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FLUTTER AT A LOW VELOCITY

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Abstract: *Aeroelastic experiments with the profile NACA0015 were realized in the suction type aerodynamic tunnel of the Institute of Thermomechanics, Czech Academy of Sciences, Prague. The profile had two degrees of freedom realized in translation and rotation motion and flow velocity was just up its critical value. The flow field was measured with interferometry method and the results obtained at the velocity M = 0.23 in the flutter regime are presented. The evaluation of interferogramms enabled to determine the components of the drag and lift forces.*

Keywords: Aeroelasticity, Flutter, Interferometry, Subsonic flow.

1. Introduction

The experimental stand was newly constructed with regard to requirements of optical methods. The profile was therefore installed on the plug in the shiftable frame. The chord was 64.5 mm, the center of rotation was in 1/3 of the chord length behind the leading edge of the profile. For optical measurement the Mach-Zehnder interferometer with the diameter of the visual field 160 mm was used, interferogramms were recorded with frequency 1000 frames/s (Hodges et al., 2002; Bernal et al., 2009; Vlček et al., 2013).

As example, the flutter at M = 0.23 (at M = 0.21 the flutter not occurred) was visualized with interferometer using the infinite fringe width. One of these interferogramms is presented in Fig. 1. Forces acting on the profile surface and their decompositions into the test section axes are shown.

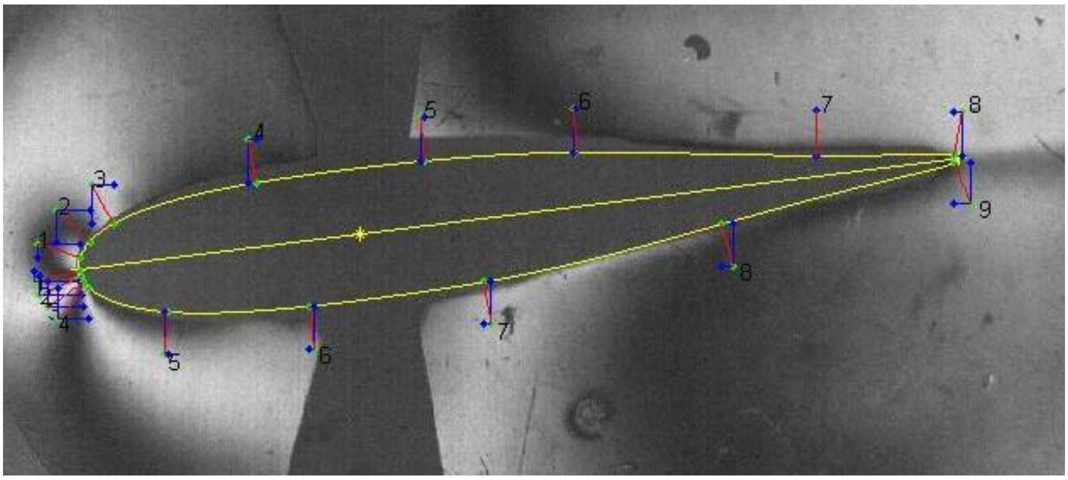

Fig. 1: Interferogramm of the flow at M = 0.23.

2. Kinematics of the Profile Motion

The translation of the profile was registered with mechanical sensors, the angle of attack was evaluated

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from interferogramms. The profile positions during flutter are in Fig. 2. As in experiments realized before, where the flow separation not occurred, the positions parallel to the flow direction in bottom and top dead translation positions are close one to other (thick lines).

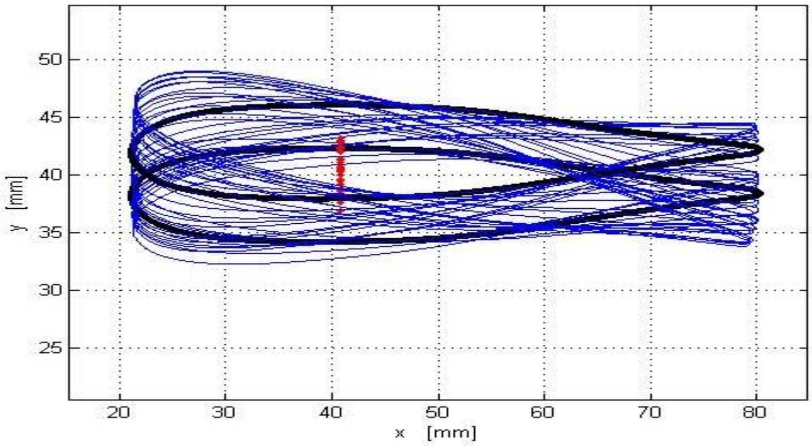

Fig. 2: Positions of the profile during one period of the flutter.

The time changes of the translation and angle of attack of the profile are depicted in Fig. 3. The positive direction of translation is upwards and the positive direction of the angle is clockwise. The phase shift between these quantities is almost half of the period.

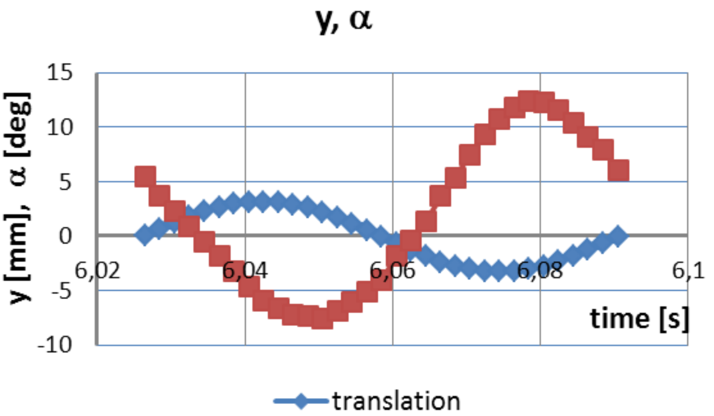

Fig. 3: Translation and angle of attack in one period of flutter.

The relation between the translation and angle of attack of the profile is visible in Fig. 4, where the direction of the movement is anticlockwise. The excentricity of the loop position is due to the nonzero angle of attack in the profile motionless position. The adjustment of the initial position was possible to arrange only after some group of experiments, because it requires also disassembly of optical glasses and subsequent adjustment of the optical system.

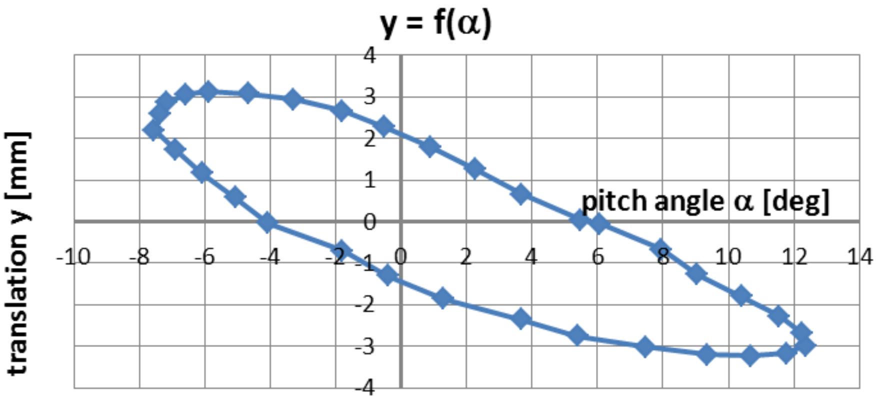

Fig. 4: Loop generated by the phase shift of translation and rotation.

3. Results of Interferogramms Evaluation

Optical measurement enabled to evaluate the force action of the flow field on the separate parts of the body. Here we used the calculation of lift forces acting on lower and upper surface separately and results are depicted in Figs. 5 and 7. Upper and lower surface are defined by their position in relation to the chord. The force is denoted by F [N], indexes x and y denotes the direction of the force action in the direction on of axes x and y; indexes l and u denotes the force action on lower or upper surface of the profile.

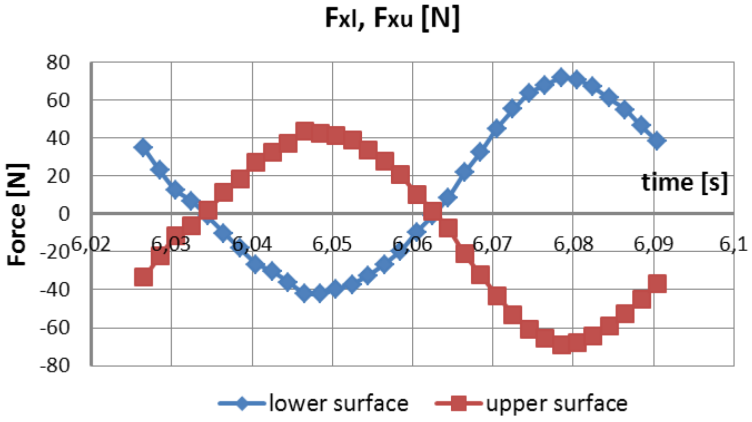

Fig. 5: Drag components of the profile.

Drag components acting on the lower and upper surface are in almost opposite phase, therefore the force resulting from their summation in Fig. 5 has a bad arranged shape.

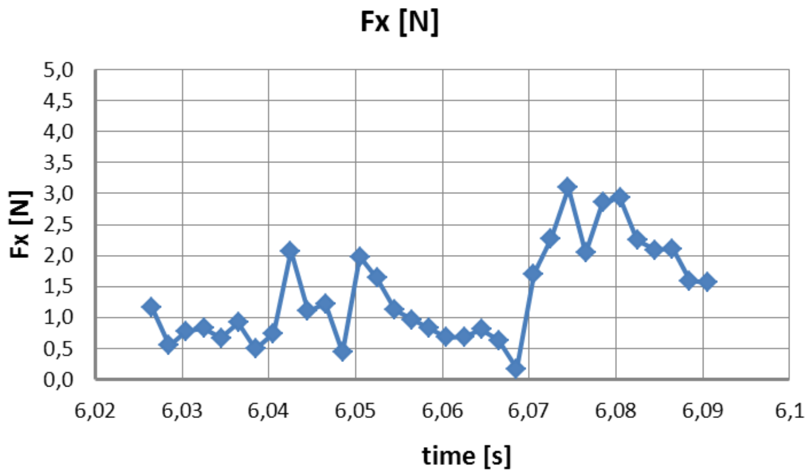

Fig. 6: The total drag of the profile determined from the interferogramms.

Lift components acting on the lower surface Fyl and on the upper surface Fyu and total lift during one period and determined from interferogramms are in Fig. 6.

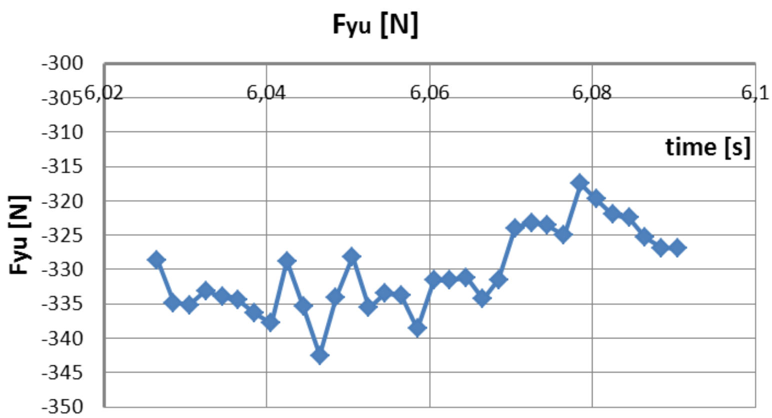

Fig. 7: Lift component acting on the upper surface.

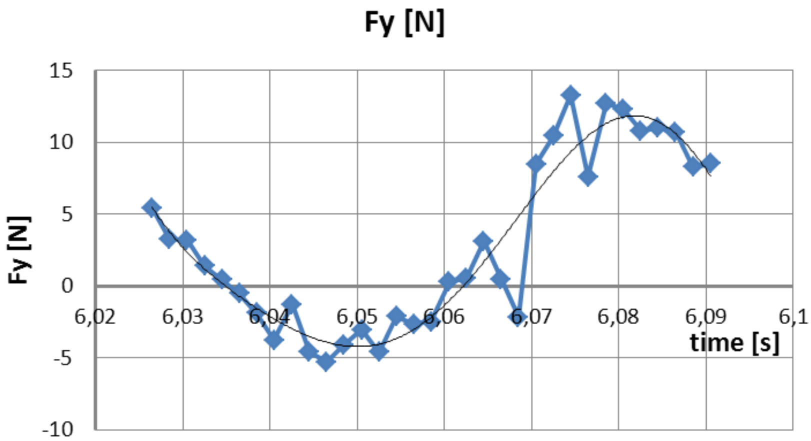

Fig. 8: Total lift of the profile during one flutter period.

The lift unlike the drag has worse arranged components and better arranged total lift.

4. Conclusion

The accuracy of the interferometric method is basically limited by the assumption of isentropic flow changes, and inside this limitation its accuracy increases with the number of visible fringes. The number of fringes increases with flow velocity and with the width of the flow section. The ability of interferometric method to measure flutter flow parameters in the same test section in the range of velocities M = 0.3 – 0.45 was verified formerly (see also Vlček et al., 2013; Zolotarev et al., 2012, Zolotarev 1987). The described experiment was an attempt to check out this method using lower Mach numbers in the same, relatively narrow test section. It is shown, that this method is useful for measuring flutter flow field in a wide region of flutter parameters.

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