The 40th International Conference on
Mechanics of Solids, Acoustics and Vibrations &
The 6th International Conference on
"Advanced Composite Materials Engineering"
ICMSAV2016& COMAT2016
Brasov, ROMANIA, 24-25 November 2016

THE RECREATIONAL KITE USED IN AIR-WATER SPORTS AS AN AERODYNAMIC PROFILE

Cristina Miclea[1], Marius Hodirnau[2], Carol Csatlos[3]
1 Faculty of Food and Tourism, Transilvania University of Brasov, miclea.cristina@unitbv.ro, mariushod@unitbv.ro, csk@unitbv.ro

Abstract: *The paper presents the dynamic of a recreational kite used in air-water sports, focusing on the wing as an aerodynamic profile. The main elements of an* aerodynamic profile *described are:* the trailing edge, the leading edge, the chord, axis profile, the upper surface, the underside, depth, average curve line, the incidence angle. *Also will be taken in consideration the string tensions responsible of launching and relaunching the airfoil and other forces involved, lift and drag.*
Keywords: *kite, air, water, sport, dynamic, airfoil.*

1. INTRODUCTION

The equipment used in air -water sports consists in wing, lines, control system and board.

The wing is made of a very light fabric (weighing up to 60g /m^2), treated in order to become waterproof. The wing surface varies proportionally with wind speed. At the end, the wing is equipped with straps crossed by lines made of resistant material that can withstand a weight of up to 2t.

The wing architecture respects the characteristics of an aerodynamic profile. This is the outline of an airplane's wing section made through a propeller or blade in a plane perpendicular to the wing surface and parallel to the axis of the airplane or in a plane tangent to a cylinder which would intersect the axis propeller and would have its axis. The purpose of an aerodynamic profile is to create a bearing strength as possible while having a drag as small.

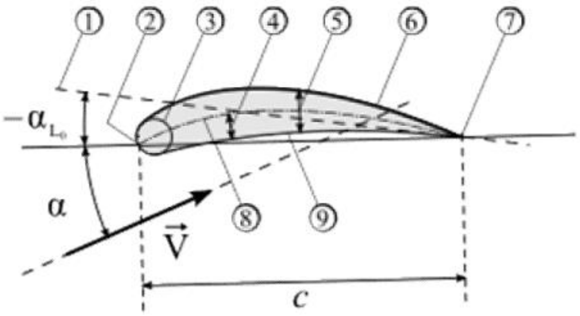


Figure 1: Aerodynamic profile components.

The characteristic elements of an aerodynamic profile are sizes that define the form, their way of generation and some functional aspects. They are:

- The trailing edge (7). It is the edge behind the profile.
- The leading edge (2). It is the edge in front of the profile and is the tangential point of the circle with the center in the trailing edge.
- Chord. It is arbitrarily selected reference line for profile definition and can be determined either as tangent at the underside of the profile or as the tangent circle of the leading edge and with the center in the trailing edge.
- Axis profile is the line connecting the leading edge to trailing edge.
- The upper surface (6). This is the face above of an airplane wing profile. Without referring to position, the upper side means the curved part of the profile.
- The underside (9). This is the opposite surface to the upper surface. If the profile shape is symmetrically to the axis, it is impossible to define which surface of the profile is which. In plane wings case, the underside is always the part below of the wing profile.

- Depth. Represent the chord length measured between two perpendicular chord, framing the profile.
- Average curve line (frame). This is the line drawn in the middle of the distances between the upper side and underside.
- The profile arrow (4). It is the maximum distance between the average curve and chord line of the profile (maximum ordinate of the frame).
- The thickness of the profile (5). It is the length of the perpendicular on the chord (or axis) defined by intersections with the upper surface and underside surface. The relative thickness is the ratio of thickness and depth, expressed as a percentage.
- The tangent circle in the leading edge (3). This circle has the radius determined by the profile curve in the leading edge.
- Lift axis zero (1). This axis indicate the direction of the fluid for which the resulting pressure forces on the profile in the perpendicular to this axis is zero. On a wing of an airplane that position does not provide a force to support the aircraft in flight.
- The incidence angle (angle of attack) (α). It is the angle at which the profile is positioned towards the general direction of the fluid flow.

After the curve of the frame, a profile may be:

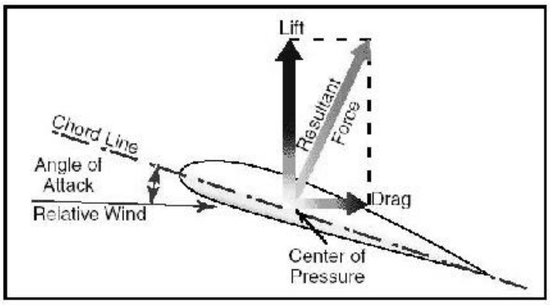
- With simple curvature, in which the frame is an arc of the curve without points of inflection.
- With double curvature, in which the frame has a point of inflection.
- After the shape of the frame and the trailing edge, a profile may be:
- Jukovski profile, with a simple curvature frame and a sharp trailing edge.
- Kármán-Trefftz profile, with a simple curvature frame and in a dihedral trailing edge.
- Von Mises profile, with a double curvature frame, general shape.
- Carafoli profile, with a double or simple curvature frame and a rounded trailing edge.

After the speed at which it is expected to be used, characterized by Mach number, we have:

- Subsonic profile, when Mach number is below unit. They are relatively thick profile, with high curvature and rounded leading edge.
- Supersonic profile, when Mach number is above unit. They are relatively thin profile, with small or no curvature and sharp leading edge (rhombic profile).

2. THE DYNAMIC OF RECREATIONAL KITES

Dynamically speaking, the resultant of the aerodynamic forces (known as total aerodynamic force) is divided into two components: the drag force, which opposes the traction and acts along with the relative air flow and lift force, which is perpendicular to the relative air flow and flight path of the profile, as shown in figure 3



[7]

Figure 2: Aerodynamical forces

The resultant force, and therefore the lift force, depend on:

a) the shape of the wing;
b) the attack angle;
c) the air density (ρ);
d) the velocity of the free fluid (V^2);
e) the shape of the wing (S).

The lift force (and the drag force) produced by a wing follows physics laws.

The velocity of the air and density (ρ) are combined in the expression for the dynamic pressure ($\frac{1}{2}\rho V^2$).

So we have:

$$Fz = Cz \frac{1}{2} \rho V^2 \quad (1)$$

Where Cz represent the lift coefficient, the lift capacity of the wing at a certain angle of attack.

For a particular wing the angle of attack is the most important control factor in static pressure distribution around the wing. This determines the amount of the lift force that is generated. Therefor the real CZ's value will vary depending on the angle of attack.

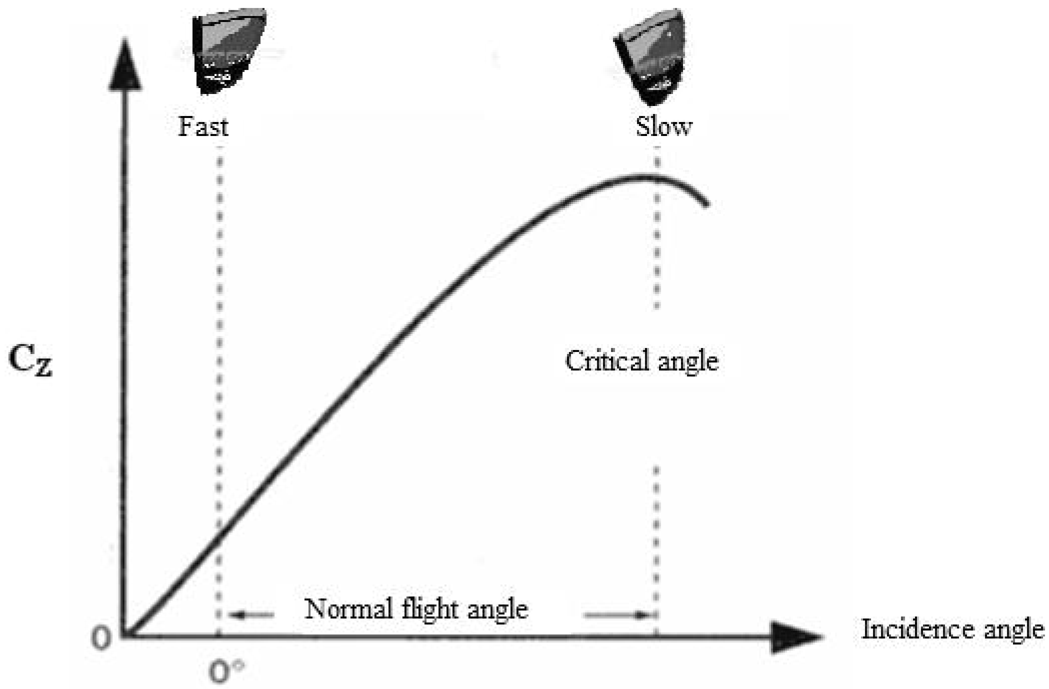


Figure 3: Chart lift coefficient with angle of attack

At higher angles of attack, lift curve begins to descend until the appropriate speed limit angle of attack that occurs after a significant decline of Cz and the capacity of the wing to produce lift. This happens when the air flow is unable to stay linear over the upper side of the wing, is separated and divided into vortices (broken air fillets / delaminate the boundary layer). This represent the limit velocity of the lift surface. Cz (the lift coefficient) is maxim just before the limit velocity.

During the flight on the airplane act the lift force (FZ), the drag force (Fx), the traction force (T) and the force of gravity (G).

Fx is the aeronautical term that defines air resistance manifested on aircraft while it relatively moves through the air, that oppose the movement and acts along and in the same direction with the relative air flow.[1]

The total drag force is the sum of the different dragging forces acting on the plane. The dragging forces are divided in two categories:

a) The dragging forces associated with the generating of the lift force, known as induced drag force induced drag (Vortex-vortices effect type that forms at the trailing edge of the wing, on the peaks especially.

b) The dragging forces which are not directly associated with the increase of the lift-known as the parasite drag force, which include the resistance given by the wing shape, the friction resistance and the interference resistance (the influence of one aerodynamic component on another). The resistance given by the wing shape and the friction resistance can often be found as the profile resistance.

To determine the performance and efficiency of an airfoil at an angle of attack (and airspeed) , should be considered portable and drag. The ratio of the two , called the ratio lift / drag is referred to as the Glide Ratio.

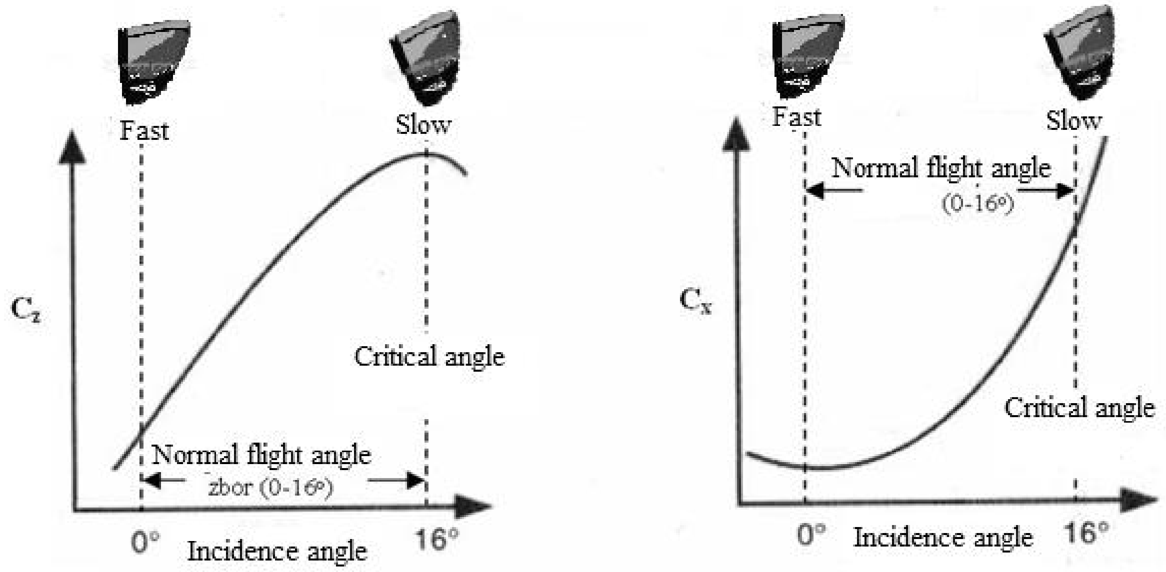


Figure 4: Chart of lift force and drag force.

Lift curve shows a steady increase in the lift coefficient. as the incidence angle increases, up to the critical angle beyond which Cz decreases dramatically.[3]

Drag curve shows that resistance increases constantly aling with the changing of the angle of incidence , taking the lowest value for small and positive angles of incidence and increasing whenever the angle of incidence rises or falls. As it approaches the critical angle of incidence , drag increases at a higher rate. At Speed limit, breaking the laminar flow and the generation of turbulence or vortices makes drag to increase. For a certain lift is necessary minimum drag , ie the best ratio FZ / Fx , the maximum aerodynamic finesse for that profile.

3. CONCLUSION

If the center of pressure is at the wing center of gravity, the wing will always balance. Also the location of the center of pressure changes with change in the airfoil's angle of attack and this may arise difficulties.

REFERENCES

[1] Deliu G..: Mecanica aeronavelor. Editura albastra ISBN 973.650.101.9
[2] Ampyx Power. (2012) [Online]. Available: http://www.ampyxpower.com
[3] Lingard J. S., The aerodynamics of gliding parachutes, in Proc. 9th Aerodynamics Decelerator all on Tech. Conf., Oct. 1986, no. AIAA-86-2427-CP, pp. 1–6.
[4] Williams P., Lansdorp B., Ockels W., Flexible tethered kite with moveable attachment points, part I: Dynamics and control, in Proc. Atmosph. Flight Mech. Conf., Aug. 2007, no. AIAA-2007-6628, pp. 1–24.
[5] Dadd G. M., Hudson D. A., Shenoi R. A., Determination of kite forces using three-dimensional flight trajectories for ship propulsion, Renew. Energy, vol. 36, pp. 2667–2678, Mar. 2011.
[6] Houska B., Diehl M., Optimal control of towing kites, in Proc. IEEE Conf. Decision Control, Dec. 2006, pp. 2693–2697.
[7] http://www.candiler.com.tr/airplane-aerodynamics-fundamentals-and-flight-principles/