State of the art – Background

The investigation on active control technologies in rotorcraft environment is currently one of the major research topics in the fields of aerodynamics and aerospace structures due to the strong demand to reduce the power consumption whilst preserving flight performance.

In a recently envisaged morphing technique, named Variable Droop Leading Edge (VDLE), a dynamically deforming leading edge control is employed to improve rotor blade performance by optimizing the blade airfoil shape. In this technique, however, a significant portion of the section lift is lost due to the leading edge deformation.

This drawback can be overcome by actively controlling Gurney flap (AGF) deployment in the appropriate portion of the rotor disk. It is only very recently that the aerodynamic performance of such devices has been investigated numerically in two- and three-dimensional configurations and experimentally in two dimensions. AGFs have never been tested on a rotor. This is the baseline where the project starts.

Objectives

The main objective of the present project is to measure the performance of a helicopter main-rotor model with an AGF integrated in each blade. The goal will be achieved by means of a comprehensive wind tunnel test campaign carried out in the Wind Tunnel of Politecnico di Milano.

In order to improve the insight into the effects of the AGFs the test campaign will involve the use of Particle Image Velocimetry (PIV) to measure the velocity field and to evaluate the pressure distribution around the blade. The derivation of a pressure field from PIV data is a very attractive technique that has been recently proposed for time-varying flow applications. This method represents a non-invasive pressure field measurement to be used in applications where traditional methods such as probes and pressure ports present some difficulties, for instance in terms of integration in the rotor blade model. Therefore, a complementary objective will be the development and the accuracy evaluation of a technique aimed to obtain the pressure distribution on the rotor blade section starting from PIV velocity data.

Description of work

In order to get a good insight into the aerodynamic phenomena related to the functioning of the AGF, an advanced testing approach will be adopted, where PIV surveys will be used to obtain the pressure distribution on the AGF blade section, both in advancing and retreating condition.

The adopted methodology will be first validated by means of 2D tests, carried out in a dedicated facility on a pitching blade section model equipped with unsteady pressure transducers that will allow a comparison between direct measurements and indirect reconstruction of the pressure distributions.

The AGF rotor model wind tunnel test activity will consists in the measurement of the PIV data necessary to reconstruct the pressure distribution over the upper and lower surface of the blade airfoil on the advancing and retreating side of the rotor.

The wind tunnel campaign will include Shake Down tests over a range of rotor rotational speeds, hover performance tests with steady deflections of the Gurney Flaps and Forward Flight Performance tests with actively controlled Gurney Flaps. The data acquisition will include the PIV images for all the test cases as well as the wind tunnel parameters (wind speed, air temperature and density, wind tunnel static and dynamic pressure).
Current achievements

In the frame of WP2, an innovative procedure for reconstructing the pressure field from PIV data was developed for the application on unsteady incompressible flow fields. The developed technique is based on a generalization of the Glowinski-Pironneau method for the uncoupled solution of the incompressible Navier-Stokes equations written with primitive variables. The underlying mathematical formulation allows indeed to overcome some of the drawbacks that influence the techniques proposed so far in the literature, such as the use of ad-hoc boundary conditions for the pressure and insufficient robustness with respect to measurement errors. The problem is discretized by Taylor-Hood finite elements and a Fortran90 solver is developed. The robustness of the method with respect to the error in the velocity measurements was investigated for both stochastic and deterministic perturbations. The technique was successfully applied to the PIV database obtained by means of a dedicated test campaign carried out to survey the flow field around a pitching blade in dynamic stall conditions. The computed pressure was compared with direct pressure measurements carried out by means of fast-response pressure transducers installed on the pitching blade mid-span section contour. The pressure comparison shows very encouraging result both at the leading edge region characterized by a strong curvature and at the trailing edge where flow separation occurs.

Unsteady case, $\alpha = 10^\circ$ downstroke, Leading edge: Reconstructed pressure field

Unsteady case, $\alpha = 10^\circ$ downstroke, Trailing edge: Reconstructed pressure field

Expected results

a) Timeline & main milestones

MS1: Web-site ready M2
MS2: 1st six-monthly meeting with GRC1 M6
MS3: Test Plan Established M6
MS4: 2nd six-monthly meeting with GRC1 M12
MS5: 3rd six-monthly meeting with GRC1 M18
MS6: Innovative Test Tech. Assessed M18
MS7: 4th six-monthly meeting with GRC1 M24
MS8: 5th six-monthly meeting with GRC1 M30
MS9: Start of Testing M33
MS10: Completion of 1st WT Entry M34
MS11: Completion of Testing M35
MS12: 6th six-monthly meeting with GRC1 M36

b) Environmental benefits

Less noisy rotor, more efficient rotorcraft, less engine power requirement, less fuel burn, less emission, less pollution.

c) Maturity of works performed

GUM aims to reach TRL4 by the end of the project. Currently, TRL 2 is reached for actively operated AGF.
Project Summary

Acronym: GUM

Name of proposal: Gurney flap actuator and mechanism for a full scale helicopter rotor blade

Technical domain: Mechanical Actuators

Involved ITD: Green Rotorcraft

Innovative blade devices

Grant Agreement: 298192

Instrument: Clean Sky

Total Cost: 455 401€

Clean Sky contribution: 341 550€

Call: SP1-JTI-CS-2011-02

Starting date: The first day of the month after the signature by the Commission

Ending date: 38 months after start

Duration: 38 months

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