Aerodynamic optimization of helicopter rear fuselage

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ABSTRACT

An optimization process for the rear helicopter fuselage part is presented using Genetic Algorithms and Kriging surrogate models. Shape parameterization is carried out with the super ellipse technique employed for the well-known ROBIN fuselage. The simulations were based on the RANS equations solved using the HMB CFD code. It is shown that a decrease of fuselage drag around 2.5% is possible without compromising the structure and the functionality of the design. Combined with an optimization of the helicopter skids, benefits of up to 4.6% were possible. The demonstrated method can be applied to fuselages of any shape during the initial design phase.

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One of the ideas for improving the fuselage aerodynamic characteristics is to change these vortical structures. This can be achieved in many ways including active flow control by flow suction and blowing [4], passive flow control using devices like vortex generators [5,16], and shape optimization [6].

Active flow control at the rear of a helicopter fuselage was investigated by Lineard et al. [4] and also in Refs. [17–21]. Investigations were carried out using experiments, as well as, numerical simulation. The active flow control was realized by blowing (steady and pulsed), and results show that the fuselage drag can be reduced by up to 10–35%. The drag reduction depends on the type of actuators and their parameters, like blowing flow ratio etc. The disadvantage of this active approach is the necessity to install additional equipment that requires additional power.

An alternative approach is based on changing the fuselage geometry. Different fuselage shapes and landing skids were investigated by Schneider et al. [21] and Reß et al. [22]. New geometries were constructed, and results of these investigations show good potential for reducing the fuselage drag.

Another way to reduce drag is to find the optimal shape of the helicopter fuselage. To this aim, different optimization approaches are used. Any optimization requires parameterization of the geometry, and geometries can be fully [3], or partly parameterized [6, 23, 24]. A fully parameterized geometry is a good approach for the first steps in the design of a new helicopter. Due to design constraints, however, a partial parameterization is more useful.

This work presents a framework for the minimization of helicopter fuselage drag employing CFD in conjunction with a surrogate model based on Kriging method [25], and a Genetic Algorithm (GA) optimization method. GA originated from the theory of natu-
### Nomenclature

- \( x_0, y_0, z_0 \) origin of super-ellipse center
- \( A, B \) length and width of the super-ellipse
- \( N \) power of curve
- \( x, y, z \) Cartesian coordinates
- \( r, \varphi \) polar coordinates
- \( CD \) drag coefficient
- \( M \) Mach number
- \( Re \) Reynolds number

2. Fuselage optimization case

This paper demonstrates an optimization approach for the fuselage of the prototype ANSAT helicopter, produced by the Kazan Helicopter Plant of the Russian Federation (Fig. 1). The ANSAT is a multi-purpose light helicopter with a classic single-rotor design. The main rotor consists of four blades and the tail rotor consists of two. The length of the fuselage is 11 m and the mid-ship sectional area is 4 m\(^2\), approximately. The maximum take-off weight is 3600 kg. The main characteristics of this helicopter are presented in Table 1.

During the early stages of this investigation a wind tunnel model of the helicopter was constructed, broadly corresponding to one of the ANSAT prototypes (Fig. 2). The wind tunnel model fuselage had a length 1.8 m and a mid-ship sectional area of 0.1085 m\(^2\). A CAD model was also constructed (Fig. 3), including the fuselage, landing skids, and tail plane. During this investigation the flow around isolated fuselage parts, as well as the complete fuselage were considered.

3. HMB CFD code

The simulation of the flow around the helicopter fuselage was conducted using the RANS equations with the HMB CFD code [29]. HMB uses the finite volume method and to close the RANS equations, turbulence models are used. The solver has turbulence models like the Spalart-Allmaras [30], the \( k-\omega \) [31], and the \( k-\omega\)-SST [32], as well as hybrid approaches like DES, SAS [33], and LES. This solver employs multi-block hexa-grids, constructed using the ICEM\textsuperscript{TM} Hexa tool. The HMB code has been used for investigations of the flow around the isolated helicopter fuselage [10–12], and for validation, wind tunnel tests were used.

The simulation of the flow around the isolated helicopter was carried out with \( k-\omega \) SST turbulence model in steady state mode. The baseline grid for the isolated fuselage contained 964 blocks and 13.5 \( \times \) \( 10^6 \) cells. An O-grid topology was used around the...
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