EUROPEAN ACADEMIC RESEARCH
Vol. II, Issue 11/ February 2015

ISSN 2286-4822
www.euacademic.org

Impact Factor: 3.1 (UIF)
DRJI Value: 5.9 (B+)

Study and Analysis of Ideal Speed and Angle of Estol Aircraft Radio Controlled *SAE Aerodesign 2014* [1]

Dr. ANTÔNIO CLÁUDIO KIELING
Dr. JOÃO NETO EVANGELISTA
ANA ISABELA MENDONÇA GONÇALVES
Professors and Researchers
Universidade Estadual Do Amazonas – UEA
Amazonas, Brazil

Abstract

Stall is an aerodynamic phenomenon in which the profile loses support. When subjected to high angles of attack, the fluid is forced to go from a region of very low pressure (leading edge) to a region of high pressure (trailing edge). Finally, the wing stole when the critical angle or angle stall is reached, point in which fillets of air to give off indicating the separation of the air flow of the extrados wing, resulting in a total loss of support, which reduce the efficiency and the performance of the aircraft. The study of the stall is an element of extreme importance for the design and construction of an aircraft, since it provides the determination and basis of important performance parameters, for example, the minimum operating speed of the aircraft, determining the runway length of the landing and take-off, presenting variances weight, air temperature, atmospheric pressure, humidity what becomes an area of studies very complex. In order to the construction of an aircraft designed to participate in the National Competition SAE Brazil Aero design 2014, was deployed a study in the area of Aerodynamics, returned to the main theme of the study of the stall, for determining the optimal speed and stall angle.

Key-words: Stall speed, stall angle, critical angle support, lift.

Introduction

This article aims to explain the importance of the study of the speed and angle of stall for aircraft participant of *National Competition SAE Aerodesign Brazil 2014*. Therefore, this document makes a brief foray into conceptual aspects of the entire area aerodynamics as regards from conception to construction of an aircraft, which is initially by the project devoted to the study of aerodynamic forces acting on the aircraft.

Wilbur Wright discovered that there is a phenomenon during the flight called stall, or lift. According to their studies, stolon is a term applied in the area of aviation and aerodynamics that indicates the dispersion of the air stream of the extrados of wing,

[1] This Research was financed by Universidade do Estado do Amazonas – **UEA**, Fundação de Amparo à Pesquisa do Estado do Amazonas – **FAPEAM**, Kevin Kenji Sinmon – Escola de Aviação Civil - EJ

succeeding the total loss of support. A vehicle air condition in stall (stall, estolling) is not flying, but in situation of loss of altitude.
In order to facilitate the understanding and decrease the limitations found in the course of the project for subsequent years, it has been proposed a specific study of the stall, since that is an area that covers many important parameters of flight performance. This is because there is the difficulty of calculating the sources, survey of calculations and references not specific.

Methodology

The structural composition of the article was lifted from bibliographical searches both virtual pages and specialist books on the subject as in laboratory research in software improved in the area and in the assembly of prototypes for the flight test.

Aerodynamics

The design of an airplane is initially by the project devoted to the study of aerodynamic forces acting on the airplane. The way that an aircraft will behave before the application of such forces vector can be divided in two different studies, that if you give the phenomenon known as compressibility of air: Aerodynamics of Low Speed and Aerodynamics of High Speed.

Because it is the design of an aircraft radio-controlled, it should focus on the study of aerodynamic subsonic speeds common in aircraft of conventional engines and the propeller, as well as model aircraft. The four forces responsible for the flight are: traction, drag, weight and support. The analysis of these forces allows a broad study focused on performance and performance of a piece of equipment, due to its large interference in variation of the center of gravity and pressure, stability and controllability.

1. Select the Profile

The front air dam is an air foil specially designed to produce sustaining or a force useful to flight and is used in wing, propeller and tail. In view of this, he began a more comprehensive study to determine the type of front air dam that fits within the goals proposed by the team, such as: high aerodynamic efficiency, low coefficient of drag (Cd) and time (Cm), high coefficient of sustaining (Cl), together aligned to the geometry of the wing.

From an assessment of teams participating in the competition SAE Brazil Aerodesign in previous years, we selected the three profiles more used in the competition for the wing that are: Eppler423, Selig 1223 and Selig1020. Within the selected profiles, were made simulations in softwareXFLR5, which is a software for easy access and handling, used for analysis of aero-foils, wings and aircraft that operate at low Reynolds number.

1.1 Graphics the Profile

Figure 1 represents the ratio of the coefficient of sustaining with the angle of attack. It is noticeable that the angle of attack has a direct connection with the support and to increase it, the support also will be increased. The graph clearly illustrates this relationship and shows that above a certain angle, the sustaining decreases and occurs the stolon. This angle of attack is called critical angle or angle of stall, from which the air is plucked forming a turbulence that will result in a drop of high support and abrupt increase of trawling. Prioritizing the increase of support, it should be noted that the profile *Eppler423* has a better performance among the profiles in analysis.

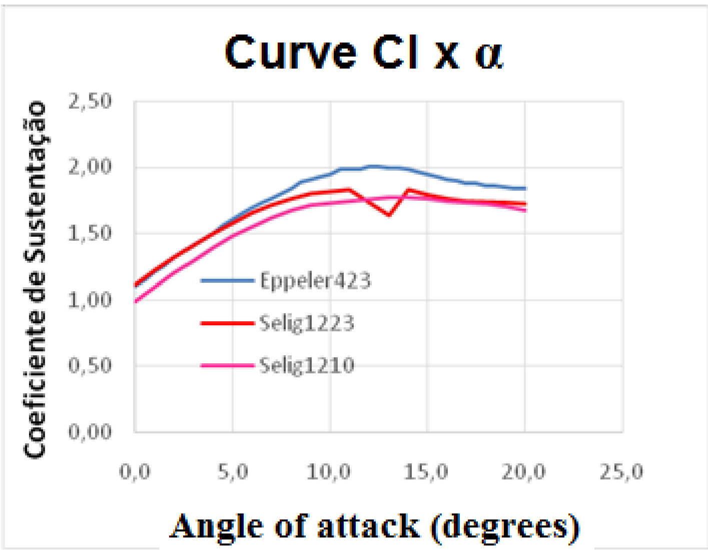


Figure 01: Curve Cl x Î± for Different Profiles

Figure 2 represents the ratio of the coefficient of drag with the angle of attack. It is noticeable that the drag is proportional to the angle of attack. The graph represents the measure of efficiency of the profile to generate the force of drag as a function of angle of attack, which is quite unwanted to obtain a high aerodynamic efficiency. In this graph, it is observed that, among the 3 profiles, the Eppler423 excels, by smoothly that is going to be designing in the course of the graph.`

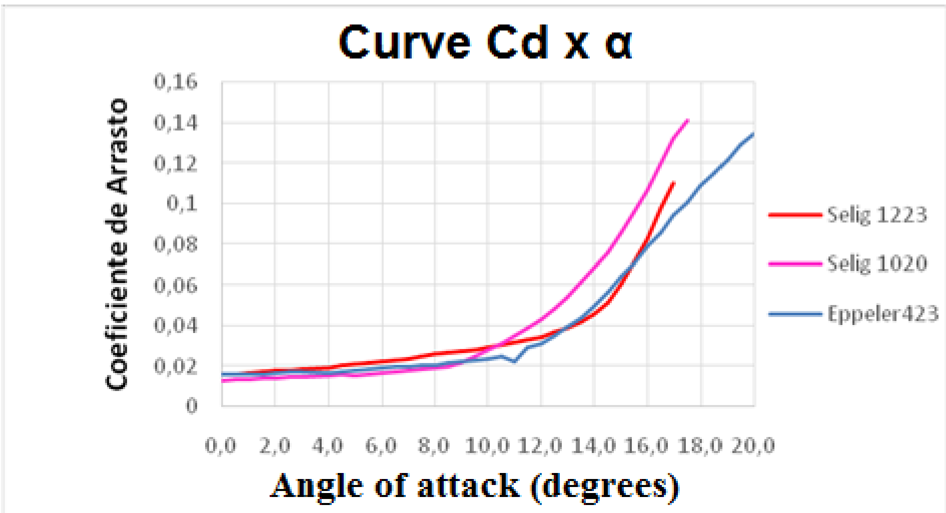


Figure 02: Curve Cd x Î± for different profiles

The figure 3 represents the ratio (Cl/Cd x Î±), i.e. the aerodynamic efficiency. It is perceived that the relationship reaches a maximum value between 65-100in three profiles. This maximum value represents the angle of attack at which gets the most aerodynamic efficiency of the profile, i.e. , the profile is able to generate the most support with a lower drag possible.

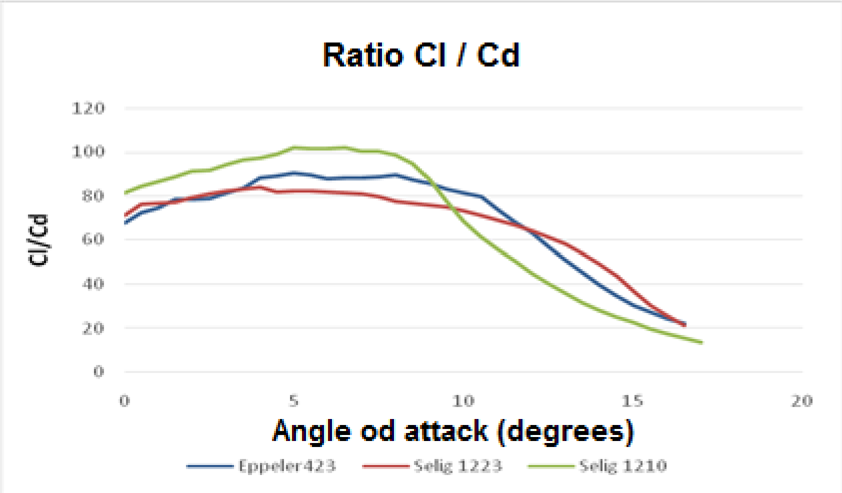


Figure 03: Aerodynamic Efficiency

Figure 4 represents the ratio of the coefficient of time around the center of aerodynamic profile with the angle of attack. This parameter is of extreme importance for the calculation of the aerodynamic center.

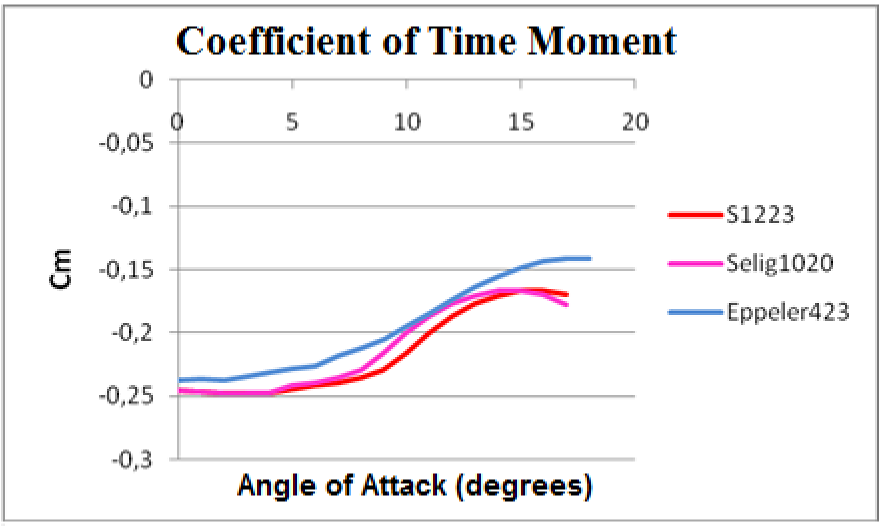


Figure 04: Curve Cm X Î±

After the analysis and study of the profiles, it was found that the Profile Eppler423 is the that more fits the requirements of the project for the construction of wing, prioritizing the gain of sustaining low speed aligned the low coefficient of drag, high aerodynamic efficiency and ease of construction. The analyses were submitted the Reynolds number in the range 300000 to 500000.

2. Angular Coefficient - Profile Eppler423

The angular coefficient represents the linear region of the graph of the coefficient of lift and the coefficient for the time being, it is of extreme importance for the definition of the position of aerodynamic center. The slope of the curve of sustaining is defined by the following equation:

$$a_0 = \frac{dcl}{d\alpha} = \frac{cl2 - cl1}{\alpha 2 - \alpha 1}$$

Already the angular coefficient of the curve of time is defined by the following equation:

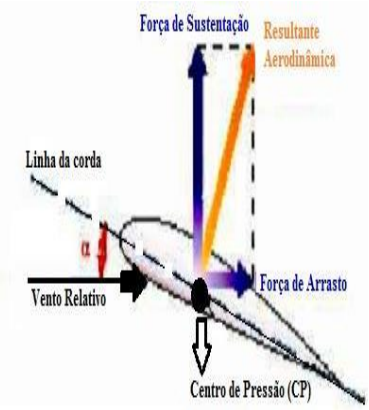
$$m_0 = \frac{Cm2 - Cm1}{\alpha 2 - \alpha 1}$$

The angular coefficients were calculated from the choice of two arbitrary points straight from their charts. The exact values of the coefficients of the angles were extracted from the software XFLR5. Was chosen for both the angles 2 and 5 (Î±1 and Î±2 respectively), with their respective coefficients of support and time.

The value of the0 found was 5,426/rad and was 0.1604 /rad.m_0

3. Determination of aerodynamic Forces and moment in Profile Eppeler423

During the normal flight of an airplane, the air flows by wing with greater speed the extrados of the intrados due to its curvature more pronounced. The difference in pressure between the intrados and the extrados of profile makes the presence of a time that tends to rotate the profile, known as the moment of profile.



The increase of speed corresponds to a decrease in pressure, according to the theorem of Bernoulli. The result is a force that pushes the wing up and backwards. This force is the Resultant Aerodynamic (RA), which is applied to a point on the front air dam called center of pressure (CP). She is represented as a vector which, when decomposed, gives rise to two forces components that are the strength of sustaining and a *Drag* (força de arrasto), as in figure 1.Thanks to this strength the front air dam is capable of lifting.

Below is the calculation of lift, drag and moment of Eppler423 profile.

Strength of sustaining

$$l = \frac{1}{2}.p.v^2.cl$$

Drag

$$d = \frac{1}{2}.\ p.\ v^2\ .c\ .cd$$

Aerodynamic Moment

$$m_{c/4} = \frac{1}{2}.\ p.\ v^2\ .c^2\ .cm$$

Where p is the air density, v is the velocity of the flow, c is the chord of the profile and cl, cd and *cm represent the coefficient of lift, drag and moment of profile respectively.*

Taking into account the equations above and the following data, it was calculated the forces and moment:

Data: v = 14 m/s; Î± = 10; *p* = 1.225 kg/m3; cl = 1,943 ;cd = 0.023;
C*m* = -0,194

***L* = 69.98% N/m** **_d_ = 0.86N/m c*m* = - 2.10Nm/m**

4. Determining the location of the centre of aerodynamic profile

The centre of aerodynamic profile is extremely important to determine the location of the centre of gravity of an aircraft, and can be defined as the point at which the time actor is independent of angle of attack . It is considered that the calculations made here act in a point located 1/4 of the rope, as measured from the leading edge. This point is called the aerodynamics as centre of aerodynamic profile, given by the following equation:

$$\frac{x_{ac}}{\bar{c}} = \frac{-m_0}{a_0}$$

Since m0 = 0, 1604/rade0 = 5,426/rad, you have to:

$$\frac{x_{ac}}{\bar{c}} = -0{,}0296$$

The above result implies that the aerodynamic centre is located in a position 2.96% ahead of 1/4 of the chord measured from the leading edge of the wing.

5. Characteristics of wing

5.1. Geometric Shape and location of the wing on the fuselage

The wing of an aircraft has the primary function to generate a force that balances the weight of the aircraft. Following this reasoning, it was a setup for easy construction, prioritizing time gains of the team, that minimize the total drag for a given support and which meets the requirements set forth by the team initially.

The geometric shape comprise much of the final result of the aircraft's performance. As well as the profile, the form of wing determines the conditions of trawling, sustaining and balance of the aircraft. In the design of the Urutau team were tested through the XFLR5 multiple geometries of wing with the profile Eppler423 and through the analysis of the behavior and performance of each one, chose to wing high in rectangular shape.

An important point in the choice of the geometry of the wing was opting for ease of construction, due to the short period of time the team for the competition. To try to minimize the drag induced generated at the tip of the wing, the obvious for the project would be the deployment of winglets, which are aerodynamics components that function induced drag decrease, related with kind of vortex wing, however, for the Urutau project, reached the conclusion that winglets at the tip of the wing does not have any efficiency, causing for the plane only the increase of weight, which is very unwanted.

5.2. Calculating the area of wing

The area calculation for the wing rectangular, is given by the equation Sw = b. c, where "b" is the scale and "c" is the rope. Data b = 2.0 m and c = 0.30 m, is that the area of the wing of the Urutau project is 0.6 m^2.

5.3. Stretching and thinning

To reduce the induced drag, the planes of high yield have wings with large elongation. The elongation (AIR) is the ratio between the scale and the rope geometric mean of wing and the relation of thinning (y is the ratio between the rope on the end and the rope in the root). Below are the equation of elongation and the relation of thinning, respectively:

$$AR = \frac{b}{c} = \frac{2m}{0,3m} = 6,67$$

$$\lambda = \frac{Cp}{Cr} = \frac{0,30}{0,30} = 1$$

Where Cp is the rope of the tip of the wing and Cr twine the root of the wing.

5.4. Rope average aerodynamic

The rope average aerodynamics is the distance between the leading edge and the edge of a leak of wing, point of great importance, both for the sizing rudders, as to the position of the CG, which is usually expressed in percentages of the rope average aerodynamics (CMA) and its location are given by equations:

$$C = \frac{2}{3} \cdot Cr \cdot \left(\frac{1+\lambda+\lambda^2}{1+\lambda}\right) C = \frac{2}{3} \cdot 0,30 \cdot \left(\frac{1+1+1^2}{1+1}\right) = 0,30 \text{ m}$$

$$y = \frac{b}{6}\left(\frac{1+\lambda+\lambda^2}{1+\lambda}\right) y = \frac{2}{6}\left(\frac{1+(2.1)}{1+1}\right) = 0,5m$$

5.5. Aerodynamic Forces and moment in wing

The four forces that act on an airplane in flight are: weight, support, traction and trawl. Have the knowledge of these forces makes it possible to understand more clearly the reactions of the airplane, which facilitates the construction of the aircraft. The following is an illustration of the forces.

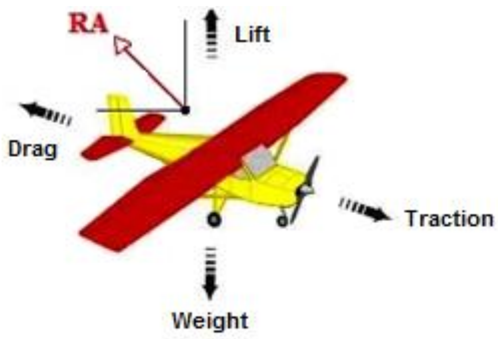


Figure 06: the Action Forces

Sustaining

The support is, by definition, the component of the resultant aerodynamic perpendicular to the relative wind. In order to explain the support we will have to make use of the principle of Bernoulli and the third law of Newton. As is well known to support is generated mainly by wing the airplane, which is a front air dam designated to support the weight of the entire plane. The wing profile asymmetric is the most used in wing, by taking advantage of the principle of Bernoulli, once a higher curvature at extrados (top of wing) causes the air has its increased speed and static pressure reduced in relation to the intrados (the bottom of the wing). This difference in pressure between the extrados and the intrados generates part of the sustaining of wing, but not all.

The other factor of total support produced by wing will be generated by deflection down air that jars with the intrados of wing. In other words, the air that is moved down by wing, in accordance with the 3RD Law of Newton, will have as a reaction pushing it upwards, producing sustenance.

Trawl

Trawling is the term used to name the resistance to air flow or movement through the air, or may be, it is the force that resists and opposes the movement of the aircraft, acting in parallel in the same direction of the relative wind. As discussed, it is the force that will oppose the motion of the aircraft; therefore, the higher the drag should be force to compensate it. This force will be the force increase traction, i.e. increase in engine power.

Weight

As well as any other body on the surface of the earth, the airplane has a weight, caused by the force of gravity that acts in CG of the aircraft in the direction of the centre of the earth. On the ground, the weight of the aircraft is supported by the surface of the earth through the landing gear and when in flight, by means of sustenance. Soon, so that the aircraft will be able to fly, it is necessary to set up a force equal to or greater, in the opposite direction to the weight, so that the aircraft can fly heavenwards.

Traction

The drawbar is produced by the group moto-propeller, in the direction of travel of the aircraft, in the direction opposite to the trawl.

6. Slope of the curve of the wing

The angular coefficient of the curve of the wing is estimated by the angular coefficient of the curve Cl x Î± of wing as a function of the angular coefficient of the curve Cl x Î± of the profile. Through the theory of line caring for Prandtl, the angular coefficient of the curve of the wing, which have AIR>4,is calculated by the following equation:

$a = \frac{a_0}{1+\left(\frac{a_0}{\pi}.e.AR\right)}$, Where he soon, the = 4.24/rad$e = \frac{1}{1+\delta} = 0{,}93$

6.1. Comparison of the curve cl x Î± of the profile with the curve Cl x Î± of Wing.

The table below shows the comparison between the curve cl x Î± profile Eppler423 and the curve C_L x Î±. The data of *cl* x Î± were imported software XFLR5 to Excel and applied in the equation below and then to draw the curve Cl x Î± of wing.

C_L = a. (Î± - Î±$_{L=0}$) Where is the slope of the curve of the wing (grade-1) ,is the variation of the angle (-15) to 15 (1) and l = 0 ; Angle where cl is null = (-15).

The graph is the result of the comparison between the profile and the wing is presented below.

Alpha	*cl*	Alpha	*CL*
-15	0	-15	0
-12	0.0739	-14	0,061
-11	0.1570	-13	0,122
-10	0.2975	-12	0,183
-9	0.3547	-11	0,244
-8	0.3898	-10	0,305
-7	0.4228	-9	0,366
-6	0.4474	-8	0,427
-5	0.5087	-7	0,488
-4	0.5838	-6	0,549
-3	0.7667	-5	0,61
-2	0.8839	-4	0,671
-1	0.9963	-3	0,732
0	1,0993	-2	0,793
1	1,2054	-1	0,854
2	1,3154	1	0,976
3,0	1,4121	2,0	1,037
4,0	1,5025	3,0	1,098
5,0	1,5995	4,0	1,159
6,0	1,6947	5,0	1,22
7,0	1,7595	6,0	1,281
8,0	1,8343	7,0	1,342
9,0	1,9000	8,0	1,403
10,0	1,9430	9,0	1,464
11,0	1,9839	10,0	1,525
12,0	2,0040	11,0	1,586
13,0	1,9966	12,0	1,647
14,0	1,9797	13,0	1,708
15,0	1,9413	14,0	1,769
		15,0	1,83

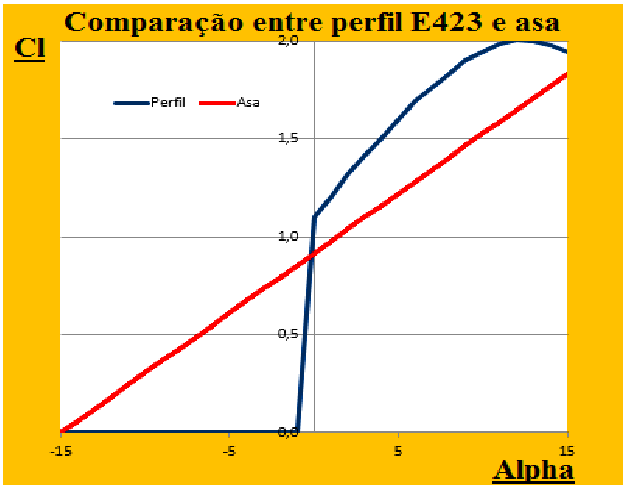


Figure 07: Comparison between the profile AND423 and the Wing

The calculation carried out allows you to observe that the coefficient of sustaining wing(Cl máx) ,is approximately 1.83, fundamental value for the calculation of speed stall.

7. Determining the Speed and Angle of Stall

"The wing stole when the critical angle or angle of stall is reached, at which point the fillets of air is plucked and become turbulent, considerably reducing the production of sustaining by wing. At low angles of attack, the fillets of air is plucked from the back of the wing, not causing any loss of sustaining significant. However, as the angle of attack is increased and approaches the critical angle (1) ,the displacement of fillets starts to occur as close to the edge of attack, up to the point at which the drag generated by turbulence (2) is so large that the sustaining produced become insufficient to maintain the aircraft in flight ." (Dennis Bianchinni, 2011, 38)

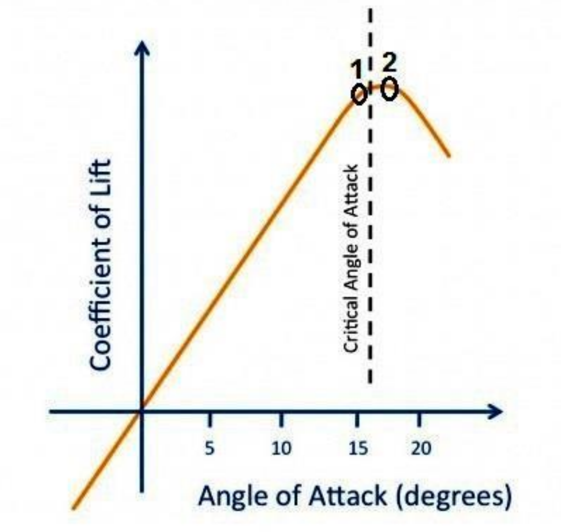


Figure 08: angle of attack in graus.

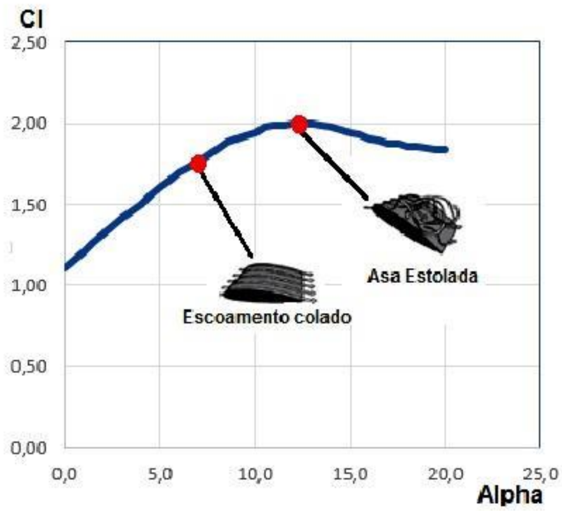


Figure 09: Representation of stolon in Urutau Wing

It is noticeable by analysing the second figure that the wing "stole" at an degree Between 10 to 15), but you need to know the speed at which this occurs.

In horizontal flight at constant speed, support is equal to the weight, and the traction is equal to trawl. To ensure that the flight is actually horizontal, the support must be constant and equal to the weight. Therefore, if you increase the speed, we decrease the angle of attack to prevent the sustaining increase and the plane starts to rise. Conversely, if lessen the speed, we will increase the angle of attack to keep the height.

But there is a limit on the increase in the angle of attack, which is the critical angle. When this angle is reached, the speed can no longer be reduced. This minimum speed possible in horizontal flight is called speed stall and can be calculated by the following equation:

$$V_{estol} = \sqrt{\frac{2.W}{\rho.S.Cl_{máx}}} = \sqrt{\frac{2.100}{1,225.0,6.1,83}} = 12,19\ m/s$$

Thus, the speed of stolon for aircraft in future construction and flight test will be 12.19 m/s.

Final Considerations

Finally, it is noticeable that exceeding the critical angle, it initiates the stolon and sustaining decrease rapidly, but it is still possible to maintain horizontal flight since the speed is increased to compensate for the reduction in support. However, small increases in angle of attack in addition to the critical require huge increases in power, due to the rapid increase of trawling after the stall.

Therefore, from all analyses in the course of the work, we tried to show in a simple way and objective procedures for calculations for the definition of stolon in aircraft. In general, the procedures shown are applicable to the Aero Design, giving greater knowledge base to obtain a safe flight, both in commercial aviation, the aircraft to the Aero Design competition.

REFERENCES

BIANCHINI , Denis. Teoria de Voo , 01ª ed, Bianch, São Paulo, 2012.

DURAND, W. F., & LESLEY, E. P., Experimental research on air propellers II, T. R. n°30, NACA 1920.

FEDERAL AVIATION REGULATIONS, Part 23 Airwothiness standarts: normal utility, acrobatic, and commuter category airplanes, USA.

HOMA, Jorge M. Aerodinâmica e Teoria de Voo - Noções Básicas, 30ª ed. , WING - São Paulo, 2011.

RODRIGUES, L. E. M. J. Fundamentos da Engenharia Aeronáutica: Aplicações ao Projeto Sae Aerodesign. 1.ed. São Paulo: Instituto Federal de Educação Ciência e Tecnologia de São Paulo, 2011. Vol.2.

ROSA, Edison da. Introdução ao Projeto Aeronáutico: uma contribuição à Competição SAE AeroDesign / Edison da Rosa ; colaboração Juliano Toporoski. - Florianópolis: UFSC/GRANTE, 2006.

Sites:

1. <http://ciencia.hsw.uol.com.br/avioes9.htm > Acesso em: 13.07 – 12h55
2. <http://www.engbrasil.eng.br/index_arquivos/aula28.pdf - 29.07> Acesso em: 15.07 - 18h49
3. <http://www.engbrasil.eng.br/revista/v222010/artigos/art1v222010.pdf > Acesso em: 29.07 – 15h39