International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 9 Issue 1 Series. I || Jan.2020 || PP 62-73

Design, Simulation and Wind-Tunnel Testing Of Co-Rotor Wind Turbine Using Solid Works - Cosmos Flow Works

R.Karthik[1]*, M,Monisha[2]
[1] Tradex Shipping Company private limited Kochi- 682036, Kerala
Department of CSE, SSN College of Engineering, Kalavakkam, Chennai.
Corresponding Author: R.Karthik

***ABSTRACT**: Wind energy has become vital and eco-friendly. Wind Turbine is the device which is used to convert the kinetic energy into electrical energy. It represents a renewable energy technology. The development of the wind turbine is an advancement around the world. Nowadays, the conventional rotor wind turbine is commonly used. The major part of the kinetic energy in the conventional wind turbine is lost and ineffective in low velocity regions. It required pitch control mechanism in order to capture power at different velocities and directions. To overcome the above issues, co-rotor design has been developed to utilize the maximum power from the existing wind and operate at normal speed. In this work, co-rotor wind turbine has been designed and performed the numerical simulations in the form of computational fluid dynamics to evaluate fundamental flow parameters. Wind tunnel testing of co-rotor has analysed to experimental investigation in order to explore practical understanding. Numerical and experimental results show that 20.40% more power was produced while compared to the existing wind turbine at design point 5 m/s, and thereby increased production of electricity from co-rotor wind turbines.*

***KEY WORDS**: Horizontal axis wind turbine, Blade length, Spacing Area, Co-rotor wind turbine, Betz's limit*

Date of Submission: 20-01-2020 Date of Acceptance: 05-02-2020

I. Introduction

During the last decade, the wind energy manufacturing has got a dramatic growth in the installation of wind turbine generator systems (WTGS) all over the world [1]. Small wind turbines are more contributing to the energy which really needs to both isolated and grid-connected consumers [2]. The technological development in combination with increase in the cost of other sources of energy has made wind energy generation one of the world, fastest-growing energy sectors in the field of alternative energy [8].Wind energy performs as a fresh and moral solution to cope with a great part of this energy demand. Presently, large wind turbines (WTs) are inexpensive than any other renewable energy source (RES) technology, and they compete head-to-head with coal-fired electricity generation at current costs. Apart from greenhouse gas reduction, WTs reduce the risk of fossil-fuel price fluctuations and decrease electricity-sector dependency [3].

It is worth noticing that wind power has the lowest relative greenhouse gas emissions, the least water consumption demands and the most favourable social impacts [4]. The use of wind energy reduces Co_2 emissions and increases new hire opportunities [5]. Wind power is a type of renewable energy source has received considerable attention worldwide and its growth is rising at an unprecedented rate in recent years. Wind power is increasing as an important source of growth, within the global renewable energy market.

Global cumulative production capacity has a forecast that it may increase to almost 500 Giga watts by 2016. This is more than double the figure recorded in 2011 [6]. With a significant 20% renewable energy power share (including wind energy, hydro-power, photo-voltaic and others), today developed countries are even now keep on growing to meet the 2020 target of 35% renewable energy share [7]. Owing to public awareness over environmental issues such as pollution and climate change, the role of green energy becomes more important. As on date one of the promising green energy is Wind energy.

Fig. 1. Horizontal axis wind Turbine

The moving air (wind) has a huge amount of kinetic energy, and can be transferred into electrical energy using wind turbines. The wind turns the blades, which spin a shaft and then it connects to a generator and makes electricity as illustrated in Fig. 1. The electricity is sent through transmission and distribution lines to a substation, then on to homes, businesses and schools.

The motivation of the work is to evaluate only a small wind turbine that is capable of producing compatible electricity that could be useful for charging the battery, ups, etc. The current research outcome would be very much helpful in reducing the current charges applicable for heavy consumed by a variety of household articles.The objective holds good to the technological perspective and produce both rotors run and the power. It increases the conventional rotor parameters when compared to other conventional rotors.

The paper is organized as follows., Section II deals about Horizontal Axis Wind Turbine. Co-Rotor and wind turbine is explained in Section III. Work flow has been analysed in Section IV with simulated results. Prototype has designed with experimental setup and procedures in Section V. Finally, Section VI deals with conclusion and future works.

II. Horizontal Axis Wind Turbine (Hawt)

In HAWT, the shaft is mounted horizontally parallel to the ground. HAWTs need to constant line up themselves with the direction of the wind. This type of turbine uses a tower as the base and the components are at an optimum elevation in relevance to the wind speed. As such, each tower takes up very little space since almost all of the components are up in the air as shown in Fig. 2. Most of the large modern wind turbines are horizontal-axis turbines. Differences in wind field features can disturb the mechanical and operative response of wind turbines. Wind field faces can be defined by time-dependent statistical factors such as vertical mean wind profile, mean wind speed, mean wind direction and turbulence intensity which primarily depend on the surface roughness (e.g. land or water) and on the atmospheric stability (e.g. day or night) [9]. Recently, research subjects of wind turbines in unsteady flows have yielded more importance, which are the effects of fluctuating wind velocity and flows direction, non-uniform inflow, turbulence, and fatigue problem. In particular, wind in Japan is more unstable than western countries, i.e. wind velocity and flow direction easily fluctuates. Thus the characteristics of the turbines in the unsteady wind must be made clear [10].

In the wind turbine system, the blades of a wind turbine rotor are generally regarded as one of the most critical components. Driven by economies of scale factors that substantially reduce the cost of wind power, the sizes of wind turbine blades become increasingly large. In the recent past years, however, structural failure of large composite blades with lengths around 50 m has attracted negative attention to the wind energy sector. The catastrophic blade failure caused by extreme loading conditions such as typhoon and blade tower impact usually results in either whole blades or pieces of the blade being thrown from the turbine, endangering adjacent wind turbines and people living/working close to the wind farm [11].

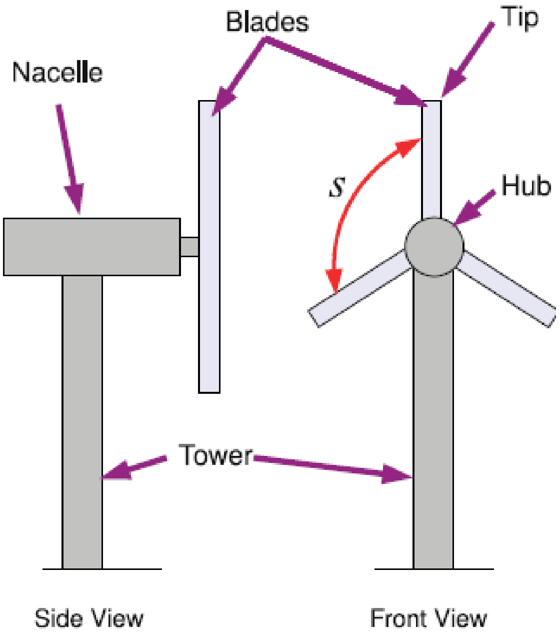


Fig. 2. Views of horizontal axis wind turbine

Bigger wind turbines and their corresponding blades execute developed loads on the wind turbine components, among others on the drive train. Moreover, these loads cannot be assumed to be quasi-static as in most industrial applications. Wind turbine loading includes aerodynamic loads at bending moments, inertial loads due to acceleration, centrifugal and gyroscopic effects, operational loads such as generator torque and loads induced by certain control actions like that of blade pitching, starting up, emergency braking or yawing.

Besides, loads caused by turbulence can result in un-balanced aerodynamic loads on different sides of the rotor. These loads lead to non-torque bending moments that feed into the drive train and induce non-symmetrical loads [12]. A large unsteady blade air load will be produced by the dynamic stall. In nature, a conventional wind turbine blade usually undergoes dynamic stall, due to wind shear, yaw/tilt misalignment, tower passage or atmospheric turbulence [13]. The power generated by the wind is proportional to the velocity of the stream; a suitable system must be constructed to increase its flow velocity. In urban environments, the wind is usually insubstantial, inconsistent, erratic in terms of buildings and other nearby obstructions. To create a reasonable amount of energy from a wind turbine located in urban environments the turbine must increase the amount of energy they capture. In other words, turbines must be designed to work effectively in areas with poor wind resources [14].

Fig. 3. A wind farm of horizontal wind turbine

Because of the power captured by the wind turbine is proportional to the swept area of the rotor disc, and to be a competitive energy resource over other energy generation systems, the overall size of wind turbines has been continuously increased. At the same time, to improve the cost-effective energy efficiency, the turbines are designed to have less weight. This results in more slender, lighter and therefore more flexible rotor blades as shown in Fig. 3. For these slender and flexible loads, the aero elastic deformation is unavoidable which leads to vibratory loads, and alters the turbine power performances. The flexible blades may also induce severe instability problems that shorten the operational life of the turbines [15]. The horizontal axis wind turbine blade is subjected to various loads. During its rotation, the Blade gets not only subjected to aerodynamic effect but also effected by centrifugal effect due to wind flow, gravity effect occurs due to its weight and also gyroscopic effect produced due to additional rotations. Particularly the direction of the gravity force which is variable**,** relatively to the blade axis causes blade vibration during its rotation [16].

Since costs are directly related to blade weight and loads, optimization of the blades is an essential concern before wind energy can become a viable large scale renewable energy source. However as blade length surpass the 60 m range, turbine costs begin to increase more quickly than energy capture, primarily due to weight growth within the blade and other components [17]. According to the Betz's limit, the maximum possible conversion coefficient of a wind rotor is 59.33%. However, in practice losses due to aerofoil blade roughness, wake effects, hub losses reduce the efficiency considerably. If the wind is unsteady the energy conversion capability of the turbine is further degraded [18].

There are reports of bird and bat mortality at wind turbines as they whirl around these huge lengthy artificial structures. Passing through the collision with wind turbines must be compared with alternatives. For example, one company reported 20 eagles deaths by wind turbines and 232 by power lines for coal plants and also anecdotal reports of negative effects from noise on people who live very close to the wind turbine. These impacts have not been supported by reliable peer-reviewed research. At this juncture, it becomes the need of the hour to rectify the above problems of the wind turbine by adopting experimental & software validations and wind tunnel testing methodology. A thorough insight over the literature teaches that a newer design that involves fewer investment costs has to be developed in no time.

To overcome the identified research gap of great societal impacts, a novel co-rotor wind turbine is developed with a clear emphasis on providing a better solution for most of the current issues prevailing in the existing design.

III. Co-Rotor Wind Turbine

The power crisis starts now and increases every day. To haul out these threatening upshots for pollution less power production. Wind energy conciliation with lacking insulation and oddly designed turbines are badly in need of a retrofit. There are so many problems associated with traditional horizontal axis wind turbine and the most important one is size. In this work, a novel solution to the mega-size problem is proposed and expected to give better performance than the existing one. To reduce the size of the existing single rotor, co-rotor configuration is modelled. In the current study, NACA 0012 air foil as shown in Fig. 4 was utilized.

It has a symmetrical and thin cross-section which reduces the blade weight acting on the rotor compared to other air foil and also generates optimal output even at sites with a modest wind speed regime. So it is considered for co-rotor design purpose.

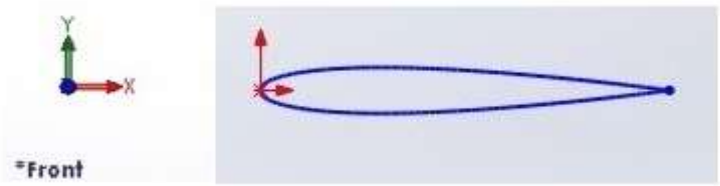


Fig. 4. NACA 0012 Air foil cross section

The air foil data for NACA 0012 is graphically represented in Fig. 5.

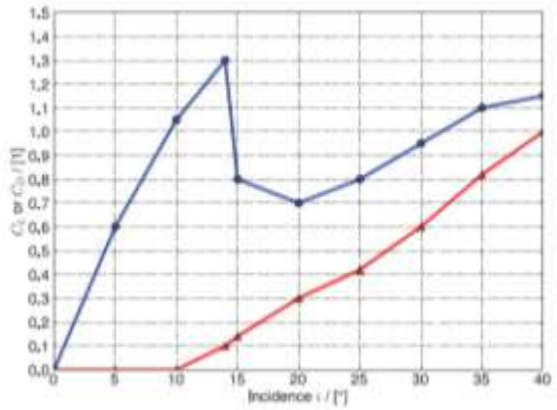


Fig. 5. Airfoil Data for NACA 0012

As illustrated in Fig. 5. Lift Vs drag coefficient is chosen as 10°, for the specific reason that it has lift force and less or negligible drag force.

Sl.no	Details	Length (mm)
1.	Chord length	50 mm
2.	Blade length	300 mm
3.	Hub radius	100 mm

Table 1: Specifications of modelled co-rotor

For the specification given in Table 1, the co-rotor was designed and is as illustrated in Fig. 6. In co-rotor configuration, a front rotor is associated with a small co-rotor at back. It is designed in such a way that both rotors rotate on separate shafts as shown in Fig. 6.

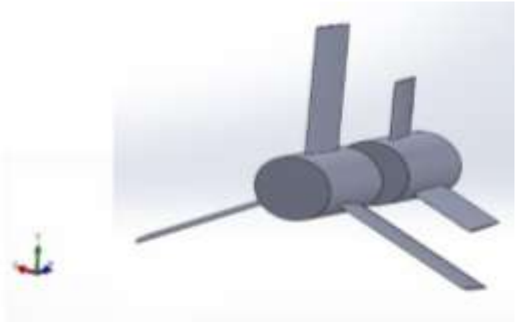


Fig. 6. CAD models of co-rotor wind turbine

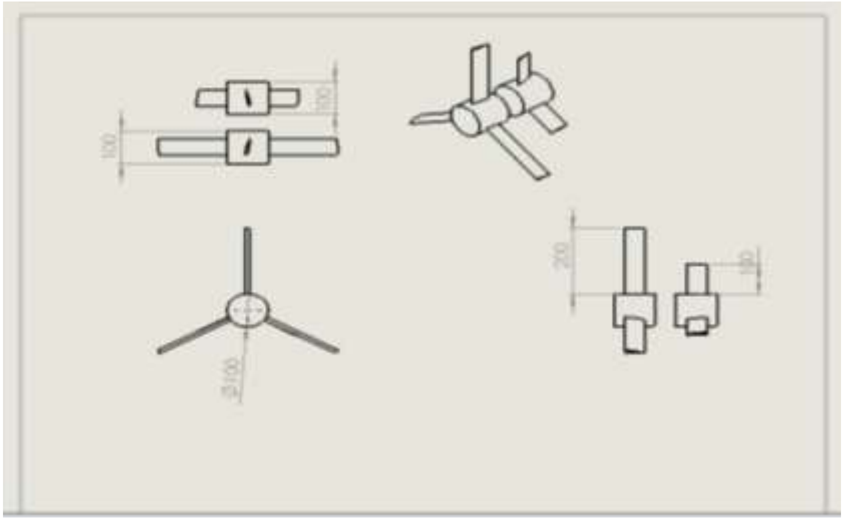


Fig.7. Dimensional views of co-rotor

Accordingly, the Front rotor has a diameter of 200 mm, which is 60% of horizontal axis wind turbines and the back rotor is designed to a diameter of 100 mm, approximating to 40% of horizontal axis wind turbines. Hub radius for both the front and back rotor is 100 mm as shown in Fig. 7. These necessary dimensions are taken to suit the available wind tunnel equipment bearing a duct of size 1.5m diameter.

Free stream velocity faced by the front rotor is known but the back rotor is unknown. Therefore, the performance of the overall system can't be identified theoretically. It is required to study the performance of co-rotor which can be studied computationally as well as experimentally. Through literature, it could be understood that most of the existing wind turbine operates at air velocity as 5, 10, 15 m/s and air density is 1.23 Kg/m3 respectively and produces optimal output electricity. For this work, the same conditions are used as shown in Table 2.

Sl.no	Details	Boundary Condition
1.	Air velocity	5, 10, 15 m/s
2.	Air density	1.23 Kg/m^3

Table 2: Boundary condition

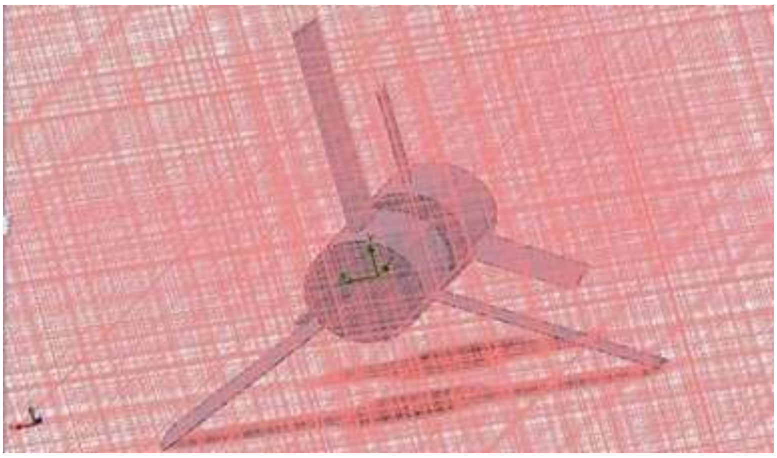


Fig. 8. Mesh image of co-rotor wind turbine

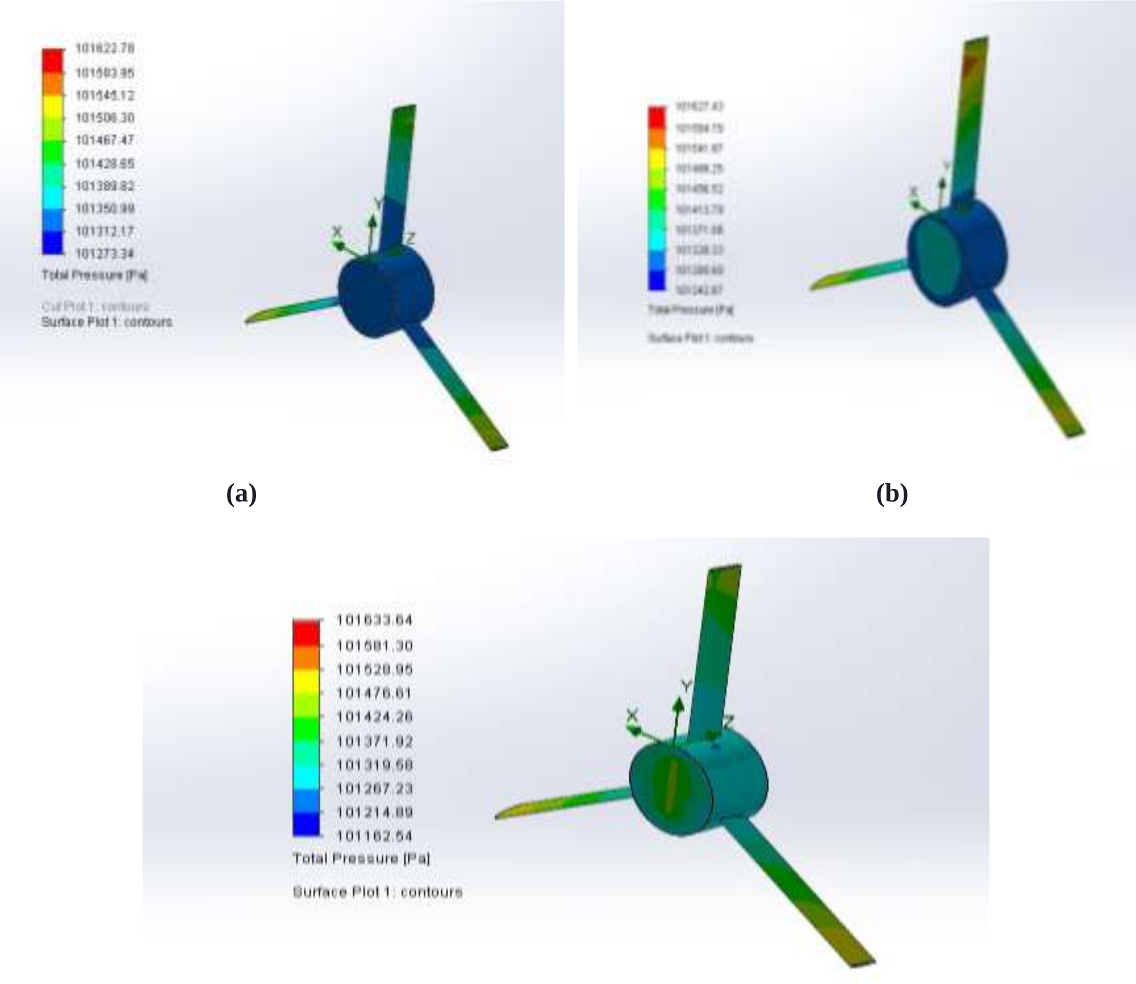
Meshing is one of the most serious phases of engineering simulation. Thus, numerous cells may outcome in long solver runs, and scarce cells may lead to inaccurate results. Hence suitable giving boundary conditions as shown in Table 2, are applied for meshing of co-rotor developed and as illustrated in Fig. 8.

IV. Work Flow Analysis

Computational fluid dynamics (CFD) provides expressive vision into the influence of fluid flow, also it addresses the problem early, reduce the need for costly prototypes, and eliminate rework. Based on the dimensions the CAD model has been developed as shown in Fig. 6. Cosmos flow works a CAD-embedded, solid works flow simulation package of solid works is employed as for determining the effects of the current design.

Further, results of pressure and velocity for co-rotor wind turbine both being simulated at an air velocity of 5, 10, 15 m/s results are obtained. After solid works flow simulation analysis, the flow trajectory of air simulated for a conventional and co-rotor wind turbine was examined and the path of air passes through and activity on the blades and rotor of the conventional and co-rotor wind turbine are generated. Simulated results are shown in **Fig. 9. and Fig.10.**enables to predict the performance of conventional and co-rotor wind turbine.

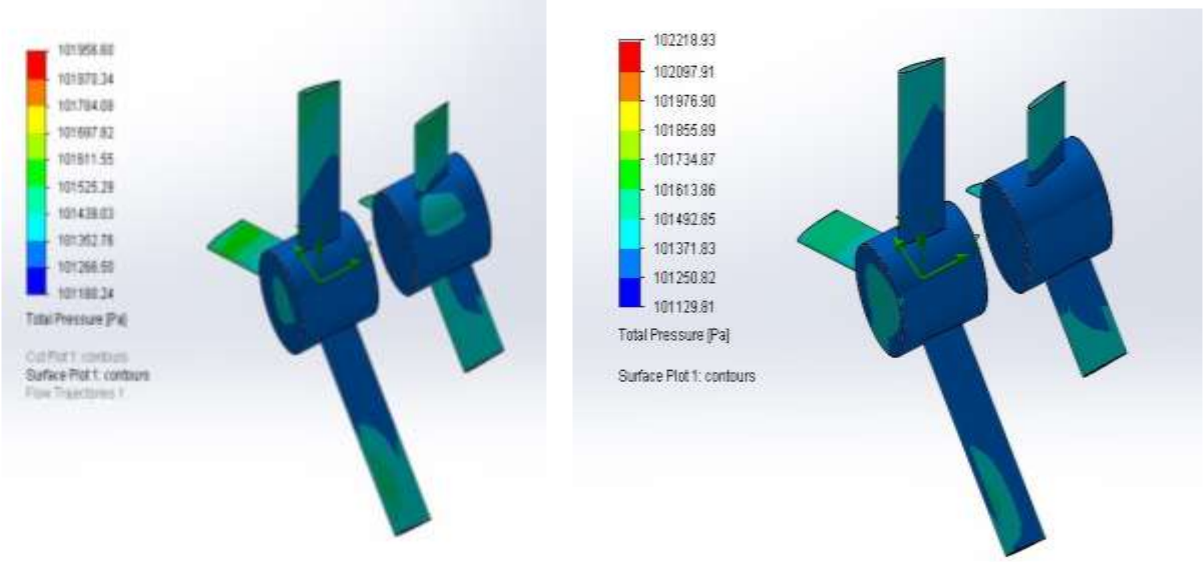
4.1. CFD RESULTS



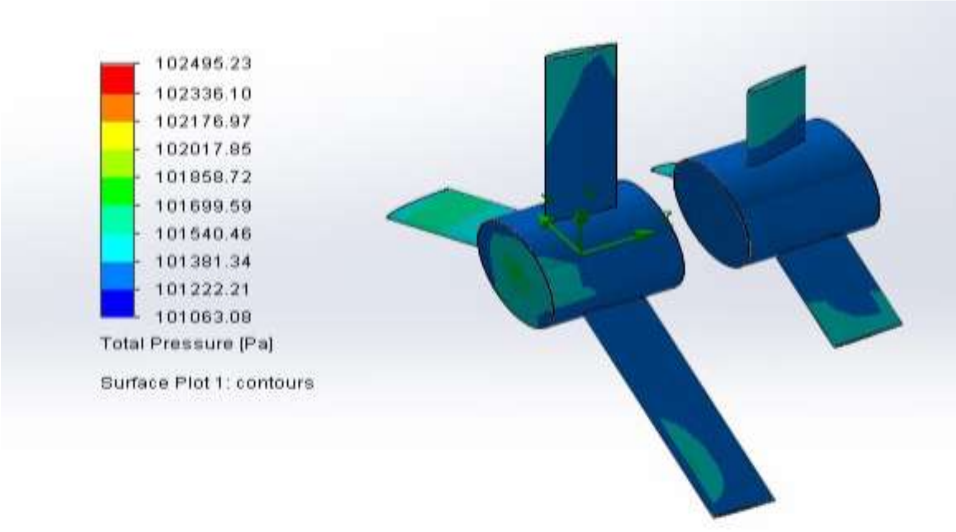
(a) **(b)**

(c)

Fig. 9. Shows the simulated results of the conventional wind turbine at an air velocity of (a) 5 m/s (b) 10 m/s (c) 15 m/s respectively.



(a) **(b)**



(c)

Fig. 10. Shows the simulated results of the co-rotor wind turbine at an air velocity of (a) 5 m/s (b) 10 m/s (c) 15 m/s respectively.

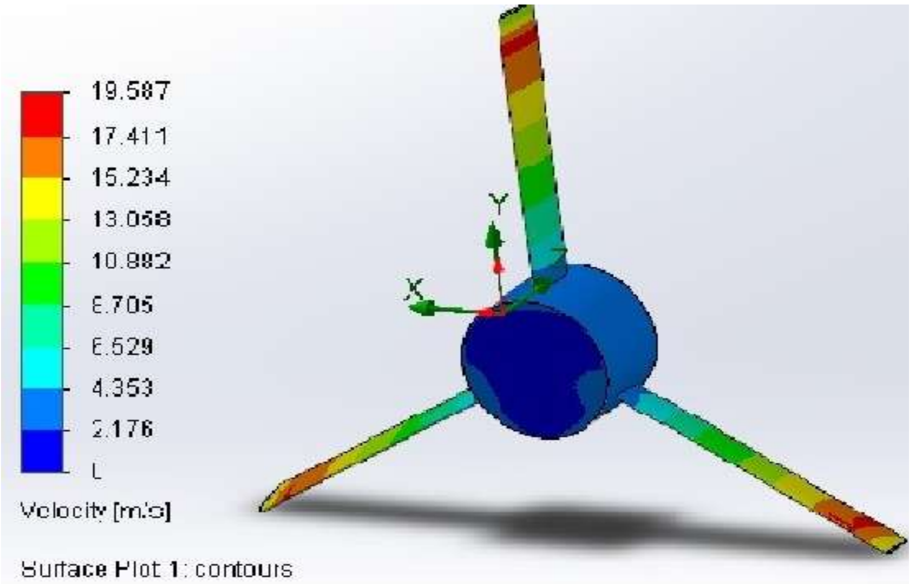


Fig. 9 (d). Simulated results of the conventional wind turbine at an air velocity of 15 m/s.

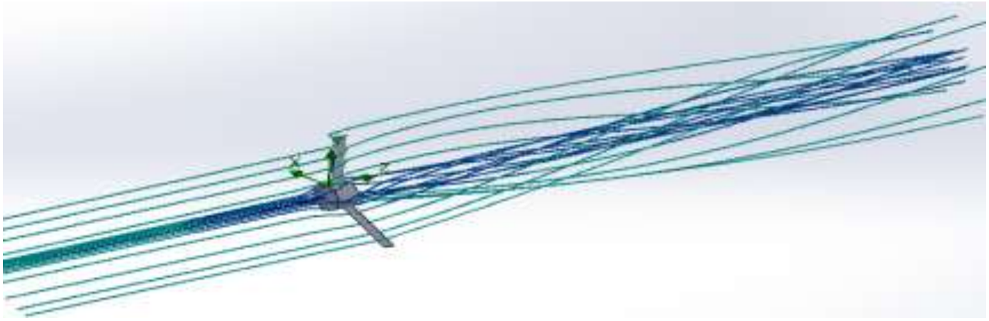


Fig. 9 (e). Simulated flow trajectory of air for conventional wind turbine

Air velocity at 5 m/s pressure acts on both conventional and co-rotor wind turbine blades and rotor as shown in **Fig. 9(a) and Fig. 10(a).**respectively. From the results, it is clear that co-rotor wind turbine has a maximum pressure compared to the conventional wind turbine. Similarly, air velocity at 10 m/s Pressure increases on both conventional wind turbine as shown in **Fig.9(b)** and co-rotor wind turbine as shown in **Fig.10(b).**

Here also it is evident that co-rotor have maximum pressure. Further air velocity at 15 m/s maximum pressure 101633.64 pa, in case of a conventional wind turbine, as shown in **Fig. 9(c).** For co-rotor wind turbine as shown in **Fig. 10(c)** maximum pressure obtained is 102495.23 pa which is again higher than conventional wind turbines simulation results.

From **Fig. 9(d)** it could understand that exhibits an air velocity at 15 m/s conventional wind turbine has a maximum velocity of 19.87 m/s and for a co-rotor wind turbine as shown in **Fig.10(d)** a maximum velocity of 32.06 m/s attained which is again higher than conventional wind turbines simulation results.

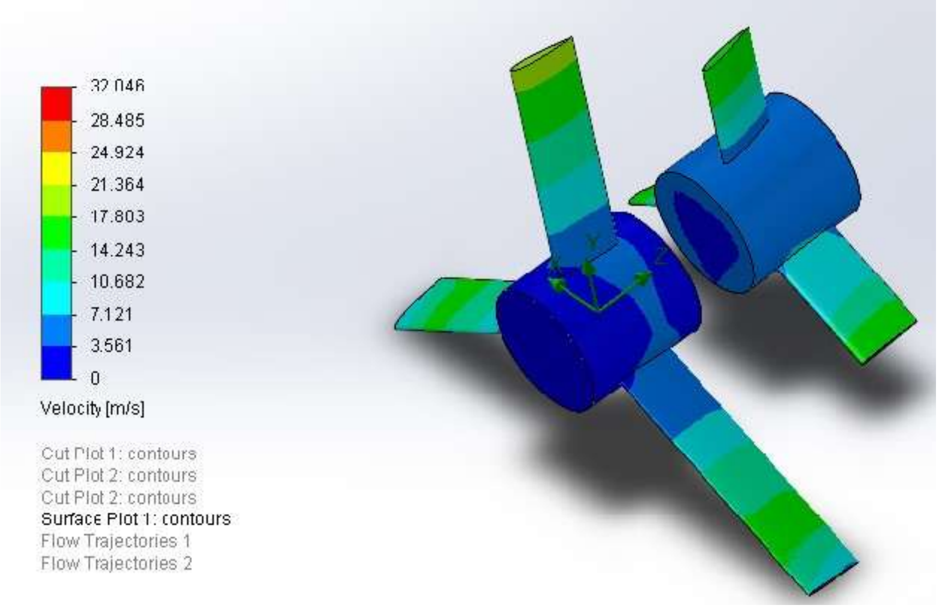


Fig. 10 (d). Simulated results of the co-rotor wind turbine at an air velocity of 15 m/s

Fig. 10 (e). Simulated flow trajectory air for co-rotor wind turbine

Fig. 9 (e) depicts the air passes over the blades and rotor besides providing a cut-throat demonstration on the way of turbine rotation and remaining air getting wasted in the form of the whirl and thereby yielding a lower torque value. **In Fig. 10 (e)** for the co-rotor wind turbine, air passes through the front rotor and starts to rotate in the anticlockwise direction and pushes the air towards the rear rotor which in turn rotates in the clockwise direction. These effects yield torque and also produce more electricity when compared to a conventional wind turbine.

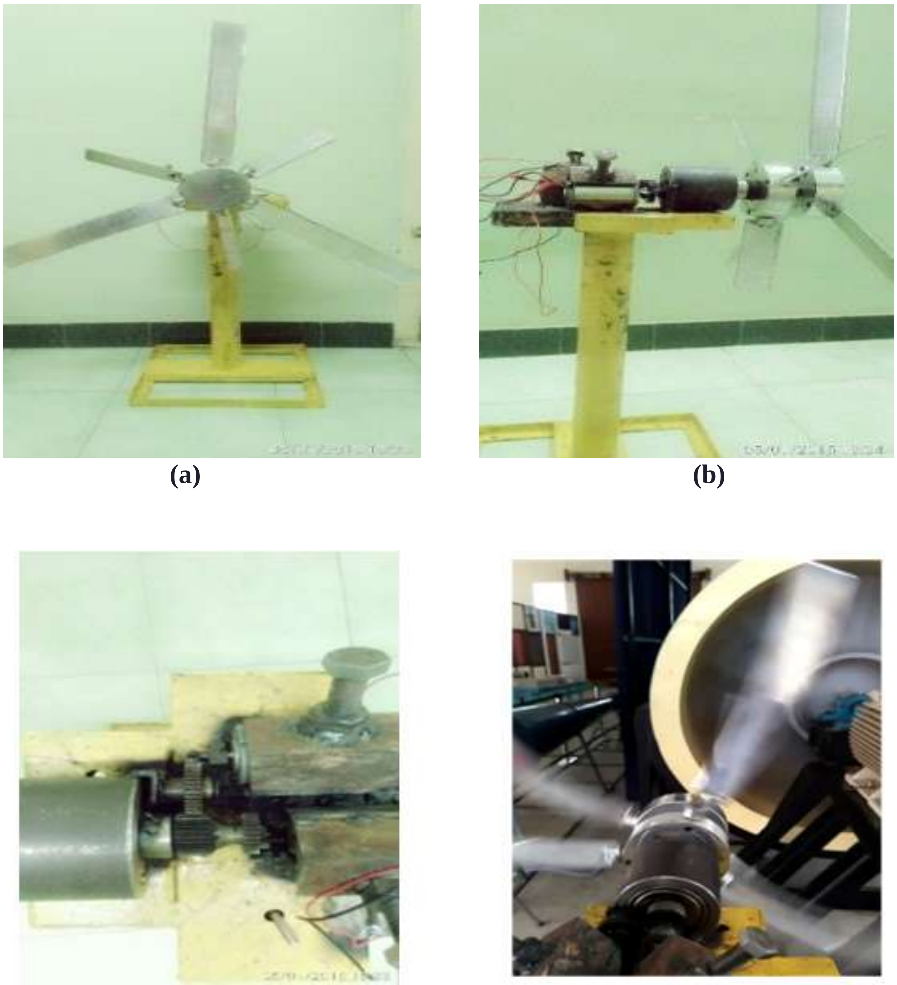
Co-rotor gets self-regulated on the speed due to the difference in torque between two rotors and enables that to make rotor operatable at low wind speed. The increase in the wind speed makes the rotor reaches a maximum rotational speed at the rated wind speed. Above all The rotational direction and speed of the rotors are adjusted to the wind circumstance instantly. Co-rotor avoids pitch control to capture airflow at different velocities and directions because the rear rotor can start rotating on low air velocity. This makes the co-rotor wind turbine exhibit better performance compared to conventional wind turbine and the same is evident from archived simulation results shown as **Fig.10 (d).**

Sl.no	**Velocity (m/s)**	**Power of corotor (W)**	**Power of conventional rotor (W)**	**Gain in power (%)**
1.	5	17.01	13.54	20.40
2.	10	27.73	27.65	0.29
3.	15	62.21	55.46	10.85

Table 3: Theoretical power variation of Co-rotor Vs Conventional wind turbine

The pressure is directly proportional to velocity. Eventually for validation So further experimental investigation of co-rotor is to be done and the performance measures to be are compared. The comparative results are as shown in Table 3.

Power is calculated from normal force time's linear rotational velocity, P = Fnormal x U, where U is rotor linear velocity, U= radius x angular velocity. Using these relations power of wind turbines was calculated and as shown in Table 3. It could be visualized that the co-rotor utilizes air velocity at a higher rate for the reason that each rotor independently rotates. Even under a modest wind speed regime, this makes co-rotor configuration a better one than the conventional wind turbine.



(a) (b)

(c) (d)

Fig. 11. Shows (a) Blade and hub are mounted on the vertical stand, (b) Blade, hub is fixed to shaft and is connected to the gear and is finally connected to dynamo motor, (c) shaft output is connected to two dynamo motor, (d) co-rotor wind turbine rotor during a test run.

V. Experimental Setup & Procedure

As the simulation results explained and discussed above, with the reference to the simulation results, the prototype has been developed. The experimental setup has been designed. Designed blades are fabricated and fixed with the hub. Blades are adjustable to the required degrees. Blades and hubs are made up of aluminium to achieve lightweight and easy handling. Hub is connected with shaft and shaft is mounted in a bearing housing. Both are made up of mild steel. Power from the generator is measured by multi-meter. The whole setup is mounted over a stand see **Fig. 11**. The wind tunnel is used to test the performance of the turbine.

The setup is mounted over the stand near to wind tunnel equipment. The wind tunnel machine runs at a fixed RPM of 500 and for a definite air velocity of 5 m/s, co-rotor starts and continues running as shown in **Fig. 12**. At this stage, voltage and current are measured using a multi meter. Then by varying velocity as 10 m/s, 15 m/s respectively voltage and current are recorded as tabulated in Table 4.

In a co-rotor wind turbine, the air is fully utilized by both the blades. The air surpassing through the front blade and it also intends to rotate the rear blade. Hence the efficiency of these types is much higher than the conventional wind turbine. Theoretical results shown in Table 3, co-rotor produces 20.40 % 0.29 %, 10.85 % more power than conventional rotor at design point 5, 10, 15 m/s respectively. Generally, design velocity is taken as the most probable velocity where the wind turbine is erected.

Sl.no	Velocity(m/s)	Voltage(V)	Current(amps)	Power(W)
1	5	10.4	1.592	16.5
2	10	12.6	2.09	26.34
3	15	18.5	3.332	61.65

Table 4: Velocity Vs Power

As the air velocity increases power produced from co-rotor increases as shown in Table 4, compared with theoretical power as shown in Table 3. By comparing the results shows that the theoretical and experimental results are following each other.

Fig. 12. Co-rotor rotor during a test run

Sl.No	Velocity (m/s)	Theoretical Power (W)	Experimental Power (W)	Variation (%)
1	5	17.01	16.5	3
2	10	27.73	26.34	5
3	15	62.21	61.65	1

Table 5: Theoretical Vs Experimental power

This study examines the performance of the designed co-rotor wind turbine over the conventional wind turbine. The computational analysis performed with the wind tunnel experiment results and it is compared theoretical power results as shown in Table 5. The further experimental investigation is done, for practical understanding of the results shown in Table 5, that theoretical and experimental results are under each other and higher than a conventional wind turbine. Thus, the design has been analysed and discussed with both the simulation and the experimental results.

VI. Conclusion

Therefore, computational results show that co-rotor configuration is better than the conventional rotor. It shows that the former configuration is better than the conventional wind turbine at the design point. The model considered for evaluation is only a small wind turbine that is capable of producing compatible electricity that could be useful for charging the batteries, UPS, etc. Thus the current research outcome would be very much helpful in reducing the current charges applicable for heavy consumed by the variety of household articles. Each blade of co-rotor rotates independently to a specific angle to capture the range of velocity and minimizes structural and electromechanical systems. Thereby it tends to increase the space of the wind turbine and enables to install of a designed and simulated co-rotor wind turbine that produces more electricity than an existing wind turbine and reduces the cost of making the wind turbine. Further for designing the prototype model of the co-rotor wind turbine, it is necessary to design the shaft corresponding to the weight of the blade acting on it. The shaft inevitably has to be designed based on the weight of the blade, Gear and gearboxes have to be designed based on the speed of the rotor to get electricity without any losses.

References

[1]. Kim J.E, J.H.Moon, Kim SJ, “Modeling, control, and simulation of dual-rotor wind turbine generator system”, 2009, pp. 2124-2132.

[2]. Joao Monterio P. Miguel Silvestre R, “Wind tunnel testing of a horizontal axis wind turbine rotor and comparison with simulation from two blade element momentum code”, 2013, pp.99-106.

[3]. Yiannis A. Katsigiannis, George S. Stavrakakis, “Estimation of wind energy production in various sites in Australia for Different Wind turbine Classes: A comparative technical and economic assessment”, 013, pp.230-236.

[4]. Francisco G. Montoya, Francisco Manzano-Agugliaro, Sergio Lopez-Marquez, Quetzalcoatl Hernandez-Escobedo, “Consolacion Gill Wind turbine selection for wind farm layout using multi-objective evolutionary algorithms”, 2014, pp.6585-6595.

[5]. Ali Mostafaeipour “Productivity and Development issues of global wind turbine industry”, 2009, pp.1048-1058.

[6]. Raymond Tran, Junhua Wu, Christopher Denison, Thomas Ackling, Markus Wagner, Frank Neumann, “Fast and Effective Multi-objective optimization Of Wind Turbine placement”, 2013, pp.1-8.

[7]. TareqSaberAbuaisha, “General study of the control principles and dynamic fault behavior of variable- speed wind turbine and wind farm generic models”, 2014, pp.245-254.

[8]. Stella Morris, The Soon Chin, Morris A.G. Ezra, and joseph Raj, “Concept design of a Modified airfoil blade with Drag Assist for a vertical Axis Micro- Wind turbine”, 2013, pp.105-113.

[9]. J.park, K. Smarsly, K.H. Law, D.Hartmann, “Multivariate analysis and prediction of wind turbine response to varying wind field characteristics based on machine learning”,2012, pp.1-8.

[10]. Kazuhiko Toshimitsu, Hironori Kikugawa, Kohei Sato, Takuya Sato, ”Experimental investigation of Performance of the Wind Turbine with the Flanged-Diffuser Shroud in Sinusoidally Oscillating and Fluctuating Velocity Flows”, 2012, pp.215-221.

[11]. Xiao Chen, Wei Zhao, Xiao Lu Zhao, JianZhongXu, “Preliminary failure investigation of a 52.3 m glass-epoxy composite wind turbine blade”,2014, pp.345-350.

[12]. DaliborPetkovic, ShahaboddinShamshirband, ZarkoCojbasic, VlastimirNikolic, Nor BadrulAnuar, AznulQalidMdSabri, Shatirahakib, “Adaptive neuro-fuzzy estimation of building augmentation of wind turbine power”,2014, pp.188-194.

[13]. Jan helsen, PepijinPeeters, KlaasVanslambrouck, FrederikVanhollebeke, WimDesmet, “The dynamic behavior induced by different wind turbine gearbox suspension methods assessed by means of the flexible multibody techniques”, 2014, pp.336-346.

[14]. Pengyin Liu, Guohua Yu, Xiaocheng Zhu, Zhaohui Du, “Unsteady aerodynamic prediction for dynamic stall of wind turbine airfoils with the reduced-order modeling”, 2014, pp.402-409.

[15]. Dong Ok yu, Oh Joon Kwon, “Predicting wind turbine blade loads and aeroelastic response using a coupled CFD-CSD method”, 2014, pp.1-13.

[16]. H.Hamdi, C.Mrad, A.Hamdi, R.Nasri, “Dynamic Response of a horizontal axis wind turbine blade under aerodynamic, Gravity and gyroscopic effects”, 2014, pp.1-11.

[17]. Richard W. Vesel Jr., Jack J. McNamara, “Performance enhancement and load reduction of a 5 MW wind turbine blade”, 2013, pp.391-401.

[18]. Keith Sunderland, Thomas Woolmington, Jonathan Blackledge, Michael Conlon, “Small wind Turbines in turbulent (urban) environments: A consideration of normal and Weibull distributions for power prediction”, 2013, pp.70- 81.

AUTHOR’S BIOGRAPHY

R.Karthik worked as a supervisor in Tradex shipping company private limited Kochi, Kerala. He completed Master of Engineering with specialization in Engineering Design from Anna University Regional Campus, Coimbatore in the year 2015. He received Bachelor degree specialization in Mechanical Engineering from Sri.Krishna college of Engineering and Technology Coimbatore in the year 2013. Research interest are Energy conservation and management, Mechanical Machineries and Equipment, Renewable energy, green energy and it’s usage methods. Published paper of Study on Thermal Conductivity of Different nano fluids on the year 2012.

M.Monisha is pursuing her Ph.D in Department of Computer Science and Engineering, SSN College of Engineering. She received B.tech in Information Technology in the year 2015 from J.N.N Institute of Engineering, Chennai, Master of Engineering in Computer Science and Engineering with specialization in networks from Anna University Regional Campus, Coimbatore. She is a life Member of International Association of Engineers, International Association of Engineering and Technology for Skill Development, ResearchID, and The Society of Digital Information and Wireless Communications. She published the articles in reputed International journals. Her research interests are Wireless Sensor Networks, Underwater Sensor Networks and Web Technologies, Machine Learning, Neural Networks, OCR, Ancient scripts.

R.Karthik"Design, Simulation and Wind-Tunnel Testing Of Co-Rotor Wind Turbine Using Solid Works - Cosmos Flow Works " *International Journal of Engineering Science Invention (IJESI)*, Vol. 09(01), 2020, PP0 62-73