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DESIGN OF 4 VANE VAWT AND COMPARATIVE ANALYSIS OF OPTIMAL PERFORMANCE OF TURBINE FOR MICRO-WIND ENERGY GENERATION TEST

[1]Mr. Sachin A. Nalawade, [2]Dr. A. D. Desai, [3]Prof. A. B. Bhane

[1]PG Scholar, Mechanical Engineering Department, SRCOE, Lonikand (Pune)
[2]Professor, Mechanical Engineering Department, SRCOE, Lonikand (Pune)
[3]Asst. Professor, Mechanical Engineering Department, SRCOE, Lonikand (Pune)

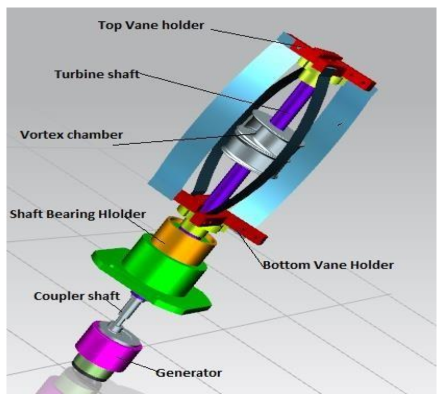
ABSTRACT - With the depleting conventional energy resources there is need for renewable sources of energy like the solar energy and wind energy. Wind energy although a good energy resource large wind farms are not practically possible in urban areas hence small or micro wind mills can prove to be a feasible method for energy generation. Present project describes one such method of micro energy generation using a micro wind turbine which will be designed as a vertical axis wind turbine using modern methods of manufacturing like Fused deposition method (FDM) for production of parts. The discusses the design development of a vertical axis micro- wind turbine with four vanes. The objective of the project being to design a turbine such that the energy generation through the turbine can be augmented through use of enhanced wind energy extraction devices like vortex vanes to improve the energy generation. The work will include the theoretical design of the turbine rotor, shaft, vane brackets, vortex vanes etc. The parts will be modelled using suitable modelling tools, the analysis will be done using Ansys Work bench and the manufacturing of the vane brackets and vortex vanes will be carried out using 3-d printing or fused deposition method. The test and trial on the turbine will be carried out for performance evaluation of the turbine in three configurations namely, without vortex vanes, with single vortex vane and with two vortex vanes. The comparative analysis will be carried out to determine the optimal performance of the turbine for micro-wind energy generation.

Keywords: Wind energy, micro-generation, micro-vertical axis turbine, fused deposition method, vortex vanes, Ansys Workbench 16.

I. Introduction

Application of wind turbines (comparatively small in size than the conventional wind turbines) for energy production at residential or otherwise small scale industrial or commercial installations is termed as micro-generation. Here in the wind energy is used to operate a micro-turbine which converts the available power in the wind to mechanical energy which in turn is used to operate a generator that converts this mechanical energy to DC power which can be stored in batteries or converted to AC power using inverters. The turbines used as micro wind-turbines can be vertical axis wind turbines or horizontal axis wind turbines. The amount of generation depends upon the wind density in the given area, so also the obstruction such as trees, buildings etc. in the area of installation of the turbine also significantly influence the generation capability.

1.1 Constructional features of the VAWT for micro-generation



1.2 Methodology, tools, and techniques Flow chart of Methodology

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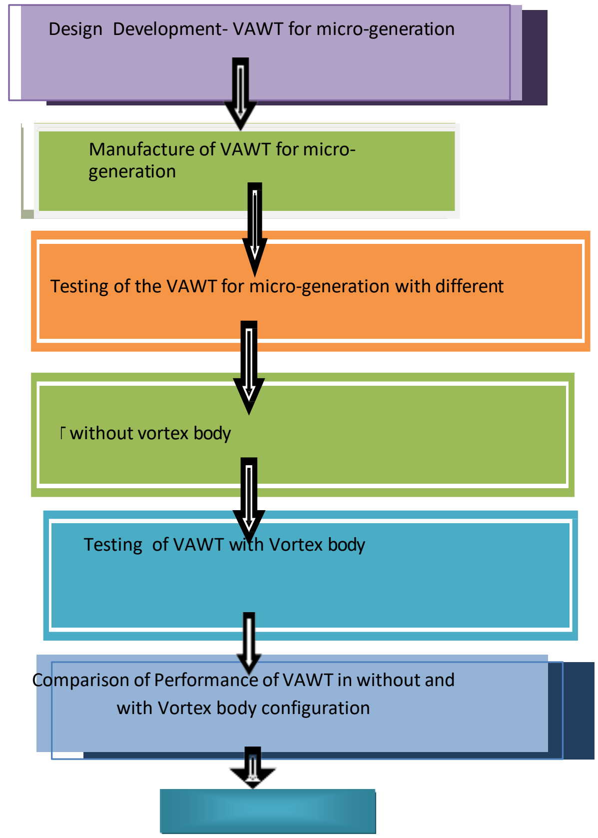

Figure 1- Flow chart indicating the plan for the research work

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II. CALCULATION AND TEST RESULTS

Design of Vane

Dimension details of vane 8 deg MATERIAL SELECTION: -Ref: - PSG (1.10 & 1.24) DESIGNATION ULTIMATE TENSILE STRENGTH (mpa) YEILD STRENGTH MPa) PTFE (Teflon) 23 310 Table 15 Material selection of vane 8 deg Check for direct shear failure of Vane 80 Direct shear stress fs (act) = Force /Area

fs (act) = Force (35.5 x2.5)

The tangential force exerted as shear force on the turbine shaft is given by Force = Torque / Radius = 0.343 x 103 / 95

Force = 3.6 N

The Turbine shaft is subjected to direct shear force (F) = 3.6 N fs (act) = 3.6
(35.5 x2.5)

fs (act) = 0.040 MPa

The maximum shear stress induced is 0.040 MPa which is well below the maximum stress, hence the vane is safe under shear load.

Case (1): Turbine without vortex body Observation table

Air Velocity m/sec	Speed (rpm)	Voltage (Volt)	Current (Amp)
2.3	65	5.2	0.01
2.7	78	6.1	0.02
3.2	152	7.8	0.03
4.5	232	9.8	0.07
5.3	346	10.8	0.12

Table 1-Observation table Turbine without vortex body

III. Result table Turbine without vortex body

z	Th Power (watt)	Speed (rpm)	Voltage (Volt)	Current (Amp)	Op_power (watt)	Efficiency
2.3	0.189661	65	5.2	0.01	0.052	27.41734
2.7	0.306821	78	6.1	0.02	0.122	39.7626
3.2	0.510792	152	7.8	0.03	0.234	45.81121

4.5	1.420468	232	9.8	0.07	0.686	48.29394
5.3	2.320713	346	10.8	0.12	1.296	55.84491

Table 2 Result table Turbine with 3 0 vane angle without vortex body

a) Graph of Turbine Speed Vs Air velocity without vortex body

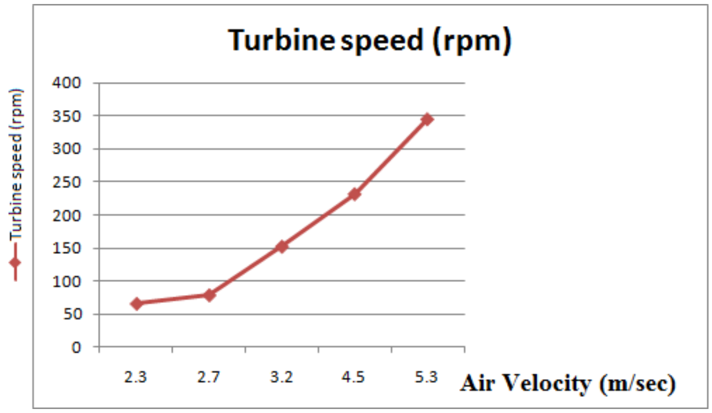

Fig. 2 Graph of Turbine Speed Vs Air velocity without vortex body

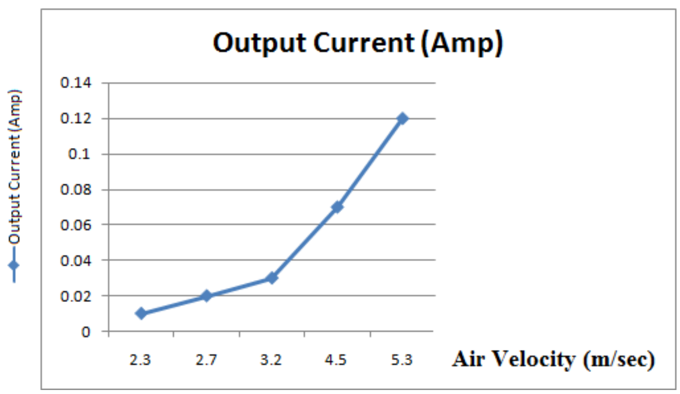

Figure3 Graph of Output current Vs Air velocity without vortex body

a) Graph of Output Voltage Vs Air velocity without vortex body

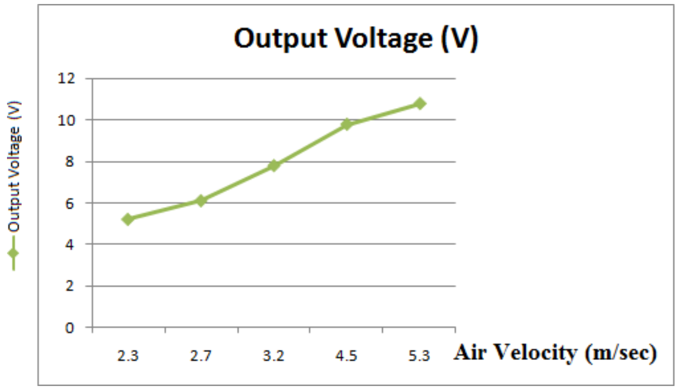

Figure 4- Graph of Output Voltage Vs Air velocity without vortex body

b) Graph of Output power Vs Air velocity without vortex body

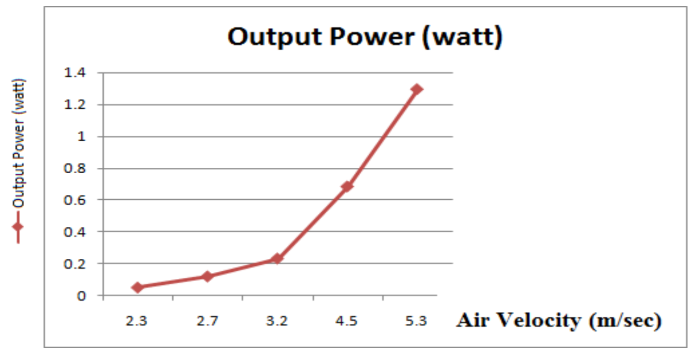

Figure 5- Graph of Output power Vs Air velocity without vortex body

c) Graph of Efficiency Vs Air velocity without vortex body

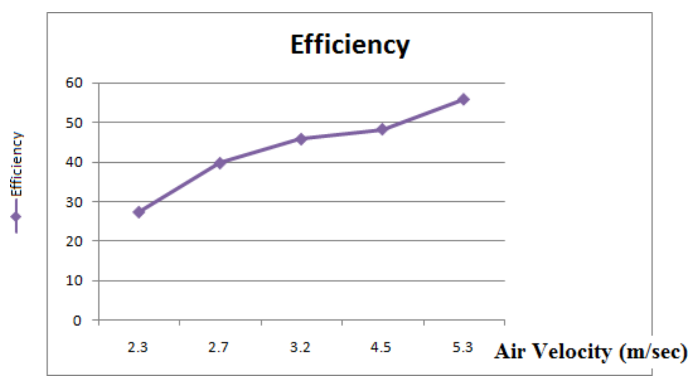

Figure 6- Graph of Efficiency Vs Air velocity without vortex body

d) Comparison Graph of Theoretical Power and Actual Power Vs Air velocity without vortex body

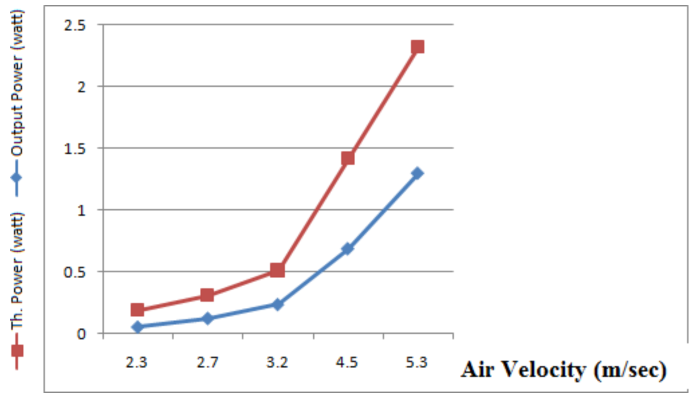

Figure 7 - Comparison Graph of Theoretical Power and Actual Power Vs Air velocity without vortex body

e) Testing of micro wind turbine with double Vortex body addition

Case (3): Turbine. with double vortex body Observation table Turbine double vortex body

Air Velocity m/sec	Speed (rpm)	Voltage (Volt)	Current (Amp)
2.3	92	6.2	0.014
2.7	156	7.1	0.023
3.2	242	8.8	0.032
4.5	312	10.6	0.079
5.3	458	11.5	0.133

Table 3- Observation table Turbine. double vortex body

IV. Result table Turbine double vortex body

Air Velocity m/sec	Th Power (watt)	Speed (rpm)	Voltage (Volt)	Current (Amp)	Op_power (watt)	Efficiency
2.3	0.189661	92	6.2	0.014	0.0868	45.76587
2.7	0.306821	156	7.1	0.023	0.1633	53.22321
3.2	0.510792	242	8.8	0.032	0.2816	55.13007

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4.5	1.420468	312	10.6	0.079	0.8374	58.9524
5.3	2.320713	458	11.5	0.133	1.5295	65.90647

Table 4- Result table Turbine. single vortex body

4.1 Graph of Turbine Speed Vs Air velocity with double vortex body

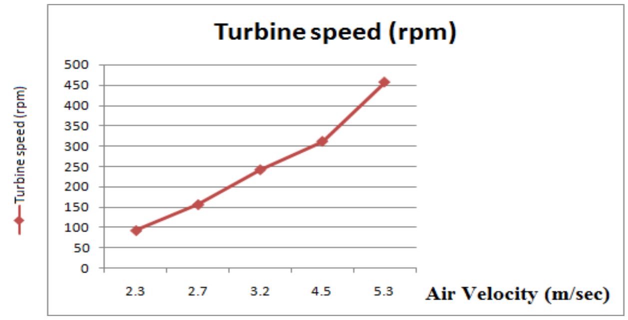


Figure 8- Graph of Turbine Speed Vs Air velocity with double vortex body

4.2 Graph of Output current Vs Air velocity with double vortex body

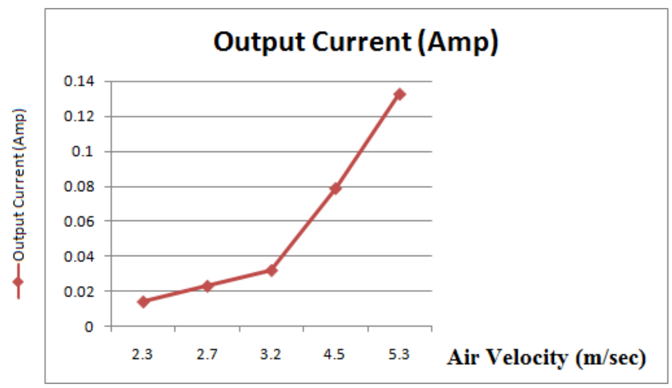
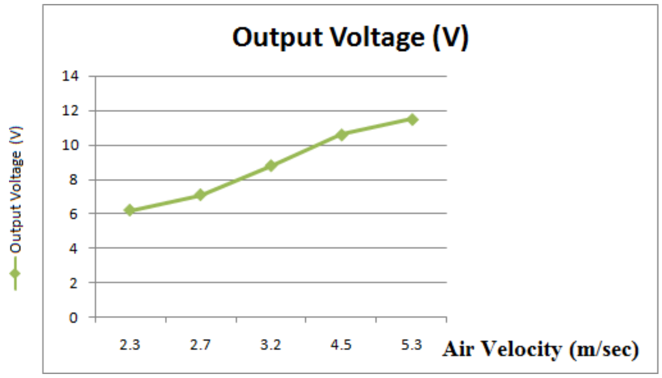


Figure 9- Graph of Output current Vs Air velocity with double vortex body

4.3 Graph of Output Voltage Vs Air velocity double vortex body



4.4 Graph of Output power Vs Air velocity with double vortex body

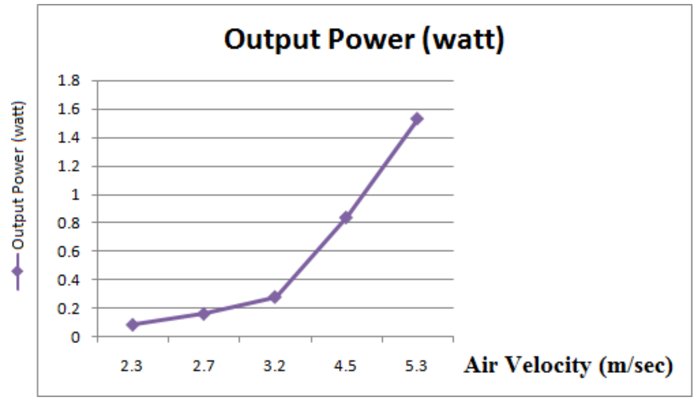


Figure10- Graph of Output power Vs Air velocity with double vortex body

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V. Comparison Graph of Theoretical Power and Actual Power Vs Air velocity 5 ^{0} vane angle with single vortex body

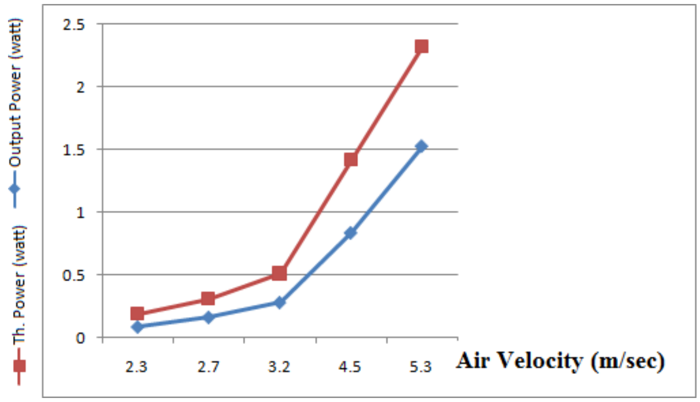

Figure 11- Comparison Graph of Theoretical Power and Actual Power Vs Air velocity with double vortex body

5.1 Graph of Efficiency Vs Air velocity with double vortex body

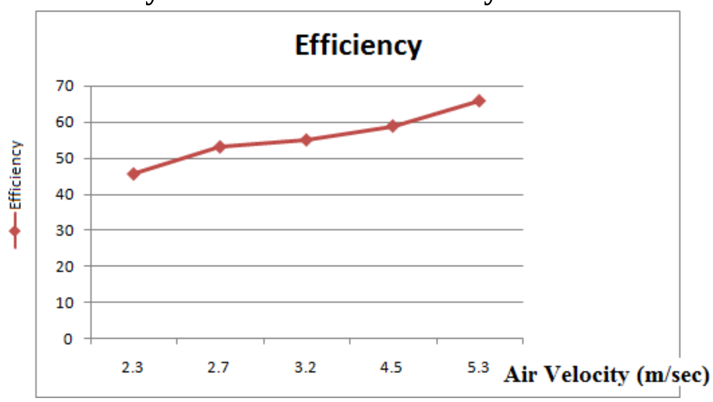

Figure12 Graph of Efficiency Vs Air velocity with double vortex body

5.2 Comparison Graph of Turbine without and with Vortex Body.

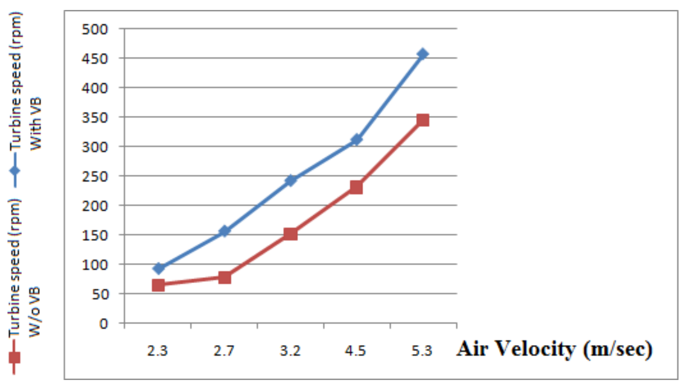

Fig 13-Comparison Graph of Turbine Speed Vs Air velocity without and with Vortex Body

5.3 Comparison Graph of Turbine Output Power Vs Air velocity without and with Vortex Body

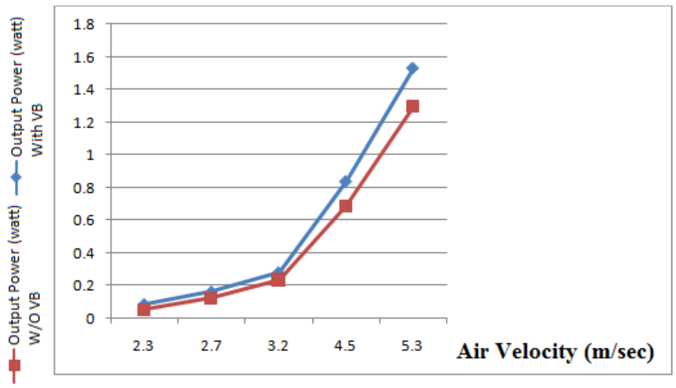

Fig 14- Comparison Graph of Turbine Efficiency Vs Air velocity without and with Vortex Body

VI. RESULT

Analyze and understand all the provided review comments thoroughly. Now make the required amendments in The turbine vane selection and derived rotor dimensions derive that the theoretical maximum Power extracted by the turbine @ 7 m/sec is 6 watt The maximum theoretical stress in the turbine shaft under torsional load is 8.08 MPa whereas the analytical stress is 1.367 MPa, suggesting that the design of turbine shaft is safe under given system of forces. The maximum dynamic capacity required by the ball bearing 6003zz is 14 N which is less than the available static capacity of 2850 N, hence the selected bearing is safe. The maximum theoretical stress in the top vane holder under torsional load is 0.067 MPa whereas the analytical stress is 0.259 MPa, suggesting that the design of top vane holder is safe under given system of forces. The maximum theoretical stress in the bottom vane holder under torsional load is 0.70 MPa whereas the analytical stress is 0.145 MPa, suggesting that the design of bottom vane holder is safe under given system of forces. The maximum theoretical stress in the coupler shaft under torsional load is 0.688 MPa whereas the analytical stress is 3.78 MPa, thereby suggesting that the design of coupler shaft is safe under given system of forces. The maximum theoretical stress in the Vortex body body under torsional load is 0.04 MPa whereas the analytical stress is 0.722 MPa suggesting that the design of Vortex body body is safe under given system of forces The maximum theoretical stress in the Coupler spring under torsional load is 4.2 MPa whereas the analytical stress is 24.94 MPa, thereby suggesting that the design of Coupler spring is safe under given system of forces The maximum theoretical stress in the Bearing housing under torsional load is 0.017MPa whereas the analytical stress is 0.043 MPa, suggesting that the design of Bearing housing is safe under given system of forces The maximum theoretical stress in the vane under torsional load is 00.04MPa whereas the analytical stress is 0.246 MPa, suggesting that the design of vane with 50 vane angle is safe under given system of forces. The turbine speed without vortex is observed to increase with the increase in air velocity, a maximum speed of 346 rpm is observed at air velocity of 5.3 m/sec.

VII. CONCLUSION

The maximum theoretical power of the turbine @ air velocity of 7 m/sec was found to be 6 watt The turbine components were designed using theoretical method and all parts were found to be safe under given system of forces. The turbine components were designed using analytical method and all parts were found to be safe under given system of forces. The turbine speed without vortex is observed to increase with the increase in air velocity, a maximum speed of 346 rpm is observed at air velocity of 5.3 m/sec. The output voltage without vortex is observed to increase with the increase in air velocity, a maximum voltage of 10.8 volt is observed at air velocity of 5.3 m/sec. The output current without vortex is observed to increase with the increase in air velocity, a maximum voltage of 0.12 ampere is observed at air velocity of 5.3 m/sec. The output power without vortex is observed to increase with the increase in air velocity, a maximum power of 1.296 watt is observed at air velocity of 5.3 m/sec. The turbine efficiency without vortex is observed to increase with the increase in air velocity, a maximum efficiency of 55 % is observed at air velocity of 5.3 m/sec. The turbine speed with vortex is observed to increase with the increase in air velocity, a maximum speed of 458rpm is observed at air velocity of 5.3 m/sec. The output voltage with vortex is observed to increase with the increase in air velocity, a maximum voltage of 11.5 volt is observed at air velocity of 5.3 m/sec. The output current with vortex is observed to increase with the increase in air velocity, a maximum voltage of 0.133 ampere is observed at air velocity of 5.3 m/sec. The output power with vortex is observed to increase with the increase in air velocity, a maximum power of 1.529 watt is observed at air velocity of 5.3 m/sec. The turbine efficiency with vortex is observed to increase with the increase in air velocity, a maximum efficiency of 65.97 % is observed at air velocity of 5.3 m/sec.The Turbine speed with vortex body is observed to be greater than that without vortex body at all air velocities indicating the positive effect of addition of the vortex body.The Turbine output power with vortex body is observed to be greater than that without vortex body at all air velocities indicating the positive effect of addition of the vortex body.

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