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POSSIBILITIES OF THE USE OF THE PAWA-1 PASSIVE ARMOUR MODEL FOR PROTECTION OF THE HELICOPTER AGAINST RPG-7

Abstract: This paper contains results of experimental tests of the use of PAWA-1 passive armour model as a protection of the helicopter fuselage model against PG-7 projectiles launched from RPG-7 hand grenade launcher. The maximum level of the PAWA-1 protection probability against PG-7 projectiles was defined. The influence of PAWA-1 model on aerodynamic coefficients (drag, side and lift forces, bank, yaw and pitch moments) of the fuselage model of the Sokol, are shown. The percentage of the increase of the aerodynamic drag of Sokol helicopter model after the installation of the PAWA-1 passive armour model is estimated. The influence of the PAWA-1 passive armour model on the helicopter fuselage model on static stability for the α and β attack angles in tunnel wind is presented.

MOŻLIWOŚCI UŻYCIA MODELU PANCERZA PASYWNEGO PAWA-1 W CELU OCHRONY HELIKOPTERA PRZED RPG-7

Streszczenie: Artykuł zawiera rezultaty testów doświadczalnych użycia modelu pancerza pasywnego PAWA-1 w celu ochrony modelu kabiny helikoptera przed pociskami PG-7 wystrzeliwanymi z ręcznej wyrzutni granatów RPG-7. Został określony maksymalny poziom prawdopodobieństwa ochrony pancerza PAWA-1 przed pociskami PG-7. Przedstawiono wpływ modelu PAWA-1 na współczynniki aerodynamiczne (siły: oporu, bocznej i nośnej oraz momentów: przechylającego, pochylającego i odchylającego) na model kabiny Sokół. Oszacowano procentowy wzrost aerodynamicznego oporu na model helikoptera Sokol po zainstalowaniu modelu pancerza pasywnego PAWA-1. Przedstawiono wpływ modelu pancerza pasywnego PAWA-1 na stabilność modelu kabiny helikoptera dla różnych kątów wiatru w tunelu aerodynamicznym α i β.

1. Introduction

One of most widely applied, the simplest, the most popular and the cheapest hand grenade launchers, used in the world, is RPG-7 one with different type of projectiles - shape charge, fragments, smoke ones, etc. A specially PG-7 shape charge projectiles are very dangerous against heavy and light armoured vehicles like tanks and light fighting vehicles. Penetration ability of this type of ammunition is from 300 mm to ~ 800 mm depth of penetration of rolled homogeneous armour RHA depending on the use of one-warhead or tandem shape charge warhead.

From the beginning of Russia war against Afghanistan PG-7 projectiles have been used against non-armoured objects like helicopters. Next the same situations took place during the wars in Iraq and Afghanistan last time as a results of fighting against terrorists. During these wars a lot of helicopters were shot down with the use of RPG-7. Now the protection of the helicopters against PG-7 shape charge projectiles launched from RPG-7 hand grenade launcher is one of the several subjects of NATO called Defence Against Terrorism.

2. The PAWA-1 passive armour

The PAWA-1 passive armour has been elaborated in Military Institute of Armament Technology in Poland. The PG-7 projectiles were initiated electrically during the static tests and they were launched from the RPG-7 hand grenade launcher during the dynamic tests of PAWA-1 (Fig. 1).

Fig. 1. PAWA-1 armour on the stand with steel witness plate

The tested PAWA-1 passive armours and soft steel plate as the witness plate were installed on the stiff stand which was stiffly mounted on the ground. As a result of this the PAWA-1 could not move during impact of PG-7 projectile. This armour was mounted at the distance of 700 mm from soft steel witness plate. The witness plate, sized 2000x1000x(3÷8) mm, was situated behind the tested armours. The data of the PAWA-1 passive armour (Fig. 1) were: the mass of ~ 60 kg/m^2, and size 500x500x(<100) mm. PG-7 projectiles were fired from RPG-7 launcher which was assembled stiffly on the stand.

After analysing the all achieved results of behaviour of the PAWA-1 passive armour it can be stated that the maximum probability of protection level of a helicopter fuselage can achieve 30%, it means that the PG-7 projectiles were mechanically destructed without explosions and without generating of shape charge jet.

3. Testing of PAWA-1 passive armour model in wind tunnel

This part contains results of experimental tests of the influence of the PAWA-1 passive armour on aerodynamic coefficients of the fuselage of Sokol helicopter model. The tests were carried out in Institute of Aviation in Low Speed Wind Tunnel T3 with diameter of 5 meters on the helicopter test stand. Measurements of aerodynamic coefficients acting on the fuselage with and without PAWA-1 protection were taken with the use of six–component strain gauge internal balance HWG-6 placed inside the model of the fuselage for angles of attack α from the wide range -90÷90 degrees every 10 degrees and for sideslip angles β= -10, 0, 10 degrees (Fig. 2). The presented results are shown only for useful angles of attack α from the range: -30÷30 degrees.

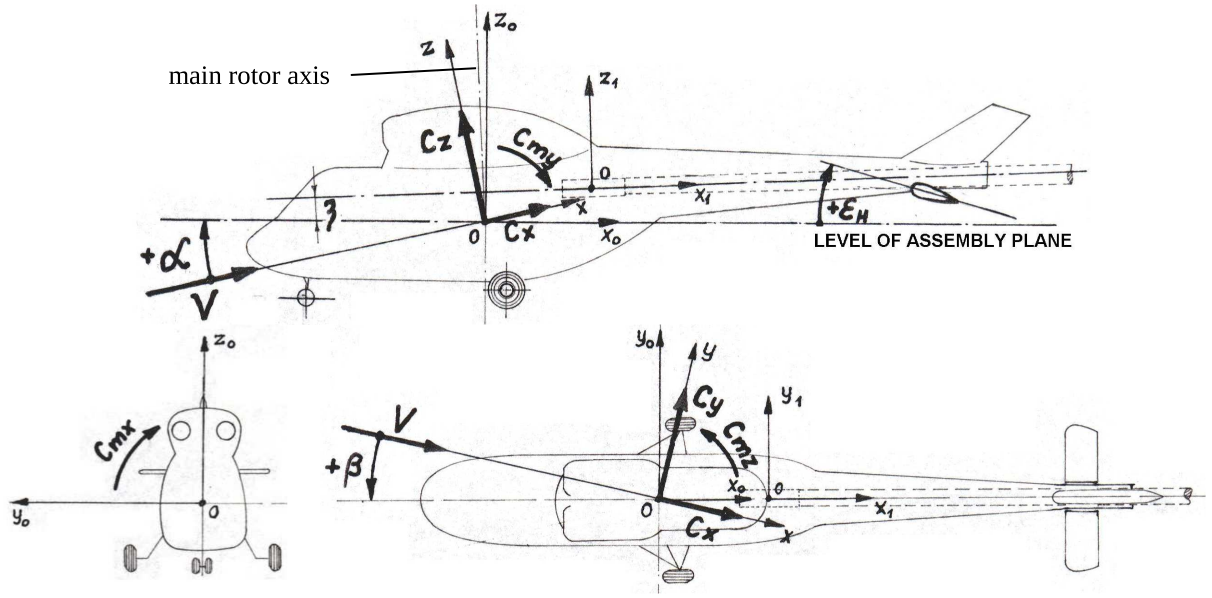


Fig. 2. The coordinate system connected with free flow in wind tunnel test chamber

Formulas for aerodynamic load coefficients calculations are as the following:

- drag force coefficient $C_x(\alpha,\beta)=\dfrac{2F_x(\alpha,\beta)}{\rho V^2 A}=\dfrac{2F_x(\alpha,\beta)}{\rho V^2 \pi R^2}$, (1)
- side force coefficient $C_y(\alpha,\beta)=\dfrac{2F_y(\alpha,\beta)}{\rho V^2 A}=\dfrac{2F_y(\alpha,\beta)}{\rho V^2 \pi R^2}$, (2)
- lift force coefficient $C_z(\alpha,\beta)=\dfrac{2F_z(\alpha,\beta)}{\rho V^2 A}=\dfrac{2F_z(\alpha,\beta)}{\rho V^2 \pi R^2}$, (3)
- aerodynamic bank moment coefficient $C_{mx}(\alpha,\beta)=\dfrac{2M_x(\alpha,\beta)}{\rho V^2 AR}=\dfrac{2M_x(\alpha,\beta)}{\rho V^2 \pi R^3}$, (4)
- aerodynamic pitch moment coefficient, $C_{my}(\alpha,\beta)=\dfrac{2M_y(\alpha,\beta)}{\rho V^2 AR}=\dfrac{2M_y(\alpha,\beta)}{\rho V^2 \pi R^3}$, (5)
- aerodynamic yaw moment coefficient, $C_{mz}(\alpha,\beta)=\dfrac{2M_z(\alpha,\beta)}{\rho V^2 AR}=\dfrac{2M_z(\alpha,\beta)}{\rho V^2 \pi R^3}$, (6)

where: *A* [m] - characteristic main rotor area; *R* [m] - characteristic length (the length of main rotor blade); α [deg] - the angle of attack of the fuselage; β [deg] - the sideslip angle of the fuselage; *V* [m/s] - an airflow velocity in wind tunnel test chamber; *Fx*, *Fy*, *Fz* [N] - the aerodynamic longitudinal (drag), side and lift force of the fuselage; *Cmx*, *Cmy*, *Cmy* - the aerodynamic rolling, pitching and yawing moment coefficient of the fuselage; *Mx*, *My*, *Mz* [Nm] - the aerodynamic rolling, pitching and yawing moment of the fuselage; ρ - density of air.

The PAWA-1 model tests have been conducted in the Low Speed Wind Tunnel in an atmospheric, closed-circuit tunnel with an open test section of 5 meter diameter, and 6.5 m length where the wind can reach velocity of 57 m/s with a dynamic pressure of 2000 N/m^2. The Reynolds number per meter ranged from 0 to 3.8×10^6. The flow in the test section is relatively uniform with a longitudinal turbulence level of about 0.5%. Turbulence factor measured on sphere was TF=1.22, and turbulence intensity measured by anemometer was τ=0.5%. Velocity field irregularity was $\Delta V=\pm0.5\%$ and airflow sweep angle irregularity: $\Delta\alpha$, $\Delta\beta=\pm0.5°$.

The six-component, internal strain gauge balance, designated HWG-6, was used for the tests of helicopter fuselage model (Fig. 3).

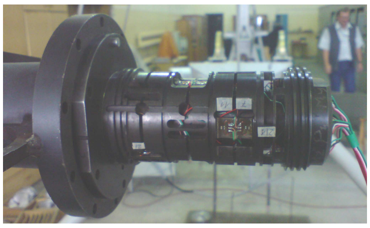


Fig. 3. HWG-6 six-component internal strain gauge balance

The measurement range of HWG-6 (static accuracy determined on the base of calibration) were: drag force 150 N and Fx < 0.17%; side force 300 N and Fy < 0.2%; lift force 200 N and Fz < 0.2%; rolling moment 50 Nm and Mx < 0.15%; pitching moment 50 Nm and My < 0.15%; yawing moment 50 Nm and Mz < 0.2%.

The fuselage of Sokol helicopter model with PAWA-1 protection is shown in Figure 4.

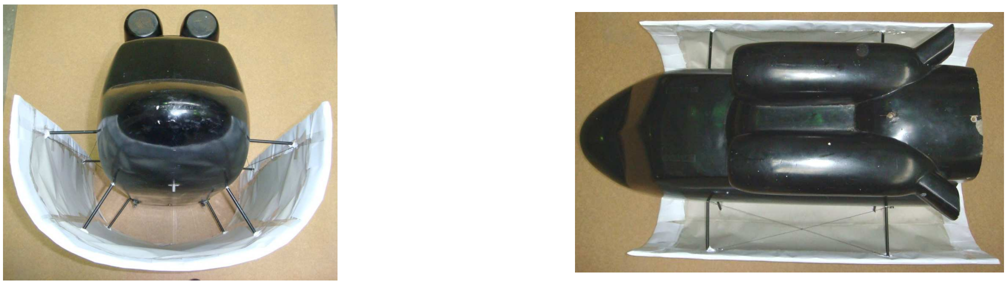


Fig. 4. The fuselage of the Sokol helicopter model with PAWA-1 protection

Data of the Sokol helicopter were:

1. The fuselage model:
   - the fuselage model scale 1:6.49;
   - the fuselage model length L=2.055 m.
2. Main rotor model (for radius R and main rotor area S aerodynamic coefficients of fuselage model were calculated):
   - the main rotor model scale 1:6.49;
   - the diameter of the main rotor model D=2.42 m;
   - the area of main rotor model S=4.5996 m^2.
3. Data of PAWA-1 protection model:
   - the protection model scale 1:6.49;
   - the length of protection model L=0.775 m;
   - the perimeter of protection model O=0.87 m.

The fuselage of Sokol helicopter model with and without PAWA-1 protection model was tested in wind tunnel. The fuselage of Sokol helicopter model with and without PAWA-1 protection model, mounted on the sting with HWG-6 six-component internal strain gauge balance is presented in Figure 5.

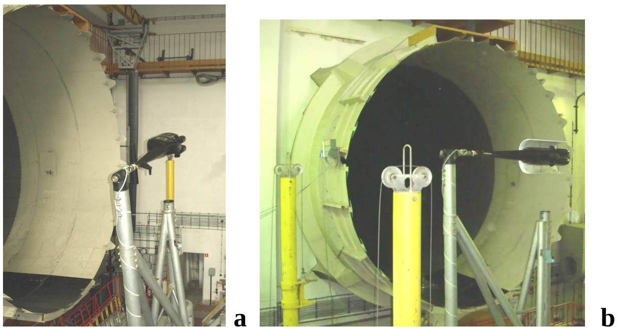


**Fig. 5. The fuselage of Sokol helicopter model on the test stand: a - without protection for α = 90 deg, β = 10 deg;
b - with protection for α = 90 deg, β = 0 deg**

Results of wind tunnel tests were presented in Figures 6÷9 as non-dimensional mean values of aerodynamic coefficients of the helicopter fuselage model for various angles of attack and sideslip. The aim of measurements was the comparison of the influence of stabiliser and protection or stabiliser and lack of protection on aerodynamic characteristics (*Cx*, *Cy*, *Cz*, *Cmx*, *Cmy*, *Cmz*) of the helicopter fuselage model for the range of attack angles:

- α = -100 ÷100 deg;
- β= -10, 0, 10 deg.

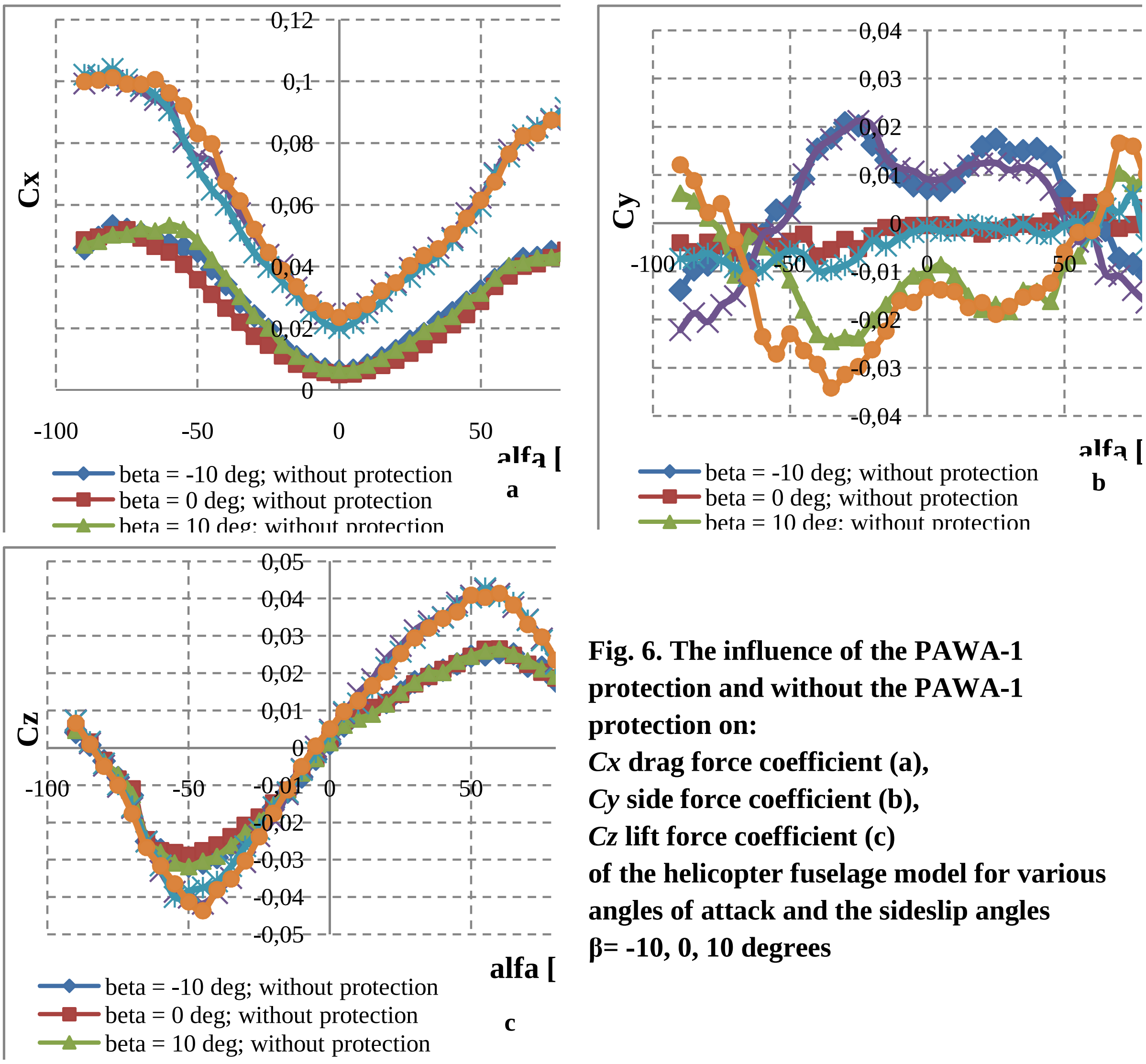
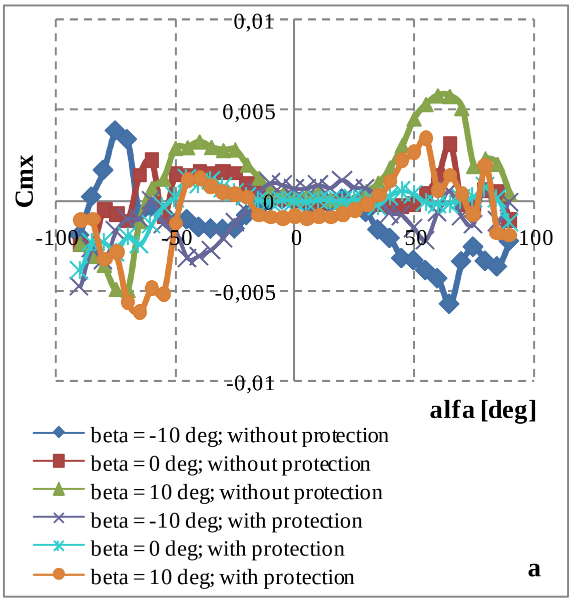
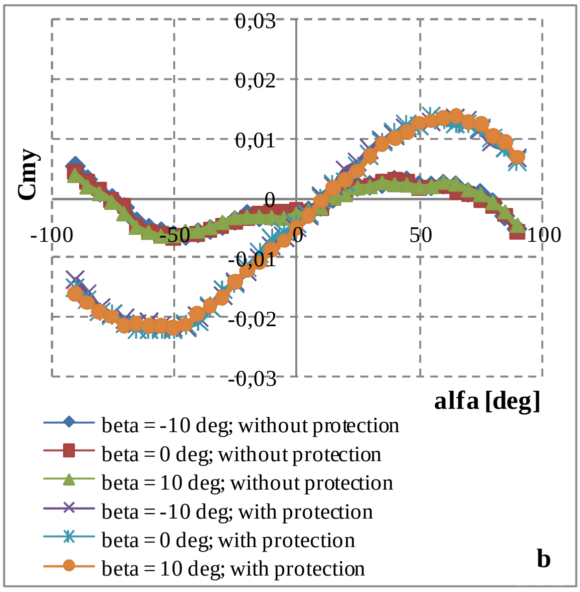


Fig. 6. The influence of the PAWA-1 protection and without the PAWA-1 protection on:
***Cx* drag force coefficient (a),**
***Cy* side force coefficient (b),**
***Cz* lift force coefficient (c)**
of the helicopter fuselage model for various angles of attack and the sideslip angles
β= -10, 0, 10 degrees





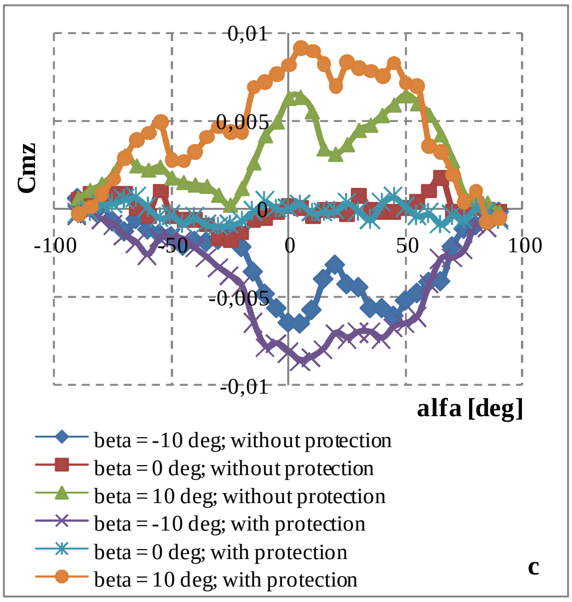
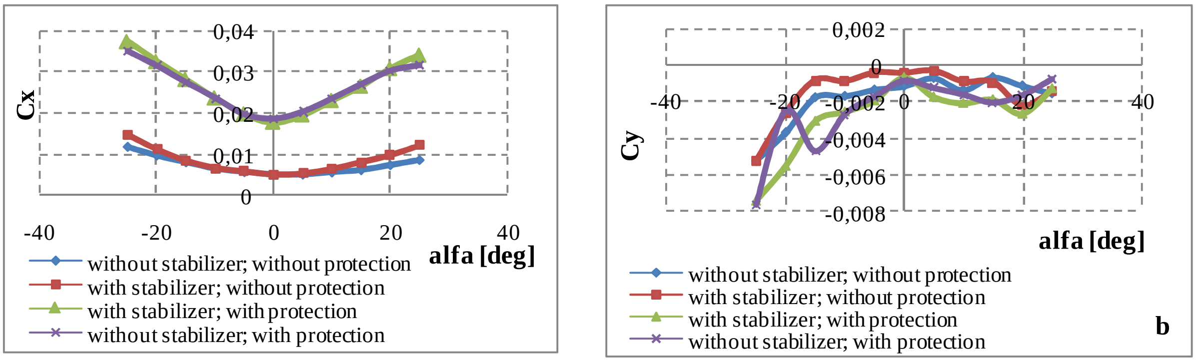


Fig. 7. The influence of the PAWA-1 protection and without the PAWA-1 on:
Cmx rolling moment coefficient (a),
Cmy pitching moment coefficient (b),
Cmz yawing moment coefficient (c)
of the helicopter fuselage model for various angles of attack and the sideslip angles
β= -10, 0, 10 degrees

a



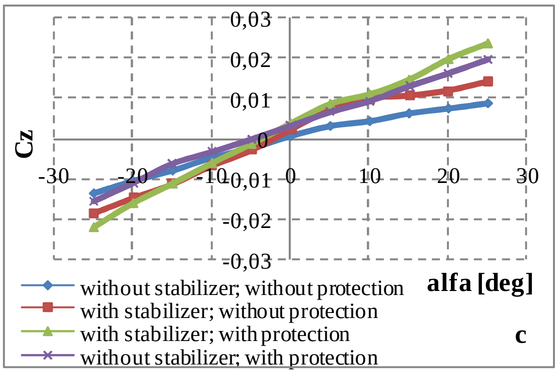
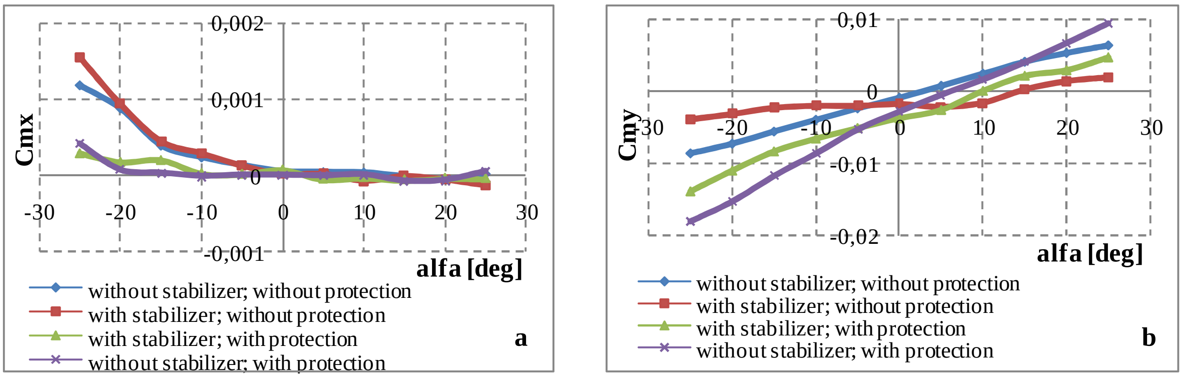


Fig. 8. The influence of: the PAWA-1 protection or without the PAWA-1 protection, and stabilizer or without stabilizer on:
***Cx* drag force coefficient (a),**
***Cy* side force coefficient (b),**
***Cz* lift force coefficient (c)**
of the helicopter fuselage model for various angles of attack and the sideslip angles β= 0 degree



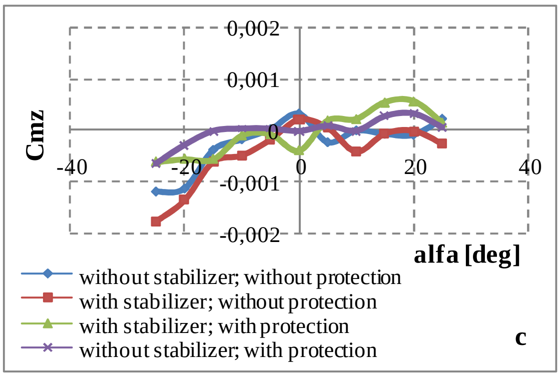


Fig. 9. The influence of: the PAWA-1 protection or without the PAWA-1 protection, and stabilizer or without stabilizer on:
***Cx* drag force coefficient (a),**
***Cy* side force coefficient (b),**
***Cz* lift force coefficient (c)**
of the helicopter fuselage model for various angles of attack and the sideslip angles β= 0 degree

The gained results show that the values of forces' coefficients: *Cx* drag, *Cy* side, *Cz* lift and moments' coefficients: *Cmx* rolling, *Cmy* pitching, *Cmz* yawing for the fuselage model of Sokol helicopter with and without the PAWA-1 protection model and with and without stabilizer for the large range of attack angles α = -100 ÷100 deg, and sideslip angles β= -10, 0, 10 degrees, are very closely.

4. Conclusions

On the basis of presented tests' results it can be stated the following:

1. The PAWA-1 passive armour can protect non-armoured objects like helicopter with the maximum probability level 30%, where the PG-7 projectiles are mechanically destructed without explosions.
2. For the fuselage model of Sokol helicopter with and without the PAWA-1 protection model and with and without stabilizer for the range of attack angles: $\alpha = -100 \div 100$ deg and for sideslip angles $\beta = -10, 0, 10$ degrees the maximum ranges of these coefficients are very small (Table 1).

Table 1. Forces' and moments' coefficients for sideslip angles $\beta = -10, 0, 10$ degrees

Forces' coefficients:			Moments' coefficients:		
drag *Cx*	side *Cy*	lift *Cz*	rolling *Cmx*	pitching *Cmy*	yawing *Cmz*
0÷0.01	-0.035÷0.021	-0.045÷0.045	-0.0052÷0.0052	-0.022÷0.014	-0.0057÷0.0059

3. The installation of the protection causes that the helicopter fuselage model becomes statically unstable for entire range of angles of attack α. It can cause the increase of a vertical stabilizer area to make a flight possible.
4. It was estimated that aerodynamic drag of „Sokol" helicopter model after the installation of the protection increased about 25%.
5. It is noticed that the increase of a vertical stabilizer area can decrease aerodynamic helicopter drags and increase airworthiness while flying.
6. The tests of the PAWA-1 passive armour should be carried out in the future in order to check:
   - possibility of the different assembling of the PAWA-1 on the helicopter,
   - final protection level with the use of helicopter wreck.

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