around. The intermediate structure will be made by reinforced plates of the same thickness of the bottom and will also close the fore and aft side of the specimen. Even though the design is still in a preliminary stage, some main features may be anticipated.

All plates and structural components will be made by AL2024 T3 alloy. The curved plate will have a thickness of 1.6 mm and an external curvature radius of 2.0 m. The same thickness will be also used for the aluminium plates located at the sides and at the fore and aft sides of the specimen. The vertical plates at the lateral sides will be bended to match the curved plate at the bottom. Reinforcements (stringers) will be used on the curved plate as well as on the vertical plates: commercial components



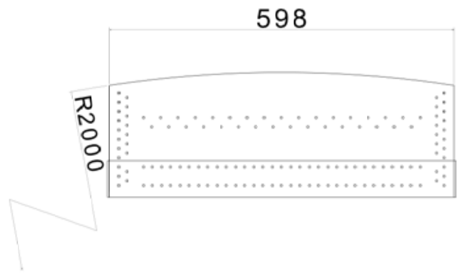


Figure 10 Top (left) and side (right) views of the aircraft-like structure to be used for tests in T 5.2.2

(not yet decided if extruded of bended) made of the same aluminium alloy will be employed. The transverse reinforcements (frames, spars, bulkheads) will be machined to follow the internal curvature of the plate. They are also machined where necessary to allow the positioning of the stringers. The external dimensions of the specimen are 598 mm by 1206 mm. The longitudinal distance between the frames is 390 mm. Hi lock pin (e.g. HL19) will be used to connect the bottom plate: diameter 5/32 inch will be used. For all other connections, protruded head pins with the same diameter will be adopted. The distance between successive pins will be 30 mm in both directions. In order to assess the main structural features, the specimen will be characterized (as an isolated specimen) before the tests.

Some pictures and sketches of the preliminary design are provided in the figures below.

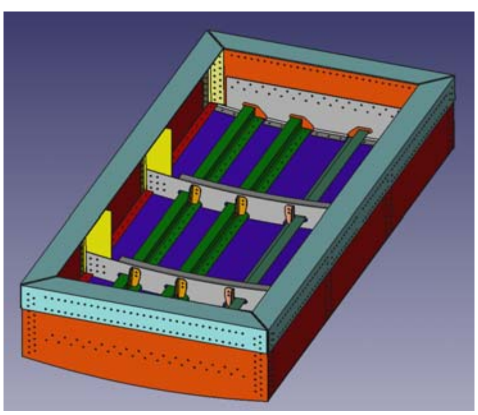
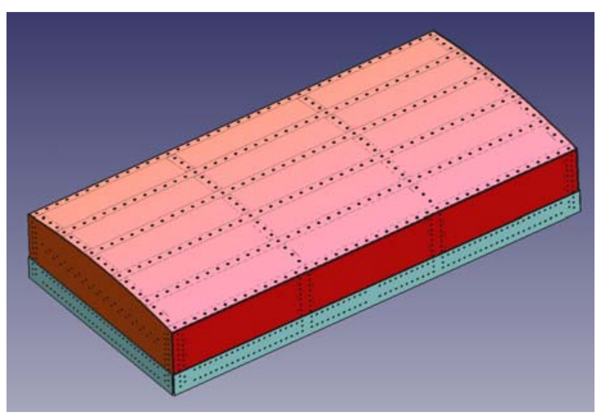



Figure 11 Top and bottom views of the CAD model of the aircraft-like structure

4.2 Test conditions

The tests will be performed at the High Speed Ditching facility (HSD). As the structural component is much higher compared to other specimen, the first contact point with the water surface is anticipated. In order to assure that the impact occurs inside the reinforced portion of the guide, the guide has to be rotated at the maximum angle, which is the one at which *V/U*=1:20.

Two specimen will be built and instrumented. The first test will be performed at about *U*=40 m/s and *V*=2 m/s, pitch angle α=6 deg. Note that, since this will be a unique test, some uncertainty in the horizontal velocity, say +/- 0.5 m/s, has to be accounted for. The velocity at the impact time will be measured anyhow. If the first test will be successful, the second specimen can be tested either at the same conditions (in order to have a rough estimate of the uncertainty of the data) or at a different pitch angle. At present it is assumed that the second test will be performed at a larger pitch angle, α=8 degrees. However, different alternatives will be considered in the course of the project.

The test conditions are summarized in Table 3. The identification number indicates task, facility, shape, velocity and pitch, whereas there are no additional conditions for this case.

Table 3 Conditions to be used for the tests on the aircraft-like structure (Task 5.2.2)

Facility	Spec.	U,V (m/s)	α (deg)	Rep	**ID**
HSD	**1**	40,2	6	1	2H4232N
	2	40,2	8	1	2H4233N

4.3 Instrumentation

The specimen will be equipped by a maximum of 36 strain gauges: the precise location will be agreed together with the interested partners (ADS, DAv, TUBS) at the final design stage. The total loads acting in the normal and tangential directions will be measured: the normal component will be recorded separately at the front and at the rear so that an estimate of the centre of loads can be also retrieved. The tests will be recorded by a high speed camera at the side which will be used to compute the velocity at the impact time, and by a submerged camera that will provide movies and images useful to support the analysis and the interpretation of the test data.

5. Tests on thin plates

5.1 Plates characteristics

Tests to be performed in Task 5.2.3 are aimed at determining the ballistic limits for rupture of the aluminium plates. The plates will be made of aluminium alloy AL2024 T3 and four different thicknesses will be considered: 0.016 inch, 0.020 inch, 0.025 inch and 0.032 inch, which corresponds to about 0.4 mm, 0.5 mm, 0.6 mm, 0.8 mm, respectively. The plates will be joined to the steel frame of the acquisition box through protruded heads bolts EN6115, diameter code 4 (6.35 mm). The external dimension of the plates will be 646 mm by 1240 mm whereas the internal size of the frame, which is the zone where the out-of-plane distortion may occur, is 476 mm by 1060 mm. In order to reduce the effect of the boundary conditions on the structural deformation, a plate made of the same alloy but 3 mm thick will be installed between the thin plate and the frame. The thick plate will have a rectangular window at the middle which reduces the area where the plates can undergo the out-of-plane distortions and eventually the rupture. On the basis of some specific needs of ADS, two different dimensions rectangular holes will be considered. A first option will be to have the reinforcement 100 mm all around, which means a window with size 276 mm by 860 mm. A second option will be a narrower window with a size which is more representative of the actual distance between stiffeners in an aircraft, which is 200 mm by 500 mm. For the identification of the windows in the tests, the first and second options will be denoted by Wide window (W) or Reduced window (R).

5.2 Test conditions

As the tests are aimed at finding the ballistic limit for rupture, a precise plan of the test sequence cannot be foreseen at this stage, but only a general approach can be provided. There are three main parameters that can be varied to achieve the rupture: the vertical velocity, the thickness of the plate and the pitch angle.

On the basis of the experience matured in the SMAES project, it seems impossible to reach rupture for the 0.8 mm plates using V=1.5 m/s. For this reason the tests will be performed using the highest inclination of the guide which corresponds to V/U=0.05: in such a way, the vertical velocity component can reach 2.25 m/s at U=45 m/s.

The tests will be started using a horizontal velocity U=40 m/s as that should allow a good repeatability of the test conditions. At first, the thinnest plates, 0.4 mm (H), will be tests at 10 degrees pitch angle, using the reinforcement plate with wide window (W). If the plate will not break, the pitch angle of the plate will be augmented to 13 degrees and eventually to 16 degrees. In case rupture is not reached yet, the velocity will be increased to 45 m/s. If rupture is not reached yet, alternative solutions will be discussed with other partners. If the rupture is reached, a second repeat of the test in the same conditions will be performed to confirm it. The tests will be repeated with thicker plates 0.5 mm (I), 0.6 mm (J), 0.8 mm (K) up to find the one which does not break.

Once the ballistic limit will be identified, if there are still plates available, additional tests will be performed using the reinforcement plate with the window of reduced size (R). The same strategy will be adopted but it will be limited to the plates which showed rupture with the wide window reinforcement.

As the test sequence is strongly dependent on the outcomes of the previous tests, it is not possible to provide a precise test matrix. A total of 15 plates are foreseen for this task, but a few additional tests will be performed in case the rupture will not be reached within that number.

5.3 Instrumentation and measurements

For this tests, as failure is sought, it was agreed not to install any electronic system on board. In the course of the project, the possibility of installing a reduced system which can measure only loads will be considered. High speed movies will be recorded by the underwater camera. In case of rupture, the position and dimension of the crack will be measured at the end of the tests.

6. Conclusion

The conditions that will be used to perform the aircraft ditching tests in Task 2 of WP5 have been presented. The main aspects concerning the specimen shapes and structures and the experimental setup have been provided together with the test conditions in terms of impact velocity and pitch angle. Some of the conditions, mainly in terms of specimen shapes (very likely for shape S1 in tests T 5.2.1) and structural characteristics, might be changed at the final design stage due to either technical constraints in the facilities or additional requests/suggestion by the partners of the consortium who are more linked with the aircraft ditching tests.

7. References

[1.] Iafrati, A., Grizzi, S., Siemann, M.H. and Benítez Montañés (2015) *High speed ditching of a flat plate: Experimental data and uncertainty assessment*, J. Fluid and Structures, Vol. 55, pp. 501-525.