GROUND MOBILE LABORATORY FOR MEASUREMENT OF AIRFOIL AERODYNAMICS CHARACTERISTICS

Róbert Šošovička*, Martin Kouřil*, Jan Friedl*
***Brno University of Technology, Institute of Aerospace Engineering, Czech Republic**

Keywords: *Aeronautics, Aerodynamics, Airfoil characteristic, Airfoil laboratory*

Abstract

The paper describes possibilities of airfoil aerodynamic characteristics measurement with a ground mobile laboratory based on a car. It also covers development, experiences and comparison between measurements on the ground mobile laboratory and in the wind tunnel. This is the first step to develop the experimental airplane testbed.

1 Introduction

Nowadays measurements of airfoils aerodynamic characteristics are taken mainly by wind tunnel testing. The tunnel itself is always bulky and rather expensive facility and anyway the final characteristics are investigated at real peace of work, aircraft prototype. This is the reason why the flight tests are considered to be more provable, not only in the field of aerodynamic characteristics. Then there is a logical sense of the effort in direct testing real aerodynamic characteristics of airfoils.

Real aerodynamic characteristics are mostly measured on the aircraft's flying prototype. Consequently, the flight tests are considered to be more conclusive, and not only for the aerodynamic characteristics. The above mentioned reasons support the basic research of the aerodynamic characteristics, especially of the design of the new wing section directly by flight tests.

Nowadays the flying airfoil testbed is designed at the Institute of Aerospace Engineering for the purpose of measuring aerodynamic characteristics of airfoils and for the flight performance and characteristic research in the area of the usage of new technologies, instruments and methods. The usage of the flying airfoil testbed makes it possible to include implicitly the influence of the real flight conditions that are daily encountered in real operation. Nevertheless, the usage of the flying testbeds encounters problems. Here also corrections on influence of the used aircraft and ambient air conditions are necessary. The flying airfoil testbed flight regime must be monitored to determine exactly the conditions of the measurement. This enlarges the requirements on the precision of piloting and the measuring apparatus on the board. Limitations also include the aircraft operational limits and meteorological conditions. With the assistance of this flying airfoil testbed, it will be possible to measure the aerodynamic characteristics of airfoils, leading edge contamination, ice imitator, manufacturing error, etc...

2 Design of the flying airfoil testbed

For the airfoil testing, an aircraft is suitable with the lowest influence on the fluid flow in its surroundings. While at a motor aircraft the fluid flow is strongly influenced by the propeller air flow, a glider appears to be more suitable in this case. For ensuring autonomy of the measuring aircraft, it was decided to use a motor glider, while the measurements will be held with the engine switched off and the propeller in feathering position.

The powered sailplane L-13 SE Vivat (manufactured by Evektor-Aerotechnik, joint stock company, Czech Republic) was the base element of the flying airfoil testbed (i.e. carrier of the wing section model) (Fig.1.). It is an allmetal aircraft re-constructed from the L-13 Blaník glider, of which the wings, the tail surfaces and the fuselage tail part with a thin wall stiffened structure were employed.

Fig. 1. Motor glider L-13 SE Vivat

The fuselage central part with the pilot's cockpit is a rod structure with a laminate aerodynamic canopy. The aircraft is equipped with a Walter-Mikron III B engine and constant-speed propeller Hoffmann V-62 R/L in the front fuselage and with a simple retraction landing gear with a tailwheel and supporting landing gears on the wing tips.
The rod structure of the fuselage with a centroplan makes it possible to fit easily the measuring stand with the wing section model (Fig.2.). The two-seat design of the glider offers the possibility to position the measuring equipment in the pilot's space.

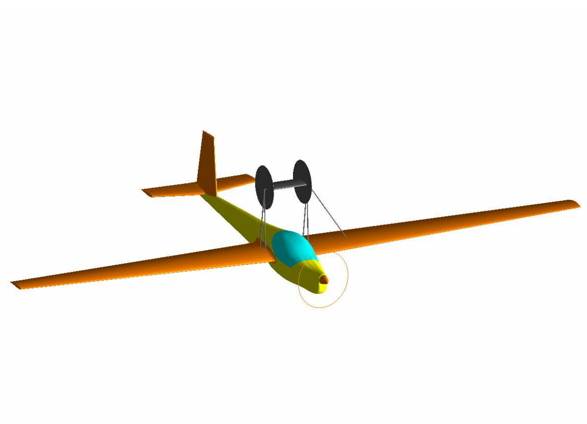

Fig. 2. Flying airfoil testbed

3 Wing section model

Building the flying airfoil testbed can be divided into several developmental and experimental stages. The first part of development covers design, production and strength tests of MS-0313 airfoil model with endplates, so-called “cablo-model”.

3.1 Model description

Model consists of rectangular wing section and two circular-shape end plates [1]. All components have sandwich construction of glass-epoxy composite and polystyrene foam. A few ash wood reinforcements in critical positions are used to transfer the local load. Pressure taps are placed chordwise at certain section. Tubes from pressure taps are connected with miniature electronic pressure scanners, which are located near the left section of the wing. Basic dimensions of our model are identical with ARTI (Aeronautical Research and Test Institute in Prague) model for comparison with the wind tunnel measurement. The rectangular wing section has span 1200 mm and chord 600 mm. The circular end plates are 22 mm thick with 1080 mm diameter.

3.2 Structural static test

The basic static tests (Fig.3.) were performed mainly to obtain an opinion about deformation and to check structural integrity of the model.

Fig. 3. Structural static test

The computed load was applied on upper wing surface by certain amount of sand filled bags.
The maximum deformation from bending was 7mm in the middle of wing span. The maximum deformation angle from twisting was 0.255 degree between two wing end sections.
These values show that the model can be considered as suitable for our purpose.

4 Wind tunnel testing in ARTI

The content of the next part of development was the measuring aerodynamic characteristics of the model in the subsonic wind tunnel (the measured area three meters in diameter) at Aeronautical Research and Test Institute in Prague (ARTI). Pressure and force measurement of the model was done in the wind tunnel up to airspeed $V = 180\ km.h^{-1}$ including above the critical angle of attack [4], [6]. The size of the used model was identical to the ones commonly used at Aeronautical Research and Test Institute in Prague because of the following comparison of measured results obtained by our experiments (Fig.4.).

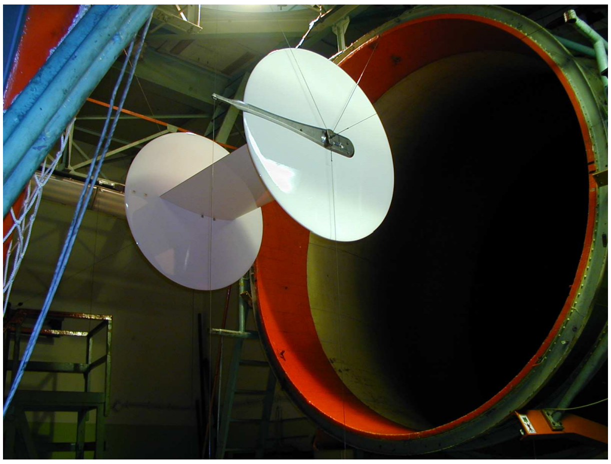

Fig. 4. Wind section model in wind tunnel ARTI in Prague

5 Ground mobile laboratory T-613

The experiments on the ground mobile laboratory are the next important part of development of flying airfoil testbed. This is based on the famous Czech car Tatra T 613, which carries the measuring stand with the model (Fig.5.).

Fig. 5. Ground mobile laboratory

The car confirms our requests for speed performance and robustness of construction. Furthermore a high total weight will have the positive effect to stabilise ride with the model and the attachment. The main modifications were realised in a luggage section of the car where a special steel frame was installed (Fig.6.). This frame is used to support the attachment for the model. The attachment consists of the dural tube system, which will be similar to aircraft mounting (L-13 SE Vivat) [2].

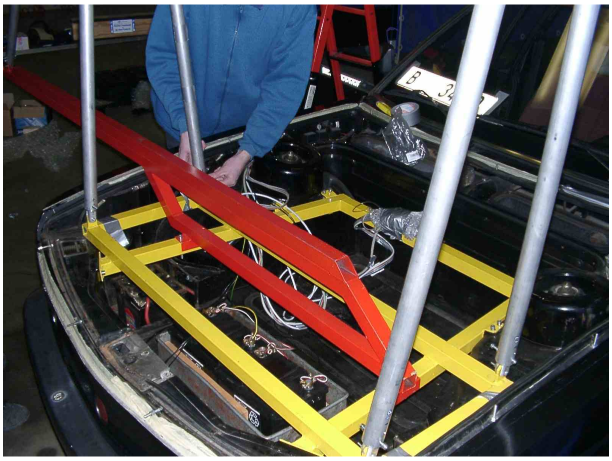

Fig. 6. Modification of the luggage section

The special steel subframe compensates the side load. This is located on the right side of the car and increases width of the car approximately twice, so careful driving is needed. An electromechanical linear actuator is used to avoid twisting of the model and to vary the angle of attack. The pitot-static boom with the angle of attack and the angle of sideslip acquisition was mounted onto the left end plate (Fig.7.).

Fig. 7. Pitot-static boom and electro-mechanics strut location

The main reason for building the ground mobile laboratory was testing of elements that will be placed on an aircraft later. Attention was aimed to verification of characteristics of the whole stand configuration with the testing wing model, its structure and the functionality of measured apparatus.

After the first testing drives, there were considered the possibilities of mobile laboratory utilization for measuring the aerodynamic characteristics of airfoils in this way. Measuring the aerodynamic characteristics was done by chordwise pressure acquisition. The data from wind tunnel measurement were used as etalon for verification of measurement correctness and influence of mounting system on flow around model.

6 Measuring process (Ground mobile laboratory)

6.1 Description of measuring

Ground tests were performed at airport Brno-Tuřany in undisturbed early morning atmosphere (Fig.8).

Fig. 8. Ground mobile laboratory at airport Brno-Tuřany

The data acquisition itself was performed during steady drive according to inboard speedometer. Each run gives roughly 40-50 sec. of measured data. Exactly the same angle of attack was tested in both directions of runway to eliminate influence of sideslip and to correct the pressure acquisition by pitot-static probe. An actual angle of attack (influenced by lift of model and velocity), temperature of atmosphere, and air speed are also collected.

DACU S8256 pressure data acquisition systems together with miniature pressure scanners ESP-32HD (Pressure Systems, Inc.) were used to collect values from airfoil pressure taps. Each miniature scanner has 32 pressure sensors. Electric power supply was realized via onboard automotive batteries.

6.2 Results discussion

So far, two models were tested. In both cases an airfoil MS-0313 was chosen. The main differences were in number of pressure taps (32–tatra kablo 1 [5] and 64) and slightly bigger diameter of end plates. The second model has exactly the same dimensions to ARTI model used in their wind tunnel for comparison purposes. The location of section for pressure taps was also identical with ARTI model (section location of first model was the middle of span).

As we expected, the results comparison between measurements in the wind tunnel and measurements on the mobile ground laboratory cannot be considered identical. This is mainly caused by correction absence for proximity of the car and ground. Further research will be primarily oriented for their determination.

Results show significant difference in pressure coefficient distribution especially on the bottom part. This is caused by 3D flow field affected with nearness of the car. The same effect is shown on lift curves. A change of lift curve slope in comparison with the tunnel data can be described as a local change of angle of attack also due to flow influenced by the car.

Nevertheless, each test of mobile laboratory confirms good repeatability of measurement, so it will be possible to determine suitable correction.

Followed figures show measured and computed data for comparison. The figure of lift curves shows also results with surface affected by rain.

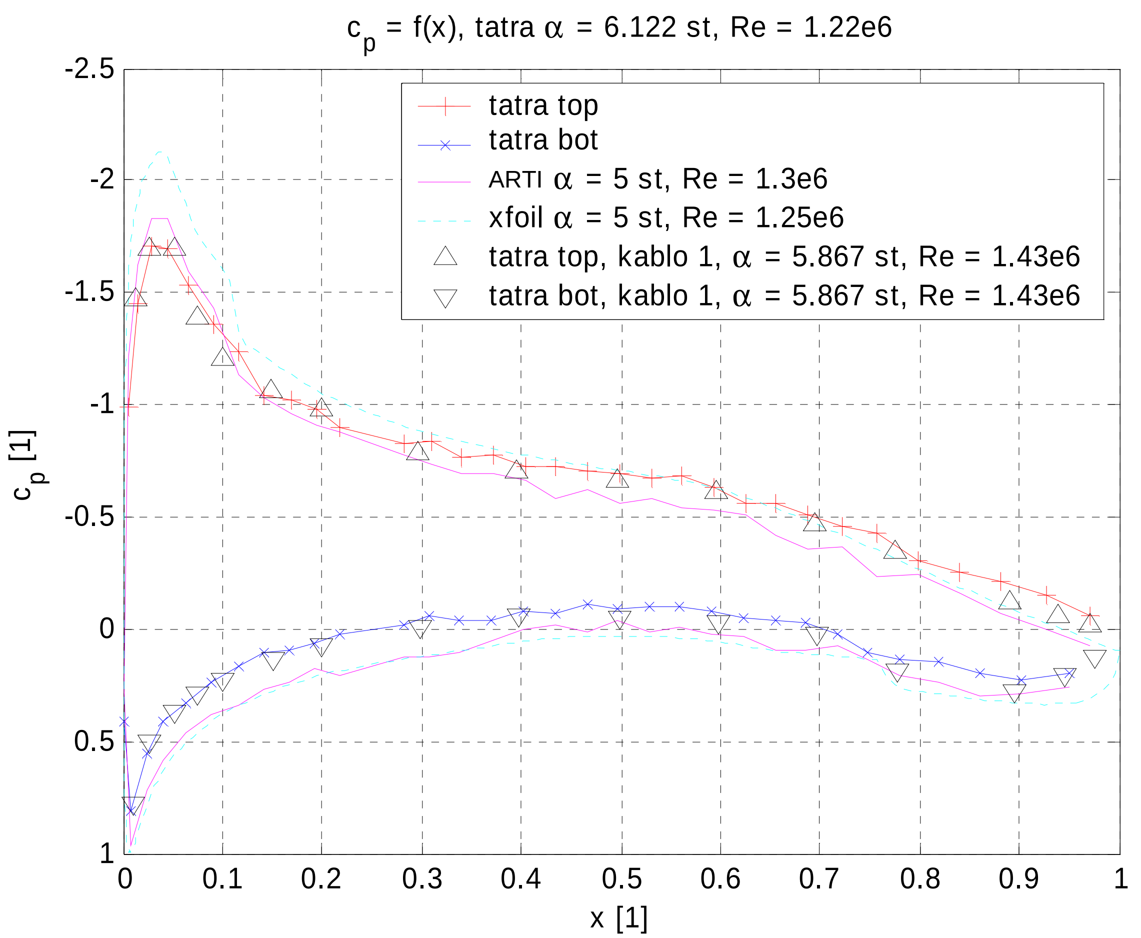

Fig.9. Comparison of pressure coefficient distribution

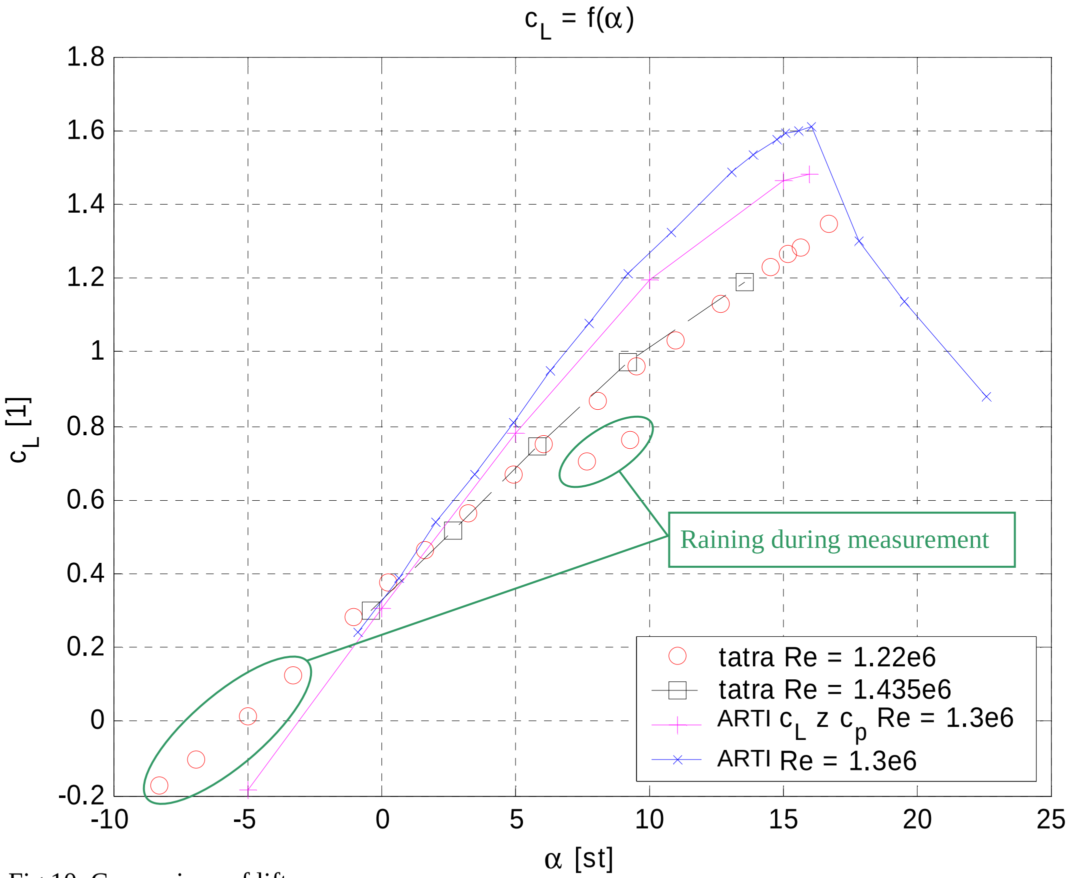

Fig.10. Comparison of lift curves

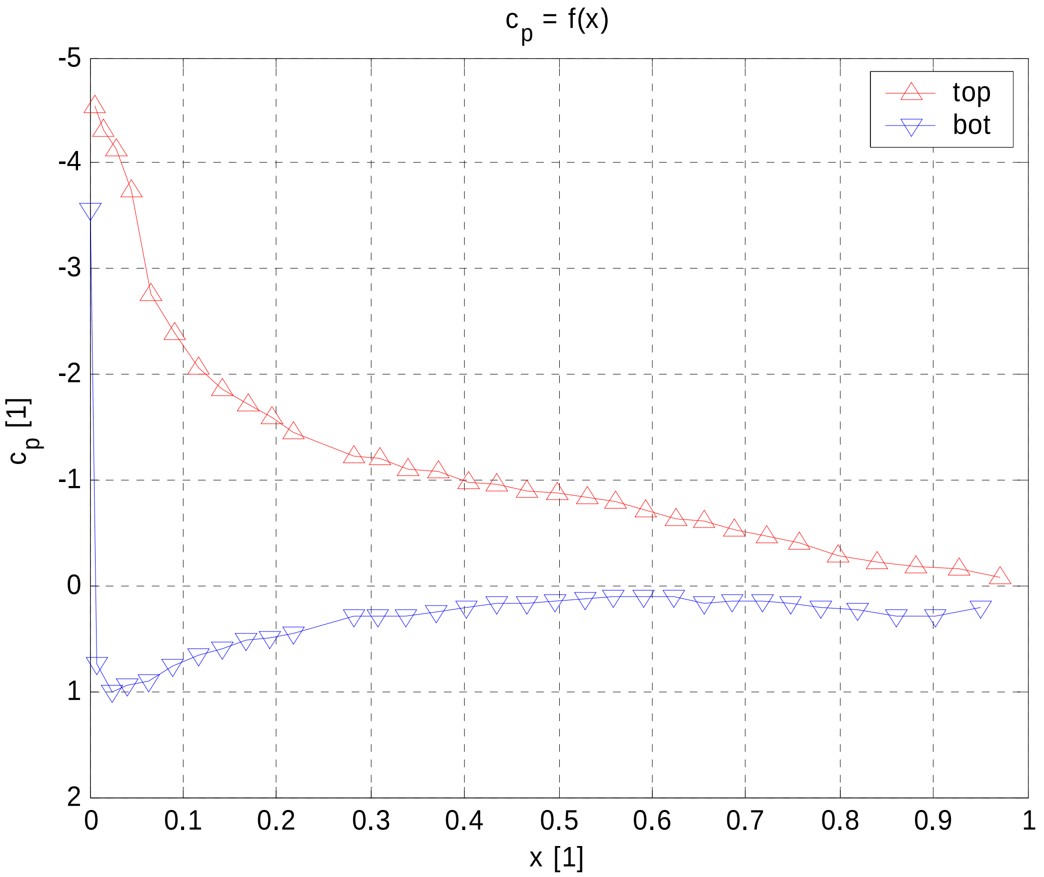

Fig.11. Pressure coefficient distribution α = 16.75°, Re=1.22e6

7 Conclusions

So far, realized experiments, i.e. measuring of wing section model aerodynamic characteristics, give good preconditions for the utilization the ground mobile laboratory to these measurements. Thus gained the airfoil aerodynamic characteristics may be a reasonable alternative to the measurement in the wind tunnels or the flying airfoil testbed. Further tests for assessment the influences of car proximity are necessary at the perfect result of measurement. After their determination, the ground mobile laboratory would be cheaper in comparison with the other methods.

8 References

[1] Fifka P, Friedl J. *Konstrukční návrh kablo-modelu pro létající laboratoř L-13 SE.*, Technical report, Institute of Aerospace Engineering, BUT, Brno 2001

[2] Šošovička R, Kouřil M. *Konstrukční návrh nosné konstrukce kablo-modelu pro létající laboratoř L 13–SE.* Technical report, Institute of Aerospace Engineering, BUT, Brno 2000

[3] Šošovička R. *Létající laboratoř L-13 SE s kablo-modelem profilu MS-0313*. Technical report, Institute of Aerospace Engineering, BUT, Brno 2002

[4] Šmíd M, Hanzal V. *Měření modelu profilu s koncovými deskami.* Research report, Aeronautical Research and Test Institute in Prague, Prague 2004

[5] Šošovička R, Friedl J, *Aerodynamická měření kablo-modelu na pozemním stendu.* Technical report, Institute of Aerospace Engineering, BUT, Brno 2004

[6] *Měření kablo modelu MS-0313 s klapkou na 0 st. při Re=1,75e6*. Technical report, Aeronautical Research and Test Institute in Prague