Subsonic aerodynamics experimental research on gas-dynamic parameters of the flow

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***Abstract**: Subsonic wind tunnels are generally aerodynamic equipment allowing to obtain in one of their elements, namely in the experimental area where the model is placed, a uniform and stable airflow of determined speed.*

Wind tunnels of low subsonic speed, usually with continuous running, are plants where the air, driven by a fan, reach in the experimental area speeds up to 180 m/s (M <0,5). They look like tubes with (convergent - divergent) variable section. In our case the wind tunnel is a Prandtl type closed circuit in a horizontal plane, with a single return circuit and closed testing room. To reduce turbulence in the wind tunnel, the number of fan blades whose peripheral speed should not exceed 200 m/s should be as large as possible (which is the case of the INCAS subsonic wind tunnel with 12 blades).

The present article is focused on the following topics: vertical and horizontal deflection and turbulence in the experimental area.

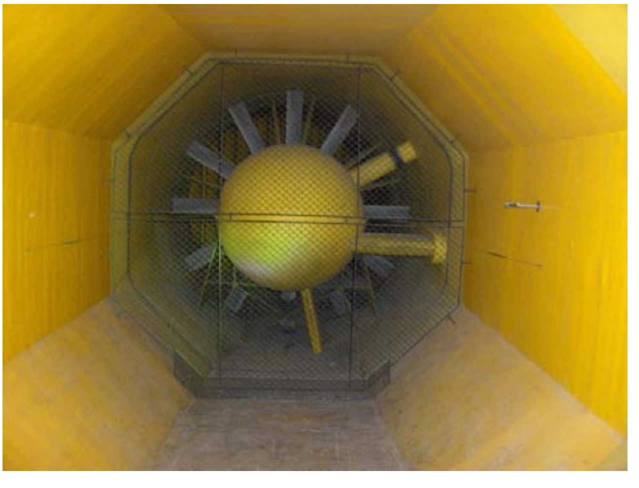

Fig. 1 – The fan of the INCAS subsonic wind tunnel

Key words: vertical and horizontal deflection, turbulence

1. INTRODUCTION

Experimental tracking of the flow crossing the experimental area of the subsonic wind tunnel is extremely difficult, as it requires the use of standard models. The reference system of the TEM aerodynamic balance is aligned parallel to the horizontal of the site, the triple reference system originating in the pyramidal balance virtual center. Thus reducing the experimental data involves knowing the precise angularity of the flow with respect to the orientation of the reference system in the given configuration.

2. VERTICAL DEFLECTION

For the vertical deflection a $\lambda = 6$ aspect ratio standard wing which has been experienced in the wind tunnel in a range of incidences sufficient for the lift force to pass through zero and change the sign, was used for this purpose. The experiment was then resumed with inverted wing in the same incidences range. The axes system of the balance was used as a reference for measuring the airflow incidence, the first assumption being that the average speed of the air flow at downstream infinity is parallel to the XOY plane determined by the reference axes. The method for determining the current direction consisted in drawing diagrams $C_z = f(\alpha)$ at the incidence ranges covered for both wing positions (normal and inverted) in the subsonic wind tunnel experimental room. As the lift variation with the incidence is linear for this domain, the intersection of curves with the $2\Delta\alpha$ abscises axis represents the double of the airflow angularity.

The order of curves $C_z = f(\alpha)$ succession on the diagram clearly indicates if the direction $\Delta\alpha$ represents an ascendant or a descendant current.

Table 1 – Values of α and Cz for both tested positions of the profile – normal and inverted

α normal	C_z normal	α inverted	C_z inverted
-9.3	-0.6	-8.3	-0.654
-7.3	-0.465	-6.3	-0.516
-5.3	-0.335	-4.3	-0.374
-3.3	-0.193	-2.3	-0.231
-1.3	-0.047	-0.3	-0.084
0.7	0.098	1.7	0.064
2.7	0.248	3.7	0.214
4.7	0.392	5.7	0.349
6.7	0.54	7.7	0.482
8.7	0.677	9.7	0.609

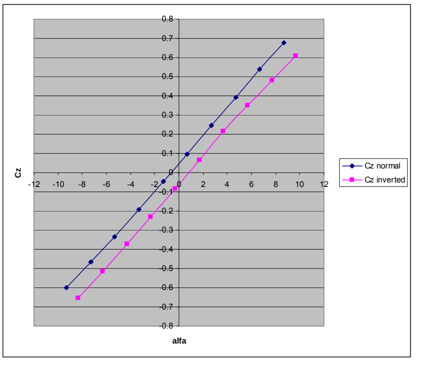

Fig. 2 – C_z normal, C_z inverted,
Reference system connected to velocity
Profile NACA 0018, $\lambda = 6$, MRe=1
The air deflection in the vertical plan, $2\Delta\lambda = 1,4$, $\Delta\lambda = 0,7$

Knowing the value of the angularity allows a correct projection of the resulting aerodynamic force components measured to the actual direction of the undisturbed upstream airflow and also to its normal direction.

The speed direction is differently oriented from the longitudinal axis of the experimental area both due to the solid blockage of the jigs and their streamline covers (thus affecting the pitch angle) and to the centrifugation of the air mass circulating in the aerodynamic asymmetrical circuit with a single return circuit (thus affecting the yaw angle).

As for the vertical velocity deviation from the longitudinal axis of symmetry, experiments were made on a rectangular wing with symmetrical profile NACA / 0018 of λ = 6 aspect ratio. The curve $C_z = f(\alpha)$ should pass through origin if the current direction is the longitudinal symmetry axis of the wind tunnel.

The experimental data presented in the paper show a deviation of 0,70°, the flow having an upward component which can be explained by the blockage made by the balance jigs and streamline covers.

The value found enables to correct the calculation of raw data measured by the aerodynamic balance during experiments, taking into account the angle of deviation.
Repeating the experiments at a slightly higher Reynolds number has revealed a noticeable change in the value of the settlement deviation angle (α) which allows assuming that this correction can be used for the entire range of experimentation speeds in the subsonic wind tunnel. The experimental assembly in the testing room can be seen in the next picture:

Fig. 3 – Experimental assembly for determination of vertical deflection

3. HORIZONTAL DEFLECTION

The deviation deformation in the direction of the yaw angle is the next step of the report. The profile used in this case was Clark Y where λ = 3.

For the horizontal deflection of the airflow the λ = 3 aspect ratio wing model with Clark Y profile was mounted vertically in the experimental area of the wind tunnel.

Fig. 4 – Experimental assembly for determination of horizontal deflection

The C_z curves were raised according to the incidence.

The change of the profile attack angle was made by turning the balance around the vertical axis (yaw) the experimentation was done with the model both in a normal and flipped position measuring the normal and longitudinal components of the aerodynamic force at the profile chord.

From these data the graph $C_z = f(\beta)$ was drawn where the normal values of the buoyancy to the current were written with reversed sign for the model inverted position.

Table 2 – Values of β and C_z for both tested positions of the profile – normal and inverted

β	C_z	β	C_z back
2	0.414906	2	0.489664
1	0.356524	1	0.441942
0	0.312059	0	0.390101
-1	0.262258	-1	0.340011
-2	0.208483	-2	0.286939
-3	0.152179	-3	0.238189
-4	0.093238	-4	0.195701
-5	0.037467	-5	0.127663
-6	-0.01116	-6	0.065102
-7	-0.05004	-7	0.015311
-8	-0.08124	-8	-0.02631

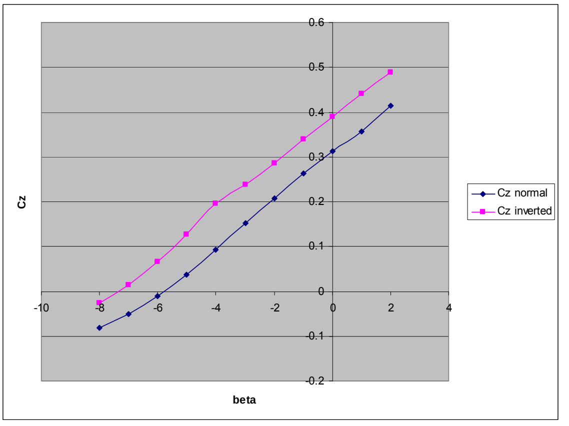

Fig. 5 – C_z normal, C_z inverted
Reference system connected to the airflow
CLARK Y profile, λ=3, MRe=1
The profile was mounted vertically
The air deflection in the horizontal plan β = +0.75; 2Δβ=1.5

The balance reference system is aligned according to the geometric longitudinal axis of the wind tunnel. The angle of distance between the "front" and the "back" C_z curves, as it can be read from the graph is twice the current deflection relative to the balance axis (according to which the positioning angles of the model are measured). Experiments were done at a speed of 40m/s corresponding to a Reynolds number relative to a chord of ~10^6. The figure below shows the location of the model in upright position on the balance jigs.

The found value can be entered in the calculation program of the "tunnel data" or can be eliminated from calculations by realigning the balance reference system, which is made by properly adjusting the yaw encoder.

4. Turbulence

To evaluate in a first analysis the airflow turbulence in the experimental area of the subsonic wind tunnel the critical Reynolds number was determined by means of a sphere.

Fig 6 – Front view

Fig 7 – Side view

In this respect, a sphere with ϕ = 123 mm was made, experimentally settling on the variation of the aerodynamic resistance coefficient depending on Reynolds number.

The results given in the table and then graphically mapped give the value Re_c = 345.000 (for. C_x = 0.3). Considering the critical Reynolds number Re_c = 385.000 in undisturbed atmosphere it results k = 1,11 for the turbulence factor *.

An effective Reynolds number Re_{ef} = 1,11Re can thus be considered for the wind tunnel of INCAS - Elie Carafoli.

The corresponding coefficient of turbulence $\frac{\sqrt{\Delta U^2}}{U}$ can be inferred from the curve DRYDEN ** that gives the value of 0.2% - 0.3%.

Table 3 – Values of C_x and MRe

C_x	Mre
0.458	0.109
0.454	0.139
0.444	0.171
0.443	0.201
0.426	0.234
0.404	0.278
0.356	0.315
0.281	0.35
0.191	0.387
0.132	0.421
0.111	0.462
0.107	0.505
0.108	0.539
0.108	0.58
0.113	0.626
0.115	0.66

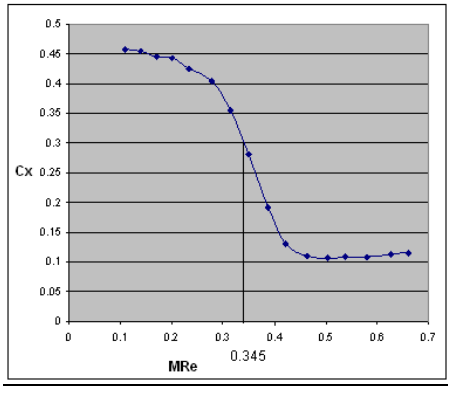

Fig 6 – Variation of C_x function MRe

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