angle of attack, ***α***

coefficient of radial force, ***Cr***

coefficient of tangential force, ***Ct***

coefficientofpower *(Betz Limit),* ***Cp***

solidity of the rotor, ***σ***

speed of the wind, ***W***

specific speed ratio, ***λ*′**

tip-speed ratio*,* ***λ* (TSR)**

angular speed, **Ω**

chord of the airfoil, ***l***

length of the blade, ***h***

speed drop coefficient ***a***

number of blades, ***z***

kinematic viscosity of air, **K**

exposed area (in the case of the H-type *Darrieus* turbine *A* = *R* · *h*),**A**

speed of the wind upstream of the turbine,***V*1**

speed of the wind downstream of the turbine,***V*2**

**Desenvolvimento numerico**

Most of the wind turbine analyses are determined by the common design and analysis method, which is known as blade element momentum method (BEM) and it was proposed by Glauert [7, 8]. [3]

1... Definir Potencia desejada e velocidade do vento que se choca com a lâmina\*

2... Definir arbitrariamente o valor de ***Cp*** *(Betz Limit ou Coeficiente de eficiência)*

***Cp***= 0.30 (a bit optimistic for small size turbines)

Betz’s law theoretical limit for a power conversion ratio in an undisturbed wind stream is 59.3% - 16/27. [2]



A = D\*H

3… Definir razão **D/H**

*h/D* = 1.4142 provides a pleasant aspect for human eyes. [1]

4… Definir número de laminas, **z**

Sandia VAWT development, writes: “. *.. the use of 3 blades appears to be optimal . . . adding more blades appears to add significant costs without reducing balance-of-system costs”.* [15] A study comparing 3- and 6-bladed designs numerically, found that the power coefficient was higher for a 3-bladed design. [31] [4]

5... Definir arbitrariamente o valor de ***σ*** *(*solidity of the rotor)

Range 8%–15%. With the method described until now, the value 13% provides the most reliable results. [1]

6…Calcular a corda do aerofólio, ***l***



7…Definir o aerofolio

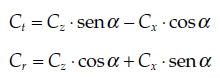
Symmetric profiles are preferable for Darrieus turbines, because the angle of incidence is negative along a part of the trajectory. [1]

For the construction of small turbines, it is easier to build straight blades, disposed as an H. Since in this type of rotor the loads on the blades will be of flexion, it is necessary to employ thicker profiles, in order to grant enough rigidity and resistant section. [1]

Small wind turbines usually operate at Reynolds number less than 5×105. In this Reynolds number range, laminar flow gets separated at the upper surface of the airfoil and is reattached to the surface as turbulent causing laminar separation bubble, which increases the drag of the airfoil. [3]

Aerodynamic behavior such as lift and drag characteristics changes due to angle of attack and Reynolds number. Appropriate selection of Reynolds number would improve the annual energy production. [3]

Re = W\* *l /K*

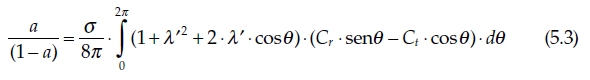


8... Atribuir valores para ***λ*′** e ***V***

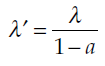
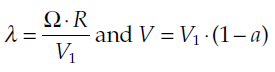
Darrieus turbines are able to turn stably as long as *λ* < 4 [1]

When *λ* > 8, the maximum incidence angle is 7°. All symmetric profiles produce little lift at small incidence angles, in other words, the blade will generate only small aerodynamic lift along most of its path, but the drag forces acting on it remain constant and hence, the total *CP* of the rotor falls drastically. [1]

9…Calcular o valor de ***a*** (speed drop coeficiente)



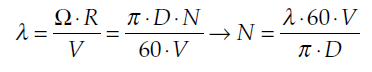
10... Calcular valor de **Ω**, ***λ****,* and ***V***1 de acordo com os valores ***λ*′** e ***V*** definidos antes.

11... Encontrar o valor de ***Cp*** *(Betz Limit ou Coeficiente de eficiência)*



12... Calcular o RPM, **N**



[1] Rosato M, “Small Wind Turbines for Electricity and Irrigation Design and Construction”, *CRC Press, Taylor & Francis Group*, 2019.

[2] Sozer Y, Bandarkar A. “Energy Harvesting from Moving Vehicles on Highways”, *University of Akron,* September 2019.

[3] N Karthikeyan and T Suthakar 2016 *J. Phys.: Conf. Ser.* **759** 012087

[4] Letcher T, “Wind Energy Engineering A Handbook for Onshore and Offshore Wind Turbines”, *Academic Press*, May 2017.

[7] Wood, D., (2011*) Small Wind turbines, Analysis, Design, and Applications*. Green Energy and Technology, Springer.

[8] Manwell, JF, McGowan, JG, Rogers, Al. (2010) *Wind Energy Explained: theory, Design and Application*, Wiley.