FLIRET-Flight Reynolds Number Testing in the Cryogenic Facility ETW
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What is Flight Reynolds Number Testing?

“Experimental Simulation of the Aircraft which is to be designed”

Basis for the simulation are - for CFD as well as for the wind tunnel -
- (Unsteady) Navier-Stokes Equations for compressible media (and theory of similarity, no heat sources, no gravity, no external forces etc.)
- Continuity equation
- Ideal gas, isentropic law
(Identical initial and boundary conditions)

The 5 unknowns are:
• $U^*, V^*, W^* (x^*, y^*, z^*, t^*)$ dimensionless velocity components, divided by respective reference quantities
• $P^*(x^*, y^*, z^*, t^*)$ and $\rho^* (x^*, y^*, z^*, t^*)$ dimensionless pressure, length, time and density, divided by respective reference quantities
What is Flight Reynolds Number Testing?

Governing differential equations:
All dimensionless solutions of compressible NS-equations, ideal gas law and conservation of mass, can be rewritten as:

\[ U^*, V^*, W^*, p^*, \rho^* = f_{1,2,3,4,5}(Re, Ma, geometry^*, Sr) \]

* dimensionless quantities

• We get similar solutions for the dimensionless quantities if the geometry, Mach, Reynolds (and Strouhal number) are equal and the initial and boundary conditions as well.

• Consequently, the dimensionless force and moment coefficients are equal.

• Conventional wind tunnels: Compromises are needed because both the Ma and Re cannot be realised in the WT (model scale <1) as for the Aircraft.

Exception: cryogenic WT’s. Mach and Reynolds number can be selected independently of each other (inside of technical limits)
What is Flight Reynolds Number Testing?

Adjustment of Reynolds number by pressure and temperature of the fluid.
Problems to be considered in FLIRET

To take benefit of the high Reynolds number similarity and the increased accuracy in comparison to the flying aircraft:

1. Very accurate Wind Tunnel corrections are needed
2. Low surface roughness requested
3. Careful optimisations of model supports are needed to keep the model-support corrections small and correctable (near field corrections)
4. Model vibrations can occur. Damping devices exist but it is necessary to remove the vibrations at the “root” i.e. where they come from
Problems to be considered in FLIRET

Half Model Testing

• Interactions of (thin) wind tunnel boundary layer with the half model (peniche, half fuselage and inboard wing)

• Limitations for half model testing in comparison to a complete model
Main Objectives in FLIRET

Main Objectives in FLIRET

- Contributions for Half Model and Complete Model Testing, including supports and unsteady flow phenomena occurring during cryogenic testing (buffeting, vibrations)
- No need to design wings for lower Reynolds numbers because of the constraints of conventional wind tunnels
- Main objective to make ETW ready for industrial Wind Tunnel Testing (including the needed high accuracy!)
- Combine advanced CFD Tools and Wind Tunnel Testing for an effective application of cryogenic testing
- Harmonisation of activities of most important European ETW users and R&T facilities
- Considerable reduction of Aircraft development costs by application of Flight Reynolds Number Testing under cryogenic conditions
- Optimised, low interference supports have a large potential for the future industrial use of cryogenic facilities
Working Structure of FLIRET

**FLIRET Coordinator A - D**

**WP 1** Dassault
Advanced Model Supports

**WP 2** A-F
Buffet Onset at Flight Re
Model vibrations

**WP 3** DLR
High Lift at Flight Re

**WP 4** A-D
Analysis & Integration

**WP 5** A-D
Management with ETW

- **T 1.1** Low interference model supports
- **T 1.2** Supports for rear end measurements
- **T 1.3** Comparison CFD vs test; recommendations
- **WP 2 A-F**
  - **T 2.1** Effect of Re on buffet onset
  - **T 2.2** Model vibrations
  - **T 2.3** ETW testing
  - **T 2.4** Comparison CFD-Exp. vs. flight Re results; recommendations
- **WP 3 DLR**
  - **T 3.1** Surface Roughness & transition effects on CLmax
  - **T 3.2** Half-model mounting effects on flow characteristics
- **WP 4 A-D**
  - **T 4.1** Integration of CFD & Prediction tools
  - **T 4.2** Integration & analysis of test result
  - **T 4.3** Model & manufacturing strategy
  - **T 4.4** Recommendations for testing at flight Re numbers
## Partners in FLIRET

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**FLIRET:**

- **Start**: 1st February 2005
- **End**: 31st January 2008
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