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UNSTEADY MEASUREMENTS OF AERODYNAMIC CHARACTERISTICS OF THE AIRFOIL

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Abstract: *This paper deals with unsteady measurements of aerodynamic characteristics of the symmetric airfoil for the angle of attack within the range from 0° to 360° with variable value of angular velocity. These results are processed for first and second revolution of airfoil NACA 0012 Mod. A special device was designed for these tests.*

Keywords: *Unsteady Aerodynamic, Dynamic Stall, Measurement, Wind Tunnel Tests.*

1. Introduction

Measurement is an integral part of the design, development and practical verification of real qualities of the proposed devices. Their use in aerodynamic applications is an integral part of development of aviation and rocket technology from the outset.

The article is a continuation of the topic presented by the author at the conference EM in the past. The new results were obtained in the Department of Aircraft and Rocket Techniques, Defense University in Brno in the period from 2006 until now.

Aerodynamic measurements are still irreplaceable in the development of new aviation techniques, although the current period is characterized by intensive development of numerical methods and computer simulations of all kinds.

Computational methods are still inconclusive in the areas of simulation blowing unconventional aircraft and do not provide sufficiently reliable results for engineers. Incorrect input aerodynamic data may cause either significant time lag in development of new aircraft, or may also lead to significant financial losses and problems associated with the late start of the new product to market. In the numerical calculations can be considered one of the main problems the absence of input and boundary conditions, which would properly characterize the real aerodynamic effects.

In the rapid and large changes of angle of attack are stationary values of aerodynamic coefficients exceeded. These values are generally used for calculations, although actual unsteady aerodynamic loads of blown airfoil reach higher loads than in stationary cases.

Differences between the courses of steady and unsteady aerodynamic coefficients are so significant that steady aerodynamic coefficients are not recommended even for approximate calculations in unsteady conditions.

2. Test stand

Implementation of the measurement of unsteady aerodynamic characteristics in the dynamic stall belongs to a particularly difficult area of experimental aerodynamics applications.

For unsteady aerodynamic measurements are normally used methods based on sensing the pressure distribution on the measured object. Integral piezometrical pressure modules are used for measurement of the unsteady pressure loads on the airfoil. This technique allows to record the actual pressure process on the airfoil without time delay.

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Another way for measuring aerodynamic forces is based on load measurements. This method was also used in the UO Brno, where a new test device was developed for implementation of this type of measuring system. This device has integrated strain-gauge load cells. These load cells transfer values of aerodynamic forces which act on the tested model.

Fig. 1: Sensing of pressure from the wall of the object, the left - IAG Stuttgart ,UO Brno - the right.

3. Types and results of measured tasks

These newly developed device furthermore permit measurements of aerodynamic characteristics of the airfoil within the range from 0° to 360°, and you can freely change starting value of the mean angle of attack, the oscillation amplitude and angular velocity.

One of the implemented variants of measurements of unsteady aerodynamic characteristics of the airfoil (the ACHP), included a set of measurements which changed the angle of attack within the range from 0° to 720 ° (2nd airfoil´s revolutions) with the default start-up angle of attack 0 ° or 90 ° or 180 ° or 270 °. Each set of measurements included 14 variations of the values of angular frequency of airfoil within the range from 7.2° s^{-1} to 360° s^{-1} (ratio 1:50) for inflow air velocity 24.m·s^{-1}, Re=10^5).

Fig. 3 shows the results obtained by measuring lift curve with the default start-up angle of attack 0°. From the process of lift curves there is clearly demonstrated the significant phase shift at which the airfoil is achieved zero lift. At the same time increasing the value of angular velocity lowers the maximum value of the coefficient of lift up to 40%. Results are plotted for the angle of attack within the range from 0° to 360° during the first and second airfoil´s revolution fig. 3 and fig. 4.

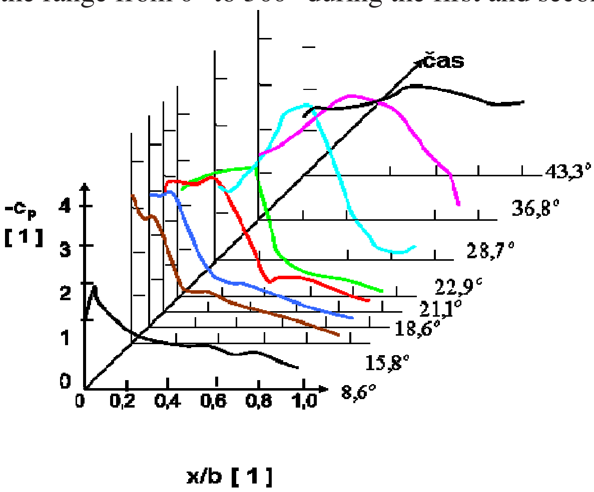

Fig. 2: Time history of pressure distribution on the NACA 0012 airfoil, a sudden change at pitching angle of attack (Francis, M. S., Keesee, J. E., 1985).

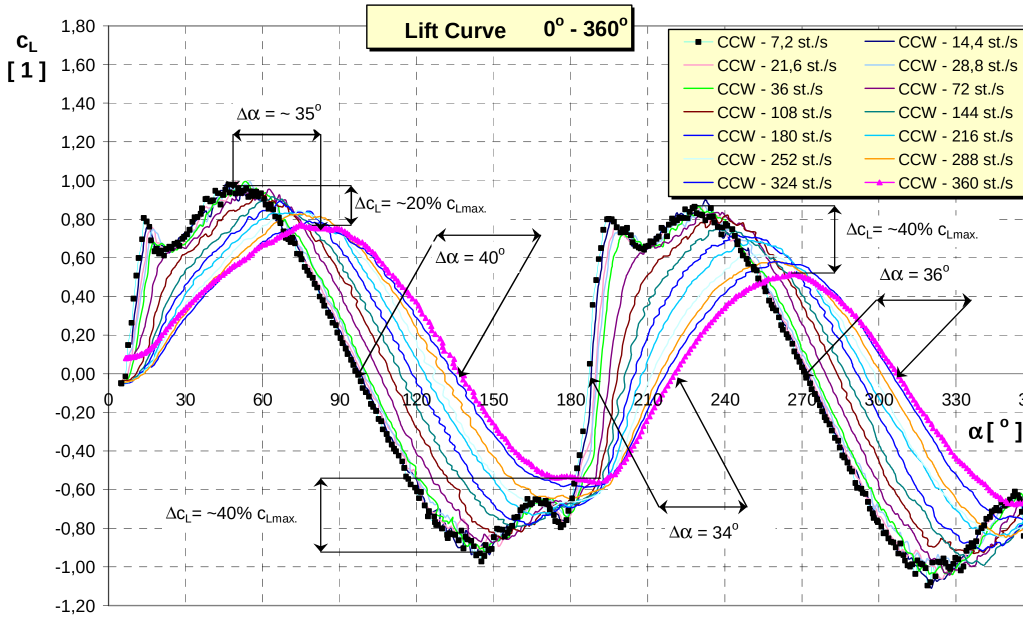

Fig. 3: Airfoil lift curve at pitching angular velocity from 7,2 deg./s to 360 deg./s, first rotation (Rozehnal, 2008).

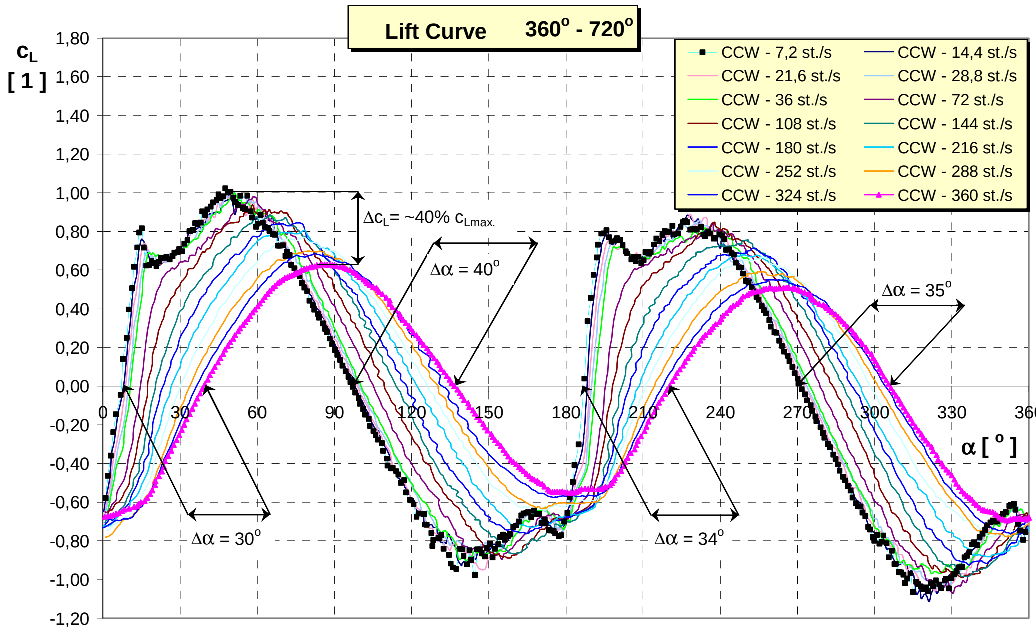

Fig. 4: Airfoil lift curve at pitching angular velocity from 7,2 deg./s to 360 deg./s, second rotation (Rozehnal, 2008).

4. Conclusion

From the experimental results it is clear that at increasing pitching angular velocity between 0° and 360° of angle of attack, the phase shift of angle of attack occurs at zero lift α_o (Fig.3 and Fig.4). The value of minimum drag coefficient increases and the maximum value of lift coefficient decreases. The aerodynamic ratio, "$K=c_L/c_D$" decreases from the approximate value of 55 in the stationary regime of flow to values k<1. This occurs at maximum pitching angular velocity α = 360 deg/s. Therefore, profile degradation of the lifting surface occurs. For calculating the bending load of the lifting surface effected by aerodynamic forces, it is necessary to take into consideration in addition to the lifting component of aerodynamic resulting force its drag component as well. The drag component now attains higher values. Under such conditions, the normal component of the resulting aerodynamic force coefficient c_n reaches more than two times the value of the lift coefficient.

Under actual operating conditions, such situations may happen to high manoeuvring planes, to wind turbine rotors as a result of sudden wind direction changes, to helicopter lift rotors etc. It appears that using the classical method of calculating the load factor based upon statistical characteristics, results in significant errors when calculating maximum loads. The resulting aerodynamic loads during the whole period do not show great differences due to the relative symmetry of the hysteresis when compared to their static course. The oscillating character of these dynamic forces results in worsening ergonomic operation of this equipment (technology). Dynamic stall, which occurs under these conditions, has a dangerous effect on rotor blades and shortens their life time.

5. References

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