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THE NUMERICAL ANALYSIS OF PROPERTIES OF THE TRAILING-EDGE FLAP ON THE ILH412M-S ROTOR BLADE AIRFOIL

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Abstract

This paper summarise initial activities concerning the design of the segment of rotor blade with a trailing-edge flap actuated by Amplified Piezo Actuator used in dynamic pressure measurements in T-1 low-speed wind tunnel of the Institute of Aviation.

This paper is focused on the design process of the shape of the trailing-edge flap on a rotor blade segment, based on the ILH412M-S profile.

After this initial step in design of the rotor blade segment it will be used to derive aerodynamic loads in a two-dimensional flow according to assumptions of the research project "Research on the active control of the airflow of helicopter rotor blade with the use of a flap oscillation and a microflap to improve aerodynamic performance of a helicopter" [1].

INTRODUCTION

The main part of the project "Research on the active control of the airflow of helicopter rotor blade with the use of a flap oscillation and a microflap to improve aerodynamic performance of a helicopter" (grant No. N 509 003 31/0251) is focused on the helicopter rotor blade segment with active control system used to deflections of the trailing-edge flap (TEF). The ILH412M-S profile, designed in the Institute of Aviation, was chosen for that segment of 480 mm (initially 440 mm) of chord and 1000 mm of span. The deflection of TEF modifies the airflow around the blade which cause changes of the aerodynamic performance of the rotor and the whole helicopter. The TEF deflection is achieved as the result of the deformation of Amplified Piezo Actuator (APA) which is connected with TEF by the mechanical system of lever and tappet. APA1000XL-SG piezo actuator by CEDRAT was chosen not only as the source of force and strain but also as the source of information about a strain (and the TEF deflection after calculations) [2, 3].

1. DESIGN PROCESS OF THE ILH412M-S AIRFOIL

Before the designing process in which properties of the TEF had been chosen, the initial analysis of aerodynamic properties of the ILH412M-S airfoil has been done in the Institute of Aviation.

This analysis was connected with another project carried out by the Institute of Aviation and PZL Świdnik to design new rotor blades for helicopter main rotor for W-3 Sokół helicopter.

One of airfoils calculated numerically in that project was ILH412M-S. It was later chosen for rotor blades of helicopter main rotor. Because one of assumptions of this project was to use the airfoil of the real W-3 main rotor blade, it was chosen as the basis for further analysis and modifications.

In the initial stage [4] the numerical analysis of ILH412M-S was made and aerodynamic characteristics were derived using AMI MSES and ANSYS FLUENT CFD software. Aerodynamic characteristics of ILH412M-S for various Mach numbers are presented in Figures 1 and 2.

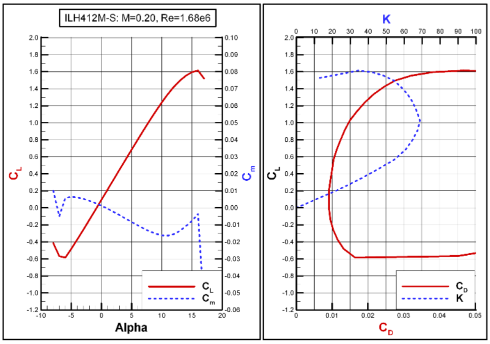

Fig. 1a. Aerodynamic characteristics of ILH412M-S for M = 0.20 (from CFD)

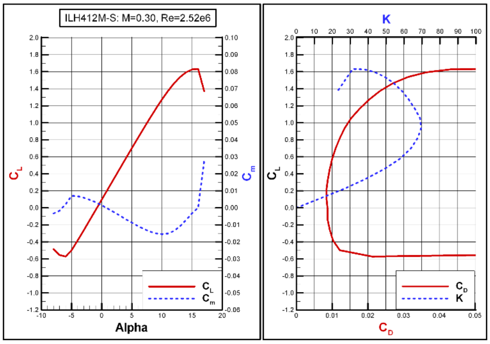

Fig. 1b. Aerodynamic characteristics of ILH412M-S for M = 0.30 (from CFD)

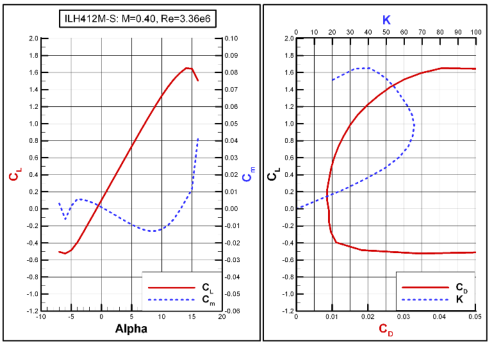

Fig. 1c. Aerodynamic characteristics of ILH412M-S for M = 0.40 (from CFD)

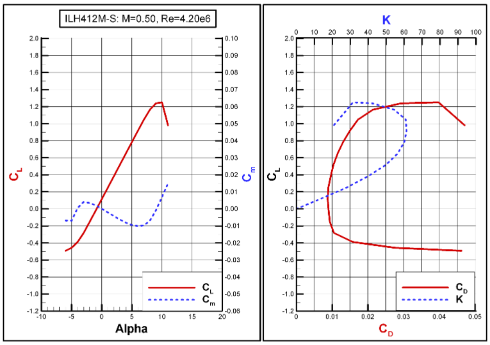

Fig. 1d. Aerodynamic characteristics of ILH412M-S for M = 0.50 (from CFD)

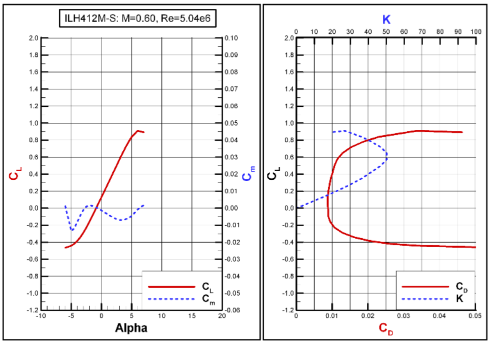

Fig. 1e. Aerodynamic characteristics of ILH412M-S for M = 0.60 (from CFD)

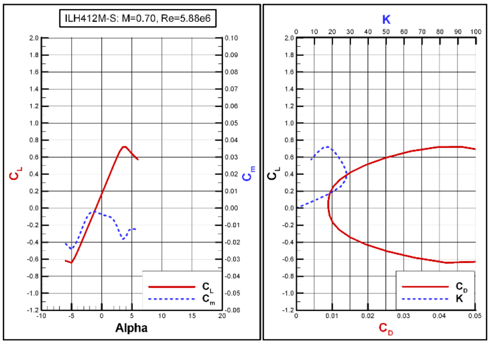

Fig. 1f. Aerodynamic characteristics of ILH412M-S for M = 0.70 (from CFD)

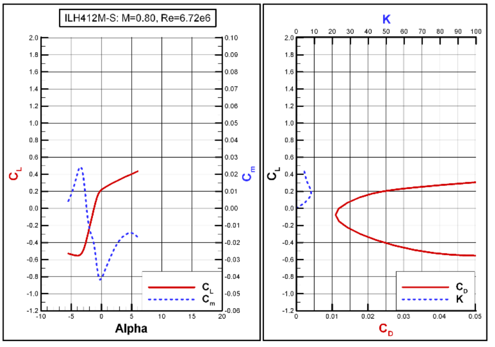

Fig. 1g. Aerodynamic characteristics of ILH412M-S for M = 0.80 (from CFD)

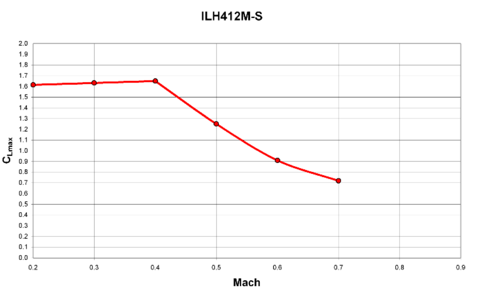

Fig. 2. C_{Lmax} for various Mach numbers for ILH412M-S (from CFD)

In the next stage [5, 6] wind tunnel tests of ILH412M-S were made in the N-3 trisonic wind tunnel of the Institute of Aviation (Fig. 3) to prove results of CFD calculations of aerodynamic characteristics made earlier in [4]. For these tests ILH412 airfoil model of chord of 200 mm was prepared (Fig. 4).

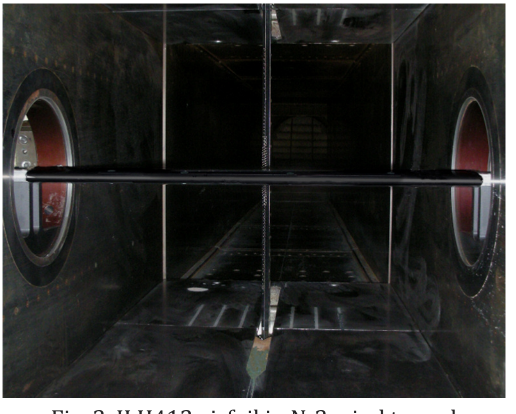

Fig. 3. ILH412 airfoil in N-3 wind tunnel

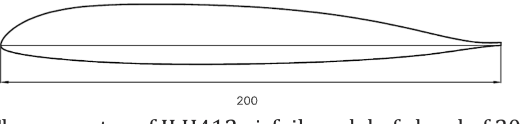

Fig. 4. The geometry of ILH412 airfoil model of chord of 200 mm

Aerodynamic characteristics of ILH412M-S for various Mach numbers are presented in Figures 5 and 6.

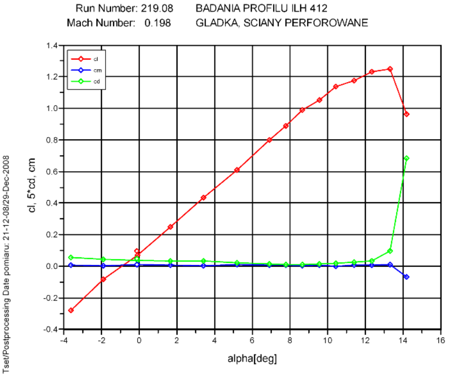

Fig. 5a. Aerodynamic characteristics of ILH412M-S for M = 0.20 (from N-3 wind tunnel tests)

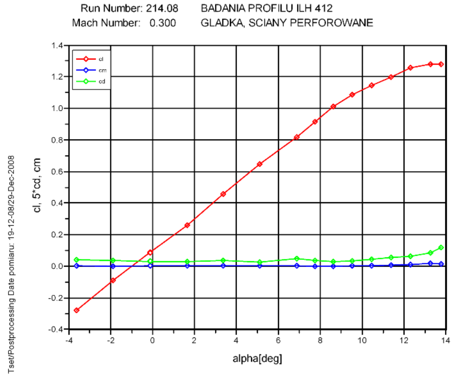

Fig. 5b. Aerodynamic characteristics of ILH412M-S for M = 0.30 (from N-3 wind tunnel tests)

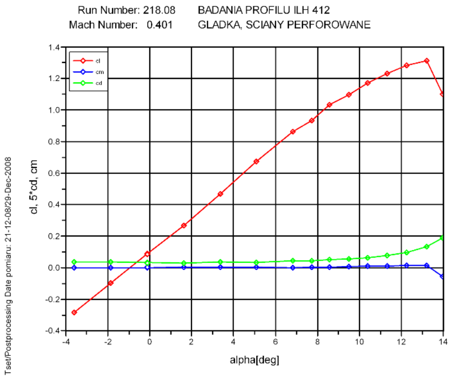

Fig. 5c. Aerodynamic characteristics of ILH412M-S for M = 0.40 (from N-3 wind tunnel tests)

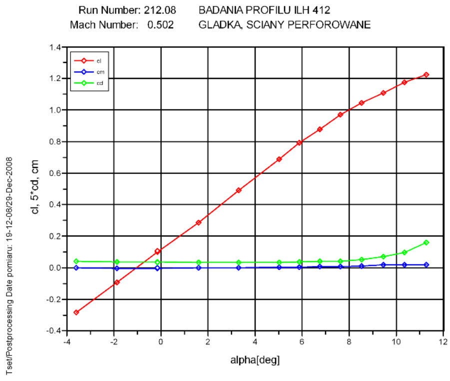

Fig. 5d. Aerodynamic characteristics of ILH412M-S for M = 0.50 (from N-3 wind tunnel tests)

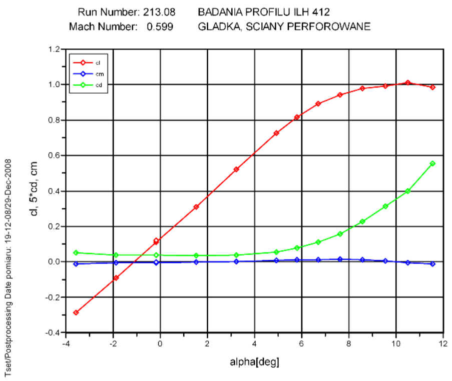

Fig. 5e. Aerodynamic characteristics of ILH412M-S for M = 0.60 (from N-3 wind tunnel tests)

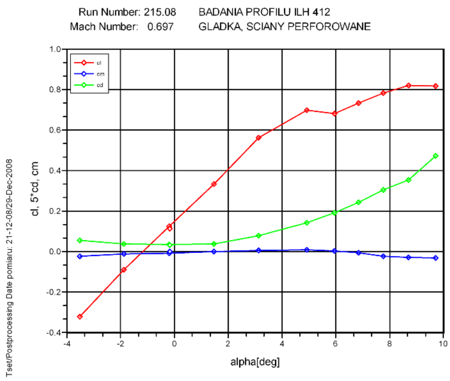

Fig. 5f. Aerodynamic characteristics of ILH412M-S for M = 0.70 (from N-3 wind tunnel tests)

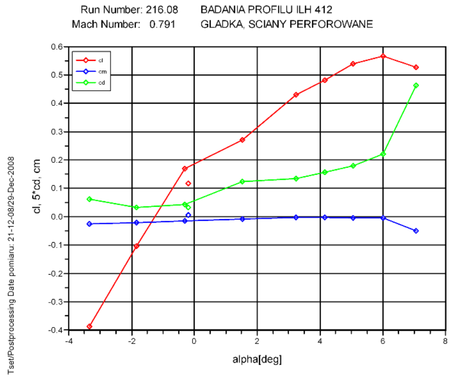

Fig. 5g. Aerodynamic characteristics of ILH412M-S for M = 0.80 (from N-3 wind tunnel tests)

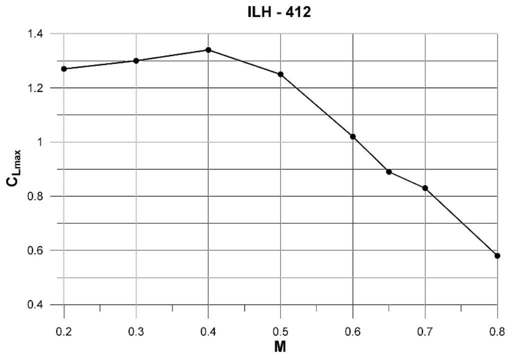

Fig. 6. C_{Lmax} for various Mach numbers for ILH412M-S (from N-3 wind tunnel tests)

DESIGN PROCESS OF THE ILH412M-S AIRFOIL WITH THE PIEZOACTUATED TEF

In the beginning of the design process of a helicopter rotor blade segment with active control system used to deflections of the TEF, numerical calculations in ANSYS FLUENT flow modelling software were made [7].

In the initial phase it was assumed that the chord of ILH412M-S is 440 mm, a thickness is 12%, an aerodynamic centre (AC) is in 25% of chord from the nose. The pitching axis of the airfoil where the angle of attack is calculated is set in AC.

Three lengths of the TEF were taken into consideration – 10%, 15% (Figure 7) and 20% of the airfoil chord – with hinges at 90%, 85% and 80% of the chord from the nose, respectively.

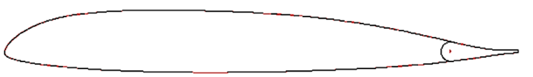

Fig. 7. ILH412M-S airfoil with 15% TEF

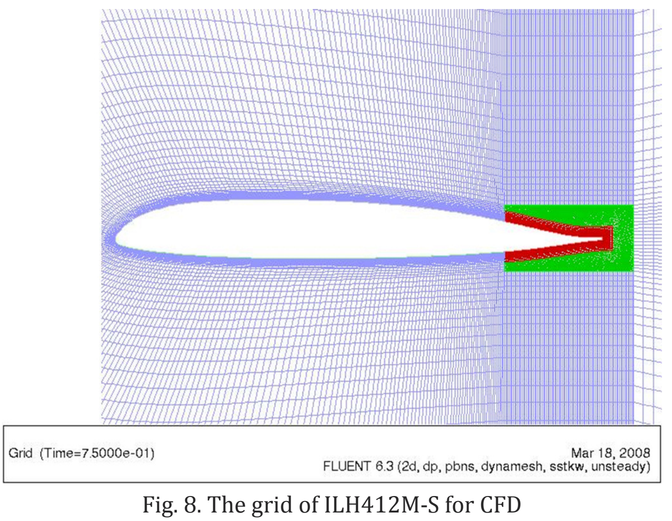

Fig. 8. The grid of ILH412M-S for CFD

In numerical calculations of aerodynamic loads oscillations of the angle of attack of the airfoil, oscillations of the deflection of the TEF and pulsations of the airflow speed resulting from a forward velocity of a helicopter were assumed. The grid for CFD calculations (Figure 8) was designed with the possibility of the modification of the position of the TEF to simulate the oscillation of the TEF.

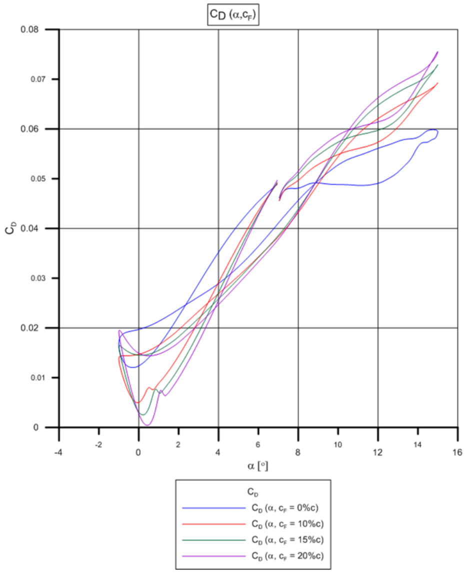

Fig. 9a. C_D (α) for various chords of TEFs

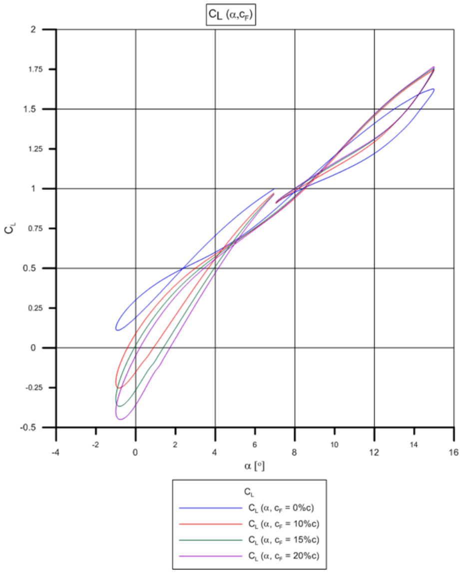

Fig. 9b. C_L (α) for various chords of TEFs

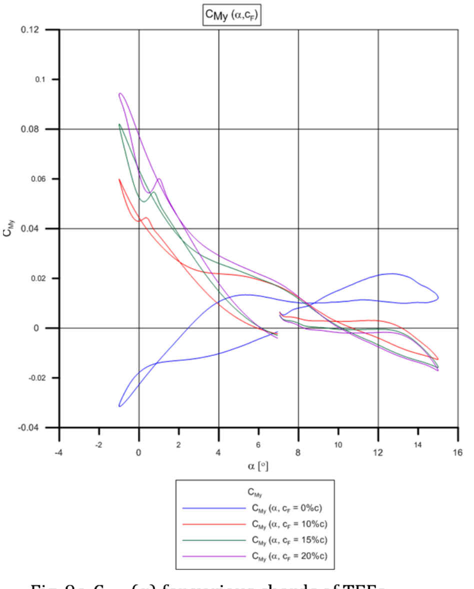

Fig. 9c. C_{My} (α) for various chords of TEFs

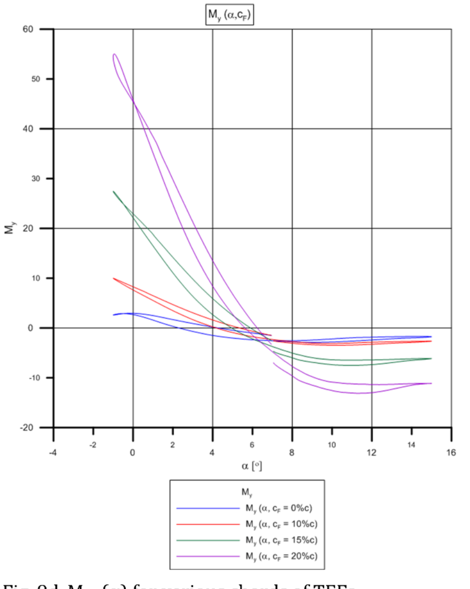

Fig. 9d. M_y (α) for various chords of TEFs

For numerical calculations it was assumed that the angle of attack oscillates in the range from -1° to 15° (the amplitude is 16°). The TEF oscillates in the range from -5° to 5° (the amplitude is 10°). The frequency of the cyclic pitch is 4.25 Hz. CFD calculations were made for

Mach number Ma = 0.60 with pulsations of ±0.15. In position where the angle of attack of the airfoil was minimal Mach number was Ma = 0.75 and where the angle of attack of the airfoil was maximal Mach number was Ma = 0.45. Aerodynamic coefficients C_D, C_L, C_{My} and moment M calculated for above parameters are presented in Figure 9.

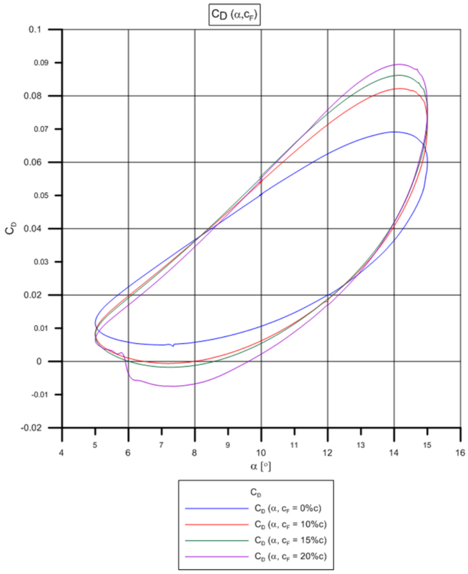

Fig. 10a. C_D (α) for various chords of TEFs

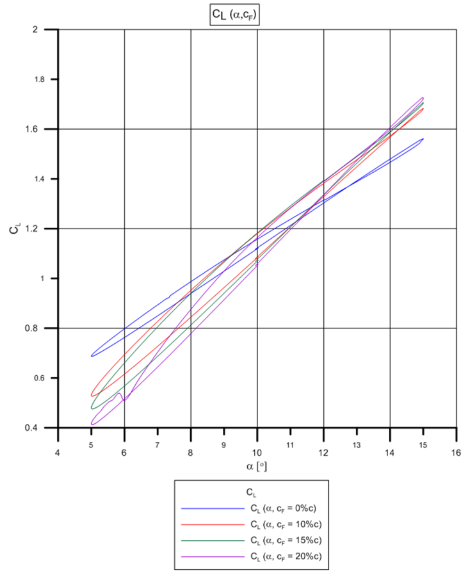

Fig. 10b. C_L (α) for various chords of TEFs

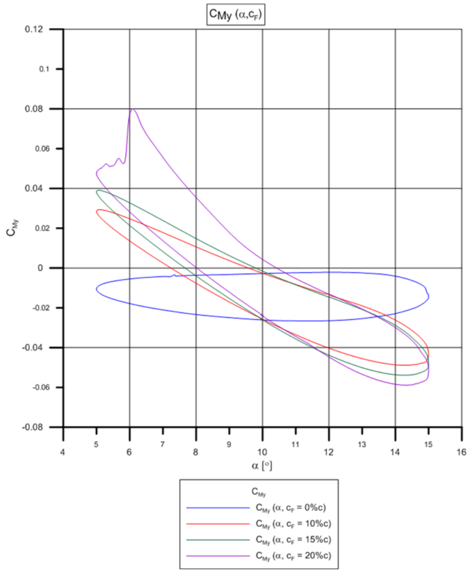

Fig. 10c. C_{My} (α) for various chords of TEFs

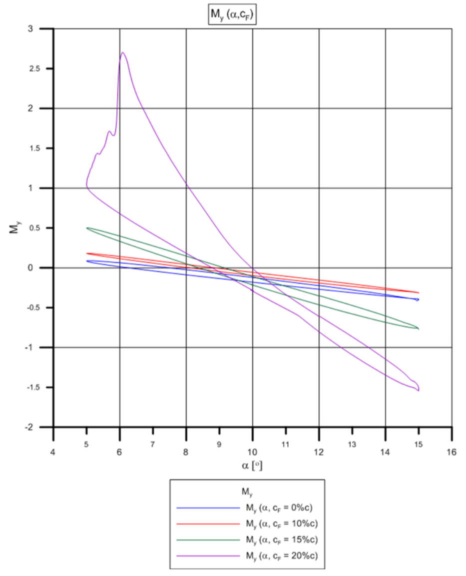

Fig. 10d. M_y (α) for various chords of TEFs

In further CFD calculations values of the angle of attack were changed. It was assumed that the angle of attack oscillates in the range from 5° to 15° (the amplitude is 10°). Aerodynamic coefficients C_D, C_L, C_{My} and moment M calculated for modified parameters are presented in Figure 10.

Results of CFD calculations obtained from the analysis confirmed the available literature and R&D works of helicopter manufacturers concerning the highest efficiency of 15% chord length the TEF. For this size of the TEF the aerodynamic lift coefficient increases by about 0.1 for flap deflection ±5° to the profile of undeflected flap (for 20% TEF the growth is slightly higher). The aerodynamic coefficient of pitching moment for 15% TEF deflected at 10° is slightly higher in a comparison to the undeflected TEF and is two times smaller than the 20% TEF deflected at the same angle. Forces (approximately 95 N) and moments obtained in CFD calculations in the TEF hinge axis required for TEF deflections could be obtained by APA1000XL-SG piezoactuator by CEDRAT TECHNOLOGIES without any problems at the desired angle of the TEF (the maximum force generated by the actuator is 745N).

CONCLUSIONS

The designed, 15% of chord, trailing-edge flap on the ILH412M-S rotor blade airfoil will be used to derive aerodynamic loads in a two-dimensional flow in the T-1 low speed wind tunnel, for further numerical analysis of the aerodynamic performance of a helicopter.

ACKNOWLEDGEMENT

This paper is the result of activities which have been carried out in the research project "Research on the active control of the airflow of helicopter rotor blade with the use of a flap oscillation and a microflap to improve aerodynamic performance of a helicopter" (grant No. N 509 003 31/0251) funded by Polish Ministry of Science and Higher Education.

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MAREK MILLER, WIEŃCZYSŁAW STALEWSKI

NUMERYCZNA ANALIZA WPŁYWU KLAPKI NA KRAWĘDZI SPŁYWU ŁOPATY WIRNIKA NOŚNEGO ŚMIGŁOWCA O PROFILE ILH412M-S

Streszczenie

Dokument ten podsumowuje wstępne działania dotyczące projektowania segmentu łopaty wirnika nośnego śmigłowca z wychylaną klapką na krawędzi spływu sterowaną siłownikiem piezoelektrycznym stosowanego w dynamicznych pomiarach ciśnienia w tunelu aerodynamicznym małej prędkości T-1 Instytutu Lotnictwa.

Niniejszy dokument koncentruje się na procesie projektowania kształtu klapki na krawędzi spływu segmentu łopaty wirnika o profilu ILH412M-S.

W wyniku działań opisanych w tym dokumencie zostanie zaprojektowany segment łopaty wirnika (w oparciu o profil ILH412M-S), który będzie wykorzystywany w celu wyznaczenia obciążeń aerodynamicznych w przepływie dwuwymiarowym zgodnie z założeniami projektu badawczego "Badania aktywnego sterowania opływem łopaty wirnika nośnego przy pomocy oscylacji klapy i mikroklapki w celu poprawy osiągów aeromechanicznych śmigłowca". [1].