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Design and Analysis of Roof Turbine Ventilator Blade Angles to Produce Electricity from Wind Energy

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ABSTRACT

This paper describes about the modified roof ventilator that can generate electricity from wind energy. wind energy is one types of renewable energy and it does not cause pollution. therefore, presently, there is the technological development of applying wind energy for the electricity generation. wind energy is used to replace fossil energy such as oil and coal, causing environmental pollution. the new modification of the roof ventilator system is by changing the blade angles to help it to spin faster and more efficient. so, we can analyse the roof ventilator system by changing the combinations of blade angles to help it to spin faster and efficient to generate electricity from wind energy. also, we can change the material of the blades to reduce its weight to get more rotation at low wind speeds. comparing the observed performance of new design with previous design to get more efficient power output. This system is mainly suitable to use for the highway places.

Key words: Roof Ventilator, Electricity Generation, Blade Angles, Wind Energy

I. INTRODUCTION

Wind energy is the fastest growing source of clean energy worldwide. A major issue with the technology is fluctuation in the source of wind. There is a near constant source of wind power on the highways due to rapidly moving vehicles. The motivation for this project is to contribute to the global trend towards clean energy in a feasible way. Most wind turbines in use today are conventional wind mills with three air foil shaped blades arraigned around a horizontal axis. These turbines must be turned to face into the wind and in general require significant air velocities to operate. Another style of turbine is one where the blades are positioned vertically or transverse to the axis of rotation. These turbines will always rotate in the same direction regardless of the fluid flow.

Air ventilation ball on the roof of buildings. The ball will be spin by wind blow to ventilate the heat under the roof or in the building. The temperature in the building will be 4-5 Degree Celsius reduced. The ventilated heat depends on the rate of the ventilated balls. For example, the ventilated balls with 24 inches diameters with the wind speed 15 (km/h) can ventilate 6,807 (m3 /h). Or at the wind speed 25 km/h, the ventilated ball can ventilate 8,512 m3 /h (Technology Transfer and Dissemination, 2014). There are 2 parts of ventilation ball. First is ventilated part made from Aluminium. Nowadays, there are many researchers who find the way to develop the air ventilation balls by using the ball to generate the electric current. There are external elements such as electric coils, permanent magnet, and small electric generator to install in the air ventilation ball. Or even adapt the air ventilation ball to move faster to stimulate the rotor.

II. METHODS AND MATERIAL

Problem solving is the method of finding the solution for the problem to be rectified. There are various problem-solving techniques in which the suitable method can be implemented based on the problem.

- Designing the new roof ventilator turbine for harvesting the highway wind energy.
- Analyzing the roof ventilator by changing its materials.
- Analyzing the roof ventilator turbine by changing its blade angles.
- Comparing the observed performance of proposed design with previous design to get more efficient power output.

To finalize the material for an engineering product or application, is it important to understand the mechanical properties of the material. The mechanical properties of a material are those which affect the mechanical strength and ability of a material to be manufactured in suitable shape. In this project we use three types of materials such as Aluminium, Zinc, High Density Polyethylene having Some of the include density, young's modulus, Poisson ratio as shown in table 1

Table 1 Material Properties

Properties / Materials	Density (kg/m^3)	Young's Modulus(Gpa)	Poisson Ratio
Aluminium	2710	68	0.32
Zinc	7135	110	0.2555
High Density Polyethylene	970	0.8	0.35

III. RESULTS AND DISCUSSION

MATERIAL CHANGING ANALYSIS

The following results and discussions of Roof ventilator turbine with changing the materials (Aluminium, Zinc, High density polyethylene) where declared by ANSYS Workbench static structural modelling software are shown in the following figures

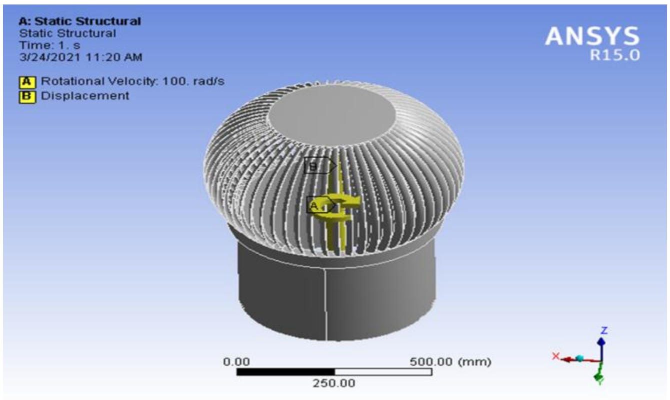

Figure 1 Isometric View of Roof Ventilator Turbine

3.1 ALUMINIUM MATERIAL

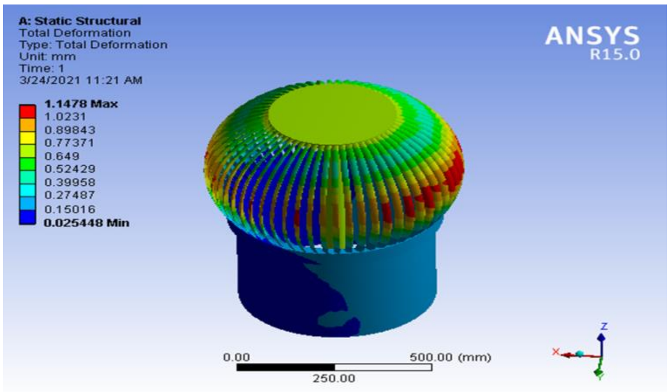

Figure 2 Total Deformation for Aluminium

Minimum Total deformation is 0.0254 mm and the maximum deformation is 1.1478 mm where obtained at the turbine blades of the roof ventilator with aluminium is shown in figure 2.

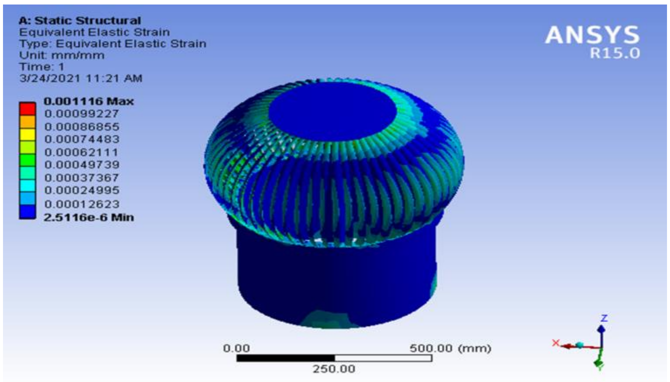

Figure 3 Equivalent Elastic Strain for Aluminium

Minimum equivalent elastic strain is 2.5116×10-6 and the maximum equivalent elastic strain is 0.001116 where obtained at the turbine blades of the roof ventilator with aluminium is shown in figure 3.

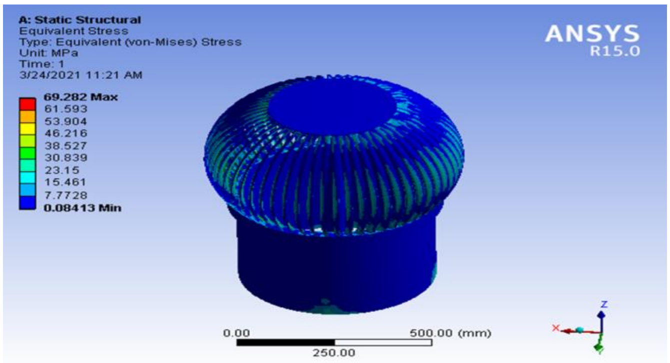

Figure 4 Equivalent (Von-Mises) Stress for Aluminium

Minimum equivalent (Von-mises) stress) is 0.08413 MPa and the maximum equivalent (Von-mises) stress) is 62.282 MPa where obtained at the turbine blades of the roof ventilator with aluminium is shown in figure 4.

3.2 ZINC MATERIAL

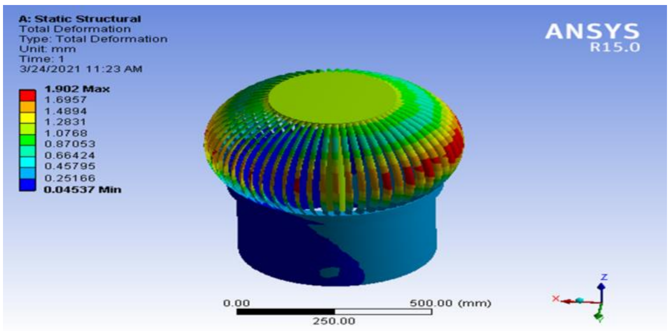

Figure 5 Total Deformation for Zinc

Minimum Total deformation is 0.04537 mm and the maximum deformation is 1.6957 mm where obtained at the turbine blades of the roof ventilator with zinc is shown in figure 5.

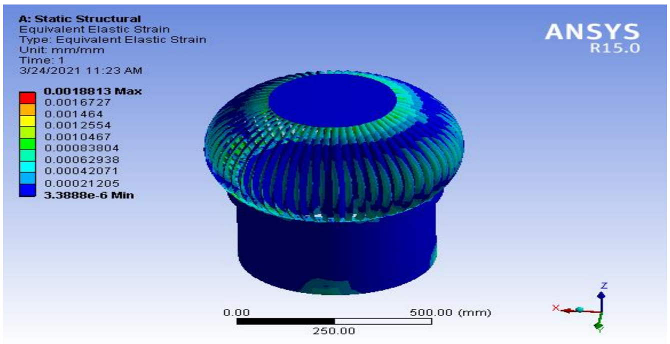

Figure 6 Equivalent Elastic Strain for Zinc

Minimum equivalent elastic strain is 3.3888×10-6 and the maximum equivalent elastic strain is 0.0018813 where obtained at the turbine blades of the roof ventilator with zinc is shown in figure 6.

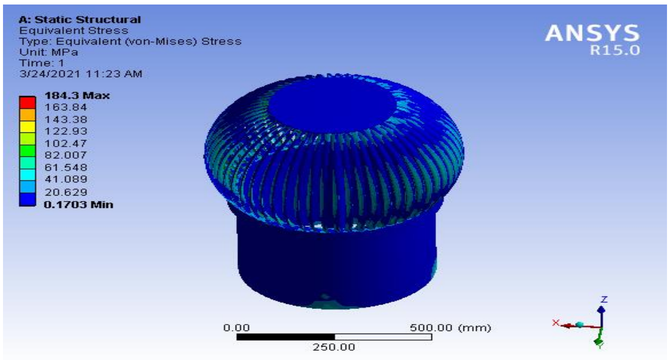

Figure 7 Equivalent (Von-Mises) Stress for Zinc

Minimum equivalent (Von-mises) stress) is 0.1703 MPa and the maximum equivalent (Von-mises) stress) is 184.3 MPa where obtained at the turbine blades of the roof ventilator with zinc is shown in figure 7.

3.3 HIGH DENSITY POLYETHYLENE

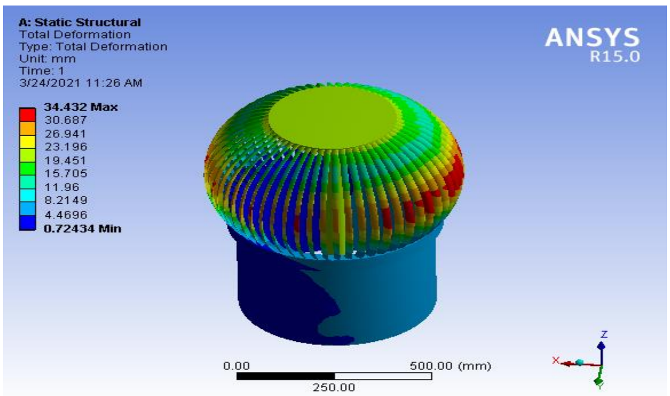

Figure 8 Total Deformation for HDPE

Minimum Total deformation is 0.7243 mm and the maximum deformation is 34.432mm where obtained at the turbine blades of the roof ventilator with high density polyethylene is shown in figure 8.

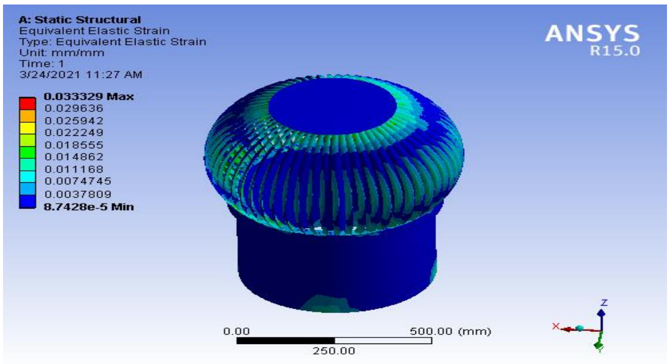

Figure 9 Equivalent Elastic Strain for HDPE

Minimum equivalent elastic strain is 8.7428×10-5 and the maximum equivalent elastic strain is 0.033329 where obtained at the turbine blades of the roof ventilator with high density polyethylene is shown in figure 9.

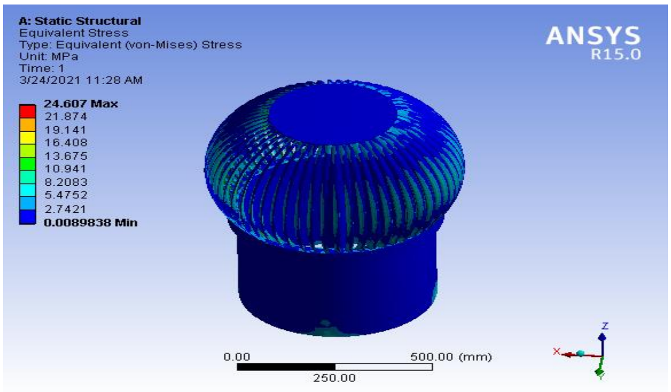

Figure 10 Equivalent (Von-Mises) Stress for HDPE

Minimum equivalent (Von-mises) stress) is 0.008983 MPa and the maximum equivalent (Von-mises) stress) is 24.607 MPa where obtained at the turbine blades of the roof ventilator with high density polyethylene is shown in figure 10.

3.4 COMPARISION CHART FOR TOTAL DEFORMATION

Table 2 Total Deformation

Materials	Aluminium	Zinc	HDPE
Total Deformation (mm)	1.1478	1.902	34.432

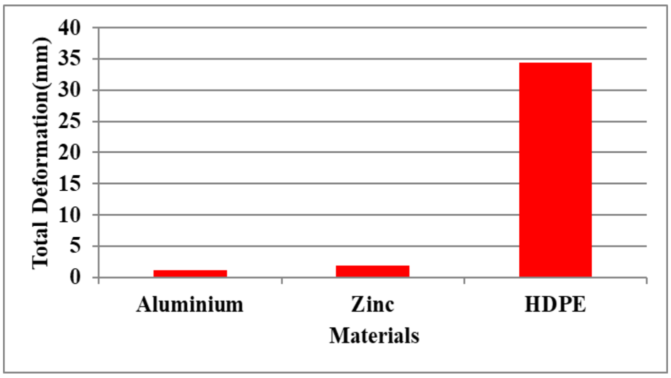

Figure 11 Deformation Chart

- Total deformation is high at high density polyethylene with the value of 34.432 mm.
- Aluminium material has low deformation.
- These comparisons of the turbulence kinetic energy values are shown in figure 11.

3.5 COMPARISION CHART FOR EQUIVALENT ELASTIC STRAIN

Table 3 Equivalent Elastic Strain

Materials	Aluminium	Zinc	HDPE
Equivalent Elastic Strain	1.12e-03	1.88e-03	0.033329

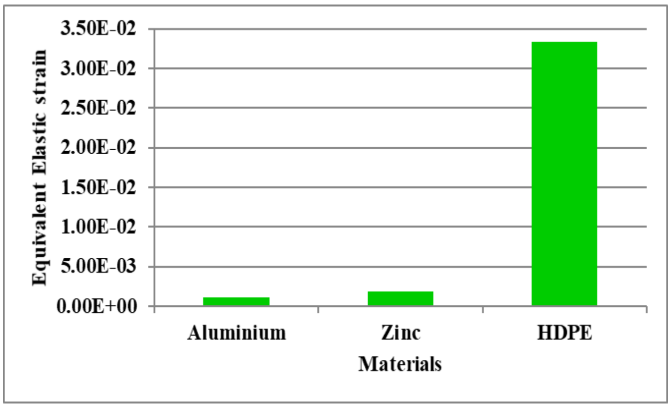

Figure 12 Equivalent Elastic Strain Chart

- Equivalent elastic strain is high at high density polyethylene material with the value of 0.033329.
- Aluminium material has less equivalent elastic strain.
- These comparisons of the equivalent elastic strain values are shown in figure 12.

3.6 COMPARISION CHART FOR EQUIVALENT STRESS

Table 4 Equivalent Stress

Materials	Aluminium	Zinc	HPDE
Equivalent Stress (MPa)	69.282	184.3	24.607

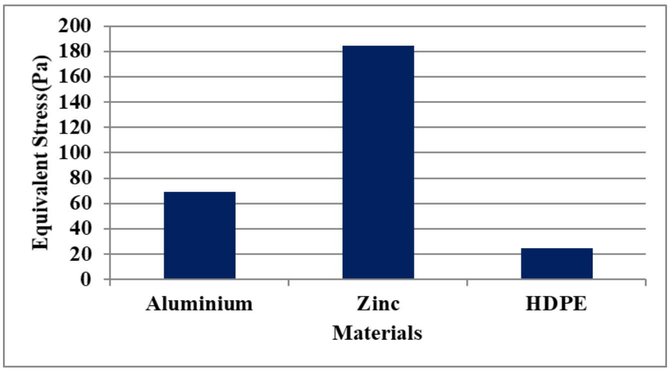

Figure 13 Equivalent Stress Chart

- Equivalent stress is high at Zinc material with the value of 184.3 MPa.
- High density polyethylene has less equivalent stress.
- These comparisons of the equivalent stress values are shown in figure 13.

3.7 PRESSURE, TURBULENCE KINETIC ENERGY AND VELOCITY ANALYSIS OF BANKI TURBINE

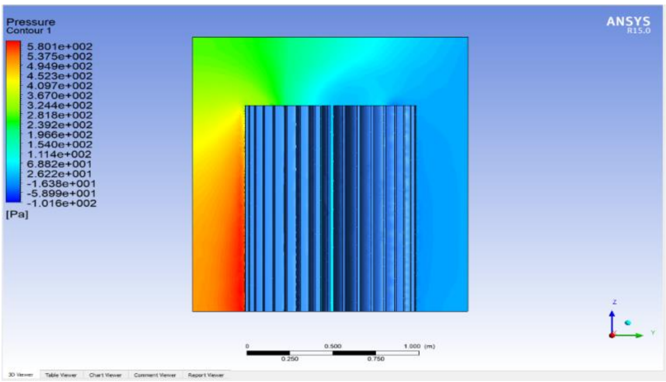

Figure 14 Pressure Contour Plot

Minimum pressure contour plot is -1.016×102 Pa and the maximum pressure contour plot is 5.821×102 Pa where obtained at the turbine blades of the Banki Model is shown in figure 14.

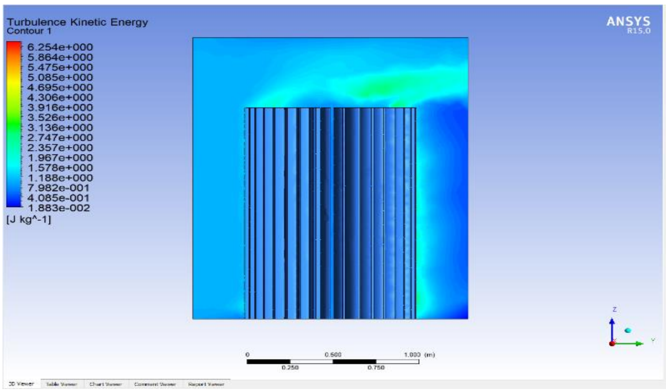

Figure 15 Turbulence Kinetic Energy

Minimum Turbulence kinetic Energy contour plot is 1.016×102 Pa and the maximum Turbulence kinetic Energy contour plot is 5.821×102 Pa where obtained at the turbine blades of the Banki Model is shown in figure 15.

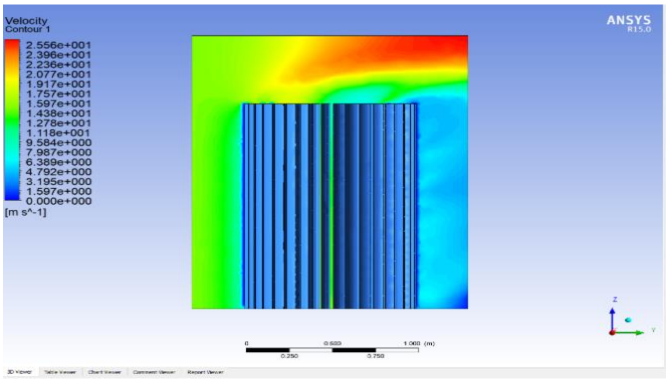

Figure 16 Velocity Contour Plot

Minimum velocity contour plot is 0 m/s and the maximum Velocity contour plot is 2.556×102 m/s where obtained at the turbine blades of the Banki Model is shown in figure 16.

3.8 PRESSURE, TURBULENCE KINETIC ENERGY AND VELOCITY ANALYSIS OF EXISTING MODEL TURBINE

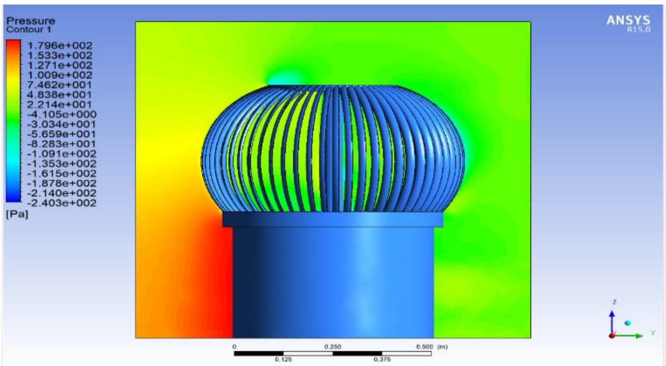

Figure 17 Pressure Contour Plot

Minimum pressure contour plot is -2.403×102 Pa and the maximum pressure Contour Plot is 1.796×102 Pa Where Obtained at The Turbine Blades of The Existing Model is shown in figure 17.

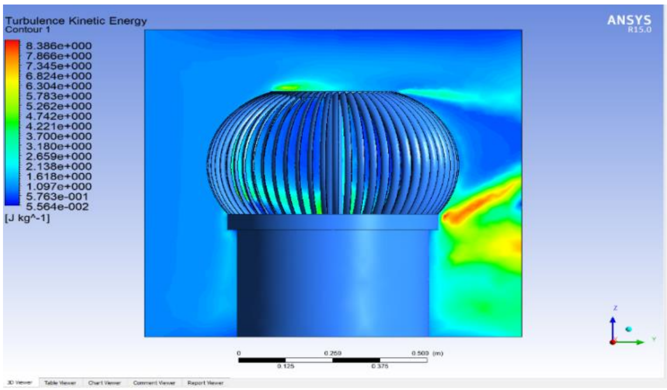

Figure 18 Turbulence Kinetic Energy Contour Plot

Minimum Turbulence Kinetic Energy contour plot is 5.564e×102 J/Kg and the maximum Turbulence Kinetic Energy contour plot is 8.386e×102 J/Kg where obtained at the turbine blades of the Existing model is shown in figure 18.

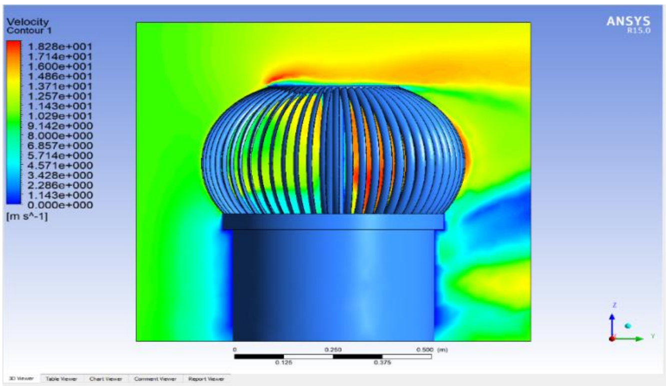

Figure 19 Velocity Contour Plot

Minimum Velocity contour plot is 0 m/s and the maximum Velocity contour plot is 1.828e×102 m/s where obtained at the turbine blades of the Existing model is shown in figure 19.

3.9 PRESSURE, TURBULENCE KINETIC ENERGY AND VELOCITY ANALYSIS OF PROPOSED MODEL TURBINE BY CHANGING ITS BLADE ANGLES

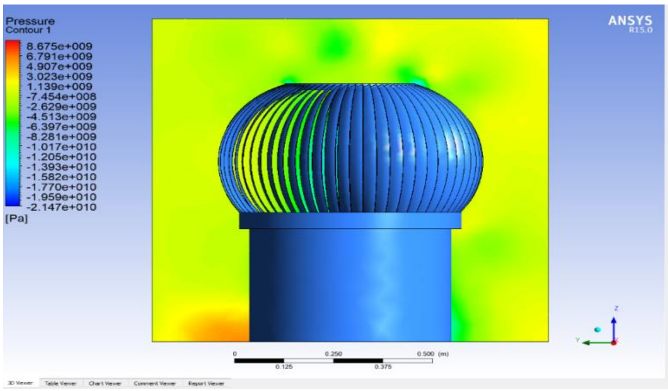

Figure 20 Pressure Contour Plot

Minimum pressure contour plot is -2.147×1010 Pa and the maximum pressure contour plot is 8.675×109 Pa where obtained at the turbine blades of the Proposed model is shown in figure 20.

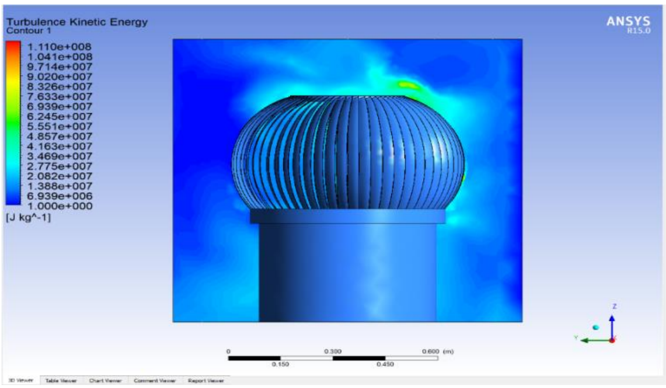

Figure 21Turbulence Kinetic Energy Contour Plot

Minimum Turbulence Kinetic Energy contour plot is 1.000 J/kg and the maximum Turbulence Kinetic Energy contour plot is 1.110e×108 J/kg where obtained at the turbine blades of the Proposed model is shown in figure 21.

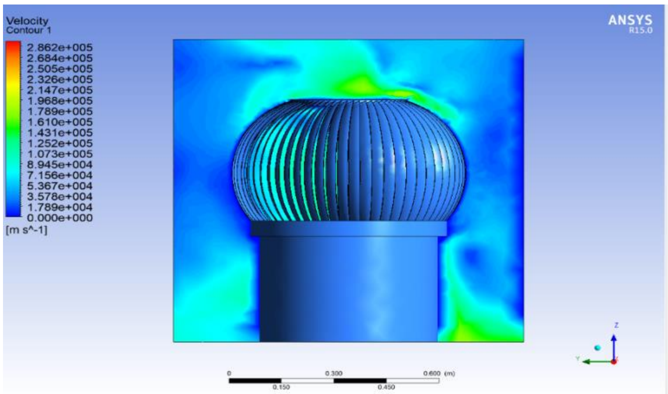

Figure 22 Velocity Contour Plot

Minimum Velocity contour plot is 0 m/s and the maximum Velocity contour plot is 2.862×105 m/s where obtained at the turbine blades of the Proposed model is shown in Figure 22.

3.10 PRESSURE COMPARISON CHART

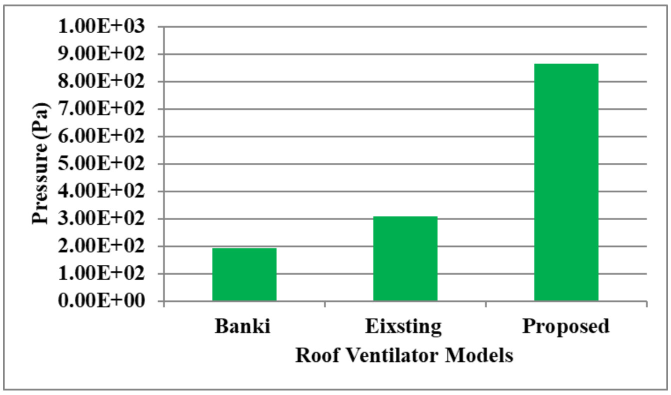

Figure 8.27 Pressure Comparison Chart

- Pressure is high at new design of roof ventilator with the value of 1.00×103 m/s.
- Banki model turbine design has less pressure.
- These comparisons of the pressure values are shown in figure 8.27.

3.11 TURBULENCE KINETIC ENERGY COMPARISION CHART

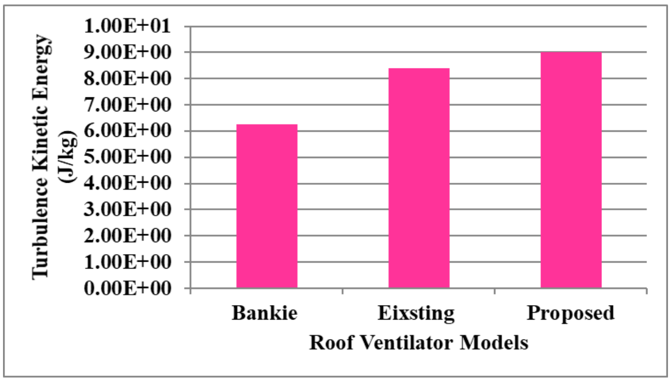

Figure 23 Turbulence Kinetic Energy Comparison Chart

- Turbulence kinetic energy is high at new design of roof ventilator with the value of 9.02 J/Kg.
- Banki model turbine design has less turbulence kinetic energy.
- These comparisons of the turbulence kinetic energy values are shown in figure 23.

3.12 VELOCITY COMPARISION CHART

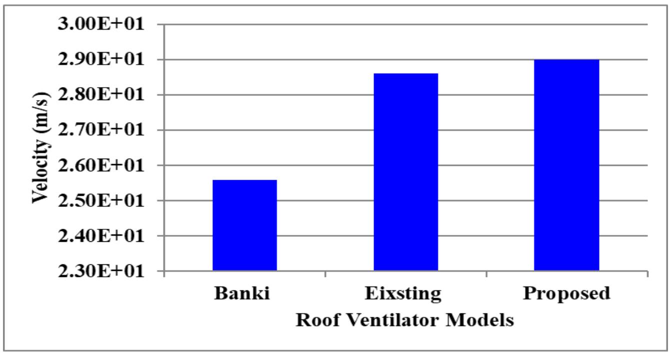

Figure 24 Velocity Comparison Chart

- Velocity is high at new design of roof ventilator with the value of 2.90×101 m/s.
- Banki model turbine design has less turbulence kinetic energy.
- These comparisons of the velocity values are shown in figure 24.

IV. POWER OUTPUT CALCULATIONS

- POWER (P) = 0.5ρAv3Cp (Watts)
- Air density (ρ) = 1.293 (kg/m3)
- Power coefficient (Cp) = 0.4 to 0.59
- V = Wind speed (m/s), = 15 (m/s)

4.1 BANKI TURBINE

- Power available (Pavail) = 0.5ρAv3Cp (Watts)
- Air density (ρ) = 1.293 (kg/m3)
- Area (A) = πr2 (mm2)
- Power coefficient (Cp) = 0.42 to 0.59
- V = Wind speed (m/s) = 15 m/s
- Diameter (d) = 500 (mm)
- Radius (r) = 250 (mm) = 0.250 (m)

4.1.1 Area

Area (A) = πr2 (m2)

= π ×0.252

(A) = 0.196 (m2)

4.1.2 Power Available

Power (Pavail) = 0.5ρAv3Cp (Watts)

P = 0.5×1.293×0.196× (153) ×0.4

Power (Pavail) = 192.44 (Watts)

4.2 EXISTING ROOF VENTILATOR TURBINE

- Power available (Pavail) = 0.5ρAv3Cp (Watts)
- Air density (ρ) = 1.293 (kg/m3)
- Area (A) = πr2 (mm2)
- Power coefficient (Cp) = 0.4 to 0.59
- V = Wind speed (m/s) = 15 (m/s)
- Diameter (d) = 670 (mm)
- Radius (r) = 335 (mm) = 0.335 (m)

4.2.1 Area

Area (A) = πr2 (m2)

= π ×0.3352

(A) = 0.352 (m2)

4.2.2 Power Available

Power (Pavail) = 0.5ρAv3Cp (Watts)

P = 0.5×1.293×0.352× (153) ×0.4

Power (Pavail) = 307.21 (Watts)

4.3 PROPOSED MODEL ROOF VENTILATOR TURBINE

- Power available (Pavail) = 0.5ρAv3Cp (Watts)
- Air density (ρ) = 1.293 (kg/m3)
- Area (A) = πr2 (mm2)
- Power coefficient (Cp) = 0.4 to 0.59
- V = Wind speed (m/s) = 15 (m/s)

When changing the angle of the turbine blades 60˚ outwards so there is a change in diameter of the blade from 670 mm to 690 mm.

- Diameter (d) = 690 (mm)
- Radius (r) = 345 (mm) = 0.345 (m)

4.3.1 Area

Area (A) = πr2 (m2)

= π ×0.3452

(A) = 0.373 (m2)

4.3.2 Power Available

Power (Pavail) = 0.5ρAv3Cp (Watts)

Pavail = 0.5×1.293×0.373× (153) ×0.4

Power (Pavail) = 325.54 (Watts)

4.4 POWER OUTPUT COMPARISION

Table 5 Power Output Comparison

Turbine models	Banki	Existing	Proposed
Power Output (Watts)	192.44	307.21	325.54

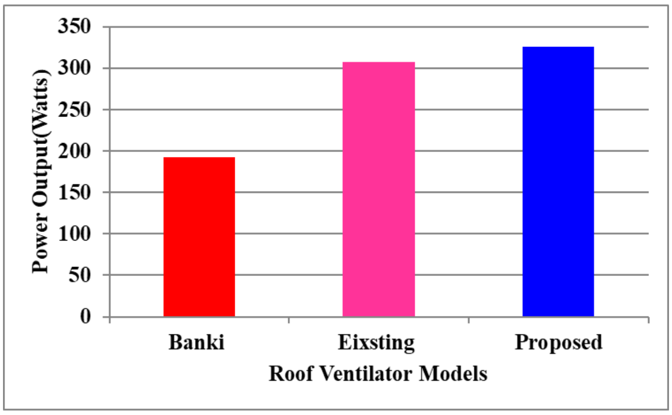

Figure 25 Power Output

- Maximum power output is 325.5(Watts) available at the Proposed model roof turbine ventilator.
- Banki model turbine has less power output.
- These comparisons of the power output values are shown in figure 25

V. CONCLUSION

The results obtained from the CFD Analysis and FEA analysis materials and roof ventilator design can be finalized, structural analysis give the result of High Density Polyethylene material give the better structural performance then the zinc and aluminium material, the results of CFD Analysis give the flow analysis comparison of Banki Model Turbines, Existing Roof Ventilator model and Proposed Roof Ventilator model, comparison of the results of power output calculations, Proposed Roof Ventilator model has high power output with the value of

325.54(Watts), The Banki model turbine has less power output with the value of 192.44(Watts) and the Existing Roof Ventilator model has 307.21(Watts) which means Proposed Roof Ventilator model give better flow performances which it is 15% performance increase from existing roof ventilator model and more than 35% performance compare to the Banki turbine model.

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