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CFD ANALYSIS OF EXTERNAL ARMOUR INFLUENCE ON A HELICOPTER AERODYNAMIC CHARACTERISTICS

Adam Dziubiński, Katarzyna Grzegorczyk, Jerzy Żółtak

Instytut Lotnictwa

Abstract

The article contains results of the analysis for the influence of external armour on aerodynamic characteristics of a helicopter fuselage. The flowfield for both configurations: with and without armour has been obtained for operational range of angle of attack and sideslip angle, using Fluent software. The results were used to calculate the aerodynamic forces and moments. Finally the influence of armour on aerodynamic characteristics was analysed.

INTRODUCTION

Adding an armour to a helicopter demands some compromises. Such armour must provide proper protection level for crew and helicopter components, and has to be as light as possible due to mass requirements. At the same time it is expected, that flight and aerodynamic performance will be saved for the widest possible range of velocities and angles of attack. In some helicopters [2], [3], armour is made as integral element of their fuselage structure.

The others may be armoured optionally. In those cases an armour is mounted as external and/or internal additional elements (shields). In [2] and [3] the concept of armour for large, over 5 700 kg (12 500 lbs) maximum certificated takeoff weight[6], multipurpose helicopter was presented. It based on experience and test methodology recommended in [5] for light armoured vehicles. Report [2] presents also the results of mass analysis for different material used for shields. Part of armour is mounted outside the helicopter fuselage. The external shields change helicopter's aerodynamic characteristics.

The presented paper focuses on the analysis of aerodynamic influence of armour according to presented in [2] concept of armoured helicopter. The study has been done using numerical methods.

The issues will be discussed as follows: modeling the helicopter fuselage with and without armor, preparing meshes and methods used in numerical calculations and setting the test conditions. Finally, selected results will be presented.

OBJECT OF RESEARCH

The object of research is large (6 000 kg of certified MTOW) multipurpose helicopter [6]. The initial geometry[7] - Figure 2 - contains many details, unnecessary from this specific CFD analysis point of view. Therefore, while preparing the geometry of model used in the calculation, the main rotor and tail rotor have been omitted and shape of landing gear and fuselage have been simplified – Figure 3a. Influence of engine's inlets and outlets has not been considered – Figure 3b. Other elements, which have influence on drag or lift, has been included in model in simplified form, if necessary. This geometry was used as a base for all external shield surfaces installation. The final geometry of helicopter fuselage, with and without armour, is shown in Figure 4 left and right respectively.

Figure 1. Armour concept for 6-ton take-off weight multipurpose helicopter

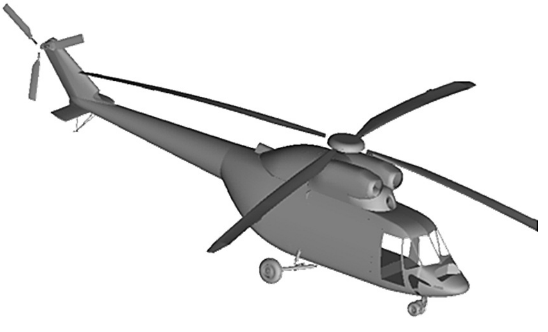

Figure 2. Base geometry of 6-ton take-off weight multipurpose helicopter

For both cases mentioned above, the tetrahedral meshes have been created, because of shape complexity. Boundary layer around helicopter shape has been modelled using prism elements, with pyramid elements transition layer. Size of baseline mesh is around 696 000 cells, and armoured - 1 566 702 cells. Mesh density increased in proximity of fuselage, especially on detailed areas with high curvature, as elevator, landing gear and armour edges. The grids were generated using ICEM software [8,1]. In the Figure 5 the mesh densities on surface of helicopter are presented. Volumetric mesh density have been shown using the symmetry plane.

CFD METHODS

Calculations were done using FLUENT [1,4] code. It allows to analyse the steady and unsteady flowfield around any complex geometry. Motion of fluid is described by the Reynolds Averaged Navier-Stokes equations. The finite volume method is used to obtain numerical solution of these equations. A set of turbulent models is implemented in the software. Several types of boundary conditions can be used.

In the presented analysis following parameters and settings were used:
- 3 dimensional steady calculation
- flux calculation – Semi-Implicit Method for Pressure Linked Equations (SIMPLE)[9]
- turbulent model –Spalart Allmaras [9]
- external boundary condition – on all external faces of domain except the backward one (outlet) a pressure far field boundary condition has been set, at outlet a pressure outlet with equal to farfield pressure has been used,
- at the surfaces of fuselage and armour – a wall boundary condition has been set.

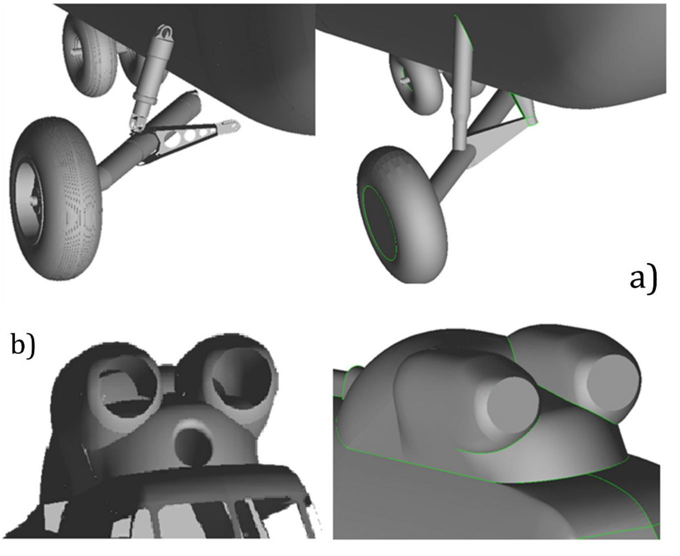

Figure 3. Simplifications on CFD geometry in landing gear and engine nacelles

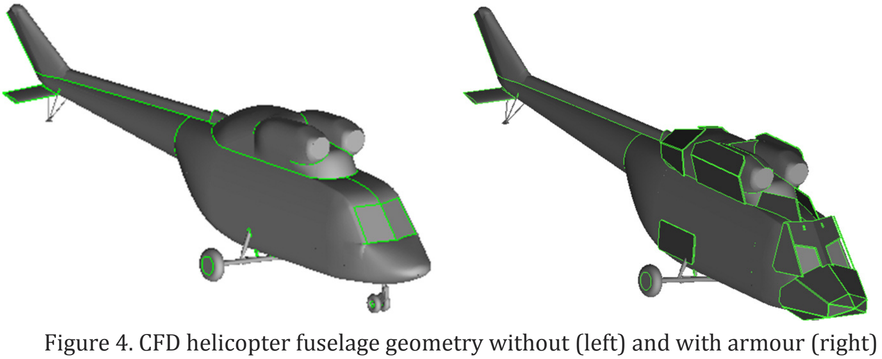

Figure 4. CFD helicopter fuselage geometry without (left) and with armour (right)

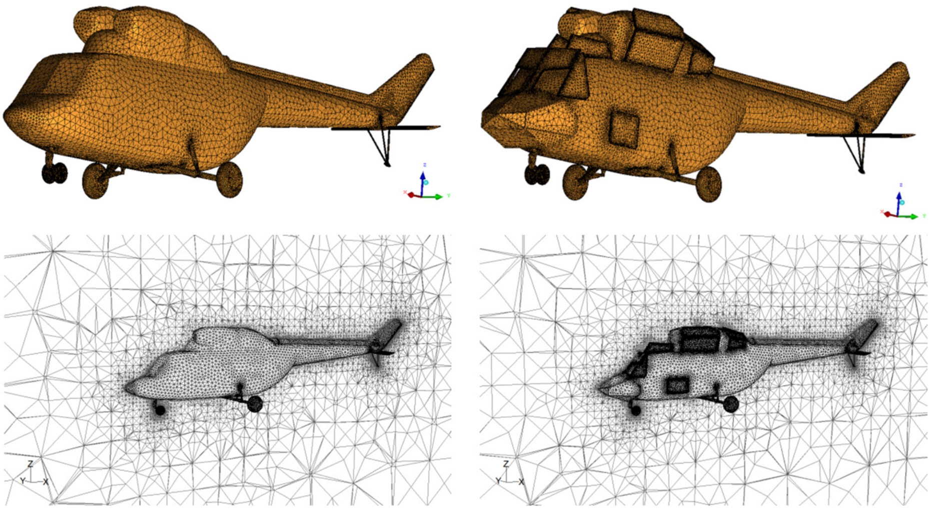

Figure 5. Mesh comparison between baseline (left side) and armoured (right side) versions

TEST CONDITIONS

Both configurations: without and with armour were tested. The schedule of tests – Table 1 – consisted of one set of calculation scanning angles of attack from α = -10° to 16°, with assumed sideslip angle β= 0° for both of configurations. Then, for chosen angles of attack set: α = -10°, -5°, 0°, 5°, 10°, sideslip angle has been also scanned from β = -10° to 10° with step equal 5°. Coordinate system has been chosen in the way, that positive angle of attack corresponded with nose down inclination – Figure 6 – (as in forward flight of helicopter). Positive sideslip was assumed as when nose of helicopter, observed from pilot point of view, moves right. All calculations were done for flight velocity V≈120 km/h (M = 0.1).

Aerodynamic coefficients are referenced to:
- main rotor radius R as linear characteristic dimension to calculate moment coefficient,
- rotor surface S = π·R2 as surface characteristic value.

Table 1. Tests schedule

Case	**Sideslip angle**	Angle of attack **α** [°]													
	β [°]	-10	-6	-5	-4	-2	0	2	4	5	8	10	12	15	16
Baseline	-10	X	--	X	--	--	X	--	--	X	--	X	--	--	--
	-5	X	--	X	--	--	X	--	--	X	--	X	--	--	--
	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	5	X	--	X	--	--	X	--	--	X	--	X	--	--	--
	10	X	--	X	--	--	X	--	--	X	--	X	--	--	--
Armored	-10	X	--	X	--	--	X	--	--	X	--	X	--	--	--
	-5	X	--	X	--	--	X	--	--	X	--	X	--	--	--
	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	5	X	--	X	--	--	X	--	--	X	--	X	--	--	--
	10	X	--	X	--	--	X	--	--	X	--	X	--	--	--

TEST RESULTS

The result of calculation was a flowfield over tested configuration for different combination of angles of attack and sideslip angles. The influence of armour, for angle of attack α = 0 deg. and sideslip angle β = 0 deg., on static pressure and wall share stress distribution on fuselage are presented in Figure 6 and Figure 7, respectively. An area with increased static pressure is clearly visible on flat shields in front of fuselage as well as in proximity of sideway shields of fuselage and those for engine nacelles.

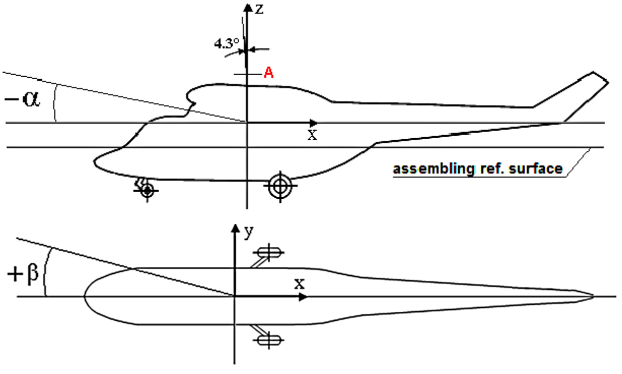

Figure 6. Coordinate system used in calculation

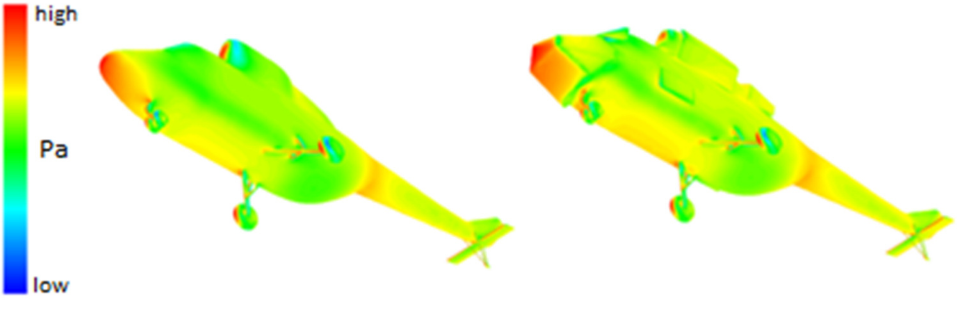

Figure 7. Static pressure distribution for fuselage without (left side) and with (right side) armour at α=10°, β=10°

Basing on the result of flowfield analysis, forces and moments have been calculated. These data was used in analysis of armour influence on aerodynamic characteristics. First the tendency of changes for case without sideslip angle (symmetric case) was obtained. The influence was defined as change (D) of the aerodynamic coefficient between the configurations of fuselage with and without armour (base):

$DC_k = C_k(\text{armoured}) - C_k(\text{base})$,

where index k = L, D, My for lift, drag and pitching moment respectively.

The results are shown in Figure 8. The armour causes increase of lift when nose of a helicopter is pointed upwards, and decrease when nose is downward. This function is roughly linear from -4° to 12°. Below -4° the influence does not change as elements of upper armour surfaces are shadowed by cockpit roof, then above 6 deg. the influence increases as increase angle of attack causes influence of, extended with armour, lifting surface of fuselage.

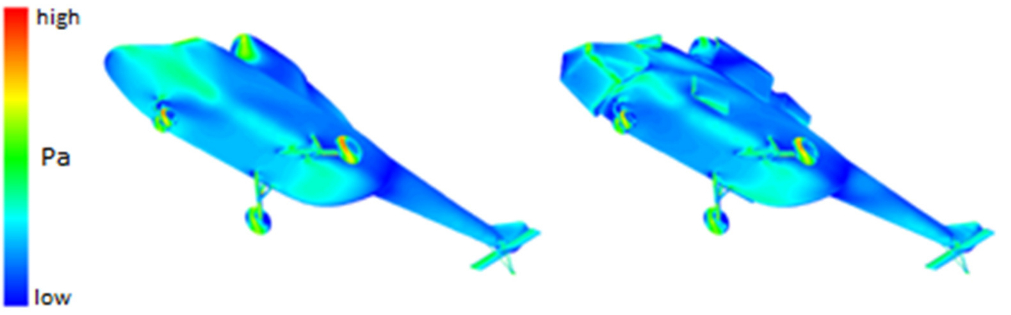

Figure 8. Share wall stress pressure distribution for fuselage without (left side) and with (right side) armour at α=10°, β=10°

Drag influence is nonlinear, and changes slowly with maximum near -4°, at -10 decreases by half and at +12 decreases by 3. The size of influence is one dragpoint, referenced to surface of main rotor. Moment coefficient influence causes decrease of moment and increase of nose down tendency of a helicopter. This tendency is non linearly decreasing as increases the angle of attack (nose moves down).

In next step armour influence on sideslip characteristics at different angles of attack was analysed.

Appears, that armour shields are strongly decreasing drag coefficient with increase of sideslip angle, more than they do with angle of attack change – Figure 9a. This characteristic decreases with negative angle of attack (nose up), as fuselage shadows (aerodynamically) the upper part of armour.

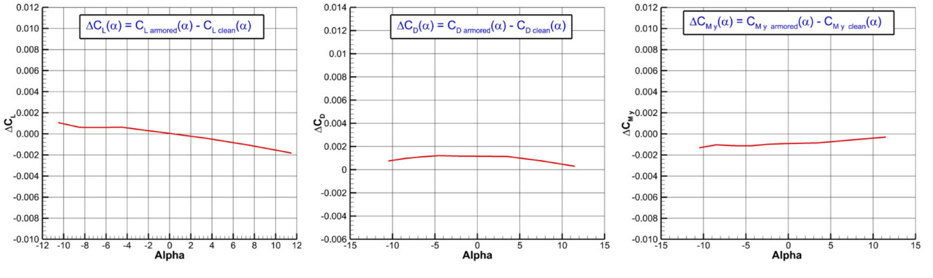

Figure 9. Influence of armour on fuselage lift drag and moment coefficients versus angle of attack

The armour influence on side force or moment coefficient are not significant – Figure 9b,c. Misleading could be a sign change in α=-5°, but parts of the armour are working as additional lifting surfaces, so this causes such unexpected behaviour. As a main factor of similar characteristics of moment could be front armour, which moves forward the pressure force centre (decreases stability) . On the other hand the armour around transmission and engines is also generating such displacement if it is not in aerodynamic shadow of a fuselage, as for positive α. That's because the influence on yaw moment changes its sign when it comes to angle of attack around α=3°.

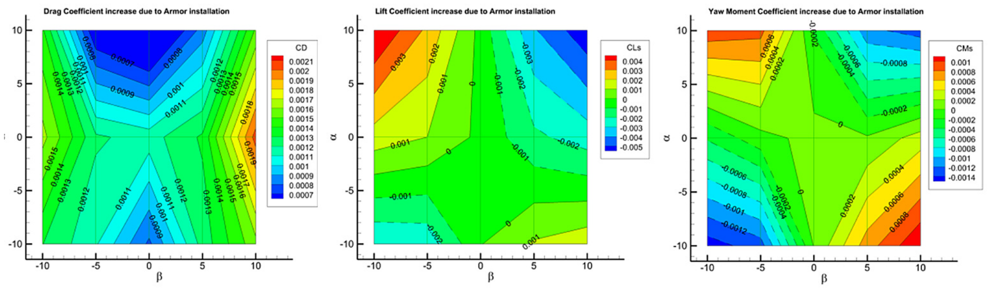

Figure 10. Armour influence on fuselage aerodynamic parameters – colour maps for Drag Coefficient (a), Side Force Coefficient (b), Yaw Moment Coefficient (c).

CONCLUSIONS

The aerodynamic characteristics of an armoured helicopter have been obtained using CFD methods. For comparison purposes the clean fuselage of the same helicopter has been also analysed. The results are consistent with suspected tendencies, that the armour external shields will decrease aerodynamic efficiency of considered helicopter's fuselage. Decrease of lift force at $\alpha >= 0°$, higher drag for all configurations of angles of attack and sideslip, increase in absolute size of pitching moment, all these are expected effect of using external armour.

The CFD methods, especially finite volume method, are a good tool for evaluating the tendencies of externally mounted devices influence, without using expensive wind tunnel or real flight tests. This concerns both design and upgrade of existing helicopter. As for wind tunnel tests, the scaling issues can be avoided, but only a validated CFD method should be considered.

ACKNOWLEDGMENTS

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REFERENCES

[1] Dziubiński A., "Generacja siatek obliczeniowych w symulacjach CFD" MIWL 2010, Bezmiechowa.
[2] Gnarowski W., Kajka R., Żółtak J., "Flying Object Armour Concept Analysis Based on Helicopter", ECMS, Simulation meets global challenges, June 2010, p. 126- 130.
[3] Gnarowski W. „Opracowanie konstrukcji mocowania paneli opancerzenia- pojazd lub śmigłowiec", Instytut Lotnictwa Internal Raport No. 182/BP1-SR/10.
[4] Grzegorczyk K. „Wykorzystanie metod obliczeniowej mechaniki płynów do modelowania szczególnego przypadku zniżania śmigłowca (VRS)" - MECHANIKA W LOTNICTWIE ML-XIV 2010, Polskie Towarzystwo Mechaniki Teoretycznej i Stosowanej.
[5] Standardization Agreement (STANAG) – 4569, NATO, January2004
[6] FAA FARs, 14 CFR 1.1, general definitions.
[7] PZL Świdnik design centre
[8] "ANSYS ICEM CFD 11.0 Tutorial Manual". 2007.
[9] "FLUENT 6.1 User's Guide. Fluent Inc". February 2003.

Adam Dziubiński, Katarzyna grzegorczyk, Jerzy Żółtak

BADANIA NUMERYCZNE WPŁYWU OPANCERZENIA NA CHARAKTERYSTYKI AERODYNAMICZNE ŚMIGŁOWCA

Streszczenie

Artykuł dotyczy analizy numerycznej wpływu zewnętrznego opancerzenia na charakterystyki aerodynamiczne śmigłowca. Dla dwu konfiguracji śmigłowca: opancerzonej i wyjściowej (bez pancerza) otrzymano obrazy pola przepływu dla wybranych z użytkowego zakresu kątów natarcia i ślizgu. Wykorzystano komercyjny pakiet oprogramowania Fluent. Rezultaty zostały wykorzystane do obliczenia sił i momentów działających na kadłub śmigłowca. Pracę zakończono analizą wpływu opancerzenia na charakterystyki aerodynamiczne.