

Water Impact Test and Simulation of Composite Panels



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Introduction

Test Set-up

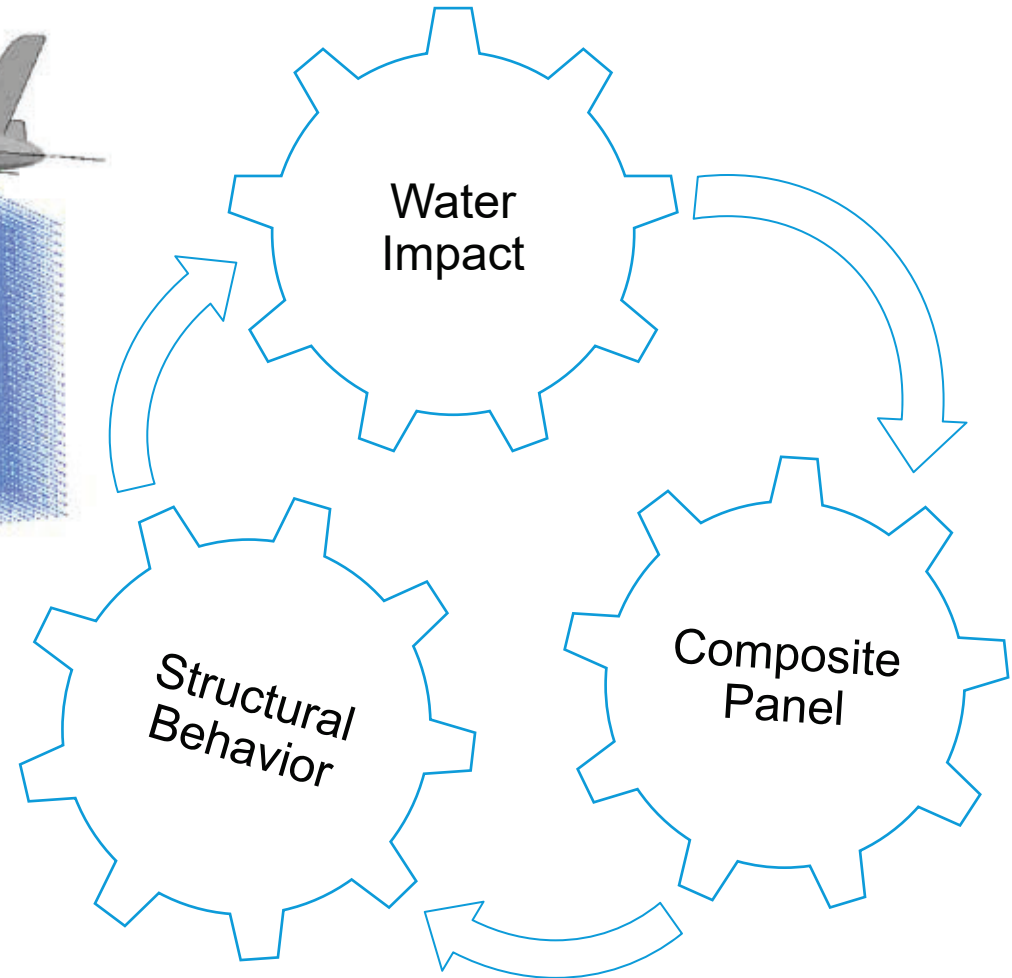
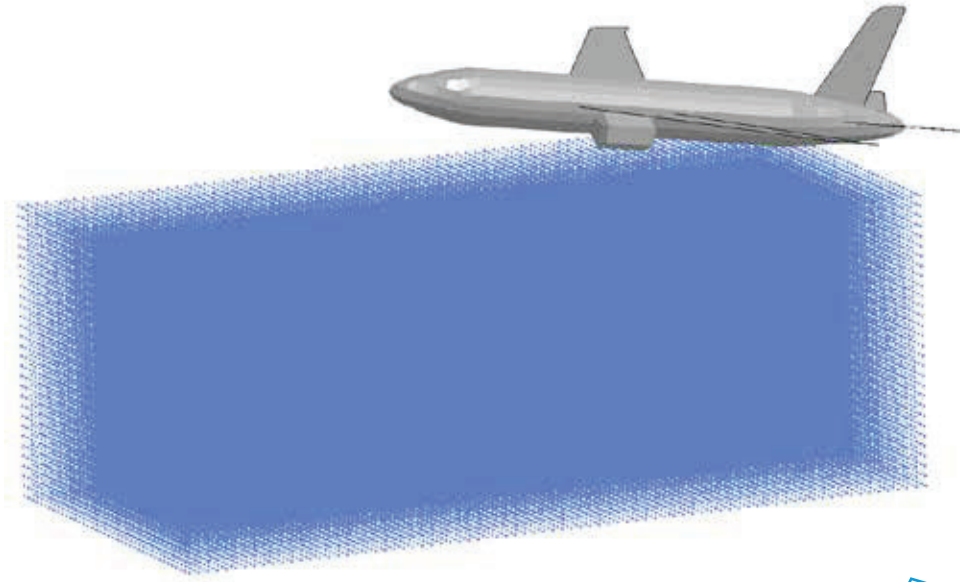
Test Results

Numerical Correlation

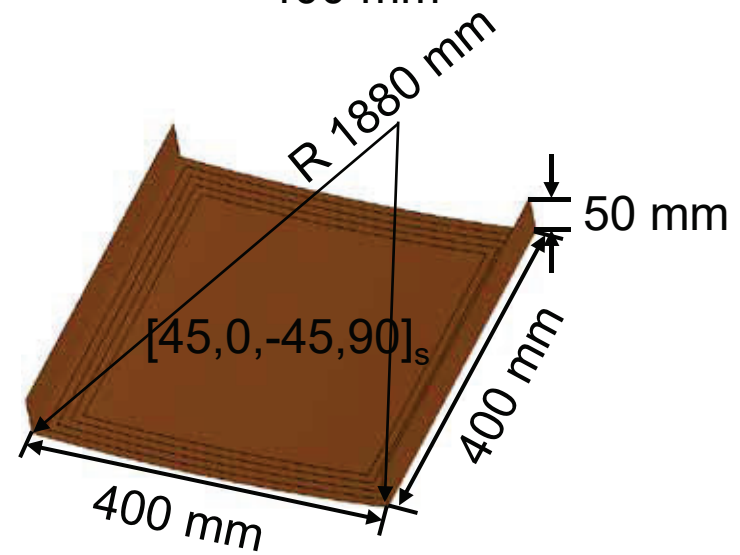
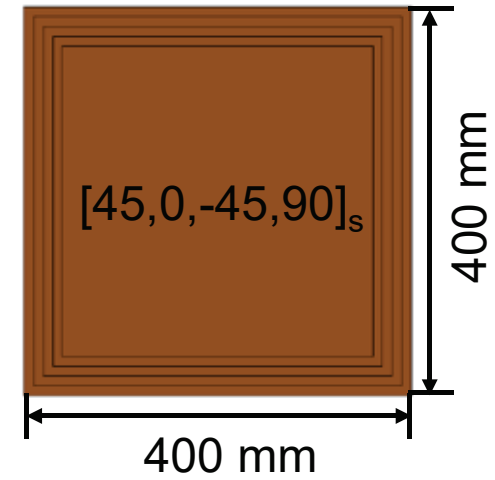
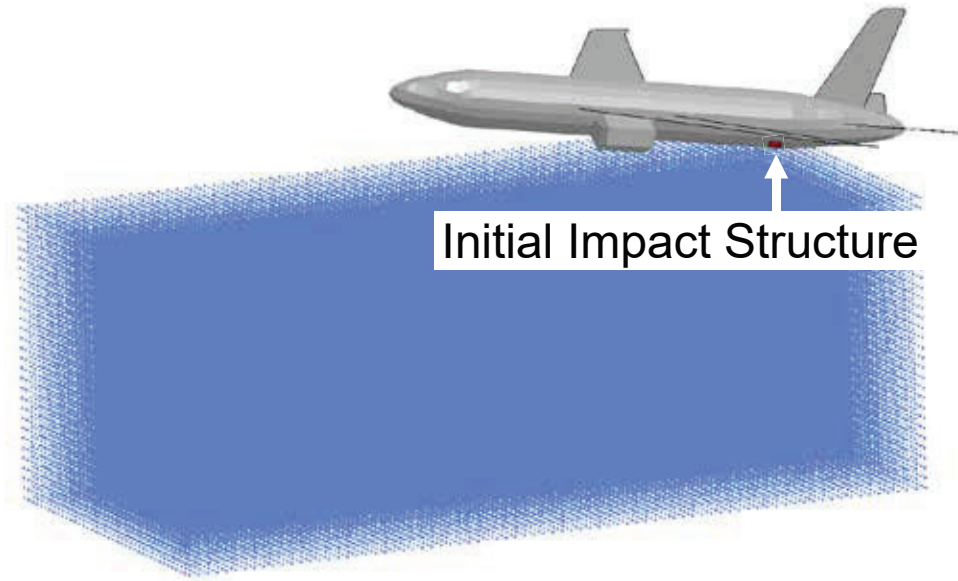
Background

- ❑ Aircraft emergency landing on water is often fatal
- ❑ Composite structural response under ditching and water impact conditions is waiting for a deep and complete investigation
- ❑ A minimum practical airspeed and a landing attitude is required in ditching provisions for large aeroplanes (EASA CS-25 Amendment 27)

Objectives



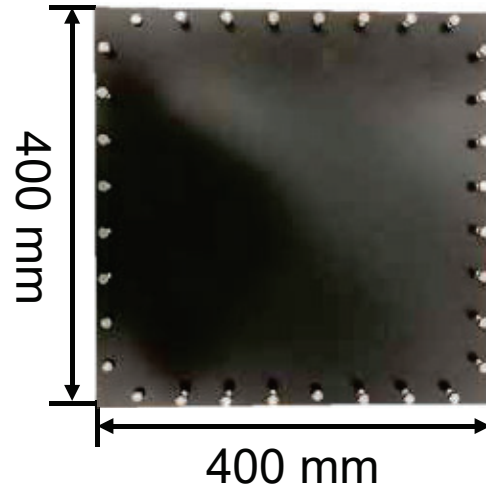
Test Preparation



| Panel | Length, mm | Width, mm | Thickness, mm | Weight, g |
|--------------|------------|-----------|---------------|-----------|
| Flat panel | 400.5 | 401 | 1.64 | 454 |
| Curved panel | 400 | 400 | 1.32 | 518 |

| Density, kg/m ³ | E ₁₁ , GPa | E ₂₂ , GPa | G ₁₂ , MPa |
|----------------------------|-----------------------|-----------------------|-----------------------|
| | | | |

Test Preparation



Panel with bolts

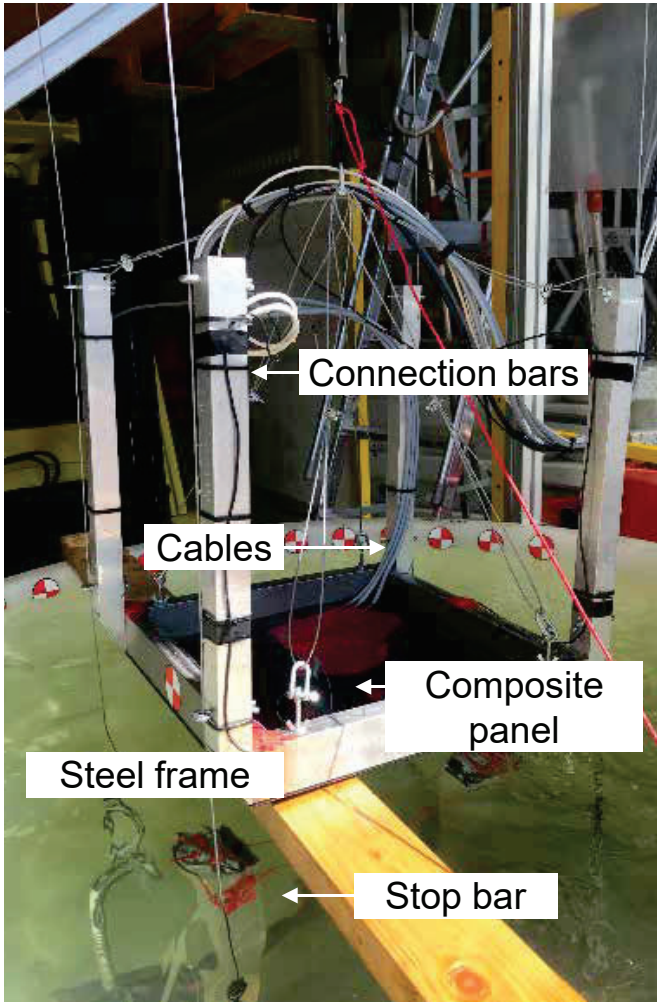
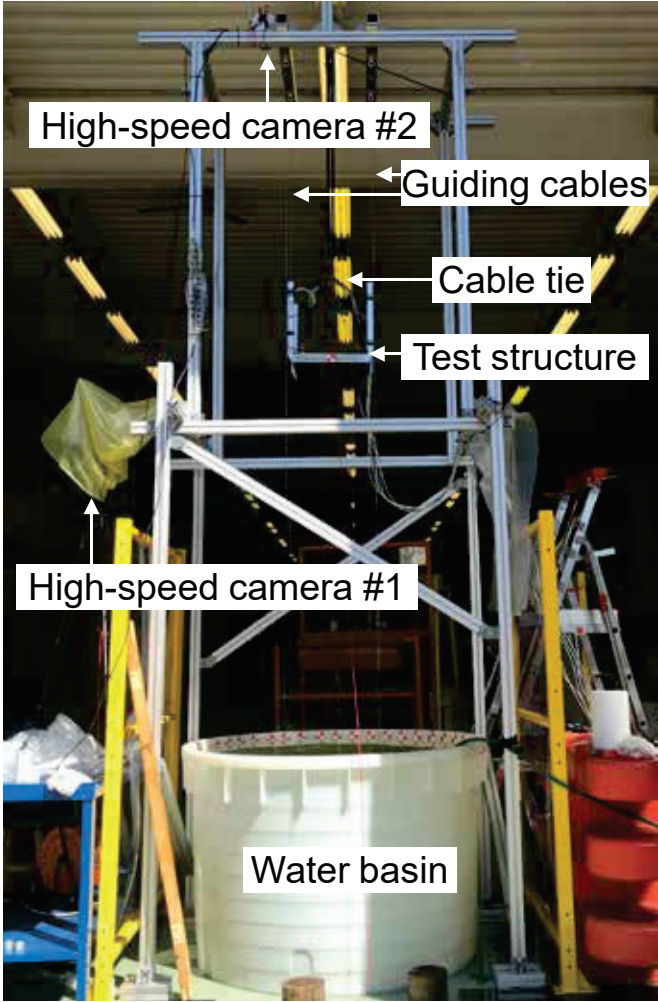


Panel with steel frame

Mechanical properties of steel frame

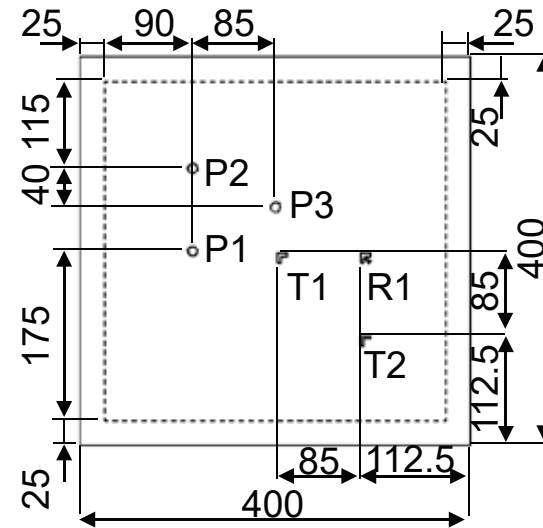
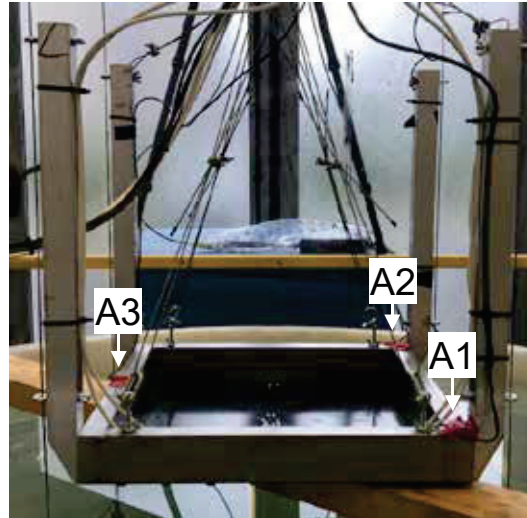
| Material | Density, kg/m ³ | Young's Modulus, GPa |
|-----------------|----------------------------|----------------------|
| Stainless Steel | 7850 | 200 |
| Poisson's Ratio | Height, mm | Weight, kg |
| 0.26 | 50 | 14.35 |

Test Set-up

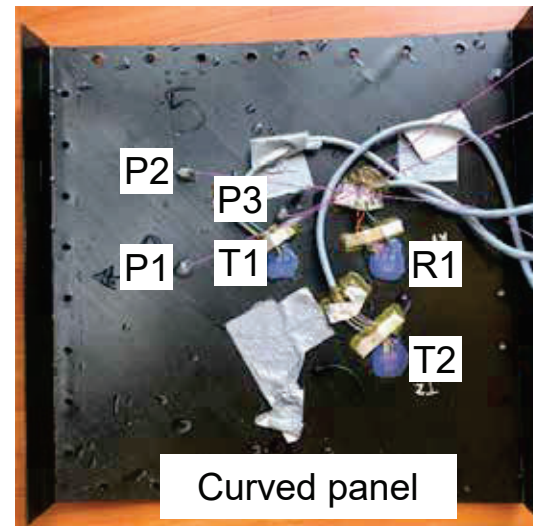
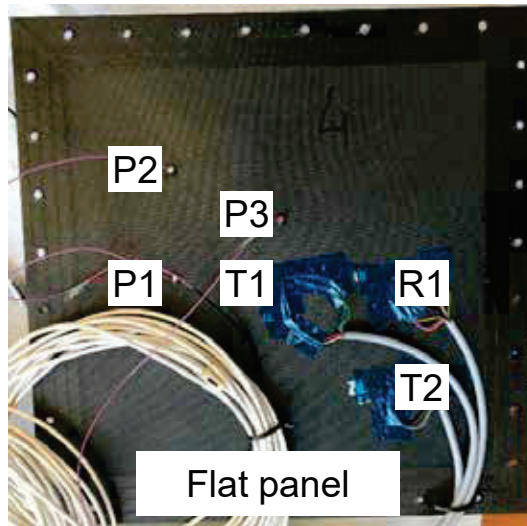


Test Set-up

Accelerometers



Strain gauges
Pressure transducers



Water Impact Test



Water impact of the flat panel
from a 3-meter height



Water Impact Test

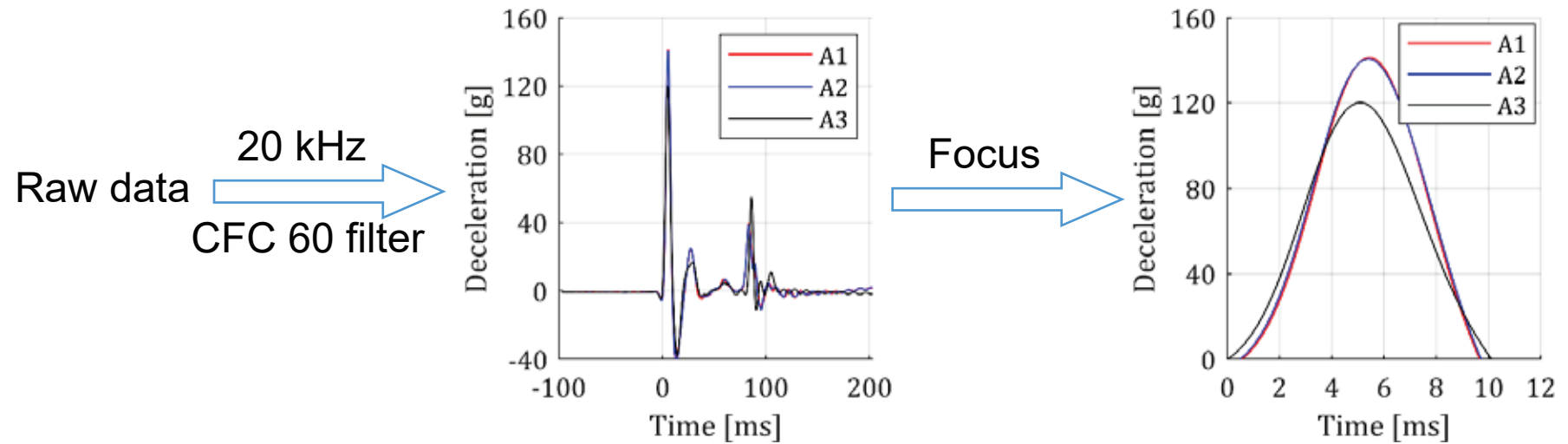




Water Impact Test

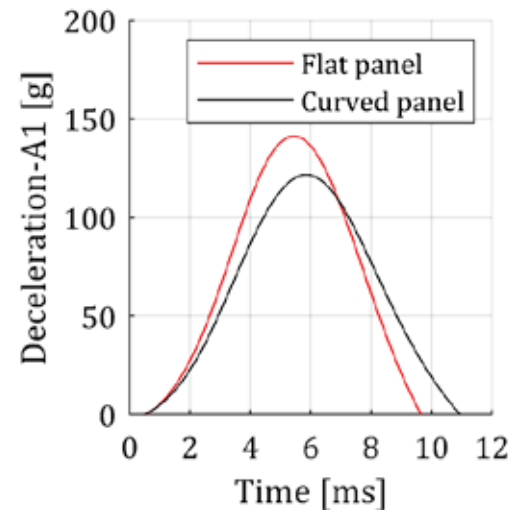
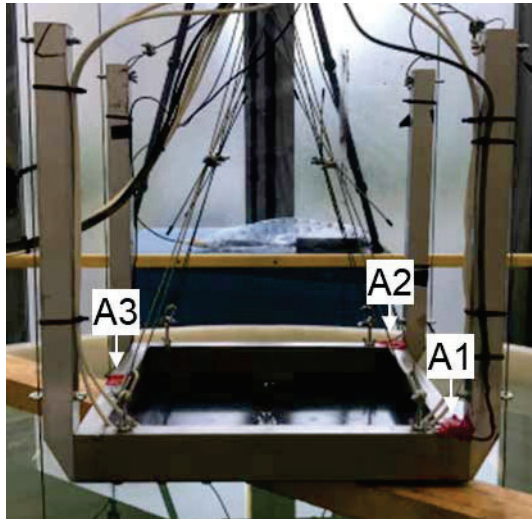


Test Results - Data Processing



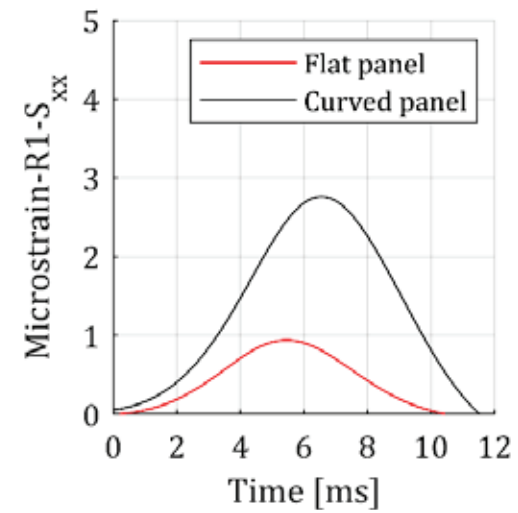
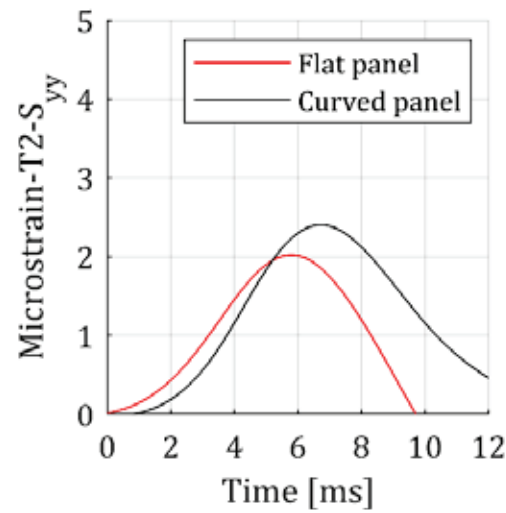
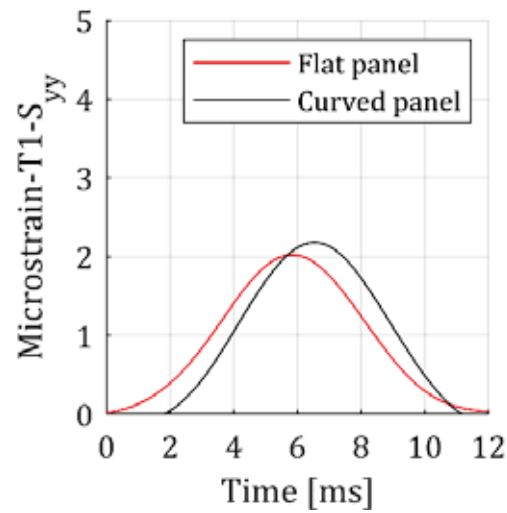
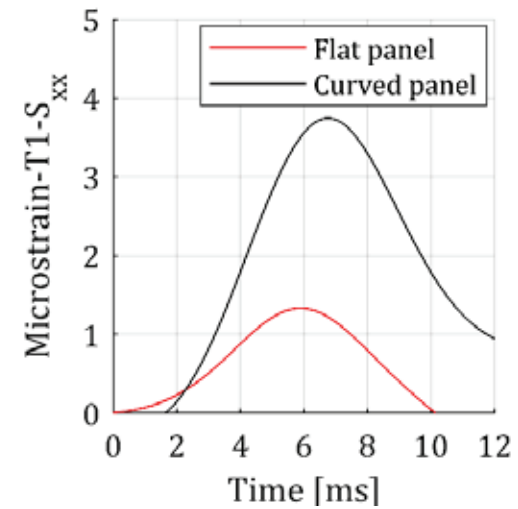
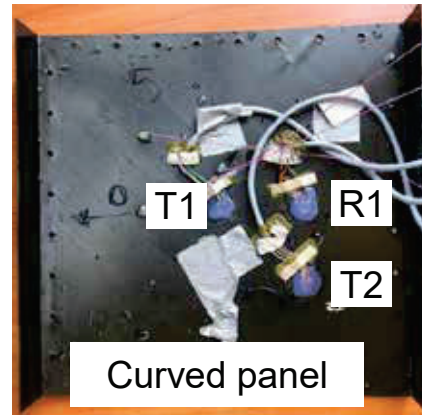
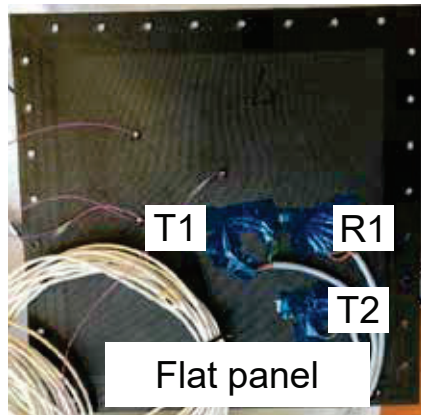
Deceleration curves of the flat panel from a 3-meter height impact

Test Results - Deceleration

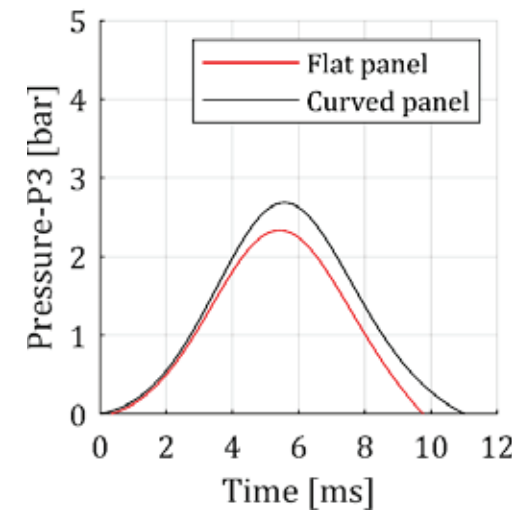
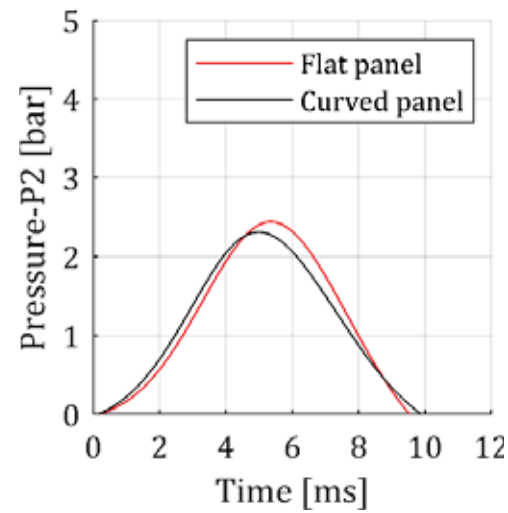
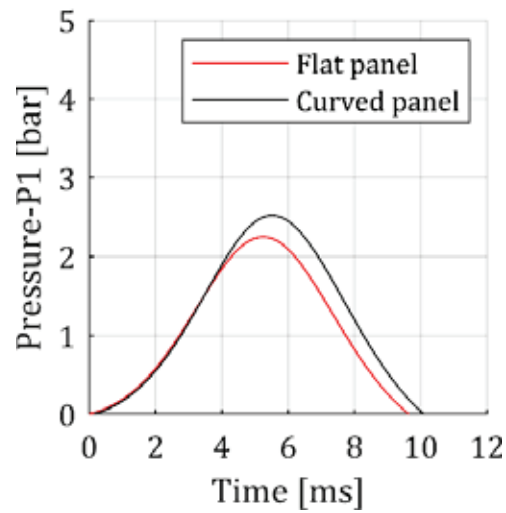
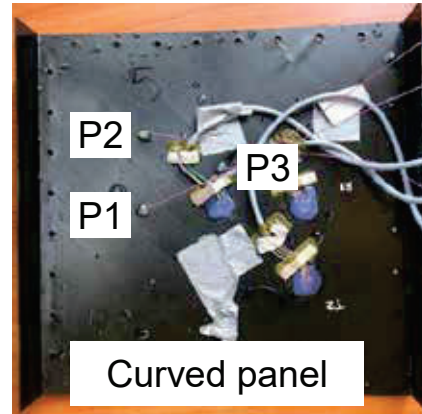
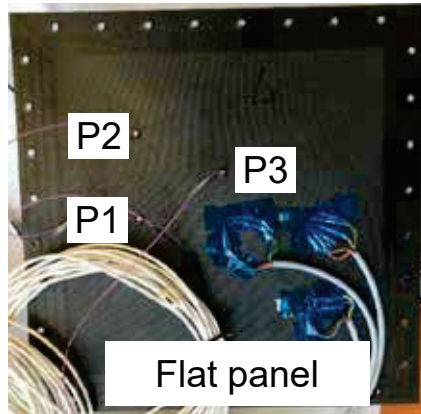


Comparison between flat and curved panels from a 3-meter height impact

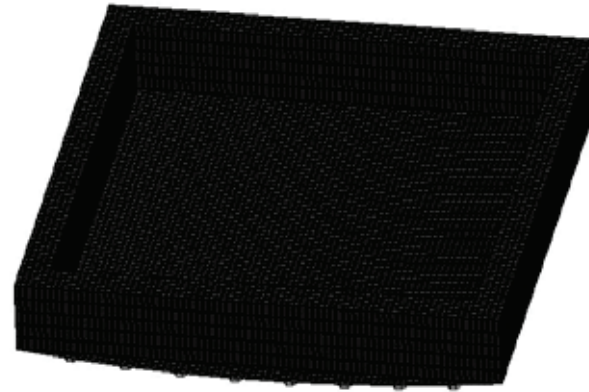
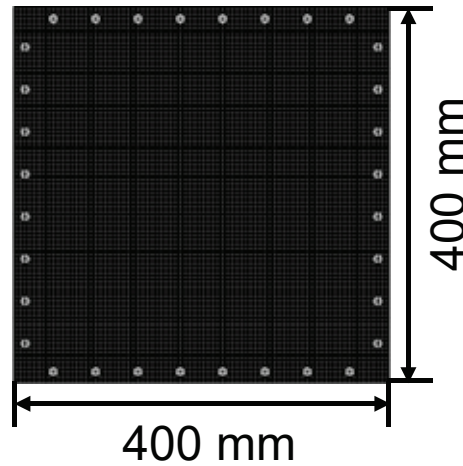
Test Results - Strain



Test Results - Pressure



Numerical Correlation - Finite Element Model

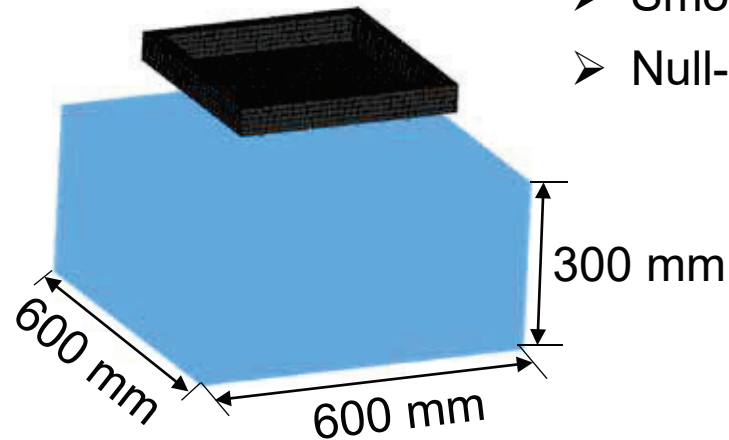


- One layer of shell elements
- 8 integration points
- Mesh size: 5 mm

Numerical model of composite panels in LS-DYNA

| | Elements | | | |
|--------------------|------------|--------------|-------------|-------|
| | Flat panel | Curved panel | Steel frame | Bolts |
| Element Type | Shell | Shell | Solid | Solid |
| Number of Elements | 6400 | 8000 | 7500 | 192 |

Numerical Correlation - Finite Element Model



- Smoothed particle hydrodynamics (SPH) method
- Null-type material coupled with an equation of state

$$P = C_0 + C_1 \epsilon + C_2 \epsilon^2 + C_3 \epsilon^3 + (C_4 + C_5 \epsilon + C_6 \epsilon^2) E, \quad \text{--- 1}$$

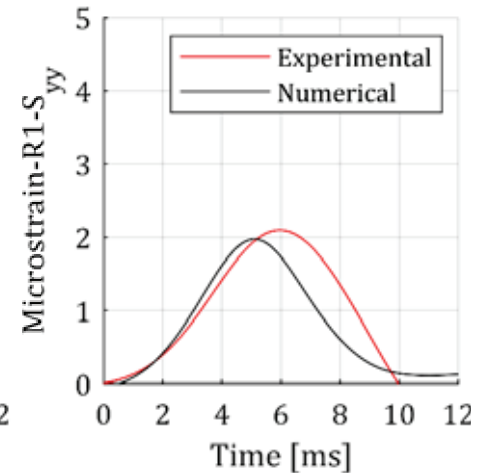
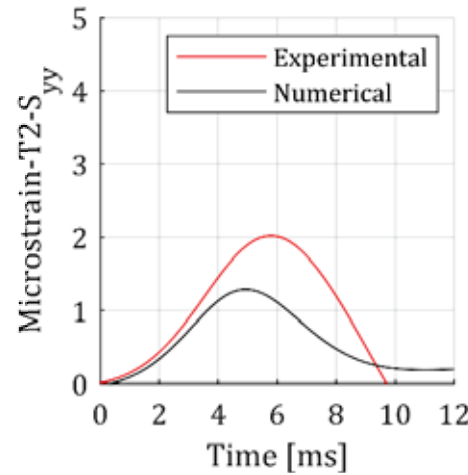
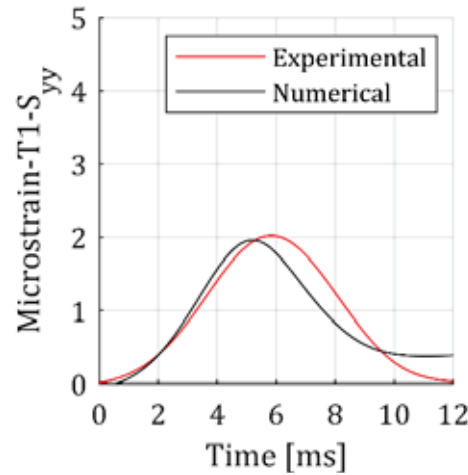
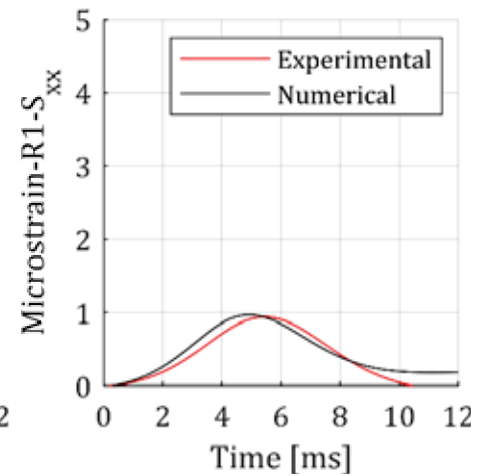
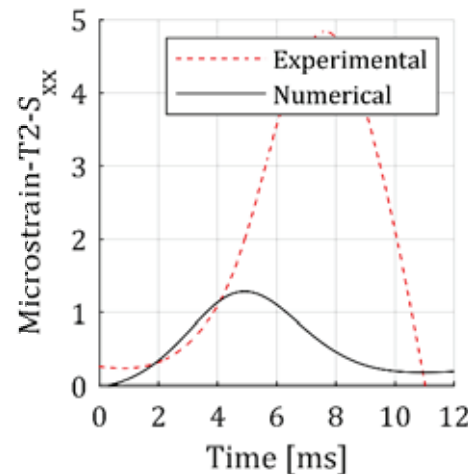
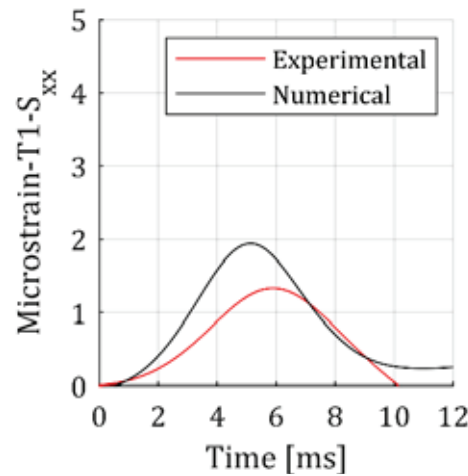
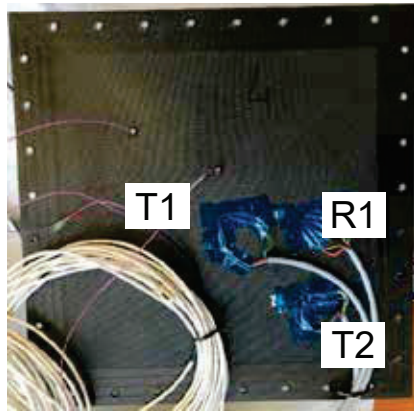
Finite element model in LS-DYNA

Linear polynomial equation of state (EOS)

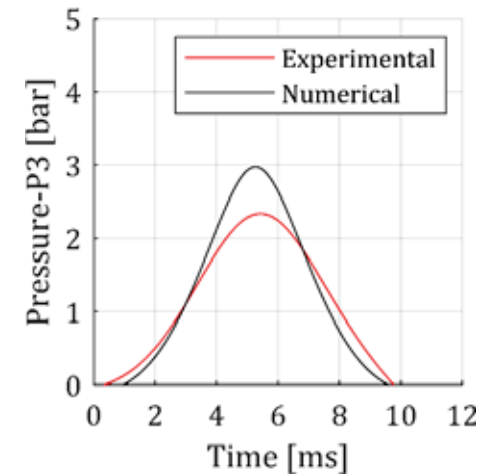
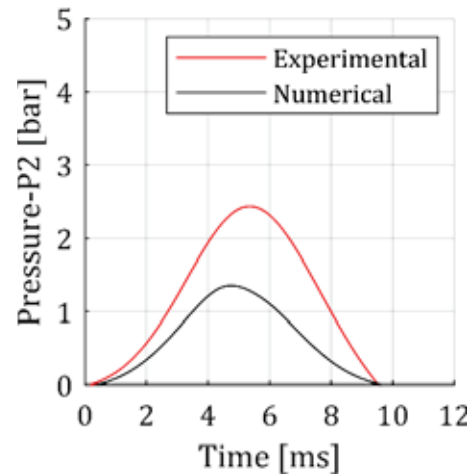
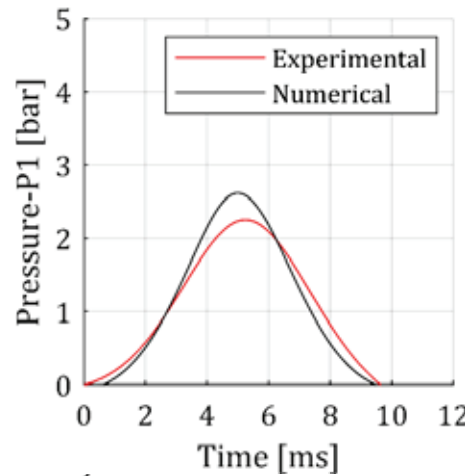
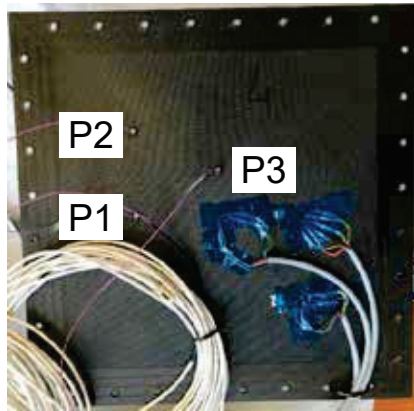
Linear polynomial parameters and SPH particles (Bisagni & Pigazzini, 2017)

| ϵ^3 | C_0 , MPa | C_1 , MPa | C_2 , MPa | Smoothing length |
|--------------|-------------|-------------|-------------|------------------|
| 1000 | 0 | 2723 | 7727 | 5 mm |
| C_3 , MPa | C_4 , MPa | C_5 , MPa | C_6 , MPa | SPH particles |
| 14660 | 0 | 0 | 0 | 1,944,000 |

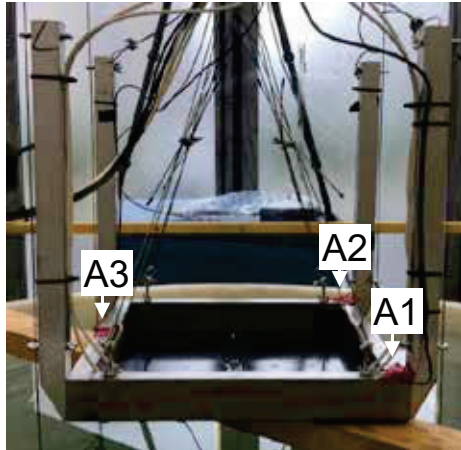
Numerical Correlation - Flat Panel



Numerical Correlation - Flat Panel

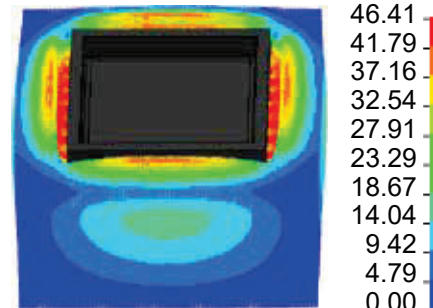
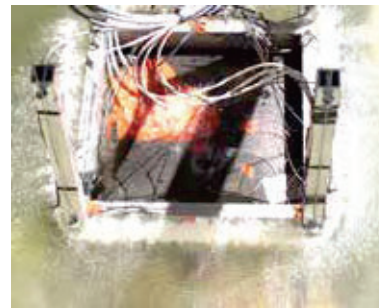


Numerical Correlation - Flat Panel

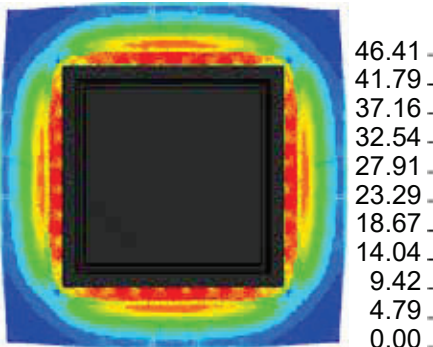
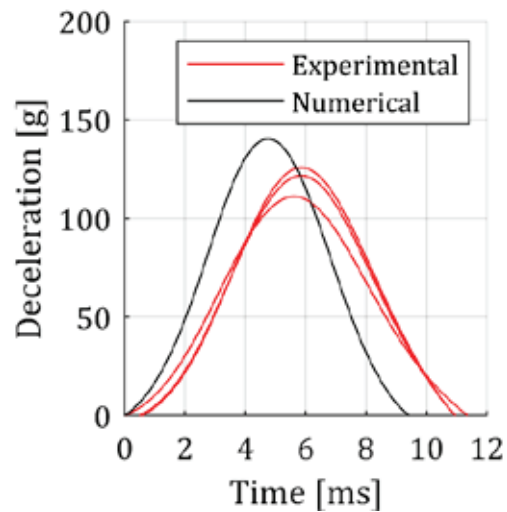


Experimental

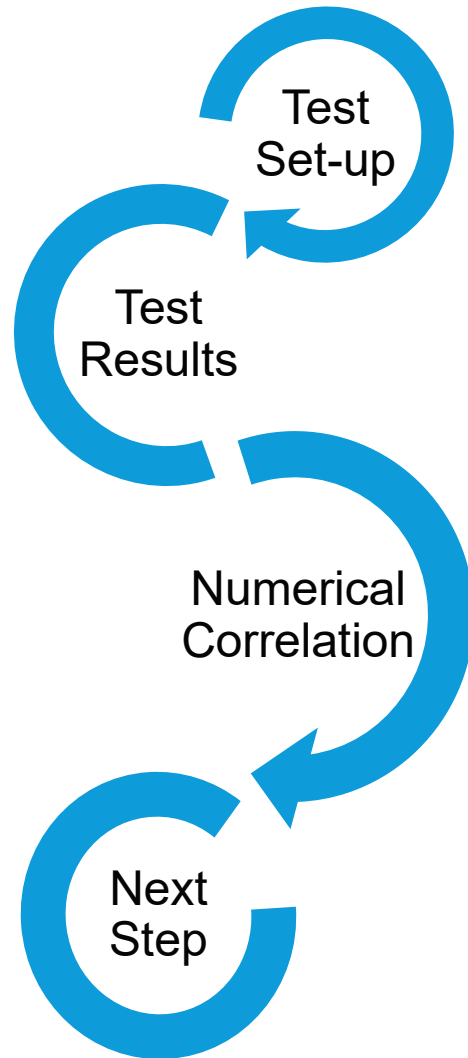
Numerical Displacement (mm)



$T=11.5$ ms



Conclusions



- 3-meter water impact tests with both flat and curved composite panels

- Only focus on the first peak of the curves
- No failure for both panels
- Curved panel has smoother impact process and absorbs more impact energy

- Shell elements for composite panels and SPH particles for fluid domain
- Good prediction regarding flat panel's structural behavior and water flow around the panel
- Boundary conditions and cavitation influence the numerical results

- Contributing to design guidelines towards composite panels under water impact
- Numerical investigation for higher impact velocity
- Cavitation effects



Thank you!