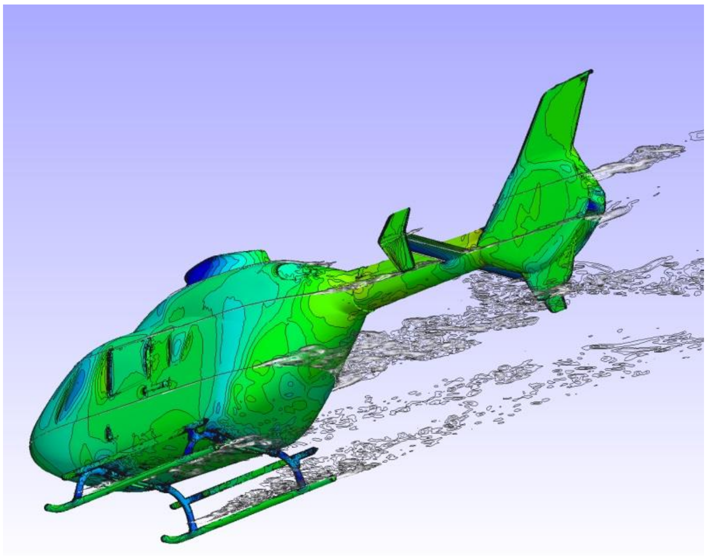
CFD Software GmbH

HELIDES: HELICOPTER DRAG PREDICTION USING DETACHED-EDDY SIMULATION



Publishable summary report

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1 Introduction

This report publishes a short summary of the principle outcome and impact of the HELIDES project. The project is entitled "Helicopter drag prediction using Detached-Eddy Simulation" and was funded in the CleanSky Joint Undertaking under the Green Rotorcraft ITD (Activity GRC2: "Reduced Drag"). The project ran from 01.04.2011 to 30.09.2013 and was coordinated by the SME CFD Software GmbH with the Technische Universität Berlin as an additional partner.

1.1 Technical background

Reduction of aerodynamic drag (and hence fuel consumption) of rotorcraft is a key goal to improving the sustainability of this means of transport. Helicopter drag in fast forward flight is dominated by the phenomenon of flow separation from the rear fuselage and rotor hub, which also gives rise to unsteady aerodynamics loads on the helicopter tail. Drag reduction may be achieved by various means, such as geometry optimisation or flow control devices. The cost-effective design of such measures requires predictive tools to enable their assessment in the preliminary design stage.

Advances in computer capacity have led to an increasingly important role being played by Computational Fluid Dynamics (CFD) in aerodynamic design across the ground and air transport sectors. The principle limiting factor in CFD arises from the phenomenon of turbulence, which introduces a fundamental cost-accuracy trade-off. The methodology to be applied in HELIDES, namely Detached-Eddy Simulation (DES), is a prominent member of a new family of turbulence modelling strategies aimed at offering a step forward in accuracy by exploiting near-future computational resources.

1.2 Objectives

The global objectives of HELIDES are:

- To contribute to the analysis of an existing fuselage and rotor-head geometry in terms of aerodynamic loads and interactional effects using state-of-the-art hybrid RANS/LES methods
    - A milestone in DES for helicopter aerodynamics
- To assess the industrial feasibility of the adopted methods with respect to:
    - Numerical performance, efficiency, parallel scalability
    - Expected "readiness date" for routine industrial application
- The demonstration and assessment of the feasibility of the DES software process for this complex application.

2 Highlighted results

2.1 Predictive accuracy of DES

State-of-the art Detached-Eddy Simulation (DES) models were implemented in the open-source, unstructured CFD software OpenFOAM®. Additionally, related solver features were integrated including a locally-adaptive hybrid convection scheme, balancing low numerical dissipation and robustness. Additionally, simulations using RANS and unsteady RANS (URANS) methods were conducted for comparison. URANS represents the current state-of-the-art in industrial practice.

An impression of the level of geometric complexity and nature of the flow field are given by a snapshot from DES of the configuration with landing skids in Figure 1 (left). The highly unsteady wake together with the large areas of thin, attached boundary layers highlight the value of the DES approach.

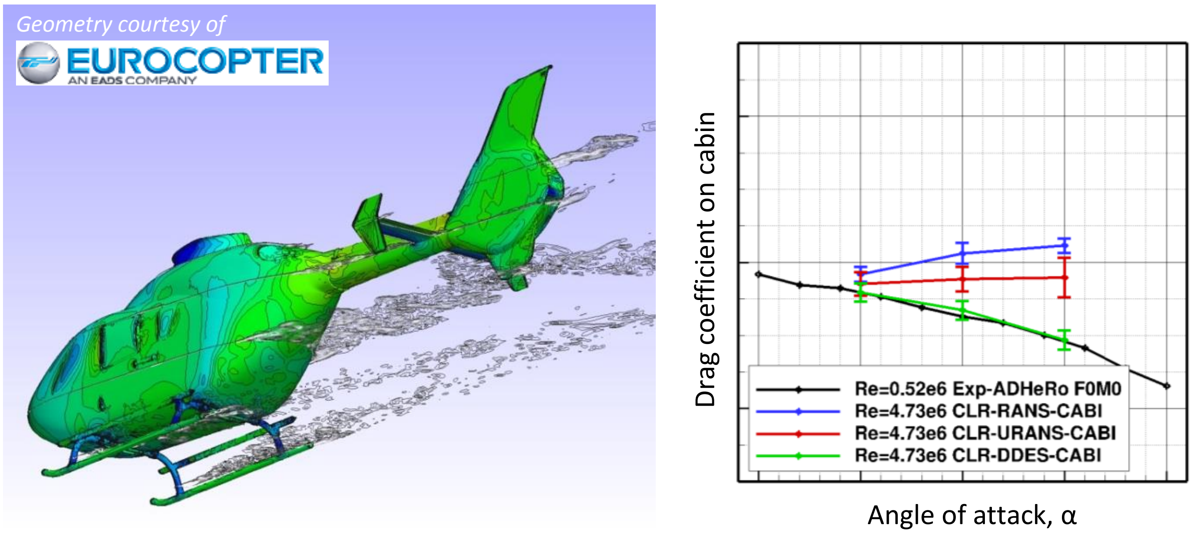

Figure 1: Snapshot of DES flow field (left). Comparison of drag coefficient on cabin between RANS, URANS, DES and experiment for configuration without landing skids (right).

For configurations with direct comparability between experiment and CFD, excellent agreement was achieved by DES for the aerodynamic loads. As an example, the drag on the cabin is shown in Figure 1 (right), where the agreement between DES and experiment is very close. For RANS and URANS however, even the trend with angle of attack is incorrectly predicted.

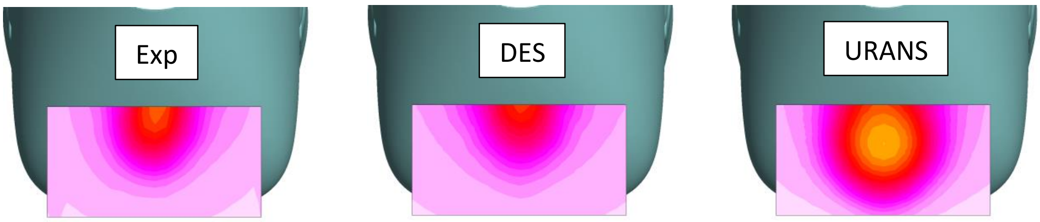

Figure 2: Comparison of mean streamwise velocity in the fuselage wake between experiment, DES and URANS for configuration without landing skids.

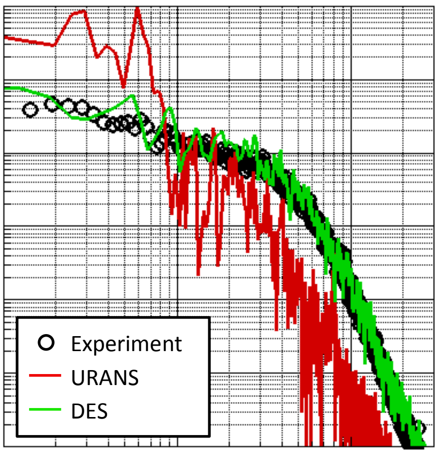

Figure 3: Comparison of surface pressure spectra between DES, URANS and experiment (with landing skids).

The superiority of DES over (U)RANS was confirmed across all flow quantities and for all simulated configurations.

The improvement in the prediction of the wake flow topology by DES relative to URANS is shown in Figure 2. As well as affecting drag prediction of the cabin, the wake topology also affects the predicted empennage loads due to upwash.

Unsteady phenomena are important to predict effects such as tail-shake, caused by the impact of the turbulent wake on the empennage. As shown by the example spectra in Figure 3, also in this regard DES shows significant improvement over URANS.

3 Assessment of industrial feasibility

The computational efficiency and parallel scalability of the simulations was recorded, allowing an assessment of the industrial feasibility of the methods from the point of view of computational expense.

An arbitrary criterion for “industrial readiness” was defined as the ability to perform such simulations within a 24-hour (computational) turnaround time. The efficiency and scalability information was combined with various projections for the future increase in computational capacity (ranging from optimistic to pessimistic). The computing hardware used in HELIDES was first available in 2009, which was used as the datum for scaling. Finally, statistical convergence criteria were used to determine the number of time steps that must be computed to achieve acceptable accuracy in mean values and fluctuating quantities, respectively. The resulting readiness dates, shown in Table 1 indicate that such methods will indeed become affordable for routine industrial application in the near future.

CPU performance projection	Readiness date (mean values)	Readiness date (fluctuating quantities)
Rapid (D. House)	2014	2016
Slow (P. Spalart)	2015	2019

Table 1: Estimated readiness dates for 24-hour turnaround of HELIDES-equivalent simulations (configuration with landing skids) giving sufficient statistical sample for accurate mean or accurate fluctuating quantities.

4 Impact of the project

HELIDES has contributed to the industrial applicability of advanced predictive tools for aerodynamics, which will play a key future role in the design of future rotorcraft with reduced drag and fuel consumption. A more direct outcome of the project is the rich aerodynamic data and analysis that can be exploited to analyse the drag producing mechanisms of the flow.

DES and related approaches have been the subject of intensive method development research over the past decade. A significant contribution to this research was and continues to be made within European-funded projects such as FLOMANIA, DESider, ATAAC and Go4Hybrid. By demonstrating the concrete advantages of high-fidelity DES over the currently used URANS approaches, as well its applicability to highly complex geometries, this work has done much to improve the readiness level of DES.

In addition to the transfer of the relevant expertise and best practice to industry, the high computational resources demanded by DES present a principal hurdle to routine industrial adoption. The forecast for industrial readiness of DES for such helicopter applications provides important information to the decision makers in industry. Furthermore, it is clear from the proximity of the predicted readiness dates that work should already be undertaken to prepare industry for adoption of DES-like methods in order to maintain competitiveness.

Acknowledgements

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