

ROTOR BLADE SEGMENT WITH PIEZOACTUATED TRAILING-EDGE FLAP FOR DYNAMIC PRESSURE MEASUREMENTS

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Abstract

This paper summarise the entirety of previous 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. The designed rotor blade segment, based on the ILH412M-S profile, 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".

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 of chord and 1000 mm of span, and a pitching axis in an aerodynamic centre in 25% of chord. 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 TECHNOLOGIES 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) [1]. On both surfaces of the blade segment 73 pressure measurement points were prepared for the connection to three ESP-32HD pressure scanners of DTC Initium pressure measurement system by Pressure Systems Inc.

NUMERICAL ANALYSIS FOR TEF PROPERTIES

The first step in the designing of a helicopter rotor blade segment with active control system used to deflections of the TEF were numerical calculations in ANSYS FLUENT flow modelling software.

As a base ILH412M-S profile was chosen (Fig. 1) which was designed for a new rotor blade for Sokol-2 helicopter. Numerical calculations made in FLUENT were aimed on the choice of the most effective size of TEF. The 2-dimensional analysis was made for the segment of 440 mm of chord and the pitching axis in the aerodynamic centre in 25% of chord. In the 3-dimensional analysis loads acting on the segment and the TER actuation mechanism, for the segment of span of 600 mm, were made. Three amounts of TEF were taken into consideration: 10%, 15% and 20% of chord. In numerical calculations small influence of 10% chord TEF was noticed. Both, 15% and 20% chord TEF, showed their bigger and similar influence on aerodynamic lift coefficients, but 20% chord TEF generated bigger aerodynamic pitching moment. After comparison with available papers and applied TEF-blade configurations (e.g. RPA blades on BK-117 by Eurocopter), 15% TEF was chosen for further consideration and design (Fig. 1). According to further modifications concerning a real rotor blade of Sokol-2 helicopter, the blade chord was lengthened up to 480 mm and the span of the segment up to 1000 mm. Both, 2- and 3-dimensional analysis was repeated.



Fig. 1. ILH412M-S airfoil with 15% TEF

PIEZOELECTRIC TEF ACTUATOR

It was assumed that 15% TEF will be actuated by Amplified Piezo Actuator (APA) designed by CEDRAT TECHNOLOGIES.

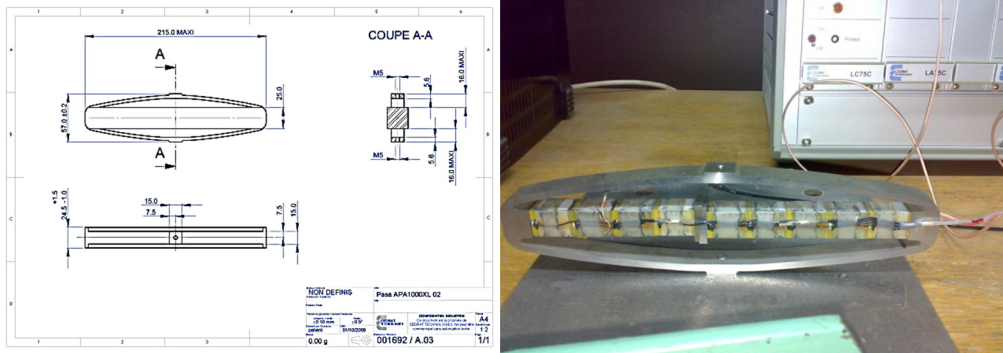


Fig. 2. APA1000XL-SG by CEDRAT

APA1000XL-SG model (Fig. 2) was chosen because its large displacement up to 1250 μm and big blocking-force of 745 N. APA with strain gauge (-SG) option was chosen because the possibility of the measurement of its displacement (that is connected with the angle of a TEF deflection). Similar, but smaller APA750 actuator was used in the test rotor of BK-117 by Eurocopter (Fig. 3), which also influenced on the decision of the choice of a tested solution using in a helicopter industry.



Fig. 3. BK-117 with RPA blades

APA1000XL-SG is driven by the set of electronic equipment (signal controller, power amplifier, etc.) by CEDRAT TECHNOLOGIES (Fig. 4). A control signal is given to an input of LC75C signal controller which takes care of the quality and range of input voltage to prevent the APA piezo actuator against a damage. Conditioned signal is given to the input of LA75C linear power amplifier with the voltage amplification of 20. SG75-1 1-channel strain gauge conditioner is used for the reading of signal emitted by the strain gauge mounted on the APA actuator (-SG option) and for a power supply for a strain gauge bridge. All above-mentioned elements are mounted in RK63F-4U rack.



Fig. 4. RK63F-4U/LC75C/LA75C/SG75-1

ILH412M-S ROTOR BLADE SEGMENT

The necessity of oscillations and the possibility of the appearance of inertial loads resulting from it caused the design of the light composite model of the ILH412M-S rotor blade segment. It was assumed that the tested blade segment would be based on a new helicopter rotor blade designed for Sokol-2 helicopter. The ILH412M-S profile, designed in the Institute of Aviation, was chosen for that purpose. Rotor blade segment based on the real helicopter rotor blade had 480 mm of chord and 1000 mm of span. It was assumed that the pitching axis is in the aerodynamic centre in 25% of chord. The segment was equipped with TEF which chord is the result of earlier analysis. The length of TEF was established as 15% of profile chord.

Drawings of a whole segment with the TEF oscillation mechanism, three ESP-32HD pressure scanners and 73 pressure measurement points are presented in Fig. 5 and 6.

In the beginning moulding plates for ILH412M-S airfoil were prepared. A few layers of composite were arranged on them to make a lower and an upper surface of the profile.

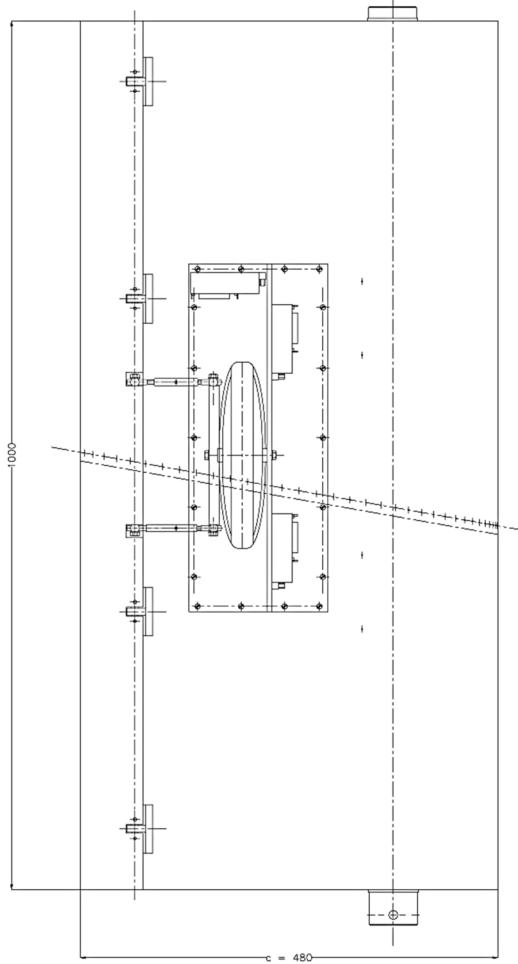


Fig. 5. The drawing of ILH412M-S airfoil with TEF oscillation mechanism

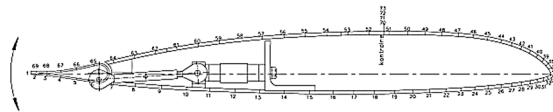


Fig. 6. The cross section of ILH412M-S airfoil with TEF oscillation mechanism and pressure measurement points

Additional composite, wooden and steel stiffening (Fig. 7) was added to the rotor blade segment, especially around the area where the TEF oscillation mechanism actuated by APA1000XL-SG piezo actuator and three ESP-32HD pressure scanners by Pressure Systems Inc. were mounted.

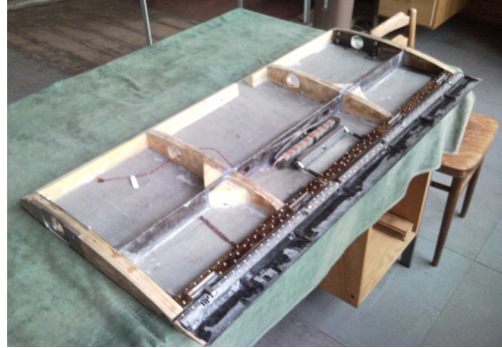


Fig. 7. The stiffening of ILH412M-S segment

DTC INITIUM PRESSURE MEASUREMENT SYSTEM

DTC Initium pressure measurement system by Pressure Systems Inc. was used for pressure acquisition. It is a pressure measurement and data acquisition system (Fig. 8) made of DTC Initium central unit (Fig. 9) connected to a computer and up to eight pressure scanners, of 16, 32 or 64 channels each. Pressure measurements and data acquisition were made in all channels with frequency of 650 Hz in case of use of 32-channel scanners.

Three 32-channel ESP-32HD pressure scanners by Pressure Systems Inc. were elements of that system which were mounted into the rotor blade segment. All of them have its pressure measurement range up to 10 inWC. They were connected to 73 pressure measurement points by silicon tubes of equal length.

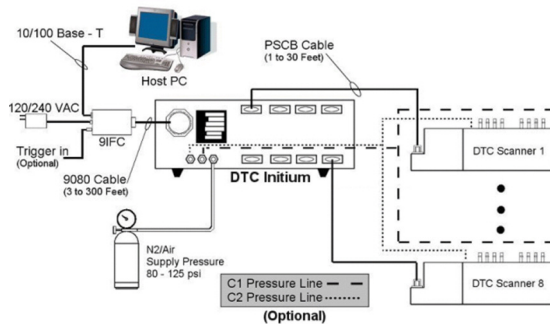


Fig. 8. The scheme of DTC Initium system



Fig. 9. DTC Initium with ESP scanners

TESTS OF PIEZO ACTUATED TEF

In the beginning general tests were made to check the correct action of CEDRAT APA1000XL-SG piezo actuator (Fig. 10). Tests were focused on the proper deflection of TEF, its amplitude according to the given voltage. The TEF oscillation mechanism was calibrated and the neutral deflection of TEF was set according to the range of supply voltage of APA1000XL-SG piezo actuator.



Fig. 10. Tests of CEDRAT APA piezo actuator

Deflections of TEF, of different flap oscillation frequencies, were registered by a high speed video camera Centurio C100 by Citius Imaging (Fig. 11). The side view of the ILH412M-S airfoil was covered by a mask on which a chord line and the hinge axis of TEF were marked (Fig. 12). After recording, single “photographs” of the deflected TEF in its minimal and maximal positions, were taken for different oscillation frequencies. And amplitudes were calculated.



Fig. 11. High speed video camera Centurio C100 by Citius Imaging

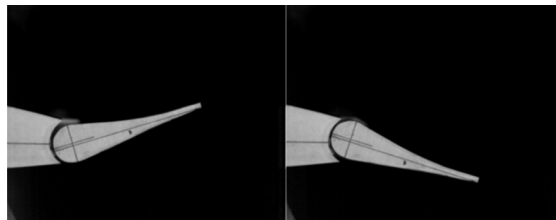


Fig. 12. Extreme TEF deflections at 20 Hz

As it is presented in Figures 13 and 14 the increase of TEF oscillation frequency causes the increase of TEF oscillation amplitude. Measured values of TEF amplitude do not grow linearly

but are almost constant for two ranges of frequencies: from 1 to 7 Hz and from 9 to 15 Hz. Further increase of TEF oscillation frequency implies stronger increase of TEF oscillation amplitude.

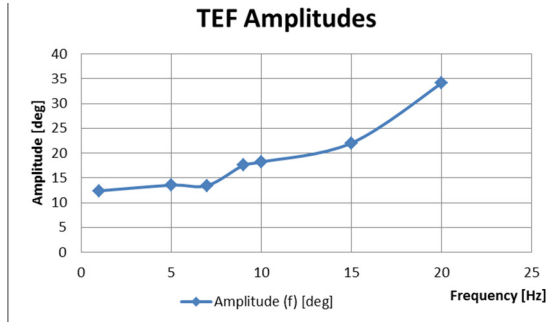


Fig. 13. Amplitudes of TEF oscillations

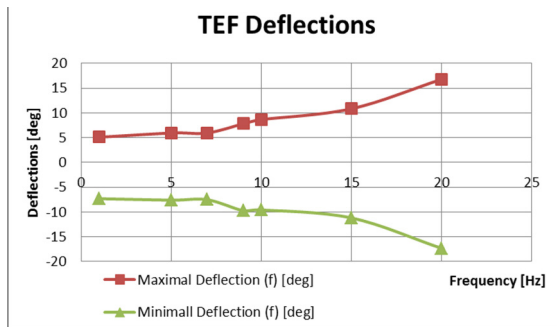


Fig. 14. Extremes of TEF oscillations

TESTS OF PRESSURE MEASUREMENT SYSTEM

Tests of pressure measurement system based on DTC Initium were made in Utility Software (Fig. 15). Each channel of three ESP-32HD scanners used in tests were checked if they measure a proper, earlier defined pressure. This test allowed to avoid further problems with the leakiness of pressure tubes, badly connected scanners, mistakes in pressure measurements.

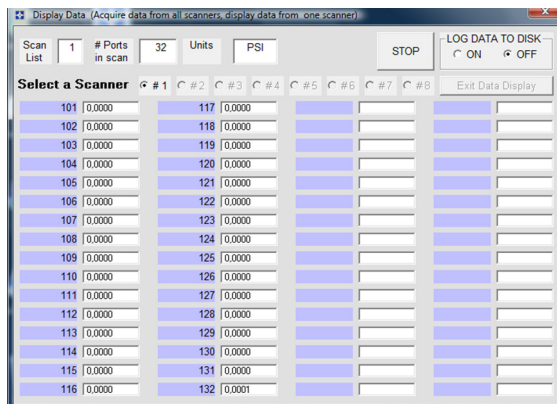


Fig. 15. DTC Initium Utility Software in "Display Data" mode

ILH412M-S SEGMENT IN T-1 WIND TUNNEL

Our rotor blade ILH412M-S segment was mounted in the test chamber of the T-1 low speed wind tunnel in a position presented in Fig. 16 and 17. It was positioned between two side plates. The lower side wall was mounted on the frame and the upper side wall was hanged on wires (Fig. 16). The pitch angle of the rotor blade segment and TEF oscillations were also monitored by CCTV set. Behind the segment a rake was installed (Fig. 17).

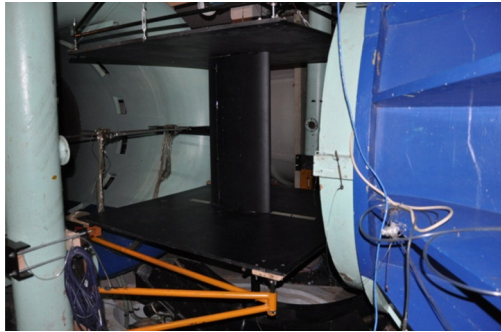


Fig. 16. The blade segment between side walls

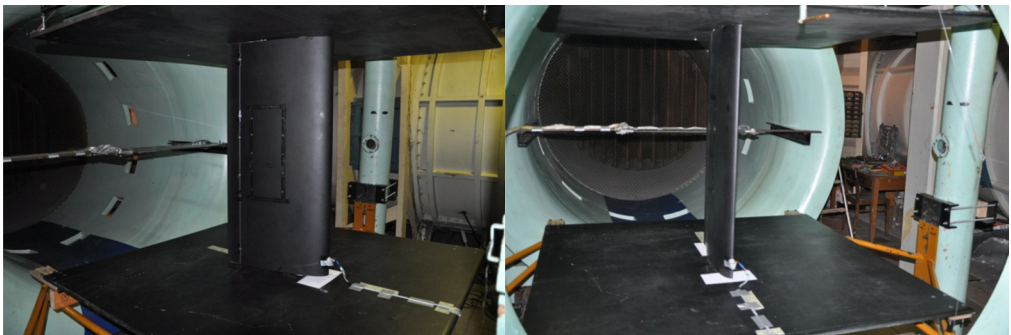


Fig. 17. The blade segment in T-1 wind tunnel

CONCLUSIONS

The designed rotor blade segment, based on the ILH412M-S profile, presented in this paper, 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

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REFERENCES

- [1] Miller M., Narkiewicz J., Kania W., Czechyra T., "The Application of Helicopter Rotor Blade Active Control Systems for Noise and Vibration Reduction and Performance Improvement", „Transactions of the Institute of Aviation”, Vol. 184 - 185, pp. 164 – 180, Warsaw 2006.

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SEGMENT ŁOPATY Z KLAPKĄ NA KRAWĘDZI SPŁYWU STEROWANĄ PIEZOSIŁOWNIKIEM W DYNAMICZNYCH POMIARACH CIŚNIENIOWYCH

Streszczenie

Artykuł podsumowuje całość dotychczasowych działań w zakresie projektowania segmentu łopaty wirnika z klapką na krawędzi spływu, sterowaną przez siłownik piezoceramiczny, używanego w dynamicznych pomiarach ciśnienia w tunelu aerodynamicznym T-1 Instytutu Lotnictwa. Zaprojektowany w oparciu o profil ILH412M-S segment łopaty wirnika 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 kłapy i mikroklapki w celu poprawy osiągnięć aeromechanicznych śmigłowca".