PRACE INSTYTUTU LOTNICTWA
218, s. 11-19, Warszawa 2011

STUDY OF THE INFLUENCE OF HELICOPTER'S EXTERNAL COMPONENTS ON THE AERODYNAMIC CHARACTERISTICS

Adam Dziubiński, Katarzyna Grzegorczyk

Instytut Lotnictwa

Summary

The paper presents a numerical analysis of flow around a helicopter in various configurations. All the configurations were simulated using FLUENT, Computational Fluid Dynamics code. The calculations were based on a three-dimensional, steady-state solver. The results have been obtained for the rotorcraft operating in forward flight with selected angles of attack (alpha). The main goal of this work was to calculate the steady aerodynamic characteristics of the helicopter and research on the effects of components on the aerodynamic characteristics.

INTRODUCTION

Modern helicopters need to be designed to perform multiple tasks. One of the methods of extending the range of their application is adding external components to the hull [2]. This is the reason of using additional components i.e. cameras (Figure 1), bays (Figure 2), wings and pylons (Figure 3). All external elements of a helicopter affect the total aerodynamic properties.

Figure 1 Examples of external components on the modern helicopters (camera) (c) Adam Dziubiński

Figure 2 Examples of external components on the modern helicopters (bays) (c) Adam Dziubiński

Figure 3 Example of external components on the modern helicopters (wings, pylons, tanks) (c) Adam Dziubiński

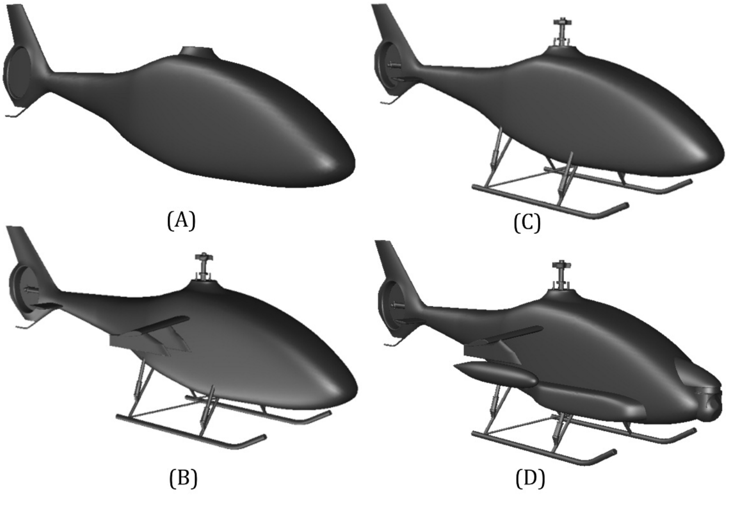

Figure 4 Geometry of helicopter configurations tested

This paper contains the simulation results the influence of selected external components. Four configurations were tested – Figure 4:

(A) base consisting of fuselage, tail boom, tail skid, tail fin equipped with ducted fan,
(B) configuration A with added landing gear, elevator, tail rotor gearbox, simplified main rotor head,
(C) configuration B with added wings and pylons,
(D) configuration C with added bays, fuel tanks and camera.

The aerodynamic properties strongly depend on the geometric parameters of the rotorcraft as well as flight conditions. Components of the configuration have an effect on the aerodynamic characteristics and performance. Size and shape of each part influences on flow field around the helicopter.

This study contains a numerical simulation of the flow around the light helicopter. All analyses have been done using CFD software (Fluent code). The calculations have been performed for the rotorcraft operating in forward flight with various angles of attack α. The computational results of the flow field around the helicopter were used to determinate the performance characteristics of the examined configuration. This allowed an estimate influence additional configuration items on changes the aerodynamic characteristics of helicopter.

NUMERICAL TESTS CONDITIONS

The numerical calculations are based on FLUENT software, part of ANSYS CFD package [6], widely recognized as industry standard. This numerical algorithm uses the finite-volume method. In present paper the fluid was simulated as an incompressible with the Spalart-Allmaras turbulence model. Geometric model was created using CATIA. All model's geometry modifications and computational grids have been made using ICEM CFD code [5]. The cubical domain was generated with the unstructured grid consisted of tetrahedral cells. Boundary layer mesh has been created as several layers of prisms. In Figure 5 grid around a helicopter (version (B)/gear) is illustrated and three-dimensional domain is presented in Figure 6.

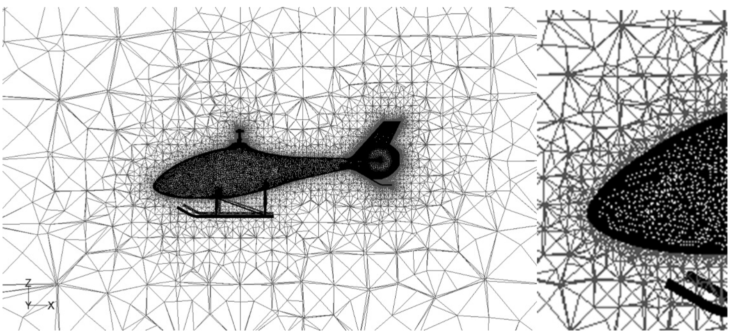

Figure 5 Mesh around the basic version helicopter (left) and around the fuselage nose (right)

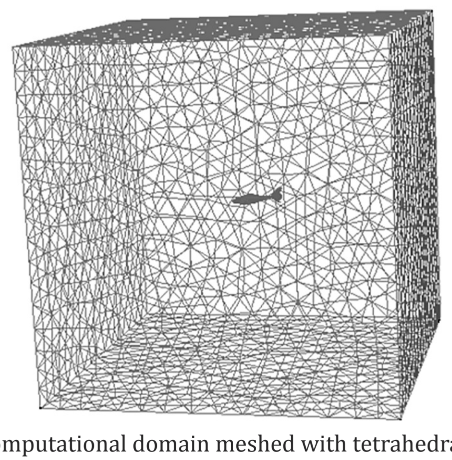

Figure 6 Computational domain meshed with tetrahedral elements

Information about total mesh's sizes is shown in Table 1.

Table 1 Mesh size for various helicopter configurations

Configuration	*Number of cells*
(A)/base	1 310 996
(B)/gear	2 824 811
(C)/wings	3 572 210
(D)/stores	4 361 478

All configurations were tested for the various angles of attack. Results of research are presented in XYZ coordinate system (related with direction of undisturbed flow) – Figure 7.

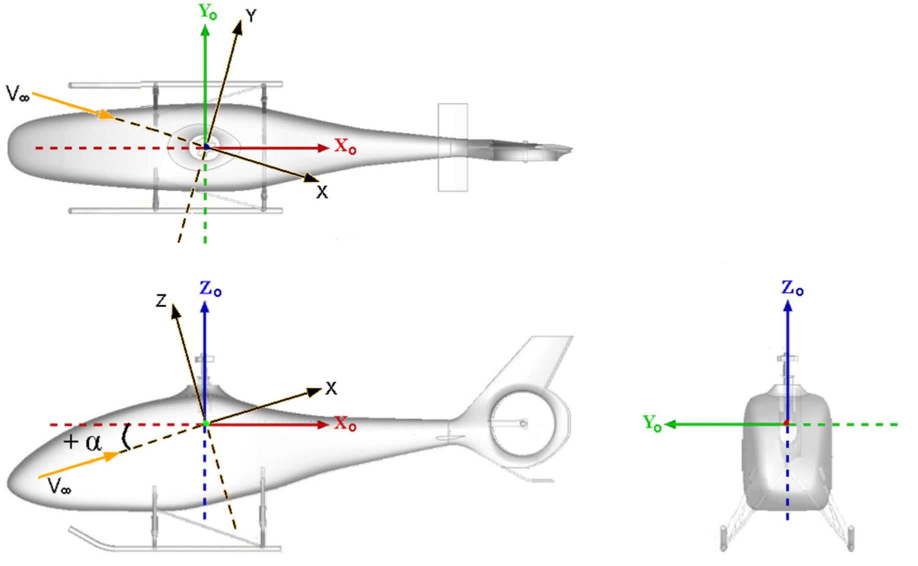

Figure 7 Coordinate systems used in calculation: XYZ – the flow coordinate system, $X_0Y_0Z_0$ – the local coordinate system

All calculations were done for forward flight.

Aerodynamic coefficients are referenced to:

- main rotor diameter D as linear characteristic dimension to calculate moment coefficient,
- rotor surface $S = \pi \cdot R^2$ as surface characteristic value.

RESULTS

Computational method allows obtaining information hardly available with experimental methods. Among other things, information about load distribution on the specified surfaces of a model and the flow field structure around model is available.

At the outset, sample images of flow field and pathlines around a helicopter are presented using visualization tools that are offered by FLUENT software. The flow around the basic version of the helicopter in forward flight is shown in Figure 8. The separation at the back of main rotor hub and reattachment of flow at sidewalls of fuselage are clearly visible. Influence of external stores (wings, pylons, bays, tanks and camera) on the flow around helicopter is presented in Figure 9.

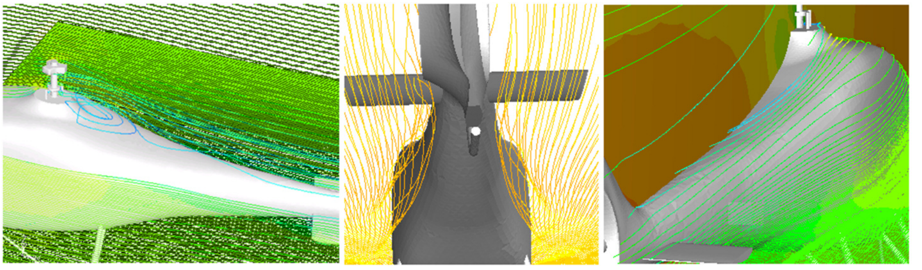

Figure 8 Visualization of pathlines around the (B) configuration of helicopter in forward flight

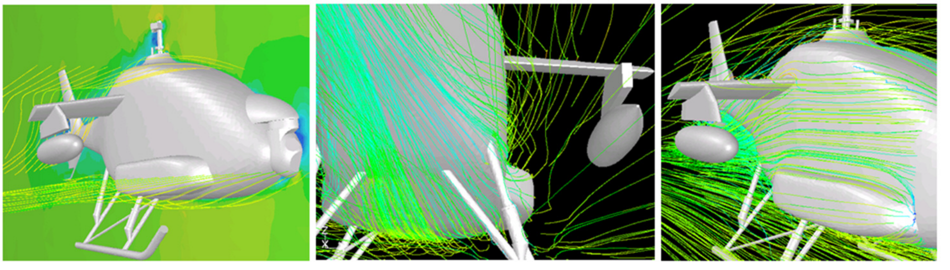

Figure 9 Visualization of pathlines around the (D) configuration of helicopter in forward flight

Basing on the result of flowfield analysis, forces and moments values were calculated for all configurations. In the graph below (Figure 10.) and Table 2 the comparison total drag for various versions of the helicopter operating in forward flight for three selected angles of attack (α= -10°, 0°, 10°) are presented.

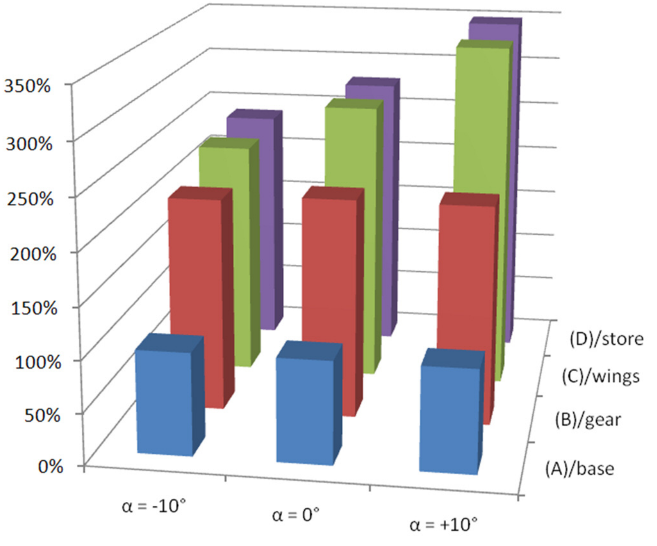

Figure 10 Comparison of tested configuration drag for three selected angle of attack

Table 2 Comparison of configuration tested drag for three selected angle of attack

Configuration	α = -10°	α = 0°	α = +10°
(A)/base	100%	100%	100%
(B)/gear	211%	216%	216%
(C)/wings	234%	279%	344%
(D)/store	239%	279%	349%

Analysis of presented data shows, that additional external components are causing an increment of helicopter fuselage drag. The drag for configuration (A)/base and (B)/gear weakly depend on value of angle of attack. For last two configurations: (C)/wings, (D)/stores situation is quite different. Drag increases with increase of angle of attack.

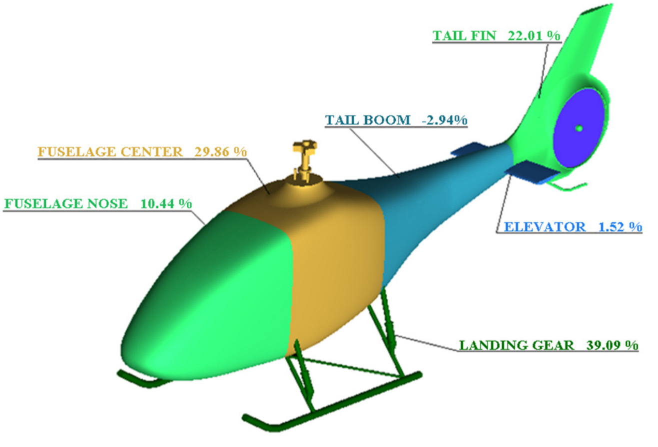

Figure 11 Percentage of particular components of total drag for (B)/gear configuration

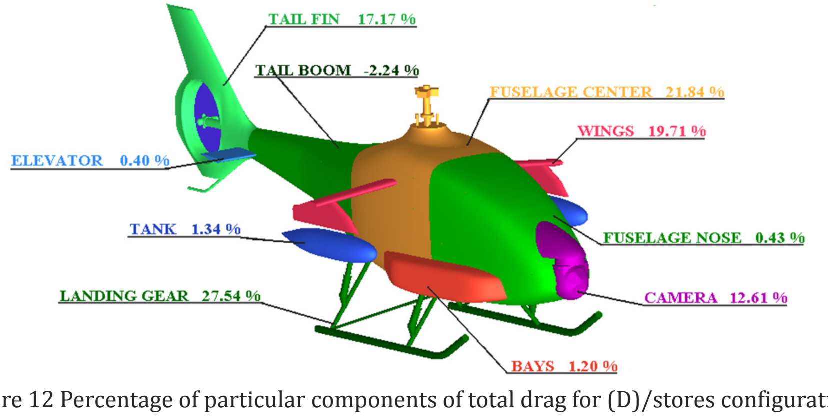

Figure 12 Percentage of particular components of total drag for (D)/stores configuration

For more detailed drag analysis of the computational model and determination of the percentage of particular components in total drag, the computational model is split into several parts as in Figure 11 (configuration (B)/gear) and Figure 12 (configuration (D)/gear). The following images are the simulation results for two versions of helicopter in forward flight condition (V=180 km/h, α=0°). In these figures percentage value of drag generated by each part is presented. It is also collected in Table 3. The landing gear is an element which causes the largest increase in the drag force in both cases. The next elements lead to the increase of drag value, but its influence of the total drag force is less significant.

Table 3 Comparison of percentage of particular components of total drag for configuration (B)/gear and (D)/stores for angle of attack α= 0°

Configuration	Tail Fin	Tail Boom	Elevator	Leanding Gear	Fuselage Center	Wings	Tanks	Fuslage Noce	Camera	Bays
(B)/gear	22,01	-2,94	1,52	39,09	29,86	-----	-----	10,44	-----	-----
(D)/store	17,17	-2,24	0,40	27,54	21,84	19,71	1,34	4,30	8,79	1,20

The influence of external components is defined as change (D) of the aerodynamic coefficient value for configuration (B), (C) and (D) compared to value of aerodynamic coefficient for configuration (A)

$$DC_k = C_k(Q) - C_k(A),$$

Where indices: Q = B, C, D are symbols of configuration, k=X, Y, Z, mx, my, mz

The results are shown in Figure 13.

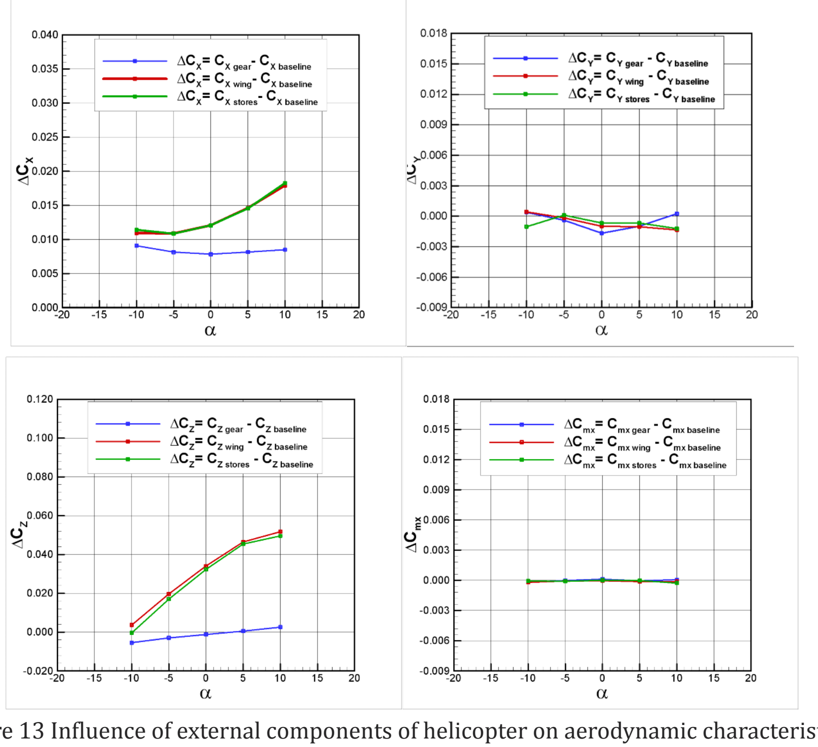

Figure 13 Influence of external components of helicopter on aerodynamic characteristics, configuration (A)/base as reverence

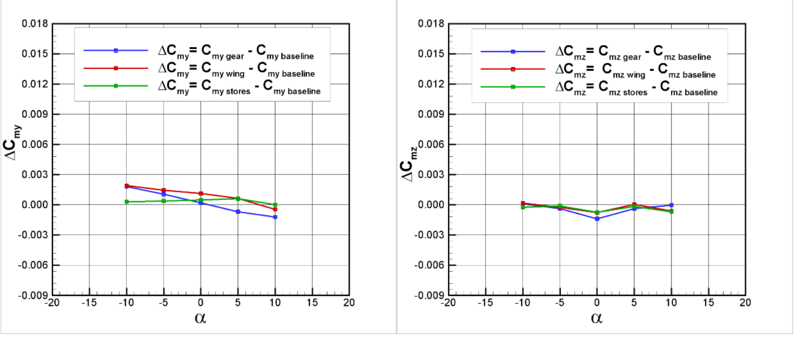

Figure 13 Influence of external components of helicopter on aerodynamic characteristics, configuration (A)/base as reverence

The results of conducted calculations showed that in the case of configuration (B) the drag coefficient depends weakly on the angle of attack. However the strong dependence of drag coefficient on the angle of attack was observed in the cases (C) and (D). Values of drag coefficient in both cases (C and D) are similar. In the case of lift coefficient an increase in derivative dCZ/dα for all configurations was detected. The highest values of lift coefficient have been obtained for the case C/wing. On the basis of characteristics can be concluded, that in comparison with configuration C/wing adding external stores causes the reduction of lift coefficient. In terms of moment coefficient's changes, it is seen that they all fluctuate around zero value.

CONCLUSIONS

The research on the influence of selected external components on the steady aerodynamic characteristics of a helicopter was studied. From the analysis of the results, it can be concluded that adding wings to helicopter baseline in forward flight conditions leads to improvement of the lift coefficient. It happens at the expense of aerodynamic drag. On the other hand adding external stores to helicopter baseline with wings practically does not have influence on the aerodynamic characteristics.

REFERENCES

[1] CZECHYRA T.: Sprawozdanie nr 2/RA/81/B: Pomiar współczynników aerodynamicznych na modelu kadłuba śmigłowca z nadmuchem wirnika. Warszawa 1981 r.
[2] GRZEGORCZYK K., BRONOWICZ J.: Projekt aerodynamiczny śmigłowca bezzałogowego o udźwigu 15 kg. / Prace Instytutu Lotnictwa Nr 3-4 (194-195), s.264-271 / Warszawa 2008r.
[3] GRZEGORCZYK K., DZIUBIŃSKI A., ŻÓŁTAK J.: Instytut Lotnictwa. Sprawozdanie wewnętrzne nr 30/BA-A2/P/10.
[4] WITKOWSKI R.: Wprowadzenie do wiedzy o śmigłowcach / Biblioteka Naukowa Instytutu Lotnictwa / Warszawa 2003 r.
[5] ANSYS ICEM CFD 11.0 Tutorial Manual. 2007.
[6] FLUENT 6.1 User's Guide. Fluent Inc. February 2003.

ACKNOWLEDGMENTS

This research was supported by project founded by Polish Ministry of Science and Higher Education, Contract no O R00 0048 08

Adam Dziubiński, Katarzyna Grzegorczyk

ANALIZA NUMERYCZNA WPŁYWU ZEWNĘTRZNYCH PODWIESZEŃ ŚMIGŁOWCA NA JEGO CHARAKTERYSTYKI AERODYNAMICZNE

Streszczenie

W opracowaniu przedstawiono wyniki obliczeniowej analizy opływu modelu kadłuba śmigłowca w różnych konfuguracjach. Symulacje wykonano wykorzystując metody Obliczeniowej Mechaniki Płynów (CFD). Zaprezentowano rozwiązanie trójwymiarowego zagadnienia stacjonarnego opływu śmigłowca w warunkach lotu z prędkością postępową dla wybranych kątów natarcia. Głównym celem pracy było uzyskanie stacjonarnych charakterystyk aerodynamicznych oraz zbadanie wpływu zewnętrznych podwieszeń śmigłowca na jego charakterystyki aerodynamiczne.