ADHeRo
Aerodynamic Design Optimization of a Helicopter Fuselage including a Rotating Rotor Head

State of the art – Background
The reduction of emissions is clearly one of - if not - the most challenging task of our society and the aeronautical industry today. Within CleanSky environmental issues in the rotorcraft domain are addressed by the Green Rotorcraft Integrated Technology Demonstrator (GRC ITD). Even though, fixed wing aircraft generally outperform rotorcraft in fuel efficiency, range, speed and noise, rotorcrafts are still of high importance.

There are several reasons for that. First, rotorcrafts provide unique Vertical Take-Off and Landing (VTOL) capabilities. Thus, they can operate in areas with limited infrastructure or in airspace where other aircraft cannot. Second, they can excel in scenarios where economy of time is crucial, e.g. search and rescue (SAR) missions. Finally, rotorcrafts are deployed when they outperform other applicable forms of transport in dynamic productivity, i.e. payload multiplied by speed. Examples are the crew change on oil platforms or the transport of service personnel to offshore wind farms. To be able to provide these services at reduced environmental impact, measures are taken by the GRC to reduce emissions and increase fuel efficiency of rotorcraft.

In many cases, the missions described above are performed by light weight utility helicopters. Therefore, it is desirable raising the efficiency of this helicopter class. The power requirements of lightweight utility helicopters in fast level flight results to
- 55 % from parasite drag
- 40 % from the main rotor
- 5 % from the tail rotor.

Thus, aiming on parasite drag constitutes a promising approach for obtaining a more efficient utility helicopter design.

Parasite drag is generally reduced by optimizing an aircraft’s shape. Unfortunately, practical considerations dominate the design process of utility helicopters. In consequence it is not always possible choosing the optimal shape. Therefore, solutions for the aerodynamic design have to be developed accounting for these operational constraints. A typical conflict resulting from the described methodology appears in the aft-body region. The requested specifications often include a rear loading capability. In consequence, it is not feasible reducing parasite drag in the aft-body region by streamlined surfaces.

Objectives
The main objective of the GRC project ADHeRo (Aerodynamic Design Optimization of a Helicopter Fuselage including a Rotating Rotor Head) is reducing the parasite drag of light weight utility helicopters in fast level flight, without increasing the fuselage down force. The latter fact is important to avoid additional power requirements for the main and tail rotor, which would deteriorate the gain in efficiency obtained through parasite drag reduction.

Analyzing the drag decomposition of this helicopter class reveals that the parasite drag of the fuselage, the landing gear and the rotor head cause some 70 % of the total parasite drag. Thus, significant reduction of emissions and fuel consumption can be achieved by optimizing the aerodynamic design of these components. For this reason, the focus within ADHeRo is set on the aerodynamic optimization of the fuselage, the landing gear and the rotor head.

If feasible, aerodynamic design optimization is to be achieved by shape optimization. As already mentioned, this is not always possible. In these cases, efficiency gains are intended to be achieved through the application of passive flow control devices, i.e. spoilers, strakes and vortex generators.

The aerodynamic analyses are planned to be primarily performed through wind tunnel (W/T) experiments. Besides the identification of feasible drag reduction methods, the experiments will be employed to evaluate the obtained gain in efficiency through design modifications. In summary, this will lead to a sounded database not available today. The database will provide a large set of global and local data including aerodynamic forces, surface pressure distributions and velocity field data. For this purpose a new W/T model has to be designed and manufactured. Since detailed drag analysis is the main scope of ADHeRo, the model design has to reflect to that.

In addition to the experimental investigations, numerical simulations are planned for selected cases to cross-check the experimental results.
Description of work
The main scope of the work is to evaluate several design modifications to a baseline model, derived from the EC135 of Airbus Helicopter, through W/T testing. The planned work is subdivided into six work packages.

Work package (WP) 1 spans over the entire project duration and is dedicated to the project management.

In WP 2, design, manufacturing and instrumentation of the new wind tunnel model are addressed. In order to perform detailed drag measurements with the new W/T model, it is requested that the model scale is as large as possible. In consequence, the spatial and temporal resolution of flow field is increased. Another important constraint for precise drag evaluation through W/T experiments is the elimination of aerodynamic interaction of the model support with the flow field of the model.

Hence, a specific tail sting mount is used. To prepare for future design modifications a modular model design is required. Finally, the design of the model rotor head must reproduce the full kinematic complexity of the original design. This includes the rotation of the rotor head and the collective and cyclic pitch motion of the rotor blades. Otherwise, no realistic drag and particularly lift data are measured.

From WP 3 up to WP 6 experimental and numerical investigations on the baseline and two modified configurations are addressed. Thereby, WP 3 defines the work on the baseline configuration, i.e. the status quo. This campaign will provide the reference data for all subsequent design modifications. In WP 4 and 5, the effect of two modified configurations aiming at reducing the drag of landing skids and rotor head is investigated. In WP 6, the impact of spoilers, strakes and vortex generators on the flow around the aft-body region is evaluated. The wind tunnel testing on all modifications is accompanied by CFD analysis.

Expected results
a) Timeline & main milestones
The entire project spans over 42 months starting from January 2011.

WP 1 is structured into three reporting periods (month: M1-M18, M19-M30, M31-M42), each associated with a milestone at the end of the respective period. WP 2 lasts from M1-M8. The milestone associated with this period is the report about the wind tunnel geometry and instrumentation layout. For WP 3, the period reaches from M9 to M18. The important milestone is the final report on the W/T data analysis of the baseline configuration. WP 4 spans over 9 months, starting with M19. WP 5 starts in M31 and ends in M42. WP 6 is connected to WP 4 and WP 5. For WP 4 to WP 6, the main milestones are related to a report on the geometry modifications and the aerodynamic data analysis.

b) Environmental benefits
Based on examples found in literature about similar configurations, a reduction of up to 20 % in parasite drag can be obtained with the planned modifications. In consequence, the power requirements for light weight utility helicopters could be reduced by some 10 % through ADHeRo. This could result in a reduction in fuel consumption of similar magnitude. Considering the technical readiness level of the planned modifications (TRL 6, i.e. pre-production entry level) the prospective benefits could enter market within a few years after project completion. Thus, ADHeRo could help reducing the environmental impact of services provided by light weight utility helicopters in the near future.

c) Maturity of works performed
The project reached the full completion in due time.

The new W/T model has been designed and manufactured, meeting all requirements given by the project leader. To minimize interactions with the model flow field a new support was designed, manufactured and tested depicted in figure 1.

![Figure 1: ADHeRo W/T model with tail sting mount and one of two faired landing gears installed.](image)

The new support employs a horizontal sting connected to the fuselage through a part of the tailboom. Thus, interaction with the flow field is reduced to a minimum.

All W/T campaigns for the baseline and the modified configuration are completed. The modification include new faired landing gears (18 % drag reduction), a smoothed cabin bottom (2.7 % drag reduction), passive flow control devices at the aft-body (1.4 % drag reduction) and a new mast fairing (1.5 % drag reduction). Thus the investigated configurations exceeded the expected drag benefits with almost 24 % in the aggregate.
Project Summary

Acronym: ADHeRo (www.ADHeRo.de)

Name of proposal: Aerodynamic Design Optimization of a Helicopter Fuselage including a Rotating Rotor Head

Technical domain: Aerodynamics

Involved ITD: Green Rotorcraft (GRC2)

Reduced drag of airframe & non lifting rotating parts

Grant Agreement: 270563

Instrument: Clean Sky

Total Cost: 825 000€

Clean Sky contribution: 618 750€

Call: JTI-CS-2010-1-GRC-02-005

Starting date: January 2011

Ending date: June 2014

Duration: 42 months

Coordinator contact details: Prof. Dr.-Ing. habil. Christian Breitsamter

Lehrstuhl für Aerodynamik und Strömungsmechanik
Technische Universität München
Boltzmannstr. 16
85748 Garching bei München
Deutschland
+49 (0)89 289 16137
christian.breitsamter@aer.mw.tum.de

Project Officer: Sébastien Dubois

sebastien.dubois@cleansky.eu

Participating members: Eurocopter Deutschland GmbH D
Technische Universität München D