CS-GA-2013-619627 COMROTAG

Development and Testing of Computational Methods to Simulate Helicopter Rotors with Active Gurney Flap

State of the art – Background

The kinematics of Active Gurney Flap (AGF) consists in continuous, harmonic vertical motion achieved through a mechanism mounted inside the helicopter blade. The physical phenomena generated by the presence of Gurney flap consist in deflecting the air stream behind the profile downwards, leading to the generation of additional lift. The flow details involve the appearance of separation bubble upstream of the Gurney flap and the appearance of two vortices of opposite sign just behind the flap. Because of the harmonic oscillations of blade and the AGF the flow is strongly unsteady with vortex shedding from the flap edge which affects the pressure distribution on the blade. Because of different geometric scales of the phenomena involved – vortex shedding from the flap of height of several millimetres and the motion of the rotor of diameter of 10 and more meters this task is very demanding for computational resources. The computational methods have to simulate the phenomena in all geometric and time scales. Currently the state of the art in the computational methods consists in the application of Reynolds-Averaged Navier-Stokes equations for the modelling of the flow with different approaches for the representation of computational space (CHIMERA or structured, multi-block mesh).

Objectives

The objectives of the project are to develop the computational method capable of modelling the flow phenomena in all important geometry and time scales and to use this method to simulate the flow in a number of cases corresponding to the wind tunnel experiments conducted in parallel. The computational cases include two-dimensional cases in wind tunnel walls, three-dimensional cases of model-rotor in wind-tunnel and three-dimensional cases of full-scale rotor on whirl tower and in forward flight. The collected results will be used for the assessment of the capabilities of the computational methods and for the assessment of the expected benefits from the application of the AGF on a full-scale rotor, where it is expected to enable decreasing rotational speed and improve lift balance between advancing and retreating rotor blades.

Description of work

In order to fulfil the project objectives the rotor model developed by the Institute of Aviation, Warsaw, called “Virtual Rotor” is being enhanced to model the kinematics of AGF. The model is using structured multi-block, sliding mesh of kinematics representing the rotation, flapping, yawing and pitching motion of the blades. It was implemented as a module of User-Defined Functions in the ANSYS Fluent solver. In order to model the kinematics of AGF a special method of redefining of the geometry of the blade surface and the computational mesh was developed, which is based on mathematical transformation of surface and space. The method controls the rearrangement of mesh nodes on the surface of the blade and in the mesh block surrounding it in such a way that the process is automatic, reversible and does not lead to excessive distortion of the mesh cells, which is very important for the quality of the results. The work packages are designed in such a way that the modelling starts from simple, two-dimensional cases leading progressively to the forward-flight full-scale modelling.

In Work Package 1 the work is oriented towards the modification of the source code. The capability of modelling of AGF is first introduced into the two-dimensional version of the code and next into the three-dimensional version. This work package is extended towards the end of the project in order to introduce into the code any modifications arising from needs encountered during the progress of the project.

In Work Package 2 two dimensional test cases are simulated. They include low speed cases of Mach 0.2 with static angle of attack and dynamic movement of AGF and near full-scale tests with Mach 0.6 and static and dynamic angles of attack and AGF movement. Effects of different turbulence models will be investigated and compared with the results of wind-tunnel investigations in order to find best approaches for modelling full-scale cases.

In Work Package 3 three-dimensional cases will be simulated. They include cases of model-rotor in wind tunnel, full-scale rotor on whirl tower and full-scale forward flight. The results will be used for the assessment of benefits from the application of AGF on helicopter rotors.

Expected results

a) Timeline & main milestones

The expected results of the project include the calibrated methods of modelling of AGF on helicopter rotors capable of application as engineering tool in rotor design. The milestones include achievement of capabilities of modelling two-dimensional cases, three-dimensional cases and completion of simulation runs of the prescribed number of two- and three-dimensional cases including blind tests of full-scale forward flight cases.

b) Environmental benefits

Possible environmental benefits include positive effects of reducing rotor rotational speed. Potentially this may lead to the reduction of power required and noise generated by the blade tips

c) Maturity of works performed

The two-dimensional version of the code "Virtual Rotor" as well as the 2.5D version capable of modelling AGF kinematics on finite-span, constant chord blade segment have already been developed. The work is currently being concentrated on the development of fully three-dimensional version of the code and on simulation of the two-dimensional test cases. The "Virtual Rotor" is a highly efficient engineering tool, as it operates as an add-on module to the widely used commercial flow solver Fluent. This means that this modelling method of AGF will not only be tested and calibrated in the current project, but it will also benefit from future development of the flow solver

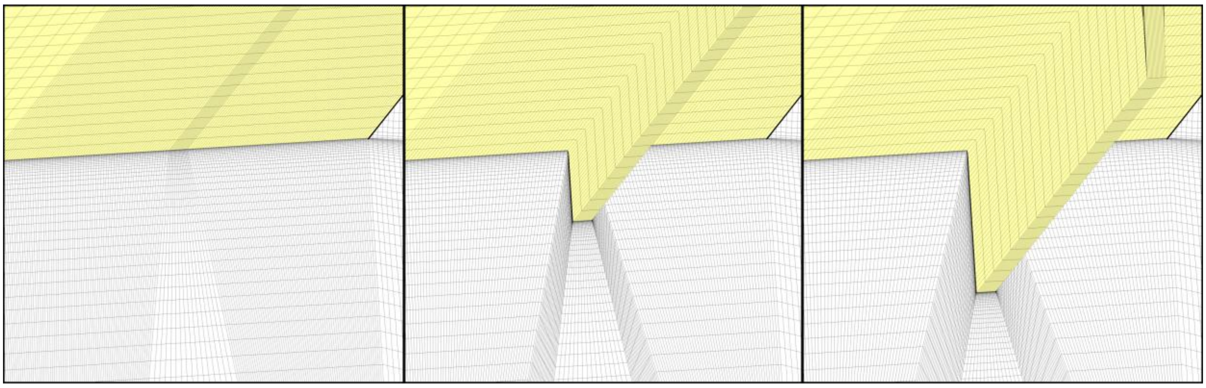

Figure 1. Developed innovative technique of dynamic deformations of fully structural computational mesh in the region of rotor-blade trailing edge and periodically deployed Active Gurney Flap.

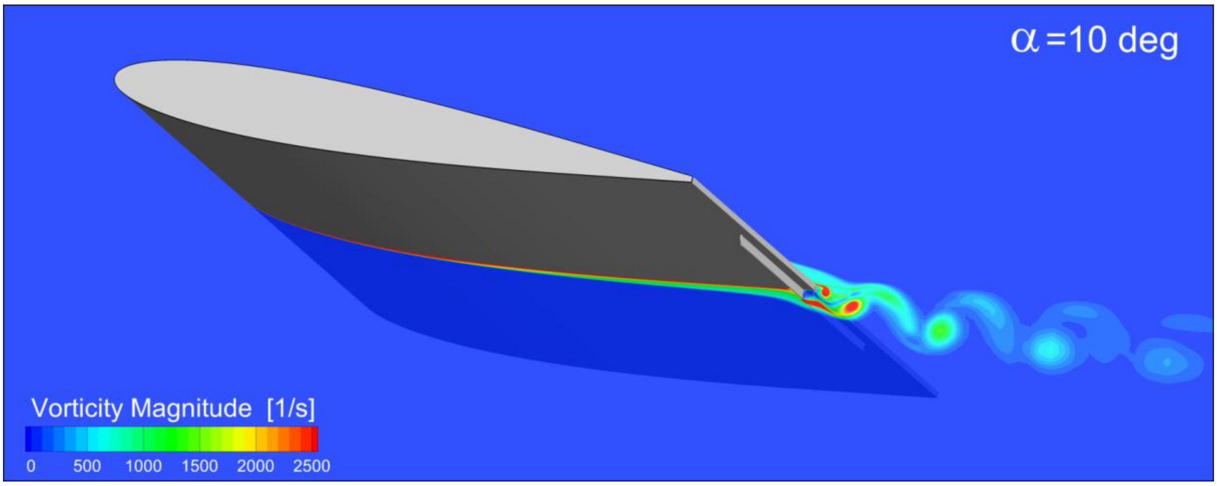

Figure 2. Vortex shedding from a trailing edge of rotor blade equipped with periodically deployed Active Gurney Flap. Results of CFD simulation conducted by using the methodology developed within the project COMROTAG.

Project Summary

Acronym :	COMROTAG
Name of proposal:	Development and Testing of Computational Methods to Simulate Helicopter Rotors with Active Gurney Flap
Technical domain:	Computational modelling of helicopter rotor aerodynamics
Involved ITD	Green Rotorcraft
Grant Agreement:	619627
Instrument:	Clean Sky
Total Cost:	320 000€
Clean Sky contribution:	240 000€
Call:	JTI-CS-2013-01
Starting date:	October 2013
Ending date:	September 2016
Duration:	36 months

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