Current Journal of Applied Science and Technology

40(31): 1-17, 2021; Article no.CJAST.65807
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Study and Design of a Horizontal Axis Wind Turbine (0.5 kW) Using Software Solid Works

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Authors' contributions

This work was carried out in collaboration among all authors. Author HEVD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DB and JNF managed the analyses of the study. Authors MT and ABA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i3131546
Editor(s):
(1) Prof. Qing-Wen Wang, Shanghai University, P.R. China.
Reviewers:
(1) Papa Mady Sy, Cheikh Anta Diop University, Senegal.
(2) Akeel M. Kadim, Al Karkh University of Science, Iraq.
Complete Peer review History: https://www.sdiarticle4.com/review-history/65807

Original Research Article

Received 10 December 2020
Accepted 22 February 2021
Published 28 October 2021

ABSTRACT

In the present work, the study and design of a horizontal axis wind turbine suitable for the Cotonou site were investigated on the coast of Benin. A statistical study using the Weibull distribution was carried out on the hourly wind data measured at 10 m from the ground by the Agency for Air Navigation Safety in Africa and Madagascar (ASECNA) over the period from January 1981 to December 2014. Then, the models, techniques, tools and approaches used to design horizontal axis wind turbines were presented and the wind turbine components characteristics were determined. The numerical design and assembly of these components were carried out using SolidWorks software. The results revealed that the designed wind turbine has a power of 571W. It is equipped with a permanent magnet synchronous generator and has three aluminum blades with NACA 4412 biconvex asymmetrical profile. The values obtained for the optimum coefficient of lift

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and drag are estimated at 1.196 and 0.0189 respectively. The blades are characterised by an attack optimum angle estimated at 6° and the wedge angle at 5°. Their length is 2.50 m and the maximum thickness is estimated at 0.032 m for a rope length of 0.27 m. The wind turbine efficiency is 44%. The computer program designed on SolidWorks gives three-dimensional views of the geometrical shape of the wind turbine components and their assembly has allowed to visualize the compact shape of the wind turbine after export via its graphical interface. The energy quantity that can be obtained from the wind turbine was estimated at 2712,718 kWh/year. This wind turbine design study is the first of its kind for the study area. In order to reduce the technological dependence and the import of wind energy systems, the results of this study could be used to produce lower cost wind energy available on our study site.

Keywords: Design; wind turbine; weibull distribution; aerodynamic parameters; solid works software.

1. INTRODUCTION

Faced with the challenge of energy self-sufficiency, the world is resorting to many sources of electrical energy such as renewable energies to feed the population and to reconcile energy sector development policies with environmental protection strategies. Among these energy sources, wind energy has been considered the main source of energy worldwide due to its rapid technological development (market acceptance, low cost, ease of use, maintenance and operation) and the availability of all sizes of wind turbines covering almost all types of applications, from homes to large grid-connected utilities [1]. Horizontal axis wind turbines, one of the wind turbine technologies, are the most efficient and most developed for small and large scale power generation [2]. This technology therefore deserves to be mastered and exploited, particularly in developing countries.

To this end, several works have dealt with the design of horizontal axis wind turbines. This is the case of Velázquez et al. [2] who made the aerodynamic design of a 1 MW horizontal axis wind turbine using the blade element theory. The generated design was scaled and built for test purposes in the discharge of an 80 cm diameter axial flow fan. The results of this approach showed a good approximation using experimental data for the below-design peak speed ratio. According to the authors, this method can be used for the design and evaluation of wind turbines when the flow is not too turbulent and the radial velocity components are negligible. Jahangiri and Shamsabadi [3] designed a horizontal axis wind turbine in South Khorasan Province. The authors used statistical analysis of wind data obtained at the site as the basis for the design of the horizontal axis wind turbine (HAWT). The estimated annual power density of 285W/m² was obtained by estimating the wind energy potential using the Weibull probability distribution function. The technical specifications of the blades (such as specific speed of the wind turbine, number of blades, power of the wind turbine, mechanical and electrical efficiency, rotor radius, optimal angle of attack, chord length, torsion angle and axis and angular contractions) were characterised by the authors. Bai et al. [4] focused on the design of a horizontal axis wind turbine (HAWT) blade with an output power of 10 kW based on the blade element theory and the modified stall model. The aerodynamics of the blade is also simulated to study its flow structures and aerodynamic characteristics. The simulation results are compared with the improved theory at a nominal wind speed of 10 m/s and show that CFD (Computational Fluid Dynamic) is a good method for investigating the aerodynamics of a HAWT blade. Benini and Toffolo [5] described a multi-objective optimisation method for horizontal axis wind turbine (HAWT) design, based on the coupling of an aerodynamic model implementing blade element theory and an evolutionary algorithm. This multi-objective problem is addressed using Pareto concepts. The two fundamental objectives in the design of a HAWT turbine are to maximise its annual energy production (AEP) and to minimise the cost of energy (COE). However, this study shows that determining the Pareto front does allow the margins for improvement in AEP and the corresponding increase in COE to be established. The chord and twist distributions of the optimised HAWT were also characterised. In the work of Azad and Kaysar [6], the authors presented the analysis of wind speed data for five windy sites and the appropriate design of wind turbines for power generation in Bangladesh. They implemented a wind turbine design algorithm to determine various design parameters such as the design coefficient of lift, angle of attack, design peak speed ratio, number of blades, design power coefficient and turbine blade diameter. The blade chord and the design torsion angle of the wind turbine were then linearised. Strength analyses for different numbers of blades were carried out and local materials were selected for the manufacture of the wind turbine. The results revealed that the designed wind turbine has a high output in Kuakata, Bangladesh with appropriate characteristic parameters for this site. The authors therefore believe that the adopted design procedure can be applied to any potential wind turbine site. Rehman et al. [1] presented in their study some approaches used to design wind turbine blades experimentally and numerically. They also discussed the methodologies used to study the performance of wind turbines experimentally and analytically. The authors believe that the review provided in their study is very useful for researchers, academics, students and consultants who plan to work on improving the efficiency of wind turbines, optimising and evaluating their performance. Shankar et al. [7] also designed and built a horizontal axis wind turbine. The objective of this work according to the authors is to develop a domestic wind turbine that operates at low wind speeds and can be made available to the population at a very low price. Polyvinyl chloride, which is readily available, was used to manufacture the blades. In the design process, the basic wing section considered with various forces acting on the blades are calculated theoretically and the design is optimised to obtain the optimum power output. The rotational speed of the wind turbine is maximised by using a gear ratio. A DC dynamo acting as a generator is used to extract the power. Lin et al. [8] worked on the design and stress analysis of the horizontal axis (1 kW) wind turbine blade. The design mean wind speed (Vavgis 4m/s) and Reynold's number (46406) were calculated as a function of viscosity, density and wind speed. The blade profile selection was calculated by the COMSOL Multiphysics software and gave the blade profile types (NACA series). From these series, the authors chose the NACA 4412 blade profile because it gives the maximum lift to drag ratio. The blade setting angles, lift and drag forces acting on the airfoil were therefore calculated by dividing the airfoil into ten divisions for this study. Biadgo and Aynekulu [9] used a design method based on blade element moment theory to optimize the chord and torsional distributions of the blades and to design a 1kW HAWT rotor. A user interface computer program is written on VISUALBASIC to estimate the aerodynamic performance of the existing HAWT blades and used for the performance analysis of the designed HAWT rotor. The program gives the blade geometry parameters (chord and torsional distributions), performance coefficients and aerodynamic forces (confidence and torque) for the following inputs: required turbine power, number of blades, design wind speed and blade profile type (airfoil). The programme shows the results with figures and also gives three-dimensional views of the designed blade elements for visualization after export to AutoCAD.

This diversity of methods used to design horizontal axis wind turbines with the aim of improving their productivity clearly shows the interest in this subject. However, the reliability of these methods depends largely on the meteorological and topographical conditions of the various sites where the wind turbine is to be installed. Very few studies have dealt with the design of wind turbines in the West African sub-region and more precisely in Benin, which is a coastal country whose wind potential can be exploited on a small and large scale in the south according to the work of Donnou et al. [10]. Unfortunately, this energy source is still not developed despite an urban and rural electrification rate of the country estimated at 54.8% and 32.6% respectively [11]. It is therefore important to have a concrete understanding of the operation and design of the appropriate wind energy system for a site in order to provide electrical energy to the population at lower cost, particularly those in rural areas and far from the conventional grid. The objective of this study is therefore to design a horizontal axis wind turbine adapted to the study site and to evaluate its energy production. In order to achieve this, the present study aims to:

- Make a statistical study of the winds at the study site
- Determine the technological characteristics of the wind turbine
- Design the wind turbine using SolidWorks software

2. MATERIALS AND METHODS

2.1 Materials

The coastal region of Benin that hosts the study site is 125 km long and extends from Hillacondji in the west to Kraké in the east. This strip of land is located between the latitude 6°15 'N and 7° 00' N. In order to carry out this study, the hourly wind speed data measured at 10 m from the ground at the Cotonou meteorological station was used over the period from January 1981 to December 2014. Fig. 1. gives an overview of the experimental site of the station, the measuring mast and the wind sensor.

2.2 Methods

The design of a wind turbine to be operated on a site using software requires a better knowledge of wind statistics, dimensioning of the wind turbine and numerical design of the device. The method adopted in this study has therefore outlined these three steps in the design approach and is presented in sections 2.2.1 and 2.2.2.

2.2.1 Statistical study of wind data

2.2.1.1 Wind speed distributions

Wind turbines use the force of the wind to turn. Wind energy is, in principle, intermittent. Before a wind farm is built, the project developer must be able to assess the potential of his site and the optimum distribution of machinery. The data used are generally values averaged over 10 min or an hour. They enable wind probability density functions to be established using the occurrences of wind speeds for a given wind range (e.g. 1 m/s). These density functions can be approximated by a so-called Weibull distribution function expressed as [13-16] :

$$f(V) = \left(\frac{k}{c}\right)\left(\frac{V}{c}\right)^{(k-1)} \exp\left[-\left(\frac{V}{c}\right)^{k}\right] \quad (1)$$

k and c are the Weibull parameters. k is the shape parameter and c is the scale parameter which has the velocity dimension (m/s). This law indicates the probability that the wind is at a speed V. It is used to characterise the wind distribution.

To determine the Weibull parameters, several methods are available, and the most commonly used is the mean speed and standard deviation [17-20]. If the mean velocity Vmean and the standard deviation σ of a site are known, the shape parameter k is determined by applying the following approximation :

$$k = \left(\frac{\sigma}{\mathrm{Vmoy}}\right)^{-1,086} \quad (2)$$

The parameter c determines the wind quality (scale factor). It is expressed as follows:

$$c = \frac{\mathrm{Vmoy}}{\Gamma\left(1+\frac{1}{k}\right)} \quad (3)$$

Γ is the gamma function, Vmoy is the average speed (m/s)

Fig. 1. Experimental site of the Cotonou-Airport meteorological station. Anemometer with cup and wind vane located on a 10 m mast (left panel). Experimentation site (right panel) [12]

2.2.1.2 The turbulence index

The turbulence index characterises the degree of turbulence (turbulence intensity) of the wind during a given period of time. It influences the lifetime of the wind turbine through the fluctuations it induces on the blades and rotor. The turbulence index is calculated over a period of 10 minutes in order to lie within the spectral 'gap' of the wind spectrum. It is the ratio of the standard deviation of the fluctuation in wind speed to the standard deviation of the fluctuation in wind speed. σ(V) and the average modulus of this speed V. It is given by [11]:

$$I = \frac{\sigma}{V_{moy}} \quad (4)$$

In the case of this study the average turbulence index I is equal to 0.2 according the works to Donnou et al [21].

2.2.1.3 Speed giving maximum energy

When dimensioning a wind turbine, the choice of a nominal speed is of paramount importance. A compromise is therefore necessary so as not to over or under-equip the wind energy recovery system. The nominal speed of the wind turbine is between the most frequent speed on site and the speed giving the maximum energy Vme or can be equal to Vme. The expression of the speed giving the maximum energy is as follows [22]:

$$Vme = \left(1 + \frac{2}{k}\right)^{1/k} c \quad (5)$$

Fig. 2. shows the classification of the different types of wind turbines according to the Betz limit and the specific speed. λ. It allows to know the output and the specific speed according to the number of wind turbine blades chosen.

2.2.1.4 Recoverable energy

Betz has shown that one cannot expect to recover more than 16/27 of the kinetic power carried by the wind and this for an ideal machine. Therefore the recoverable wind energy for a period T is given by [24-26]:

$$E_m = \frac{1}{2}\, T\, \rho\, Cp\, S\, (1 + 3I^2)\, f(V)\, V^3$$

With T: the period in hours (h), I: the turbulence intensity (I = 0.2), Cp is the theoretical maximum efficiency, Em: the recoverable energy (Wh) and f(V): the probability density of the Weibull distribution for each speed.

2.2.1.5 Useful energy

The useful energy Eu supplied by the wind turbine to power a domestic load has been calculated from Eqs. (7), (8) and (9) and represented as a function of wind speed in Fig. 5:

$$E_u = P_u * T \quad (7)$$

Its useful power P_u is given by the formula [27]:

$$Pu = fc\, P_n \quad (8)$$

With:

$$fc = \left\{ \frac{\exp\left[-\left(\frac{V_d}{c}\right)^k\right] - \exp\left[-\left(\frac{V_n}{c}\right)^k\right]}{\left(\frac{V_n}{c}\right)^k - \left(\frac{V_d}{c}\right)^k} - \exp\left[-\left(\frac{V_c}{c}\right)^k\right] \right\}$$

fc is the capacity factor, P_n is the nominal power.

2.2.2 Sizing of the wind turbine

The methodological approach for the dimensioning of the wind turbine consists firstly in identifying the speeds Vd, Vn and Vc of the wind turbine adapted to the Cotonou site thanks to the statistical study of the wind. Three-bladed wind turbines were adopted for this study. This choice made it possible to identify the parameters Cp and λ from Fig. 2. We opted for the use of a permanent magnet synchronous generator to design a 571 W direct drive wind turbine. We then determined the mechanical power of the alternator, the swept area and the suitable blade length. The biconvex asymmetrical NACA 4412 profile was chosen because it has good lift and a very stable angle of attack. This profile is widely used in aerodynamics and its aerodynamic parameters (angle, fineness, thickness, chord, blade surface, lift and drag coefficients cl and cd) have been characterised. The digital design and assembly of the wind turbine components were carried out using SolidWorks software. The design method for the horizontal axis wind turbine is summarised in the diagram in Fig. 3 [3,6].

Where Pm is the mechanical power (W), Pn is the nominal power (W), ηalt is the efficiency of the generator, S is the area swept by the rotor (m²), R is the radius of the rotor, ρ air density

($Kg.m^{-3}$), V is the wind speed (m/s), emax is the maximum thickness of the blades, t is the relative thickness of the blades, C is the length of the blade chord, Clopt: the optimal lift coefficient, Np: the number of blades, λ: the specific speed, μ : the ratio of the local radius to the actual radius, r is the hub radius, s is the fineness of the blades, Cl is the coefficient of lift, Cd is the coefficient of drag, SG is the rudder area, D is the rotor diameter, lr is the distance of the rotor from the mast axis, lf is the distance between the rudder and the mast axis, Vd is the starting speed (m/s), Vn is the rated speed (m/s), Vc is the cut-off speed (m/s).

2.2.3 Design on solid works

Scientific numerical simulations are based on the use of theoretical models, which are used to study the functioning and properties of a modelled system and to predict its evolution. Graphical interfaces allow the visualization of the results of the calculations by means of computer generated images. SolidWorks is a 3D computer-aided design software that runs under Windows. It is a 3D modeler using parametric design. It was used in this study for the digital design of the wind turbine. It generates 3 types of files relating to three basic concepts: the part, the assembly and the drawing. These files are related. Any modification at any level is passed on to all the files concerned. Fig. 4. shows the interface of the software.

3. RESULTS AND DISCUSSION

3.1 Variation of the Weibull Curve and Theoretical Energy

After studying wind statistics in Cotonou (data processing by 1 m/s interval class), we determined the Weibull probability function shown in Fig. 5.

Analysis of Fig. 5. indicates that the most frequent wind speed at the Cotonou-Airport site is 4 m/s with a frequency of occurrence of 20%. Wind speeds between 2 and 7 m/s have a frequency of occurrence of more than 5% and wind speeds above 10 m/s are much less frequent at the site. The recoverable and useful energy supplied by the wind turbine are shown in Fig. 6. as a function of wind speed.

The annual energy production (E_u) of the wind turbine was estimated at 2712.718 kWh/year (7.43kWh/day). This production is higher than that obtained in the works of Akpo et al. [18], which focused on a 1kW wind turbine with an estimated annual production of 1.45 MWh. This difference would therefore be due to the optimal choice of the nominal and cut-off speed of the wind turbine designed in this study, which is better adapted to the meteorological conditions of the Cotonou site.

3.2 Wind Turbine Characteristics

The lift and drag coefficients are determined according to each blade profile and according to several parameters (angle of incidence, profile shape, relative speed, wing surface, air density). For this reason, they are determined in wind tunnels by means of software simulations. For this purpose, simulation software was used to determine the C_l and C_d coefficients of our NACA blade profile. We opted for the JAVAFOIL software, which enabled us to obtain these coefficients thanks to the chosen profile and the optimum angle of attack. We also obtained the aerodynamic stall angle. Fig. 7 gives an overview of the NACA 4412 blade profile.

Table 1 shows the different C_l and C_d values obtained from the JAVAFOIL software for our profile. The fineness corresponding to each angle of attack was then determined so that the maximum fineness could be identified.

The curve of the variation of the coefficient of lift as a function of the angle of attack obtained is shown in Fig. 8.

It can be seen that C_l starts to decrease from the attack angle **α =** 11˚ so an aerodynamic stall occurs, which is not good for normal wind turbine operation. However this stall can be used for regulation. So the maximum angle of attack is 11˚. According to the calculated glide ratio, the maximum glide ratio gives s_{max} = 63.28, which corresponds to an optimum angle of attack $\boldsymbol{\alpha_{optimal}}$ = 6˚. The coefficient of maximum lift C_{lopt} is estimated to be 1.196 and the coefficient of drag C_{dopt} is estimated to be 0.0189. The wedging angle required for regulation between the optimum angle of attack and the maximum angle of attack is estimated at θ = 5˚. For rope calculation, Table 2 shows its distribution along the blade as a function of the ratio μ.

We have opted for a constant cord blade. The average of the rope distribution therefore gives the value of the rope. Table 3 summarises the results of the sizing of the wind turbine.

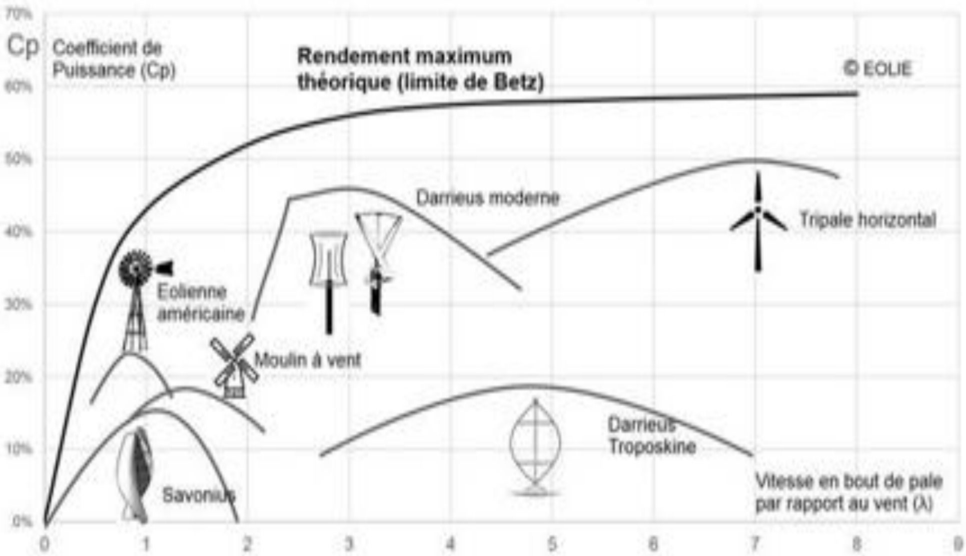

Fig. 2. Theoretical maximum efficiency of the Betz limit [23]

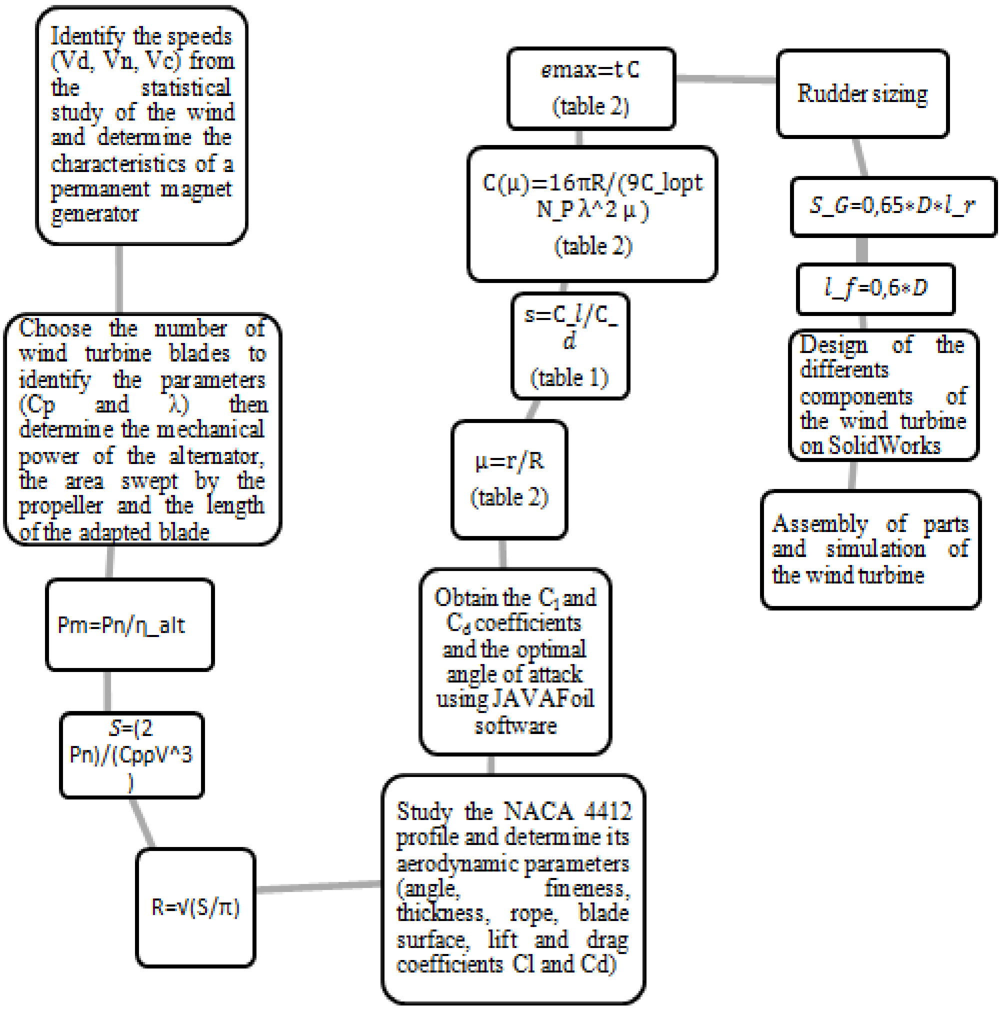

Fig. 3. Diagram of the sizing procedure

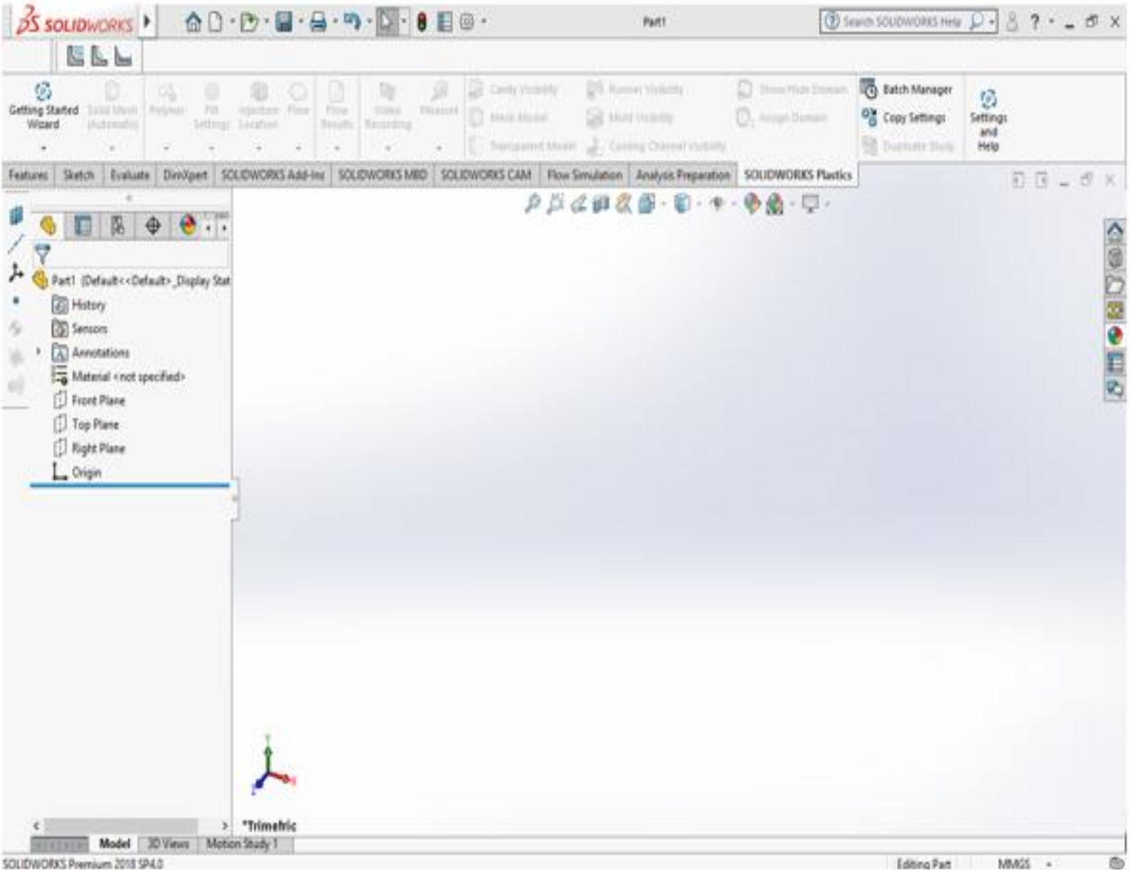

Fig. 4. SolidWorks 2018 interface

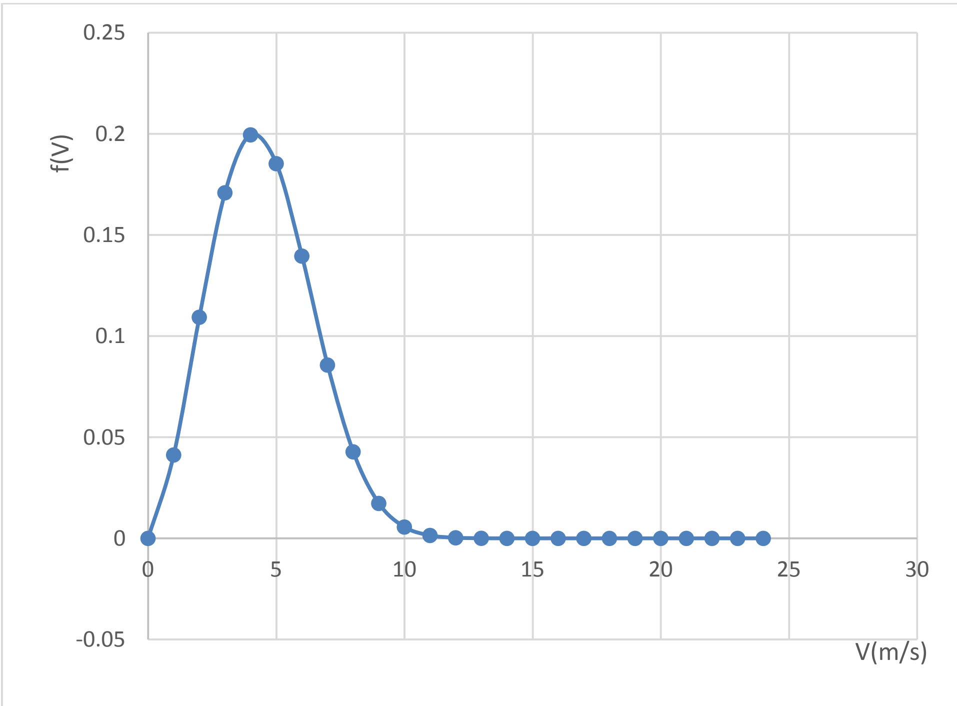

Fig. 5. Weibull probability function depending on the wind speed

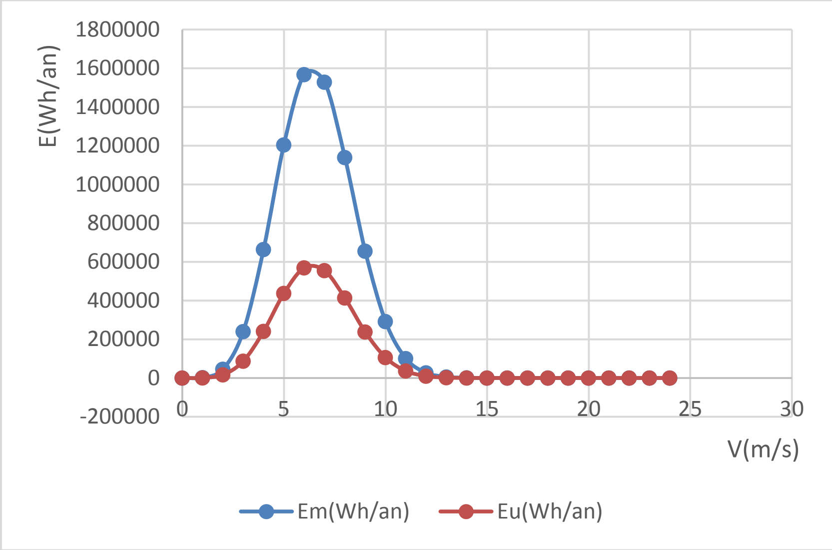

Fig. 6. The theoretical energy curve of the wind energy system as a function of wind speed

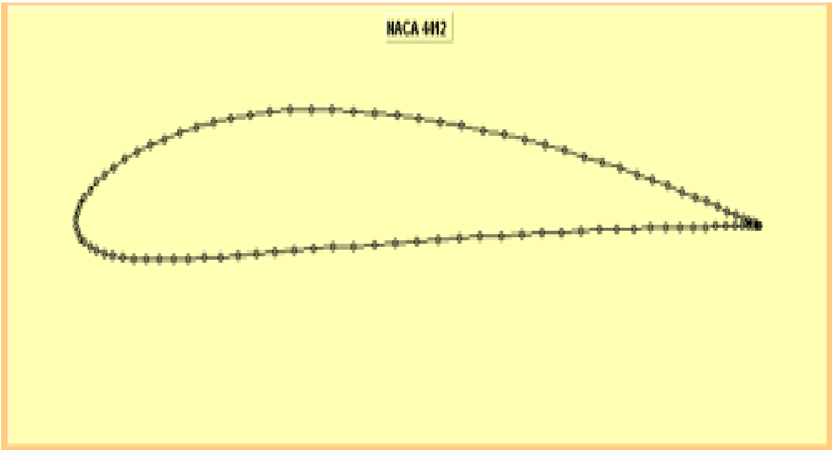

Fig. 7. Profile view in the JAVAFOIL software

Table 1. Variation of coefficients as a function of attack angle α

NACA 4412 profile data			
α (˚)	C_l	C_d	s (C_l/C_d)
0	0.51	0.012	41.08
1	0.63	0.014	45.01
2	0.75	0.0146	50.98
3	0.87	0.0149	58
4	0.98	0.0159	61.40
5	1.09	0.0173	63.06
6	1.196	0.0189	63.2804233
7	1.296	0.02097	61.8025751
8	1.383	0.02706	51.1086475
9	1.454	0.03048	47.7034121
10	1.508	0.03446	43.7608822
11	1.527	0.0417	36.618705
12	1.346	0.09148	14.7135986
13	1.357	0.10444	12.9931061

Table 2. Rope distribution

The ratio (r/R)	The rope c (r/R) in m	Maximum thickness (emax)
0.1	0.76	0.09
0.2	0.38	0.04
0.3	0.25	0.03
0.4	0.19	0.02
0.5	0.15	0.018
0.6	0.12	0.015
0.7	0.10	0.013
0.8	0.09	0.011
0.9	0.08	0.01
1	0.076	0.009

Table 3. Characteristics of the wind turbine components

Designation			
Wind turbine operating characteristics	Starting wind speed Vd V_d (m/s)		2
	Nominal wind speed V_n (m/s)		6
	Wind speed at cut-off Vc (m/s)		12
	Performance coefficient (Cp)		0.44
	Specific wind λ		6.5
Generator	Type		Permanent magnet synchronous
	Nominal power Pn (W)		571
	Performance (η_{alt})		0.75
	Voltage (V)		244
	Shaft length (m)		1.1
	Shaft diamter (m)		0.1
	Rotational speed (tr/min)		650
Blade	Number of blades		3
	Blade length (m)		2.5
	Material		Aluminium
	Surface swept by the propeller (m²)		19.55
	Maximal tickness (e_{max})		0.032
	Hub (m)	Outside radius	0.25
		Inner radius	0.05
	Rope (m)		0.27
Rudder	Surface (m²)		3.56
	Length (m)		3
Mast	Height (m)		10
	Radius (m)		0.17
	Type		Tubular
Air density ρ (Kg/m^3)			1.225

These aerodynamic parameters obtained were compared with the values observed in the work of Azad and Kaysar [6], Lin et al. [8] and Biadgo and Aynekulu [9] who also investigated the design of a horizontal axis wind turbine. As a result of this comparison, the values of the chord length, angle of attack, number of blades, selected NACA 4412 profile etc. are confirmed by these works. However, the maximum lift and drag coefficients as well as the maximum blade fineness obtained in the work of Lin et al. [8] are different from the values obtained in this study. This could be due to the software used to simulate these aerodynamic parameters in the absence of wind tunnel testing (COMSOL Multiphysics and JAVAFOIL software).

3.3 Description of the Design of the Wind Turbine

3.3.1 The basis

The base is the first part designed under the software. As shown in Fig. 9. it is 1 m long and 0.58 m of thick.

3.3.2 The mast

Fig. 10. gives an overview of the cylinder-shaped mast which is 10 m long with a radius of 0.17 m.

3.3.3 The hub

The hub is the part that connects the blade to the nacelle. It has three cavities in which the three blades will be fixed. Its inner radius is 0.05m. It has a length of 0.40m and an outer radius of 0.25m as shown in Fig. 11.

3.3.4 The nacelle

The nacelle is the part that contains the rotor shaft and the generator. Here we have a vertical section of the nacelle with all dimensions. Inside we find the cavities that will house the different parts necessary for the correct operation of the machine (Fig. 12).

3.3.5 The blade

The blade is the main element of the wind turbine. The NACA 4412 blade profile whose coordinates were generated by the JAVAFOIL software is shown in Fig. 13. As shown in the dimensioning, the blade is 2.5 m long and 0.27 m wide (rope).

3.3.6 The generator

The generator whose characteristics were chosen at the beginning of this study was designed in SolidWorks according to its dimensions. As shown in Fig. 14. it is 0.7 m long and has a radius of 0.35 m.

3.3.7 The rudder

The rudder is a component that allows the wind turbine to always be pointed into the wind (Fig. 15). It has an overall length of 4.78 m, its shaft is 3 m long and has a radius of 0.10 m. The upper part is a square with a side length of 1.78m.

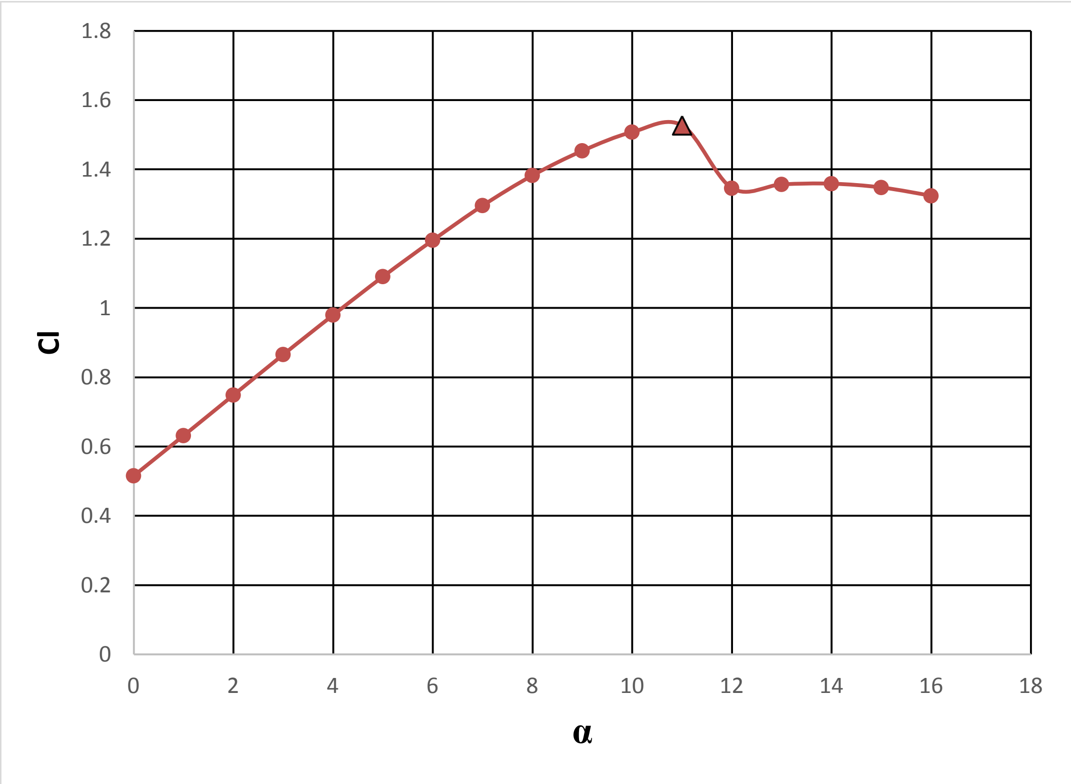

Fig. 8. Curve of the variation of the coefficient of lift as a function of angle of attack

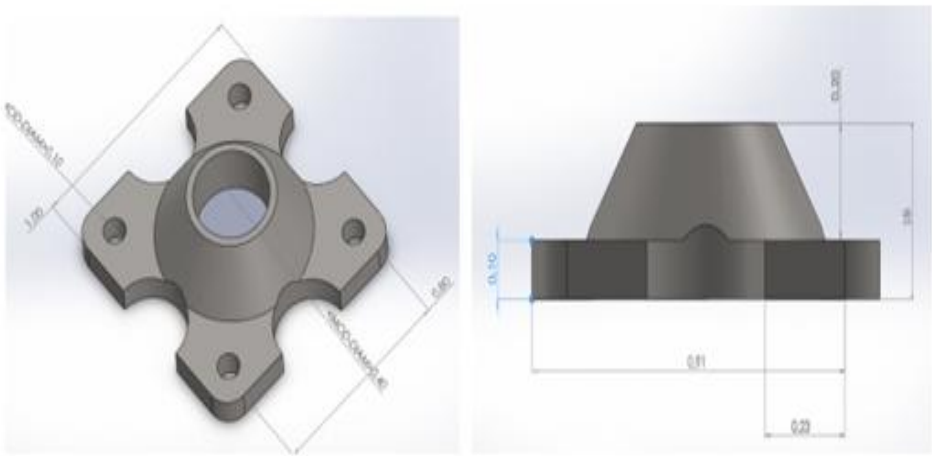

Fig. 9. The base of the wind turbine

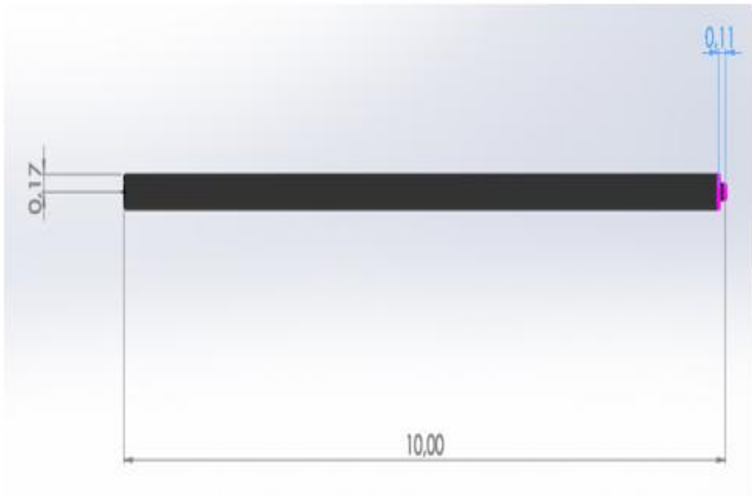

Fig. 10. The mast of the wind turbine

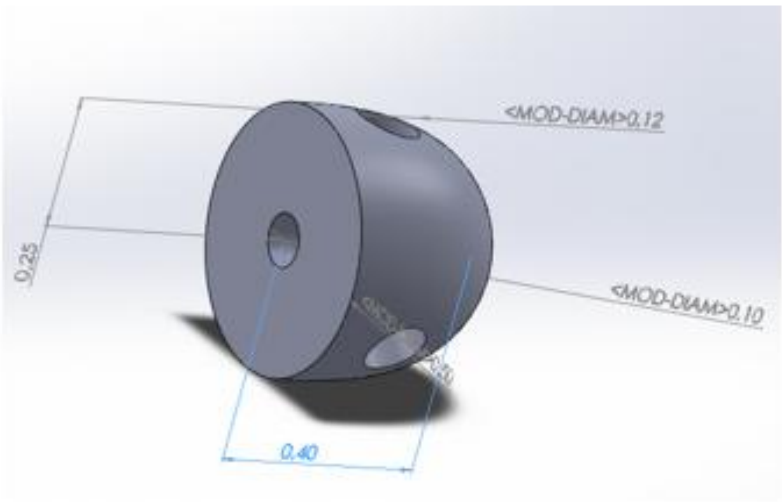

Fig. 11. The hub

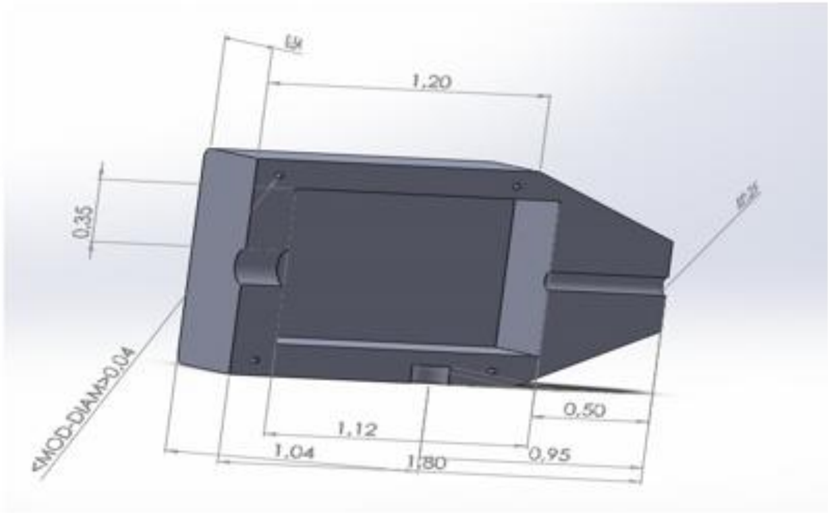

Fig. 12. Vertical section of the nacelle

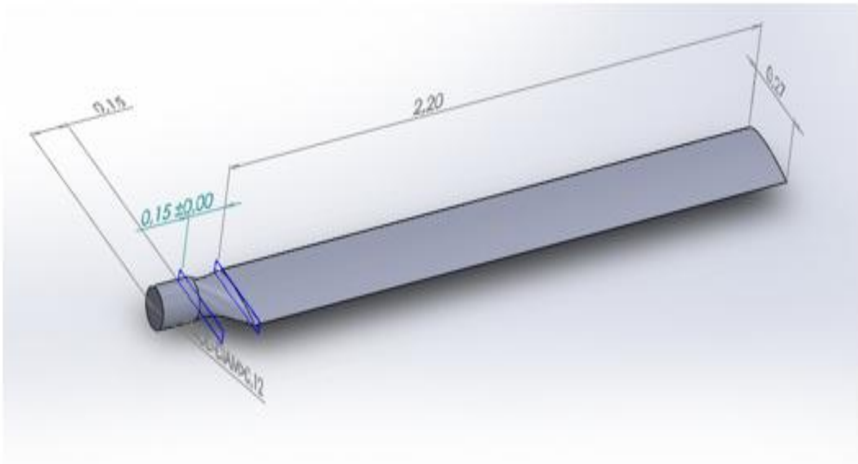

Fig. 13. The NACA 4412 profile blade

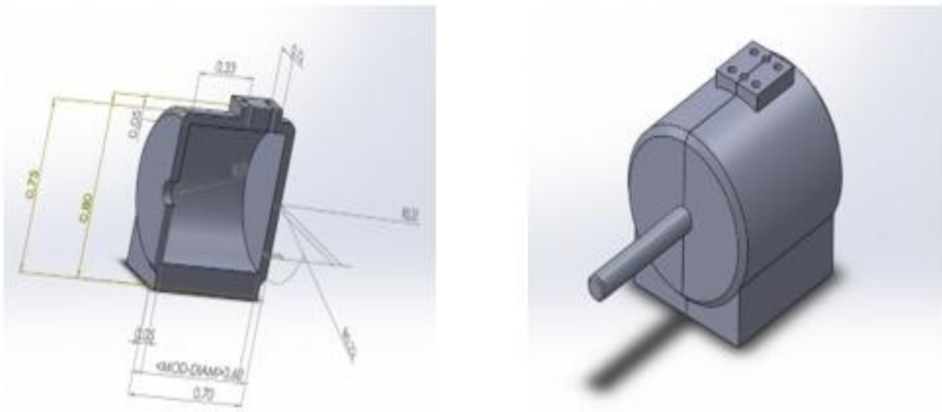

Fig. 14. The generator (in right-hand section and left-hand perspective view)

3.3.8 Assembly of parts and simulation

After the design of the parts is completed and registered, they are assembled. To do this, click on the assembly icon as shown in Fig. 16. An assembly interface will open and the process of pooling the parts will start, resulting in the wind turbine shown in Fig. 17.

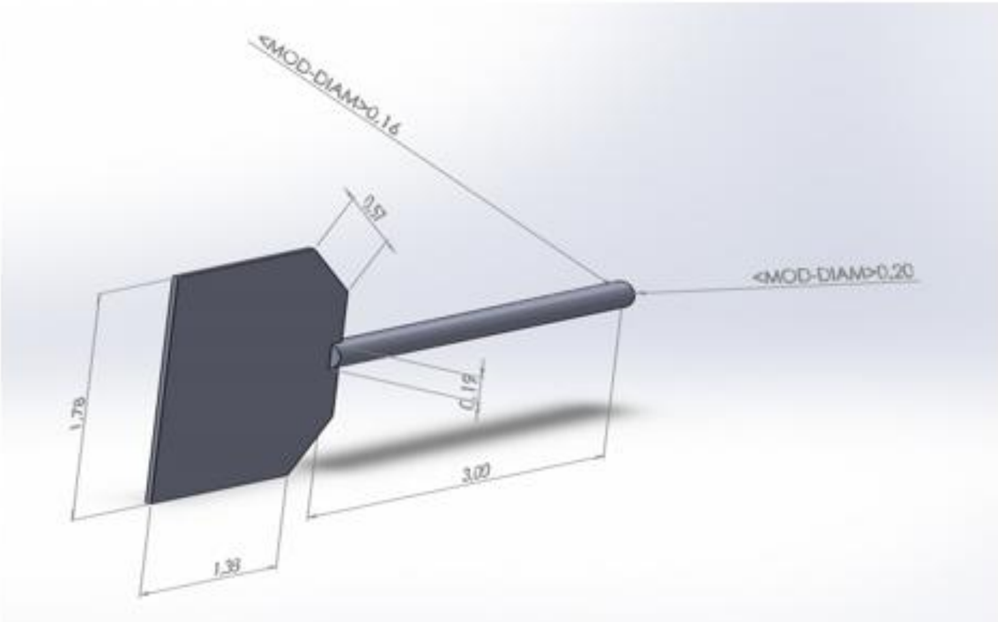

Fig. 15. The rudder

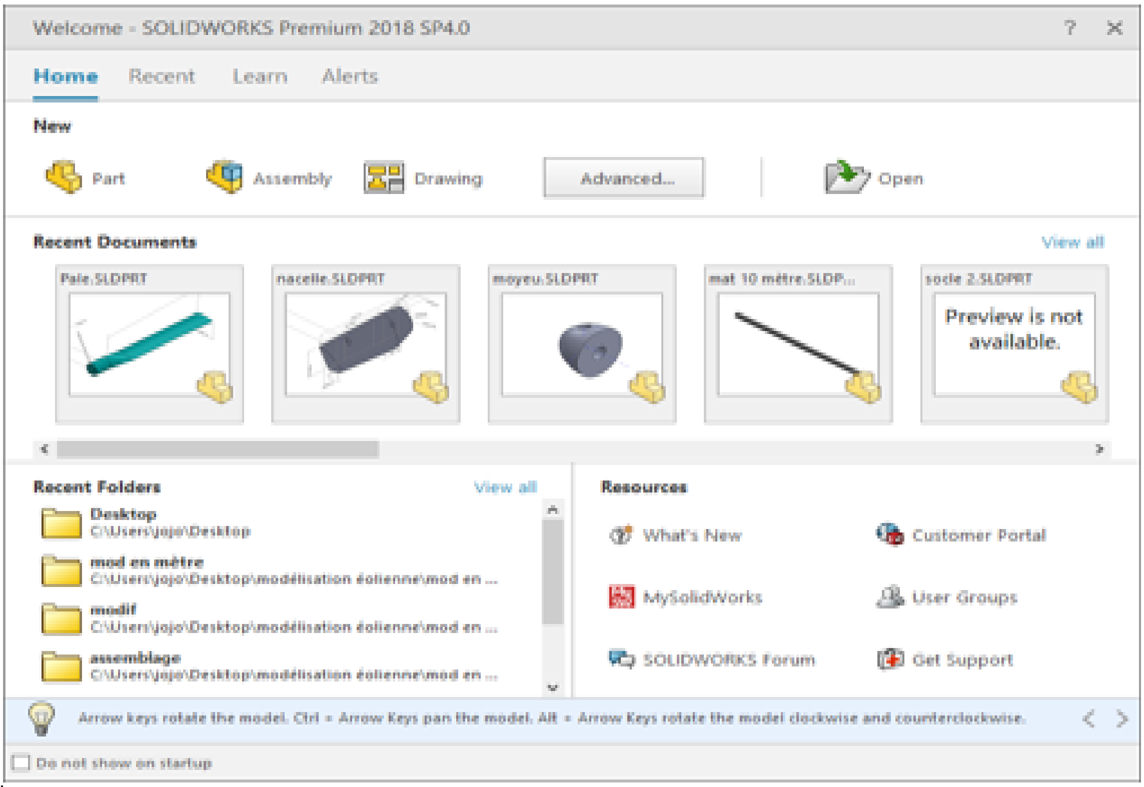

Fig. 16. SolidWorks modeling options window

Fig. 17. Assembled wind turbine

4. CONCLUSION

This work focused on the study and design of a horizontal axis wind turbine using SolidWorks software. In this study, a statistic of the winds recorded by the meteorological station of Cotonou-Airport for the period from January 1981 to December 2014 at an altitude of 10 m was carried out. Then from these statistics, the aerodynamic parameters characterising the wind turbine blades were determined as well as the characteristics of the other components such as the hub, the generator, the mast, the rudder, the transmission shaft, the nacelle without forgetting the operating parameters of the wind turbine. Finally, the stage of computer-aided design under SolidWorks software using the determined parameters was carried out. The main results obtained can be summarised as follows:

(i) The wind turbine has a power of 571W and is equipped with a permanent magnet synchronous generator. It has three aluminium blades with an asymmetrical biconvex profile.
(ii) The blades are characterised by a length of 2.50 m, a maximum thickness of 0.032 m, a chord length of 0.27 m, an optimal angle of attack evaluated at 6˚ and a wedge angle of 5°.
(iii) The optimum lift coefficient of the blades is 1.196 and the drag coefficient is estimated at 0.0189. The hub has an outer radius of 0.25m and an inner radius of 0.05m.
(iv) the specific speed of the blades is estimated at 6.5 and the rudder area at 3.56m²
(v) the efficiency of the wind turbine is 44% with a starting speed of 2m/s, a nominal speed of 6m/s and a cut-off speed estimated at 12m/s.
(vi) the average daily energy production of the wind turbine is estimated at 7.43Wh.

In sum, this work made it possible to determine some characteristics of a 0.5kW wind turbine adapted to the Cotonou site. Based on these characteristics, the wind power system could be built in order to reduce the importation of wind turbines and to optimize the production of energy at a reduced cost. The determination of the mechanical properties and aerodynamic constraints of the blades as well as wind tunnel tests could also improve the model designed in this study in the future.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ACKNOWLEDGEMENTS

The authors of this paper sincerely thank the Agency for Air Navigation Safety in Africa and Madagascar (ASECNA) for having made the wind data available to them, which were used to carry out this research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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