Simulation Tools for Aircraft Ditching

Dr James Campbell

Brunel University London
Smart Aircraft in Emergency Situations (SMAES)

- The focus of SMAES was the development of tools to support the design and entry into service of safer aircraft.
- Two principal research areas:
  - Prediction of the ditching loads for fixed wing aircraft – both analytical and detailed numerical approaches.
  - Predictive aircraft models that incorporate non-linear dynamic structural behaviour, linked or coupled with the hydrodynamic models.
- An extensive experimental campaign supported both these areas.
- Metallic, composite and hybrid composite-metallic structures were studied.

- February 2011 to October 2014 (duration 45 months).
- Total budget 5.73M€, EC funding 3.83M€.

The SMAES project received funding from the European Community's Seventh Framework Programme under grant agreement no FP7–266172
Project Context

- Ditching can be defined as a controlled emergency landing of an aircraft on water. It is assumed that the pilot has sufficient control to perform a landing close to the instructions in the flight manual.
- Phases of ditching

  ![Diagram showing phases of ditching: Approach, Impact, Landing, Floatation](image)

- Key features
  - Ditching generates high hydrodynamic loads on the structure.
  - Due to high speed of fluid flow, effects such as cavitation and ventilation influence both aircraft kinematics and local structural loads.
  - Floatation must be ensured to allow occupant evacuation
- Design consequences of CS25.801
  - Ditching is a design driver for the shape of the aft bottom fuselage and a sizing load case of some structural parts
  - Floatation analysis depends on the ditching analysis
Project Context

• Traditional design practice
  ▪ Experience from previous model tests (fuselage shape, empirical pressure loads)
  ▪ Model tests. Example: Airbus Military CN235

• Numerical analysis
  – Semi-analytical models (von Karman and Wagner theory). For example the ‘Ditch’ code, developed by TUHH, that calculates hydrodynamic forces and pressures for use in structural analysis.

• Predictive numerical tools are required for cost effective introduction of innovative materials and structures that are compliant with safety requirements.
Key Developments

• Prediction of ditching loads:
  ▪ Extension of the semi-analytical Modified Logvinovich Model (established in naval field) to aircraft ditching.
  ▪ Reduced CPU cost for Coupled-Euler-Lagrange (CEL) and Smoothed Particle Hydrodynamics (SPH) fluid models.
  ▪ Improved water physics models in all numerical approaches. In particular: aeration, cavitation and suction.
  ▪ Simulation results show that, correctly used, all fluid models are capable of accurately capturing the structural loads during ditching.
Key Developments

• Aircraft structural models linked to fluid models
  ▪ Integration of the improved fluid models with deformable structural models. Provides capability to analyse both global aircraft behaviour and local structural response.
  ▪ Correlation with experimental data demonstrates that both the SPH and CEL methods allow prediction of local structural deformation.
  ▪ Demonstration of full-scale deformable aircraft models within ditching calculations.
  ▪ Development and demonstration of tools and methodologies developed for ditching analysis within industrial test cases.
Experimental Campaign

• Additional experimental data was required to supplement existing data.
  ▪ New guided water impact facility (INSEAN) developed to allow high-velocity, low angle water impact experiments. Model scale tests do not capture key aspects of flow behaviour.
  ▪ Capability $V_x$ 30-45 m/s, $V_z$ 1.5 m/s
    1.0m x 0.5m specimen
  ▪ 47 tests on flat & curved thick plates
  ▪ 17 tests on metallic and composite deformable plates
  ▪ 2 tests on stiffened panel component

• Material and structural characterisation experiments to support the two industrial demonstration cases.
Experimental Campaign

• Additional experimental data was required to supplement existing data.
  ▪ New guided water impact facility (INSEAN) developed to allow high-velocity, low angle water impact experiments. Model scale tests do not capture key aspects of flow behaviour.
  ▪ Capability \( V_x \ 30-45 \text{ m/s}, \ V_z \ 1.5 \text{ m/s} \)
    1.0m x 0.5m specimen
  ▪ 47 tests on flat & curved thick plates
  ▪ 17 tests on metallic and composite deformable plates
  ▪ 2 tests on stiffened panel component

• Material and structural characterisation experiments to support the two industrial demonstration cases.
Experimental Campaign

- Additional experimental data was required to supplement existing data.
  - New guided water impact facility (INSEAN) developed to allow high-velocity, low angle water impact experiments. Model scale tests do not capture key aspects of flow behaviour.
    - Capability \(V_x\) 30-45 m/s, \(V_z\) 1.5 m/s
      - 1.0m x 0.5m specimen
    - 47 tests on flat & curved thick plates
    - 17 tests on metallic and composite deformable plates
    - 2 tests on stiffened panel component

- Material and structural characterisation experiments to support the two industrial demonstration cases.
Experimental Campaign

$V_x \ 40 \ m/s, \ V_z \ 1.5 \ m/s, \ 10^\circ \ plate \ pitch$

Thick plate specimen

Test conditions designed to cause failure

Structural component (underwater view)
Validation and Demonstration

- Thick plate simulations
Validation and Demonstration

• Deformable plate simulations
Validation and Demonstration

Additional test cases included:

- Airbus Military CN235, based on model ditching experiments

- A321 ditching study originally used as a test case in the FP5 CRAHVI project
  - ONERA (RADIOSS) – SPH & CEL
  - DLR (PAMCRASH) - SPH
Industrial Demonstration Cases

- **Alenia**
  - **Context** – use of composite fuselages in future aircraft designs
  - **Structure** – composite regional aircraft fuselage concept
  - **Objective** – demonstration of a multi-scale modelling methodology supported by drop tests on simple structural elements
  - **Methodology** includes material characterisation experiments and impact tests on structural elements at CIRA.
Industrial Demonstration Cases

• Dassault Aviation
  - Context - new aft fuselage concepts are emerging on future business jet studies
  - Structure - Hybrid metallic-composite.
  - Objective – demonstration of methodology combining FE whole aircraft model and semi-analytical hydrodynamic loads model along with detailed local structural and fluid models.
  - Methodology includes material characterisation experiments and impact tests on structural elements at ONERA.
Key Achievements

• The key achievements of are:
  § Completion of extensive experimental programme providing novel test data to support future development of ditching analysis methods.
  § Improved numerical tools suitable for predicting the global behaviour of an aircraft during a water impact within a reasonable CPU cost.
  § Improved numerical tools providing a significant step forward for matching local ditching pressures and strains for prediction of local structural response.
  § Demonstration that numerical tools can support the development cycle of an aircraft from early pre-design studies, through design and detailed sizing to final testing.