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CFD Analysis of Giromill Type Vertical Axis Wind Turbine

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***Abstract*: The need of the efficiency has been rising over the period of time. This leads to the innovative developments of the design. Hence the usage of CFD has come to the existence. In the current project CFD Analysis is performed on the vertical axis wind turbine blades in such a way to increase the maximum lift of the blade for the small area of wind impact. The project also concerned about the study of the auxiliary equipment for the storage and usage of the potential generated by the turbine. The equipment dimensions will be of convenient size and can be installed over the roof tops of the residencies.**

***Keywords*: Power harvesting, vertical axis wind turbine, blade design, non-conventional energy sources.**

1. Introduction

The function of vertical axis wind turbine is converted the wind power to electricity. Particularly this type of turbine has the main rotor shaft arranged vertically. For it a power study is made in which the size of the wind turbine is defined. Nowadays there are several types of vertical axis wind turbine: Savonius, Darrieus and Giromill. The Savonius turbine is one of the simplest turbines. Looking down on the rotor from above, a two-scoap machine would look like a ¨S¨ shape in cross section. Savonius turbines are used whenever cost is much more important than efficiency. The Darrieus turbine consists of a number of curved and vertical aerofoils which are attached to the central mast by horizontal supports. The advantages of variable pitch are: high starting torque; a wide, relatively flat torque curve; a lower blade speed ratio; a higher coefficient of performance; more efficient operation in turbulent winds; and a lower blade speed ratio which lowers blade bending stresses. The giromill turbine is a subtype of Darrieus turbine, this turbine has a straight blades. This turbine is the type of wind turbine that I am designing. It is typically formed by two or three vertical aerofoil's but these aren't the only options. Giromill turbine is cheaper and easier to build than a standard Darrieus turbine, but also requires strong winds (or a motor) to start. However, they work well in turbulent wind conditions and are an affordable option where a standard horizontal axis windmill type turbine is unsuitable. One advantage of this arrangement is that the turbine does not need to be pointed into the wind to be effective. The Giromill blade design is much simpler to build, but results in a more massive structure than the traditional arrangement, and requires stronger blades, for reasons outlined above. The disadvantage of this type of wind turbine is the performance that present. They have a low performance, because to turn all the wind energy to electrical energy is impossible, but sometimes this solution is cheaper than to take the electrical network to the wiring, the cost of kW generated h is minor that in the case of contracting the services of a company. And it is a process of transformation of energy that does not cause environmental damages.

2. Aim of the research

The main objective of this project is to evaluate the design of a vertical axis wind turbine, specifically one Giromill wind turbine with various angle of attacks. The project development requires study of the vertical axis wind turbines currently development. This study has to be performed before starting to design the wind turbine. Other very important aim is to evaluate the air foil configuration of a new vertical axis wind turbine. The after CFD analyses that will result in the final design of the wind turbine in future. The project requires performing the analysis of efforts and the analysis of performance. These analyses will be made with the help of the software Fluent and CAD packages. The suitable angle of attack for the vertical axis wind turbine turbines are evaluated from the results. Finally the main objective of this project is to evaluate the angle of attack of the vertical axis wind turbine based on the results obtained in the flow analysis and suitable angle. A 2D model is used for the analysis.

3. CFD methodology

In all of these approaches the same basic procedure is followed. During pre-processing

- The geometry (physical bounds) of the problem is defined.
- The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform.

- The physical modeling is defined – for example, the equations of motions + enthalpy + radiation + species conservation
- Boundary conditions are defined. This involves specifying the fluid behavior and properties at the boundaries of the problem. For transient problems, the initial conditions are also defined. The simulation is started and the equations are solved iteratively as a steady-state or transient.
- Finally a post-processor is used for the analysis and visualization of the resulting solution.

Below figure shows how the total CFD works.

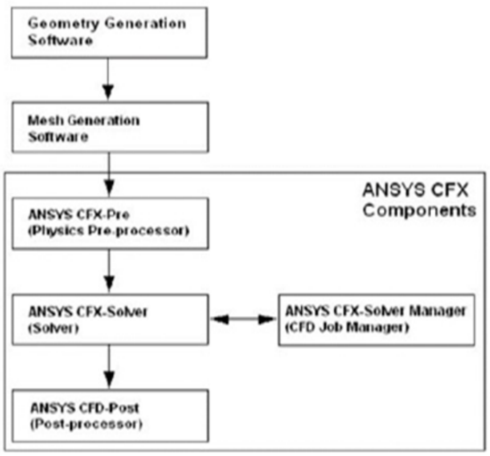

Fig. 1. Working of CFD

4. Computational fluid dynamics setup

A. Aim of the project

The main of the project is to evaluate the several of angle of attacks for optimum efficiency for a constant wind speed of 3 m/s.

B. Design Considerations

- A 2D model has adopted for the flow analysis over the blades.
- The analysis is carried out for the angles 0, 2.5, 5, 7.5, 10, 12.5, 15 degrees
- The wind speed is taken as constant 3m/s for the entire analysis
- The profile of air foil is NACA 0015 series profile (Symmetrical airfoil).
- The certain flow boundary with inflation on the airfoil boundary for the boundary layer is applied.
- The k-ε turbulence model is selected for the present analysis.

C. Design of the domain

- The domain is designed with the airfoil configuration with various angle of attacks.
- Initially the airfoils are arranged in the configurations of above mentioned and the surface is extracted from the surface and air foil profiles are made Boolean from the surface.

D. 2-D geometry: Meshing

The quad meshing is done for the each and every configuration and the carried out for the analysis the mesh setting (local and global settings) are same for the every configuration but due to change in the angle of attack the element count may differ from one to model to other.

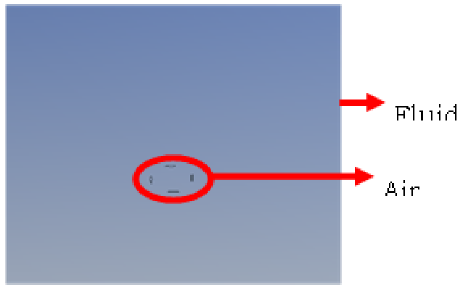

Fig. 2. Meshing

Table 1
Dimensions

S. No.	Scope	Geometry	Sizing
1	Body sizing	Domain	50 mm
2	Edge sizing	Airfoil	60 divisions
3	Inflation	Airfoil	2 layers

Table 2
Mesh statistics

Model	Elements	Nodes
0^o	24177	24727
2.5^o	29266	29956
5^o	31578	32394
7.5^o	31027	31833
10^o	31729	32540
12.5^o	31708	32526
15^o	31203	31992

E. Named selections

Basically the named selections are given to a particular model to specify the boundary conditions at that position. The named selections in this model are:

- Inlet (air inlet)
- Outlet (air outlet)
- Air 1-1 (air foil 1 top edge)
- Air 1-2 (air foil 1botom edge)
- Air 2-1 (air foil 2 top edge)
- Air 2-2 (air foil 2botom edge)
- Air 3-1 (air foil 3 top edge)
- Air 3-2 (air foil 3botom edge)
- Air 4-1 (air foil 4 top edge)
- Air 4-2 (air foil 4botom edge)

5. Fluent

After the geometric designing, geometric cleaning and meshing of the model the further flow analysis is carried out in fluent package. Basically fluent package deals with the flow

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analysis in a prescribed domain. Initially to run the problem

Step 1: General settings like type of analysis, solver preference and velocity formulation has to be specified in this step. The gravity is not needed in this case.

Step 2: In the second step the solving equations has to be selected depending upon the scope of the analysis. As the present analysis is accompanied only with flow analysis only k-ε model is selected. It is the turbulence model for the flow analysis. Easy steps are to be provided in the fluent interface.

Step 3: The flow material has to be assigned to the domain for the assigning of material properties.

Step 4: The boundary conditions has to be initiated for the named selections i.e. inlet and outlet.

- Inlet type: Velocity-inlet
- Outlet type: Pressure-outlet

Step 5: The residual plots are to be assigned to the airfoils to study the variation of the coefficient of lift with the variation in angle of attacks.

Residual plots – Forces – New – Lift & coefficient of lift

After the above process select the edges with the named selections mentioned above and click on the compute to find the coefficient of lift on that particular airfoil. Repeat for every arrangement to get the values and tabulate them.

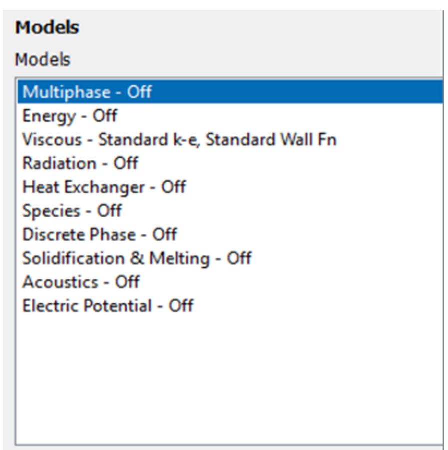


Fig. 3. Equation models

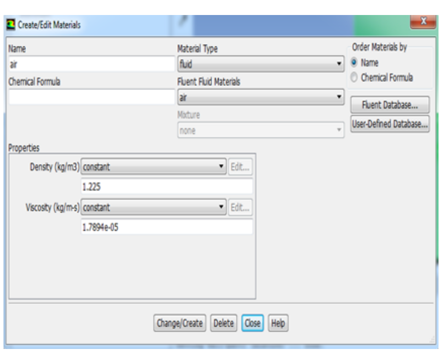


Fig. 4. Flow materials

Step 6

- Initialize the model using hybrid initialization and then calculate with certain number of iterations
- Stop the calculation process when the solution is converged (no change in the value of residual plots even if the iterations are incomplete).

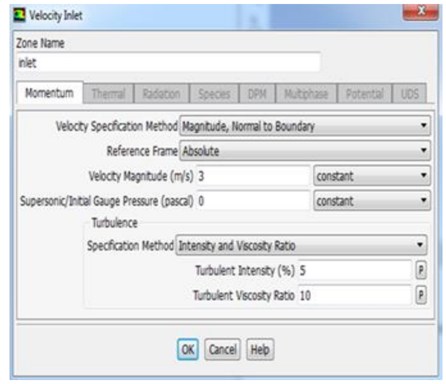


Fig. 5. Velocity inlet boundary conditions

The coefficient of lift and drag and the resultant forces are tabulated below:

Table 1
Lift force for certain degree of angle of attack

S. No.	Angle of Attack	Lift Force			
		Air foil 1	Air foil 2	Air foil 3	Air foil 4
1	0	0.047	1.556	0.0143	0.0525
2	2.5	0.0557	2.36	0.0018	-0.0323
3	5	0.8069	-8.689	-0.714	-9.539
4	7.5	0.1593	1.5	0.0913	0.0648
5	10	0.2	1.507	0.2169	0.2106
6	12.5	0.2404	1.624	0.5559	-0.2498
7	15	0.2739	1.51	0.8037	-0.1754

Table 2
Coefficient of lift for certain degree of angle of attack

S. No.	Angle of Attack	Coefficient of Lift			
		Air foil 1	Air foil 2	Air foil 3	Air foil 4
1	0	0.0777	2.541	0.0233	0.0857
2	2.5	0.091	3.854	0.0029	-0.0527
3	5	1.3175	-14.18	-1.167	-15.57
4	7.5	0.2601	2.45	0.1491	0.1058
5	10	0.3275	2.46	0.354	0.3439
6	12.5	0.3926	2.65	0.9077	-0.4079
7	15	0.4472	2.466	1.3122	-0.2863

Table 3
Coefficient of drag for angle of attack

S. No.	Angle of Attack	Coefficient of drag			
		Air foil 1	Air foil 2	Air foil 3	Air foil 4
1	0	-0.66	0.4672	2.412	0.0394
2	2.5	0.3698	0.16	0.5869	0.1804
3	5	-15.86	-1.536	-0.178	1.066
4	7.5	1.1177	-0.178	2.08	0.00289
5	10	1.559	-0.209	2.446	0.0012
6	12.5	2.051	-0.154	3.736	0.1595
7	15	2.2429	-0.276	3.072	0.1105

Table 4
Drag forces for angle of attack

S. No.	Angle of Attack	Drag forces			
		Air foil 1	Air foil 2	Air foil 3	Air foil 4
1	0	-0.661	0.4672	2.4124	0.0394
2	2.5	0.2265	0.098	0.3594	0.1105
3	5	-9.72	-0.9411	-0.109	0.652
4	7.5	0.6845	-0.1091	1.274	0.00177
5	10	0.954	-0.1284	1.498	0.00073
6	12.5	1.256	-0.9478	2.288	0.0977
7	15	1.373	-0.1695	1.881	0.0676

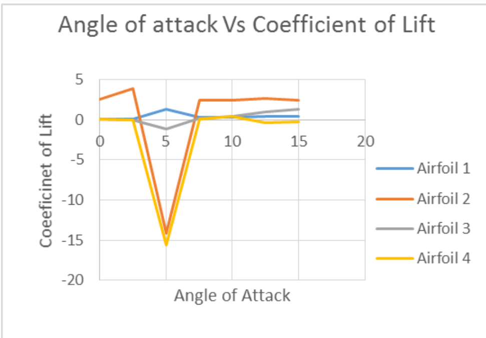


Fig. 6. Angle of attack vs. coefficient of lift

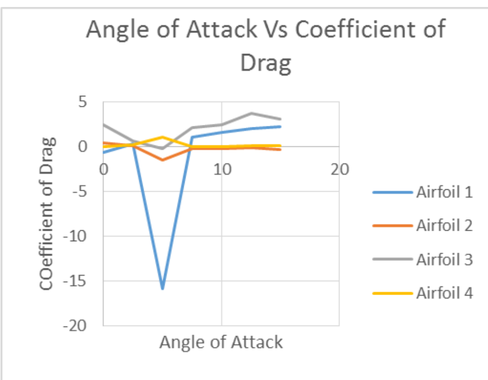


Fig. 7. Angle of attack vs. coefficient of drag

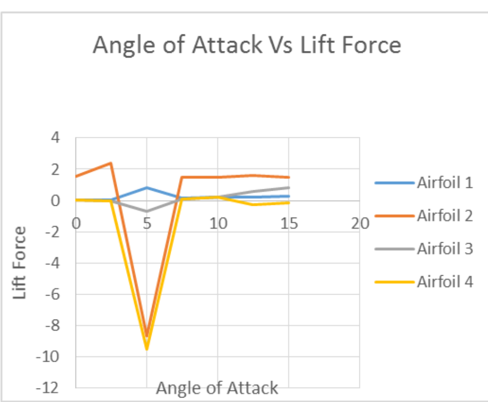


Fig. 8. Angle of attack vs. lift force

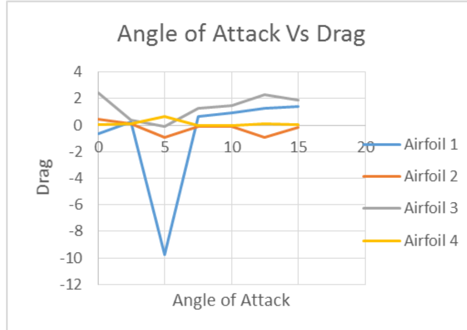


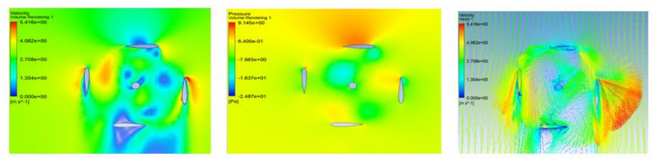
Fig. 9. Angle of attack vs. drag

6. Results

Simulation represents the following

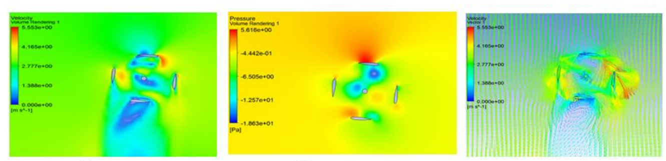
- Contours of Velocity
- Contours of Pressure
- Velocity vector plot

A. *For angle of attack 0º*



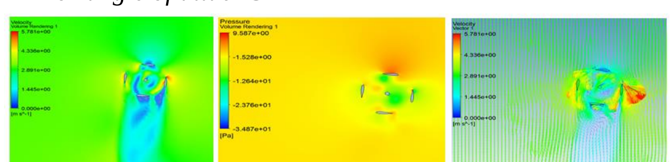
(a) (b) (c)

B. *For angle of attack 2.5º*



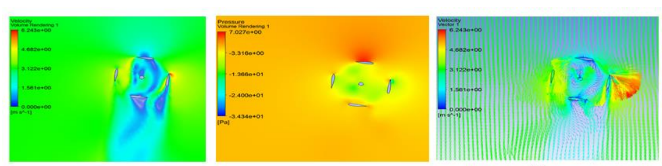
(a) (b) (c)

C. *For angle of attack 5º*



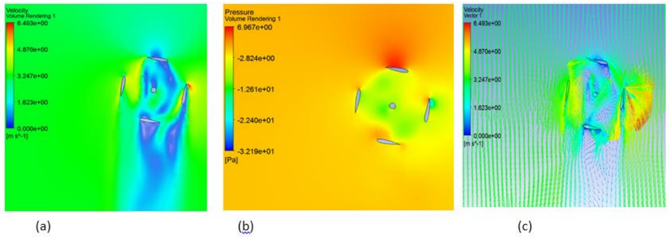
(a) (b) (c)

D. *For angle of attack 7.5 º*

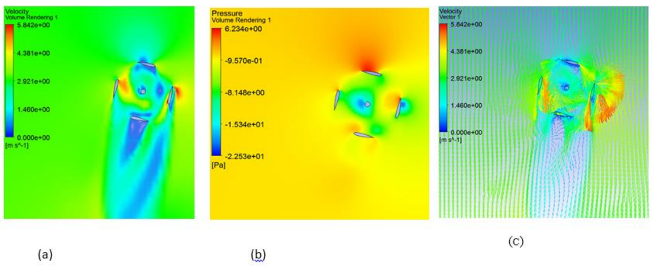


(a) (b) (c)

E. For angle of attack 10º



F. For angle of attack 12.5º



G. For angle of attack 15º

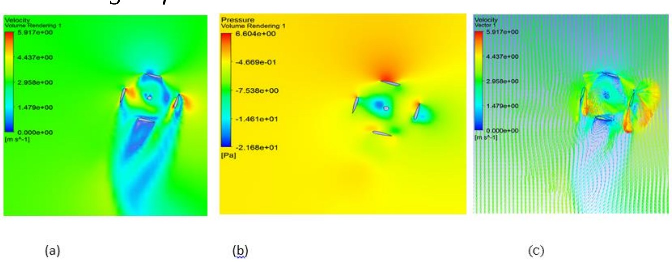


Fig. 10. (a) Contours of velocity, (b) Contours of pressure, (b) Velocity vector plot

7. Conclusion

- The CFD analysis has been performed on vertical axis wind turbine blade positions containing the NACA 0015 airfoil as blades
- The Blades are oriented at the angles of 0, 2.5, 5, 7.5, 10, 12.5, 15 and the analysis is carried out.
- The velocity and pressure contours are extracted from the top and bottom of the surface of a blade
- The parameters like coefficient of lift, lift force, coefficient of drag and drag force which define the air foil performance are evaluated and the graphs are drawn.

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