A98-31554

ICAS-98-3,6,4

COMPARATIVE FORCE AND MOMENT MEASUREMENTS ON FULL AND HALF MODELS IN THE YUGOSLAV T-38 TRISONIC WIND TUNNEL

Nikola ZRNIC,
Yugoslav Aerospace Society
University of Belgrade
FR of Yugoslavia

Abstract

The intention of the author in this paper is to verify an installed half-model configuration integrating positive experience in its application through systematic comparison of measurement results with those obtained with a full model.

The investigation was performed on hypothetical scaled ONERA full and half-models of the transonic aircraft configuration adapted to the test saction of the T-38 Yugoslav trisonic blowdown wind tunnel.

The results obtained with the ONERA M4 model are compared with those for the ONERA M5 full model investigated in North American wind tunnels and daclared as reference data to be applied against those obtained with the ONERA M2 half-model.

The significant differences in aerodynamic coefficients C_L, C_D and C_m were found at high angles of attack.

The causes of this phenomenon are discussed in this paper, as well as a method of overcoming the problem of future application of the half-model technique in the aerodynamics lab.

In symmetrical model configuration tests, in symmetrical flow field a reflection plate as the longitudinal plane of symmetry is the basis of the half-model testing concept.

It is also the main reason for differences in the flow pattern without sideslip, relative to the conventional 3D test set-up including the sting. It is therefore necessary to correct the results obtained by applying the half-model configuration technique in relation to those of a 3D configuration.

The formulation of a mathematical model is a very complex undertaking in view of the complicated 3D secondary flow pattern and the horseshoe vortex phenomenon in the area of the plane of symmetry, as well as its effect on the primary flow along the half-model span, represented by separation vortices and half-wing tip vortex.

Nomenclature

C_L	-	Lift coefficient
C_D	-	Drag coefficient
C_m	-	Pitching moment coefficient
M	-	Mach number
R_e	-	Reynolds number
b	-	Wing span
VTI	-	Vazduhoplovnotehnicki institut – Zarkovo
ν	-	Free stream velocity
α	-	Angle of attack
Γ	-	Circulation
dS	-	Surface element

Introduction

A convenient method to obtain the characteristics of a large aircraft model in the Yugoslav T-38 wind tunnel [1] [5] is to use the half-model test technique. The concept of half-model testing is based on the reflection plate, installed in the model's plane of symmetry. Assuming a symmetrical flow field, this permits the testing of only one half of the model, which gives a number of advantages when compared to 3D-model testing:

- For a given test section size, the model can be made at least 50% larger than a 3D model,
- Larger model scale gives a larger Reynolds number and better simulation of the actual aircraft.
- Larger model scale makes production of fine-detail model parts such as nacells, airbrakes, flaps etc., simpler and more accurate.
- In a large model there is more space for instrumentation, pressure tubing, etc.
- Manufacturing of the model is simpler and less expensive, as only one half of the model has to be produced.

21st ICAS Congress
13-18 September 1998
Melbourne, Australia

However, there are some well known disadvantages of the half-model technique:

- The influence of the reflection plate boundary layer on the flow over the half-fuselage, and a relatively large wall interference from the surrounding test section walls. At higher angles of attack, the interferece effects on lift, drag and pitching moment can be quite large, in which case they have to be compensated by mathematical correction methods.

The T-38 half model set-up

The half-model test set-up in the Yugoslav T-38 wind tunnel (Fig. 1) comprises an integral half-model balance with support mounted on the left sidewall of the 3D-transonic test section, and reflection plate mounted on spacers at a distance of about 115 mm from the sidewall as illustrated in Fig. 2 and Fig. 3. The set-up is not equipped with a filler plate to compensate for the displacement effect of the wall boundary layer, which simplifies evaluation of the drag coefficient.

The model support is driven by an external hydraulic cylinder and the balance can rotate, together with the model, in the pitching plane and an angle of attack range of ± 25° is available. Maximum pitching rate is 20 deg/s and the setting accuracy is 0.05° , and angle of attack is measured by a resolver with 0.005° resolution.

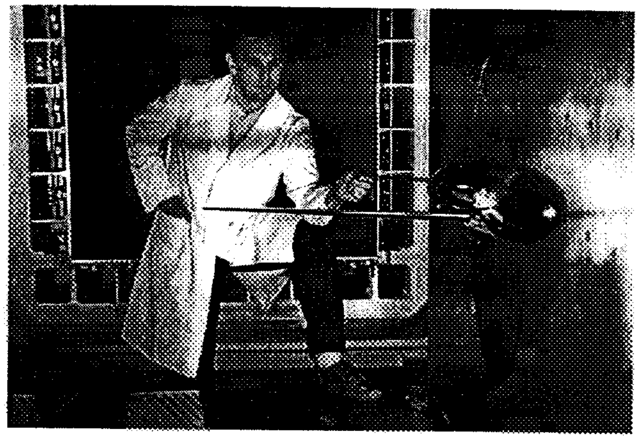


Fig. 1. - ONERA M2 half-model set-up in the T-38 transonic test section

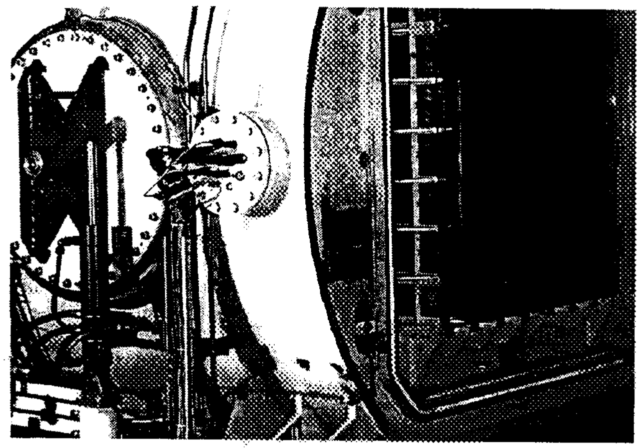


Fig. 2. - NAE half-model balance/support with hydraulic cylinder

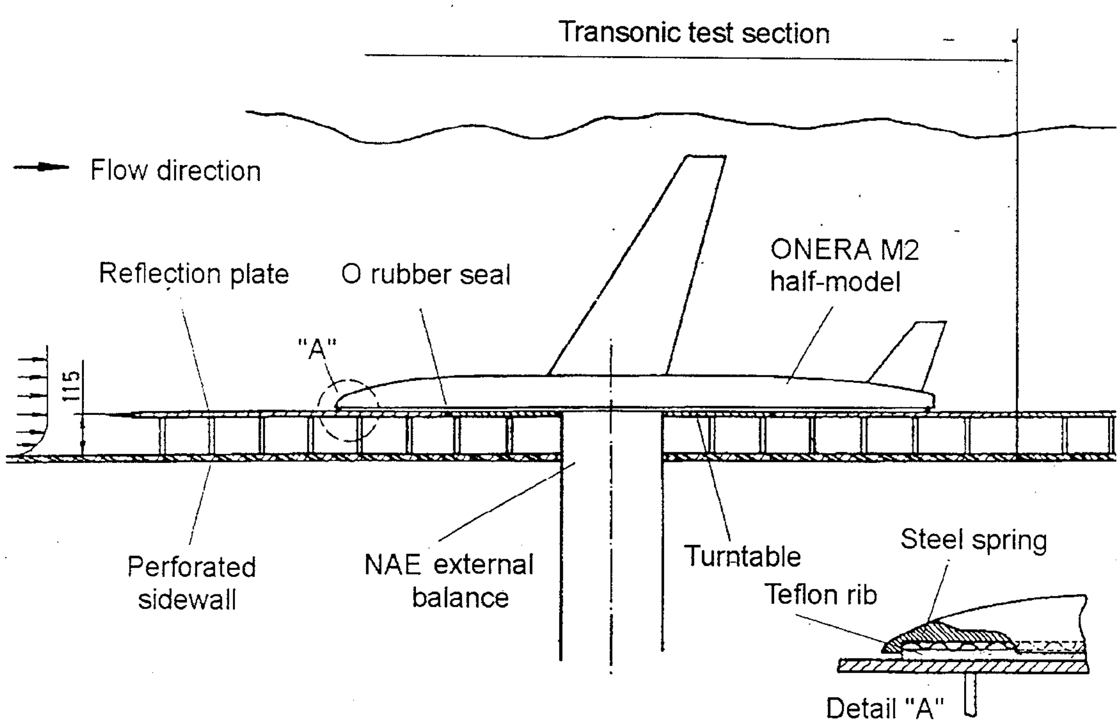


Fig. 3. – Half-model arrangement in the Yugoslav wind tunnel

Pressure measurements can be performed simultanously with force tests, as there is a provision for passing the pressure tubing outside the plenum shell through the pitching axis of the support mechanism. A desired number of scanivalves can be located outside the wind tunnel for easy access, but in this test pressure measurements were not included. Standard set-up comprises a maximum of five scanivalves, involving many pressure measuring points.

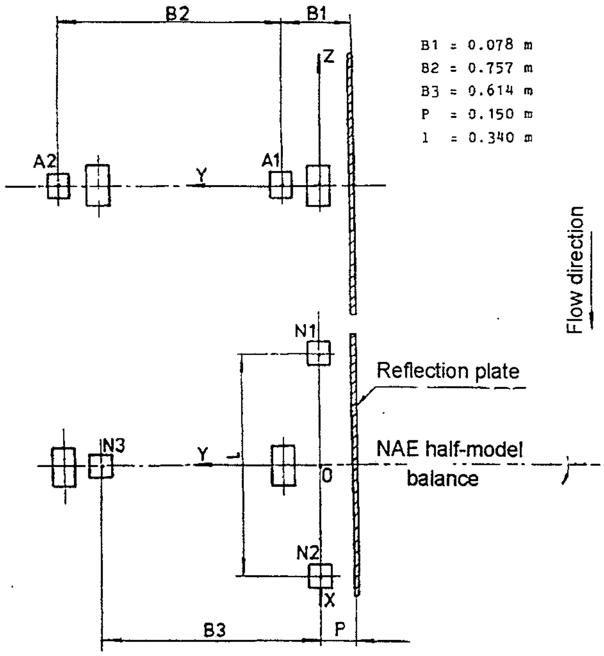
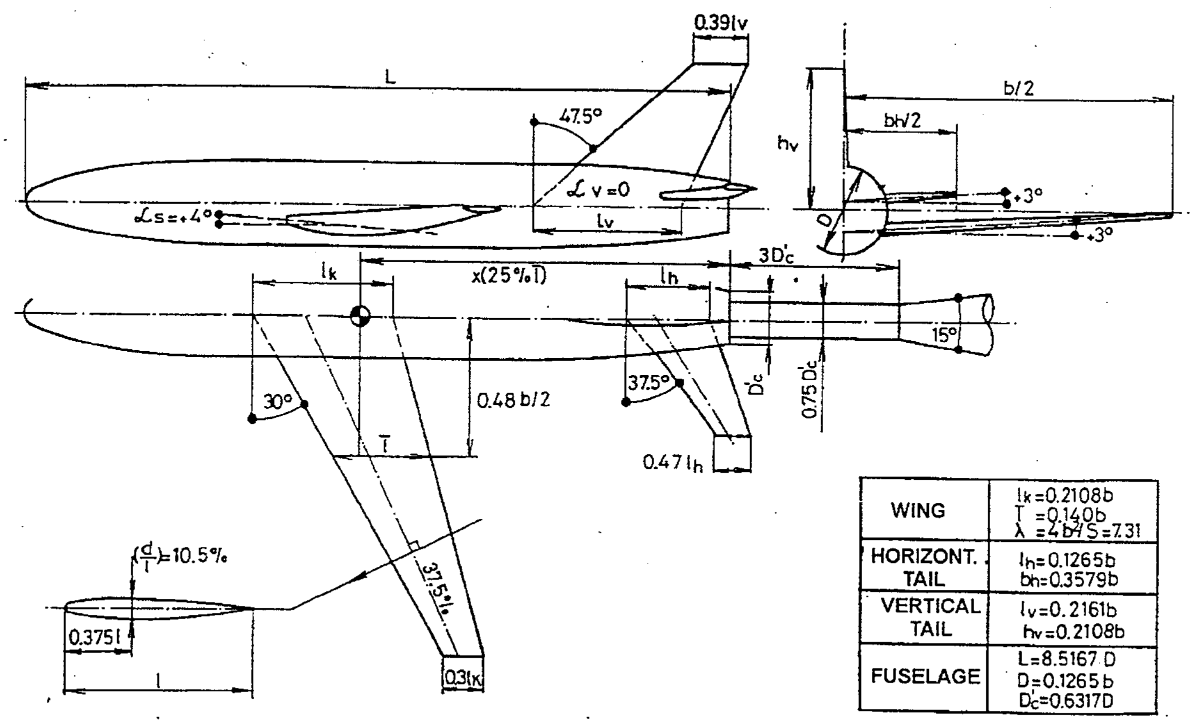


Fig. 4. – NAE half-model balance – Flexure element geometrical arrangement

The ONERA M2 half-model is mounted as shown in Fig. 3, on the balance/support via a block located around the pitching axis. The gap between the half-fuselage is sealed by teflon ribs located along the entire contour of the fuselage. The ribs are pressed against the reflection plate by springs. The purpose of this seal is to prevent leakage between lower and upper surfaces of the ONERA M2 half-body. The half-model support/balance was designed and manufactured by NAE (Canada). It comprises a five component external strain-gauge balance in a single self-contained module. This module is designed to be bolted into position in the fully assembled T-38 transonic test section, access being through the openings in the plenum shell and the test section sidewall provided for the Schlieren window (see Fig. 2). The NAE-balance is located on the left sidewall of the test section. The balance is primarily intended for measurement of the normal and axial forces, and the pitching and wing bending (rolling) moments on the test model, but the design also permits measurement of the yawing moment. Side force cannot be measured as is reacted by non-instrumented flexure element. The instrumented flexures are arranged as shown in Fig. 4. which also indicates the nomenclature which has been adopted. Three flexures are arranged to measure forces in the normal force direction, and two to measure the axial force components. The set of flexures can be exchanged for another to suit the required load range. The load capacities of individual flexures used in the ONERA M2 test are:



WING	lk=0.2108b T =0.140b λ =4b²/S=7.31
HORIZONT. TAIL	lh=0.1265b bh=0.3579b
VERTICAL TAIL	lv=0.2161b hv=0.2108b
FUSELAGE	L=8.5167 D D=0.1265 b D'c=0.6317D

Fig. 5 - Hypothetical ONERA transonic model-sting configuration-geometrical arrangement

Normal force:	N1,N2 = ± 90 kN	(each)
	N3 = ± 80 kN	
Axial force	A1 = ± 27 kN	
	A2 = ± 12 kN	

It should be noted that an external balance such as this one does not have a unique load capacity, as it will vary with the position of the applied load. The maximum load set of flexures provide the capability of measuring a normal load of 100 kN located on the balance rotational axis and at a spanwise distance of 340 mm from the reflection plane. If the load is displaced from the balance centerline in the axial direction so as to produce a pitching moment, the allowable load is reduced. Recalibration of the NAE half-model balance [6] [7] was performed by mounting in a calibration rig in the manner similar to that used for mounting in the wind tunnel. Calibration loads were applied by a hydraulic actuator and measured by high precision load cell.

Testing of the ONERA M4 model

A family of hypothetical transport aircraft configurations was designed and cosntructed by ONERA for the aerodynamic phenomenon investigation in the transonic speed range. ONERA M1, M2, M3 and M5, geometry illustrated in Fig. 5., cover wing span of 0.3 m to 1.0 m approx., for testing in varios wind tunnels world-wide. The ONERA M4 model (b=0.8 m) is selected because the existing ONERA M3 and M5 models are not quite representative both in scale and expected loads for the T-38 1.5 m transonic test section. The inside space of the model is adapted to accept ABLE 2 in. dia. MK XVIII strain gauge balance installed on specially designed ONERA sting.

Test results

The frontal area of the selected ONERA M4 model does not exceed 1% of the wind tunnel cross-section, because the test results are not corrected due to the blockage effect. Otherwise, the experiment was not able to achieve the condition of aerodynamic similarity (the same or similar Mach and Reynolds numbers) with those in North-American wind tunnels. The cause is the safety loading factor 2 for ONERA M4 model which limited the stagnation pressure below 4 bars. The results are corrected for base drag as well as model-sting deflection. Presented here are comparative test results at nominal Mach numbers M=0.7 (Fig. 6) and M=0.94 (Fig. 7) obtained with ONERA M4 (VTI-T38) and ONERA M5 models (NAE AEDC,.NASA).

A systematic comparison was performed in the range between M=0.7 and M=0.94 [2], [4]. Small differences in flowstream conditions and geometrical similarity of ONERA M4 and ONERA M5 models should be the source of data scatter because geometrical similarity could not be properly quantified. Generally, the correlation of the results is quite good, so that the ONERA M4 full model results are declared as the reference data against those obtained with the ONERA M2 half-model.

Comparative test results of ONERA M4 and ONERA M2 are presented in Fig. 8 and Fig. 9, at M=0.7 and M=0.94, respectively.

Conclusion

Obviously, there is no satisfactory agreement at higher angles of attack. The cause of this phenomenon is separated vortices generated by the reflection plate close to the ONERA M2 plane of symmetry. It is the essential reason for differences in the flow pattern, relative to the conventional ONERA M4/ONERA M5 test set-up, including a sting.

Complex 3D secondary flow field and horseshoe vortex (Fig. 10), as well as their effect on the primary flow along the half-model span, should be taken into account by mathematical corrections.

Non-conformity of the results obtained from wind tunnel measurements with those obtained on the actual aircraft, is not only due to the impossibility of achieving full dynamic similarity, but is also a consequence of changed flow field caused by tunnel side walls or reflection plate.

Having in mind that the model is small compared to the test section, which is generally the case, so the changes of the flow field caused by wind tunnel walls are small and can be described by small flow disturbances.

This implies linearisation of the problem. The equation can be solved by well-known methods. For specification of the boundary condition certain parameter measurement on wind tunnel walls and reflection plate will be performed.

By solving the interference potential flow equation, local speed and pressure gradients will be calculated and corrected to the local velocity, including flow deflection.

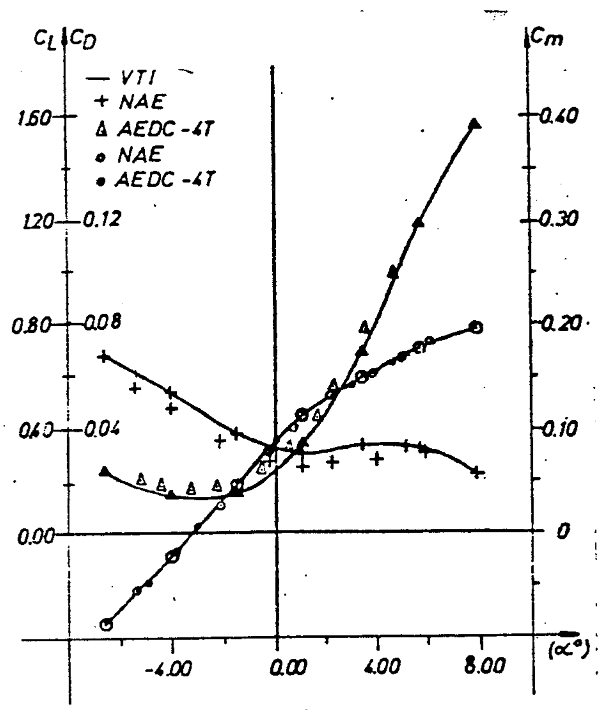


Fig. 6. – Comparison of ONERA M4/M5 results at M=0.7

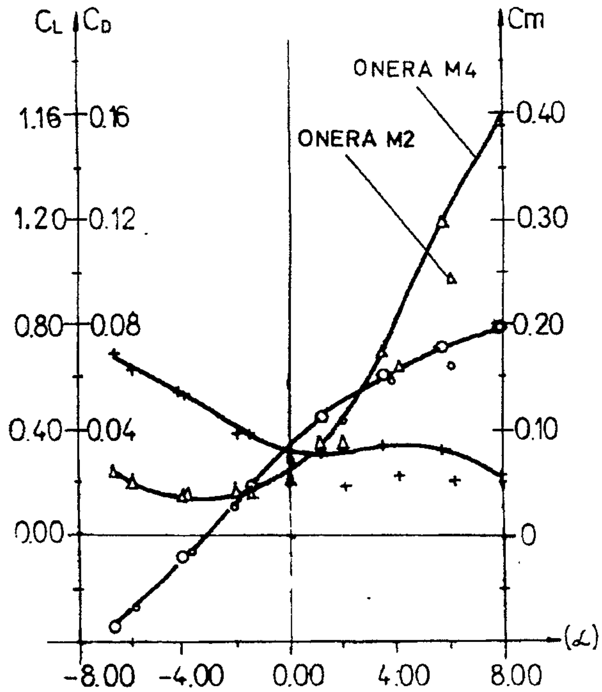


Fig. 8. – Comparison of ONERA M4/M2 results at M=0.7

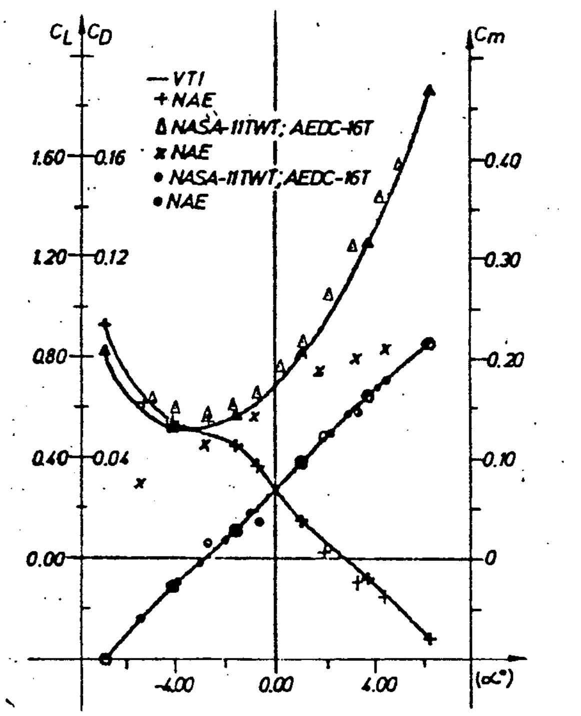


Fig. 7. – Comparison of ONERA M4/M5 results at M=M0.94

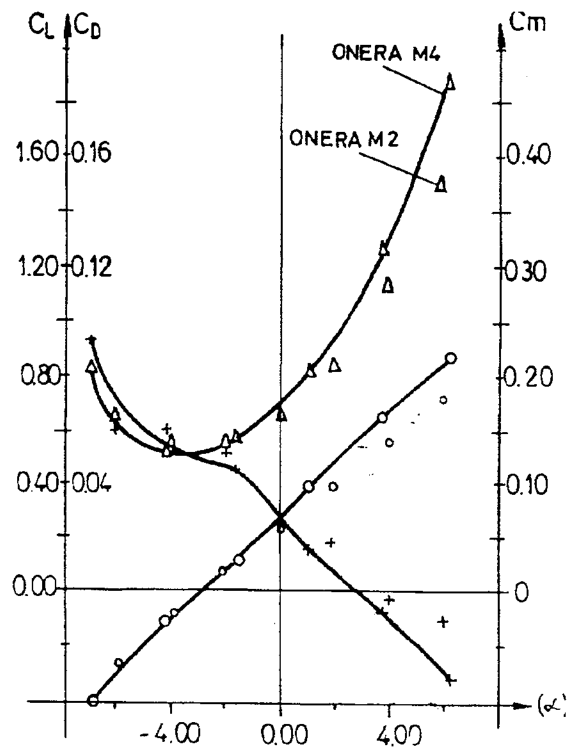


Fig. 9. – Comparison of ONERA M4/M2 results at M=0.94

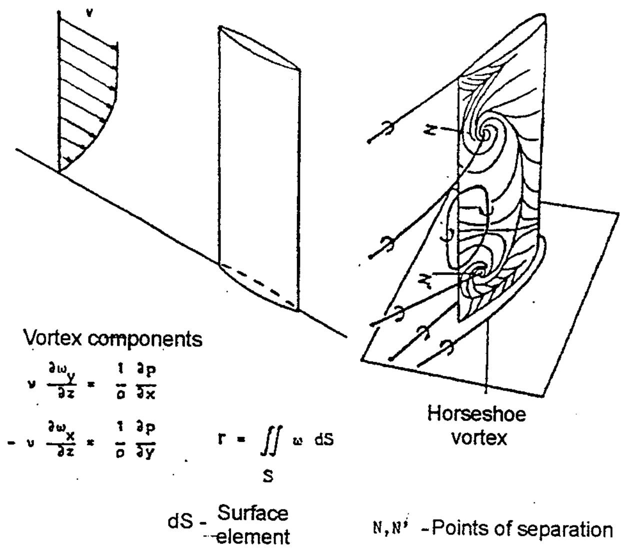


Fig. 10. – 3D – Secondary flow pattern and horseshoe vortex close to the reflection plate

References

[1] Medved, B. and Elfstrom, G.M. “The Yugoslav 1.5m Trisonic Blowdown Wind Tunnel” AIAA Paper B6-0746-CP, 1986.

[2] Galway, R.D. and Mokry, M. “Wind Tunnel Tests of ONERA Aircraft Models “Volume I and II, NAE, Ottawa, Canada, 1974/1975.

[3] Group of authors, “Test of the Calibration Models in Three Transonic Wind Tunnels “AEDC-TR-76 133

[4] Zrnic, N. “Qualitative Evaluation of Results obtained in Comparative Full and Half-model Test Technique in Wind Tunnels”, Master's thesis, Belgrade University, Yugoslavia, 1988.

[5] Isakovic, J., Zrnic, N., Janjikopanji, G. “Testing of the AGARD B/C, ONERA and SDM Calibration Models in the T-38 1.5 m x 1.5 m Trisonic Wind Tunnel”, 19th Congress of the International Council of the Aeronautical Sciences ICAS, Anaheim, California, USA, 1994.

[6] Galway, R.D. and Bowker, A.J. “Operation Manual for T-38 Wind Tunnel, Model Support Balances and Calibration Equipment supplied by NAE/NRC, Canada, NAE Technical Report LITR-HA-69, Ottawa, Canada, 1982.

[7] Galway, R.D. and Bowker, A.J. “Calibration of the Half-model Balance for the Yugoslav Wind Tunnel T-38”, NAE Technical Report LTR-HA-70, Ottawa, Canada, 1982.