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COANDA EFFECT ANALYSIS IN THE BANDEIRANTE AIRCRAFT AERODYNAMIC PROFILE

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Abstract. *The analysis in aerodynamic performance has been a recurring theme in engineering research. However, the objectives are to determine the optimal angle of attack as well as the coefficient of support of the profile. This fact increase of cargo transported, fuel consumption and others. However, several phenomena occur in the airfoils, among them the Coanda Effect, which basically consists in adhesion of the flow on surface, generating a pressure gradient on the aircraft leading edge, causing one remain flow close to the surface of the wing. Understanding of this phenomenon is very important to determine the angle of attack can be changed to reduce the forces in turbulent regime. This research investigate the NACA 23012 profile of the EMB 110 - Bandeirante aircraft a relevant aircraft to national aviation. The main purpose is verifying the drag and lift coefficients for one range of angles by CFD simulation at JavaFoil and Star CCM+. To this was compared the processing time and the variables calculated by them to a better applicability.*

Keywords: *EMB 110 – Bandeirantes, NACA 23012, Coanda effect, Numerical Simulation, CFD.*

1. INTRODUCTION

Aerodynamics, a study of fluid behavior, is a part of the science that has been studied and has gained importance in recent times with the emergence of the need for reductions in the effects of friction in general vehicles, such as in aircraft, race cars and so on. In aerodynamic studies, the main objective is the understanding of phenomena when there is variation in the parameters such as Mach number, Reynolds, attack angle, among others of an airfoil. Studies on the aerodynamic profile used in the aircraft have been developed over the years and attracted new looks to the airline industry. Several effects related to the concepts of lift and drag have been developed in order to improve the performance of aerodynamic profiles, such as the "balloon" effect, Magnus effect and the Coanda effect. With the help of the technology and software industry, there has been a great advance in the analysis of forces that act on the wings profile. The numerical analysis, made through computational simulation, has emerged as an important tool to aid engineers. This type of analysis becomes more advantageous from the temporal point of view when compared to the experimental work, with prototyping and simulations in wind tunnels. The verification of the Coanda effect in the Bandeirante aircraft is of great value since it associates the effect of the sustentation in an airfoil. For this purpose CFD JavaFoil and Star CCM + software were used in an increasing order of complexity. Figure 1 below shows the main measurements of the aircraft.

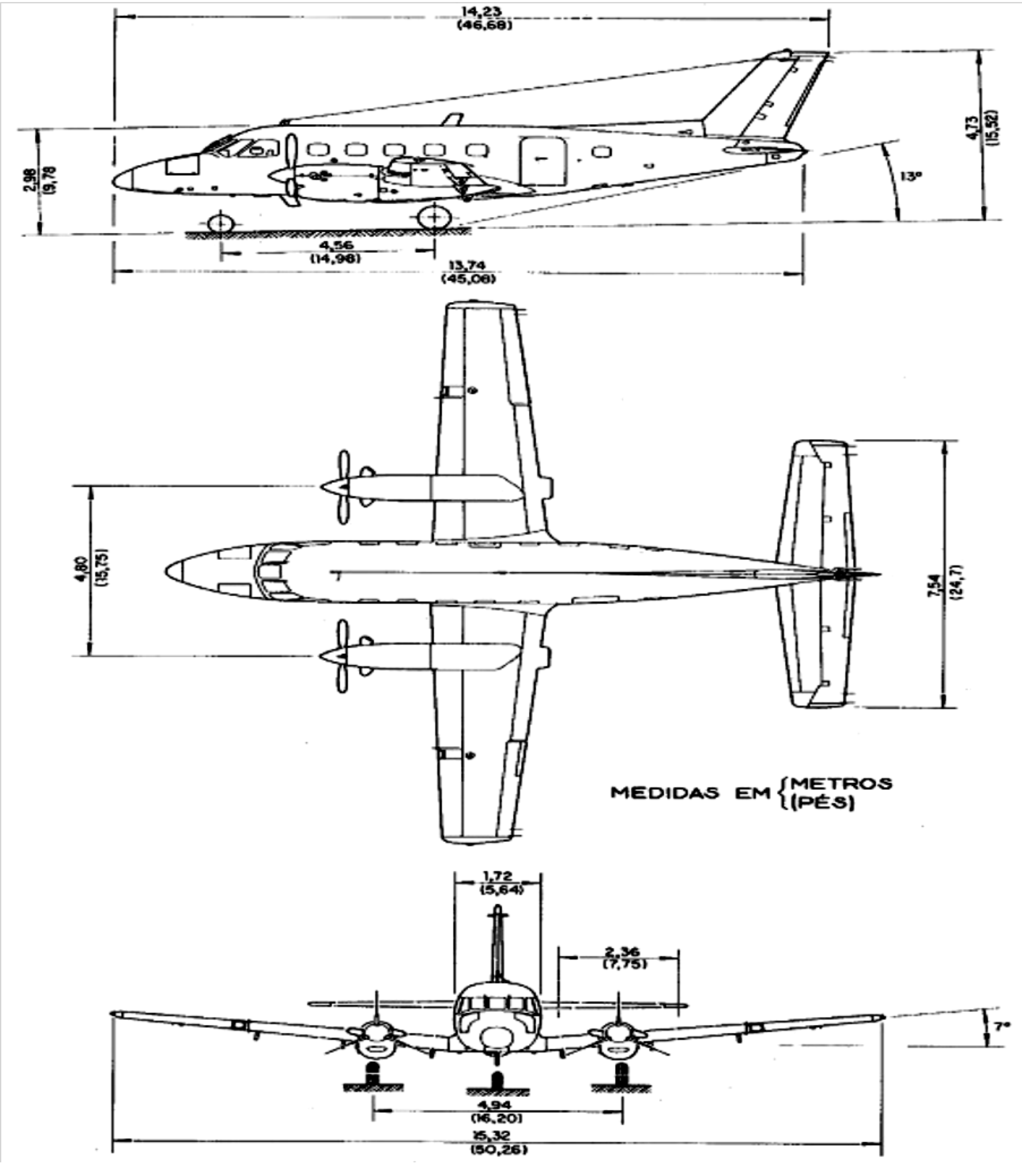

Figure 1. Project IPD 6504 – Bandeirante.

2. METHODOLOGY

In order to study the Coanda effect on the Bandeirante aircraft's aerodynamic profile, the two-dimensional simulation was started in the Siemens Star CCM + commercial software using the data obtained in the simulation in the JavaFoil software, considering that the graphics of the draft are illegible.

The CFD programs codes are structured around numerical algorithms that can solve flow problems through sophisticated interfaces that allow the input of parameters and the analysis of results. All codes contain three main elements: pre-processing, mathematical solution and post-processing, according to Fig. 2 (Malalasekera, 2007).

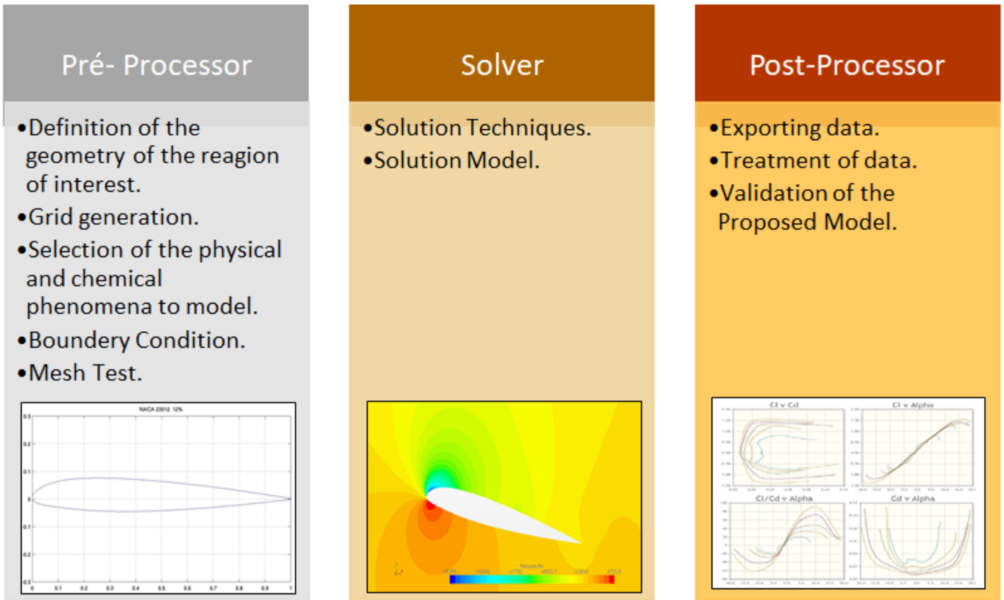

Figure 2. Processing steps using CFD.

In JavaFoil, after inserting the boundaries conditions obtained through the draft, a table was extracted containing the coefficients of support in relation to the angle of attack and this one varying from -6 ° to 24 °.

In the Star CCM + we have chose to use the 1:1 scale regarding the relationship between the model and the prototype, in order to facilitate the visualization in the region of interest and to simplify the calculations, thus not needing to use the similarity theory.

The base element size allowed in the study was 1.15m. In this way a 10% growth rate of the base element was applied in the direction of the center of the control volume outwards. Thus, a mesh with 8699 cells, 25189 faces, 16653 vertices was obtained; as Fig. 3.

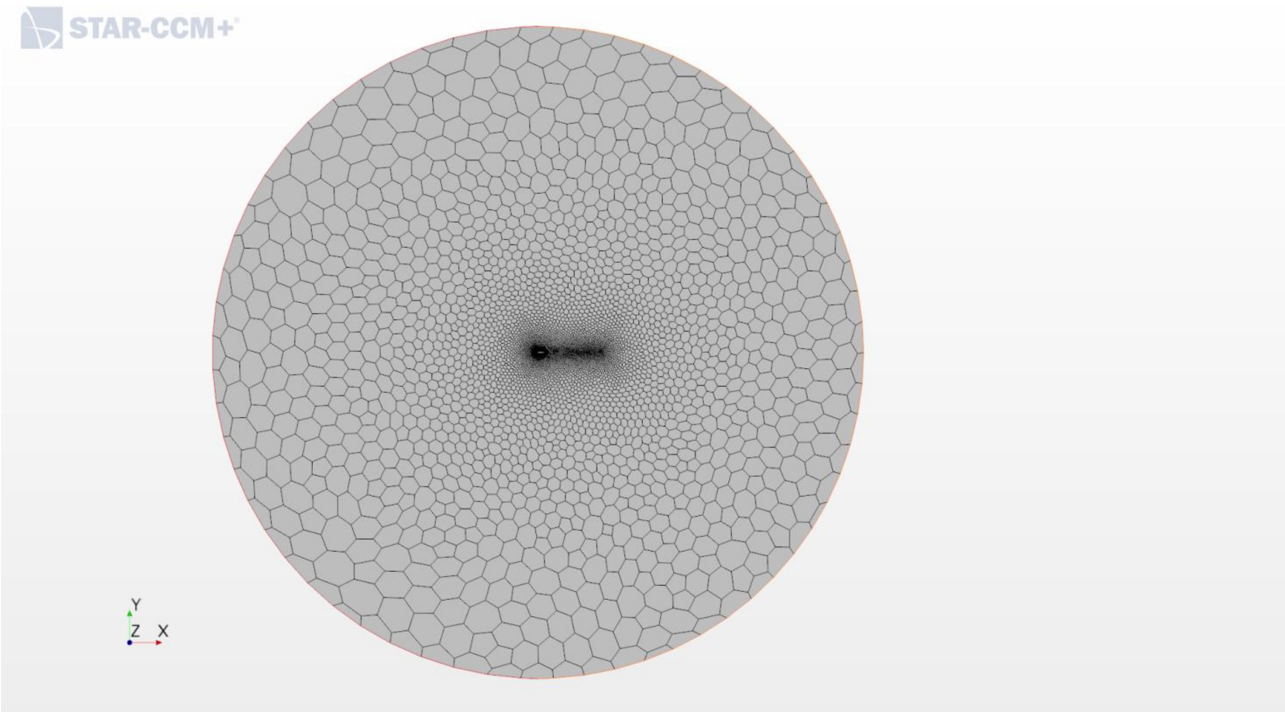

Figure 3. Mesh overall view.

The boundary conditions were obtained in Lopes (1958) in order to assume a temperature of 20°C, dynamic viscosity of $1{,}8x10^{-5}$ N*s/m² and density of 1.2 kg/m³ , in order to determine the state of the atmospheric air used. In the same way an average rope of 2.43m and a cruising speed of 120 m/s is assumed.

To confirm the mesh test the solution residuals were analyzed and they obtained values in the order of 10^{-18} in order to indicate that the mesh is well dimensioned, according to table 1.

Table 1. Mesh test.

Attack angle 8°								
Base Size	**Iteration**	**Continuity**	**X-momentum**	**Y-momentum**	**Energy**	**Tke**	**Sdr**	**Cl**
1,20	1810	8,87E-17	1,49E-16	3,55E-17	9,90E-16	1,85E-18	3,31E-18	1,1782040
1,15	1310	9,23E-17	1,50E-16	3,65E-17	1,10E-15	2,21E-18	2,48E-18	1,2111250
1,10	5000	8,40E-14	1,63E-14	8,17E-15	2,32E-14	5,31E-15	3,27E-16	1,2148770
0,90	5000	3,59E-16	1,12E-16	6,57E-17	3,12E-16	8,47E-18	1,08E-17	1,2164790
0,75	5504	4,96E-16	1,50E-16	7,47E-17	4,22E-16	5,16E-18	7,25E-18	1,2198421
0,50	5500	5,89E-16	1,83E-16	9,10E-17	4,83E-16	4,86E-18	6,31E-18	1,2270445
0,30	9515	7,86E-16	2,32E-16	1,09E-16	6,43E-16	4,76E-18	4,58E-18	1,2408294
0,25	10000	9,93E-16	2,95E-16	1,20E-16	8,23E-16	4,42E-18	4,15E-18	1,2479160
0,10	5500	3,05E-16	4,25E-16	1,02E-16	3,41E-15	1,14E-17	1,09E-17	1,2797390

3. RESULTS DISCUSSION

After the simulation in both software, a table containing the lift coefficient by angle of attack was extracted for both programs. From this data, comparative graphs were generated, as Figure 4 below.

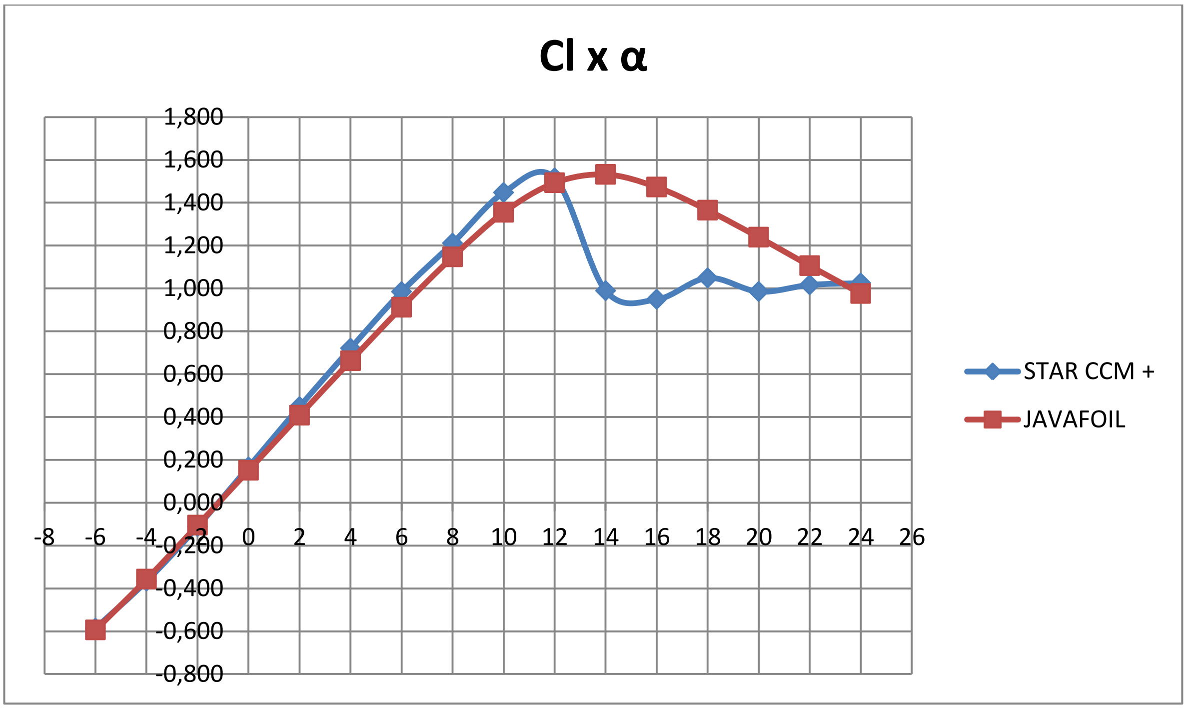

Figure 4. Lift coefficient graphics by attack angle.

When analyzing the graph, there is an abrupt drop in the lift coefficient in the Star CCM + curve after passing through the stall angle in comparison to the JavaFoil curve. This sudden drop in stall support is expected to confirm that

JavaFoil does not have the precision required for calculations in high turbulence situations. This is due to the absence of a turbulence model to close the calculations.

Thus, when looking at the curve of Star CCM +, it is possible to observe the intimate relationship between the attack angle and fluid adhesion to the airfoil curved surface, NACA 23012, and the lift.

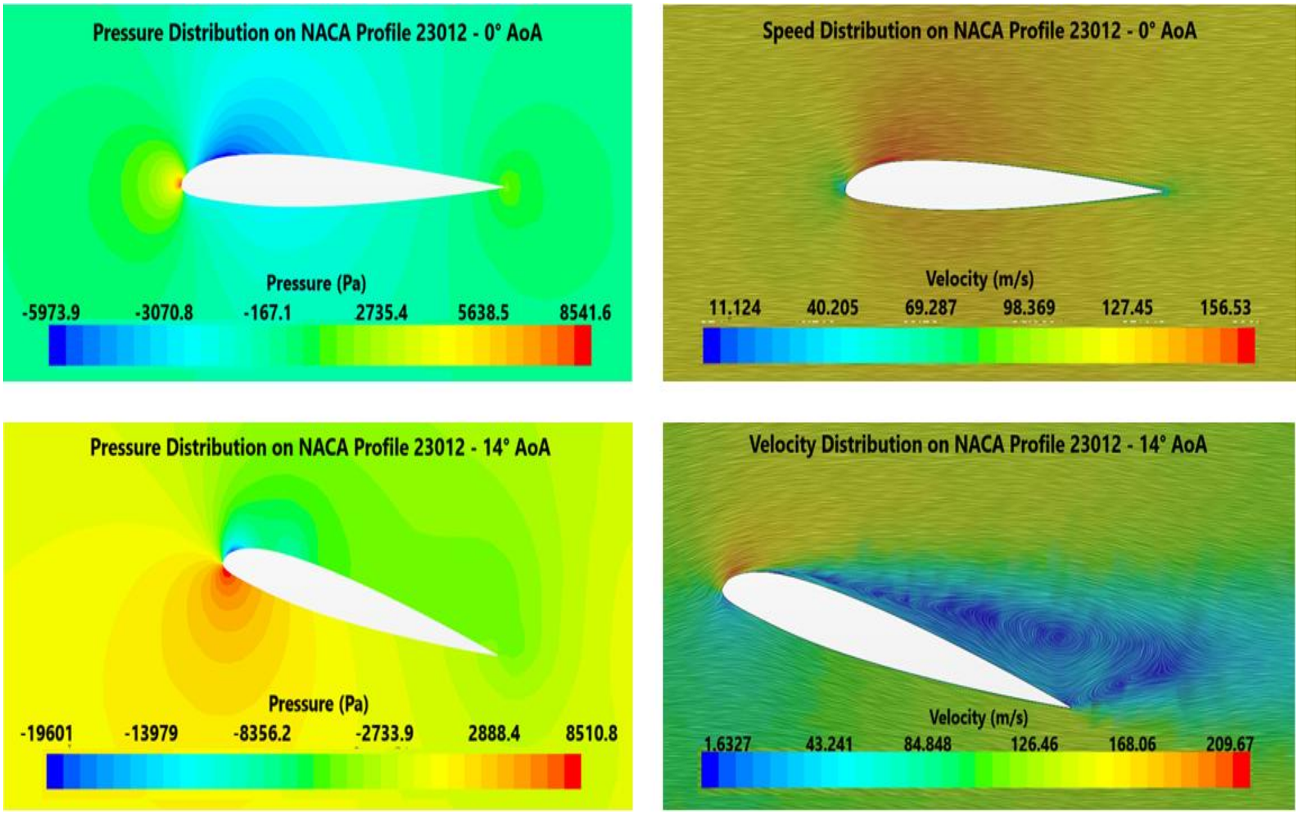

Figure 5. STAR CCM+ simulation of the NACA 23012 from the angles 0° to 14°.

For Bernoulli equation alone cannot explain the lift existence at high attack angles or even in inverted flight. Based on the results, we can see the relation of the lift coefficient with the way the flow behaves next to the Bandeirante aircraft's profile. Bernoulli's theorem is a succinct explanation of the lift generation in an aircraft, but the viscosity effect is neglected. The effect generated by the flow interaction and the profile geometry explains the creation of a fluid adhesion near the leading edge in both parts. This, in turn, correlates to the attack angle and the lift generation, since, in the stall point we do not have the fluid following up in the part of the extruder, which entails in a sudden loss of sustentation.

It can be concluded that between the simulated angles and the comparison with the values extracted from the draft, the action of the Coanda Effect is directly related to the sustentation. The effect itself is, until then, difficult to quantify, given its complexity. But, the same is perceptive in the broader understanding of what aerodynamic lift is.

4. CONCLUSION

Based on the results, the relationship of the lift coefficient with the way the flow behaves by the Bandeirante aircraft profile. Bernoulli's theorem is a brief explanation of what is the generation of lift on an aircraft, but despises the effect of viscosity. The effect generated by the interaction of the flow and the geometry of the profile explains the creation of a fluid tack near the leading edge on both sides. This correlates to the angle of attack and the generation of lift, since that in the stall point don't have the monitoring of fluid in part of the upper camber which carries in a sudden loss of lift. The effect itself is, so far, are difficult to quantify, since your complexity. But the same is perceptive in understanding more comprehensive what is lift.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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