Technological efforts for future rotorcraft

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OUTLINE

● Past, Present and Future of Rotorcraft
● Motivations behind our rotorcraft activities
● Recent R&T activities dedicated to rotorcraft
  ✷ Aerodynamics
  ✷ Aeroacoustics
  ✷ Active Rotor Technologies
  ✷ Icing Wind Tunnel
Challenges to be tackled for Future Rotorcraft

- Increasing global demand for a smart air mobility and transport system: more flexible, resilient, effective, affordable

- Rotorcraft operations, such as medical evacuation, rescue, civil protection, aerial work and law enforcement, are expected to grow sharply in the future to face the European citizen’s demand for a safer and more secure society;

- Rotorcraft traffic for passenger transport is expected to develop rapidly as it is driven by the large growth in passenger air travel demand that is foreseen for the future

- This growth in demand goes in parallel with the requirement to guarantee the sufficient environmental compatibility

- The market expectations seem to call for more speed and longer range in several segments such as passenger transport, emergency, search and rescue. Innovative rotorcraft configurations can achieve these objectives more easily than the conventional helicopter.
V/STOL Aircraft and Propulsion Concepts

V/STOL Ellipse

- Augmented Power Plant for Hover
- Same Propulsion System for Hover and Forward Flight
- Combined Power Plant for Hover
- Lift + Cruise
- Tilt Jet
- Deflected Slipstream
- Tilt Wing
- Tilt Prop
- Tilt Duct
- Tilt Shaft Rotor

Selected ENGLISH

Legend:
- Production
- Demo extensively tested

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Fast Rotorcraft Concepts

Sikorsky/Boeing SB-1
Bell V-280 Valor
Airbus Helicopters X3 (2010)
AgustaWestland NextGen TiltRotor
What motivates CIRA rotorcraft activities

- Maintain highest level of know-how
- Support AgustaWestland’s RTD efforts
- Participate in the evolution from the *classical* helicopter toward advanced rotorcraft configurations
CIRA Rotorcraft R&T Activities

- Industrial Development
- Industrial Research
- Applied Research
- Basic Research
- Upstream Research

Volume of Resources vs. TRL (Technology Readiness Level)

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Recent R&T activities dedicated to rotorcraft

- **Aerodynamics / Design Optimization**
  - Rotor Blade for extended natural laminar flow in forward flight
  - Blade Planform Optimization for a Dual Speed Rotor Concept
  - Helicopter tail plane optimization
  - Fuselage drag reduction through Active Flow Control systems

- **Aeroacoustics**
  - Tilt-Rotor noise impact assessment
  - Environment friendly rotorcraft flight path
  - Community noise simulation in an urban environment

- **Active Rotor Technologies**
  - Active Gurney Flap Rotor Concept

- **Icing Wind Tunnel**
Rotor Blade optimization for extended natural laminar flow in forward flight

• An example of CIRA competences in airfoil design optimization (well consolidated for fixed-wing) applied to a rotor blade design process.

• The activity was performed within Clean Sky JTI Green Rotorcraft ITD, GRC1 “Innovative Rotor Blades” project, for the development of “passive” technologies to reduce rotor power.

• Flow laminarity is a means for reducing the total power required by a rotor although the promotion of flow laminarity on a helicopter rotor is an extremely challenging task.
Rotor Blade optimization for extended natural laminar flow in forward flight (cont.)

- **Design Constraints:**
  - Geometrical: leading edge radius and airfoil thickness
  - Aerodynamic: limits to the negative Cm

- **Design Variables:**
  - 64 shape modes for each airfoil

- **Design Points:**
  - 8 spanwise airfoil locations and 7 azimuthal locations.

- **Design Objectives:**
  - Single-Objective / Multiple-Objective Genetic Algorithm optimizations;
  - Target: Quadratic penalties introduced at each design point if local drag coefficient is increased by more than 3% (wrt baseline value);
  - Explicit satisfaction of maximum thickness constraint via airfoil scaling after any shape modification.
Rotor Blade optimization for extended natural laminar flow in forward flight (cont.)

The Design Loop

MOGA Optimization

Drag reduction

Optimized airfoils
Blade Planform Optimization for a Dual Speed Rotor Concept

- Study of a DSR for the power reduction and noise abatement of a medium-size helicopter rotor (100%RPM-90%RPM)
- Multi-disciplinary, multi-objective design optimization procedure
- Optimization of the blade planform by varying sectional chord, local sweep angle and local twist angle in 5 radial station and 4 flight conditions
- Tools: FlightLab© + OptydB (in house FW-H) + a Fast Rotor Noise (FRN) model

\[
\begin{align*}
OBJ_1 &= \pi_1 P_1 + \pi_2 P_2 + \pi_3 P_3 + \pi_4 P_4 \\
OBJ_2 &= v_1 SPL_1 + v_2 SPL_2 + v_3 SPL_3 + v_4 SPL_4
\end{align*}
\]
Helicopter tail plane optimization by taking into account rotor wake effect

- Airfoil and planform design
- Use of genetic algorithm
- An important drag reduction has been obtained
  - The drag reduction is more evident when the rotor is taken into account
  - About 11% rotorcraft drag reduction in cruise condition was obtained
Fuselage drag reduction through Active Flow Control systems

- Helicopter fuselage drag reduction
- Flow control devices (unsteady blowing, SJ) simulation and test
- Small and medium scale WT test
- CFD simulation (URANS and DES)
- WT test are in progress and will be used both for CFD validation and flow control device effectiveness assessment
Tilt-Rotor noise impact assessment

Development of a numerical noise characterization of the ERICA Tilt Rotor configuration:

- To study and to evaluate the integration of the tilt-rotor in the context of the European Air Traffic Management System
- To develop a procedure for evaluating the noise emitted by a tilt-rotor during a complete operation, including take off and landing, by mean of the FAA’s INM and/or HELENA computational tool.
- Proprotor-Wing-Fuselage Interactional Aerodynamic Effects
- HELENA noise hemisphere database to allow the representation of a generic flight procedure
Environment friendly rotorcraft flight path

Design of a Low Noise Algorithm (LNA) for the autonomous on-line generation (tactical planning) and tracking of environment friendly rotorcraft flight path

- Development of a Fast Noise Numerical Tool for the on-ground noise prediction (Fast Rotor Noise model, Generic Helicopter Acoustic Database, Environmental Noise Analysis model)
- Development of the algorithm for the optimal trajectory real-time on-line generation taking into account performance and procedural constraints
Community noise simulation in an urban environment

One of the emerging problems in helicopter operations in urban areas is the prediction of the noise impact on buildings and its indoor transmission.

It is well recognized that low frequency and impulsive noise has a higher psychological impact on the majority of the population compared with higher frequency noise of equal loudness.

HENCE

It is important to predict the near-field fuselage noise scattering effects and the far-field wave reflections due to buildings.

The coupled FW-H/FEM model requires that the noise generated by the rotor be computed at all points on the fuselage and on the chimera interface.
Community noise simulation in an urban environment

Noise print on a set of buildings.
Active Gurney Flap for Dynamic Stall alleviation

Dynamic stall is a complex non-linear unsteady aerodynamic phenomenon. It can lead to violent vibrations and dangerously high loads and it can determine performance and operational limits of helicopters.
Active Gurney Flap for Dynamic Stall alleviation (cont.)

- AGF 2D unsteady aerodynamic design
- AGF control law design for the reduction of power, control loads and vibration while preserving rotorcraft handling qualities.
- Wind Tunnel test campaign of an oscillating blade section equipped with an AGF
Active Gurney Flap for Dynamic Stall alleviation (cont.)

A Pitching Oscillating System was designed and manufactured to characterize the AGF concept in WT. The oscillating device, the test article and the AGF system as well as the WT setup were defined considering technical parameters (Blade size, rotor speed, Mach and Reynolds numbers) of a medium-size helicopter (NH-90 like).
Active Gurney Flap for Dynamic Stall alleviation (cont.)
IWT—ICING WIND TUNNEL

• **Goal:** Simulate the flight conditions requested for ice certification.

• **Use:** Test ice protection systems and ice accretion effects on flight safety

• **Operational** since 2003

• **Max speed:** Mach 0.7

• **Max test duration:** 4 hours

• **3 Test Sections:** 2.35x1.15m - 2.35x2.25m - 2.35x3.60 m

• **Calibration** according to international standard (SAEARP5905)
NH90 Air Intake T700/T6E1 Icing Qualification Tests, IWT, 2003

NH90 Main Rotor Blade Icing Qualification Tests, IWT, 2004

ALH-02 - Variable Speed Hydro Drive Tail Rotor, IWT, 2007

MJ615 – Research project aimed at investigating the Main Rotor Blade electrical deicing system performance, IWT, 2011

Inlet icing certification tests for non-European helicopter manufacturer, IWT, 2012

MJ392 – Research project aimed at investigating the Main and Tail Rotor Blades electrical deicing system performance, IWT, 2013
End of the long march?