DESIGN ANALYSIS OF COMPONENTS OF COMPACT MICRO GENERATION CAPABILITY VERTICAL AXIS WIND TURBINE

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Abstract: With the conventional energy resources new diminishing the employment of renewable energy sources like the wind energy, solar energy is need of the time. One of the potential area for micro generation by harnessing wind energy is to use the pressure variations attained due vehicle motion by application of innovative lightweight materials and with aid of additive manufacture technology development of a compact vertical axis wind turbines h. Present paper discusses the component design of one such novel design of an vertical axis wind turbine with four vane profile having micro generation capability. The paper deals with design development of the, top vane holder, bottom vane holder, vortex chamber, turbine shaft, coupler shaft and shaft bearing holder. The theoretical design of the components has been done after appropriate selection of materials, followed by solid modelling of the components using Unigraphix Nx. The static structural analysis of the components has been done using Ansys work bench 16.0. The design of the component suing the theoretical method is thus validated using the ansys results. The structural strength of the critical components of vertical axis wind turbine is thus validated using analytical results.

Keywords : Wind energy , micro-generation , compact vertical axis turbine , additive manufacture technology , vane holders , turbine shaft , vortex chamber , coupler shaft , shaft bearing holder

I. INTRODUCTION

Apart from the conventional methods of wind energy generation there is enough scope for development of low scale or micro-generation of energy using wind through application of pressure variations due vehicle motion either transport road vehicles or, railways. Devices can be effected for harnessing wind energy through the development of a compact design vertical axis with turbine that uses lightweight materials and the complex geometry of the vanes attained through innovative design of the vane holders that can be produced without much difficulty using fused deposition method using cad design which will make the adoption of these micro generator units easy due to their compact size, easy of manufacture and low cost.

A. Schematic of the Compact micro generation capability Vertical Axis Wind Turbine

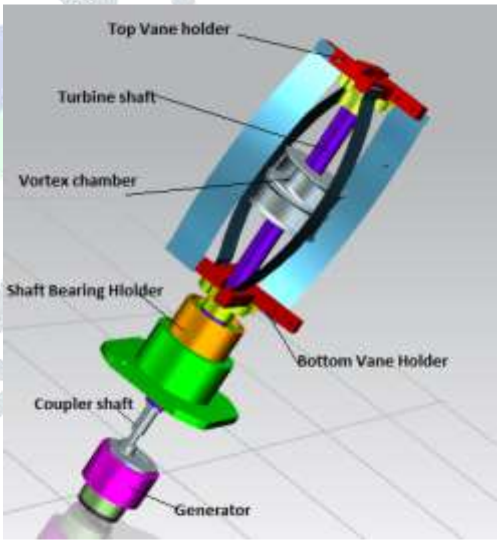


Fig. 1 : Schematic of compact VAWT

The figure above displays the constructional features of the proposed compact vertical axis wind turbine where in the four vanes are held on the turbine shaft with the help of the top vane holder and bottom vane holder. The top and bottom vane holders are designed to hold four vanes and the combination of the face tapers and vertical axis skew in the assembly enables to create the design vane opening angle without any special machining process. The vanes are fabricated from flexible poly propylene sheets where as the top and bottom holders are fabricated by fused deposition method which employs a3-d printing machine and ABS polymer is used as the material for the vane holders. Addition of the vortex chamber will supposedly increase the power output of the turbine

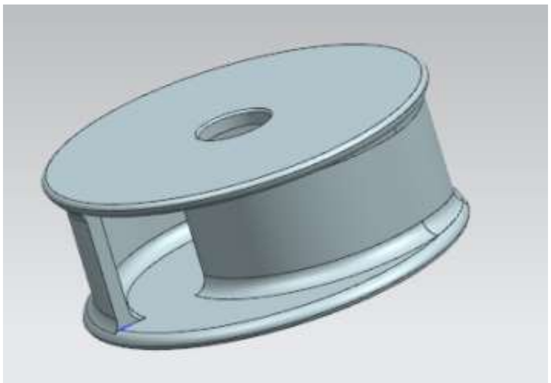


Fig. 1 : Schematic of vortex chamber

Input data for design through sizing of the VAWT

The following results for design of the compact vertical axis wind turbine are as follows:

1. The minimum power extracted by the turbine at speed of 30 kmph is 12.85 Watt
2. The minimum power extracted by the turbine at speed of 80 kmph is 103.2667 Watt
3. The rotor diameter is 180 mm the turbine height is 215 mm, minimum wing width is 25.2 mm whereas the minimum wing chord is 50 mm.
4. The component weight of the turbine vane holder is as low as 28.2 gm
5. Maximum torque @ turbine shaft = 1.12 N-m

Compact micro generation capability Vertical Axis Wind Turbine

II. DESIGN OF TURBINE SHAFT

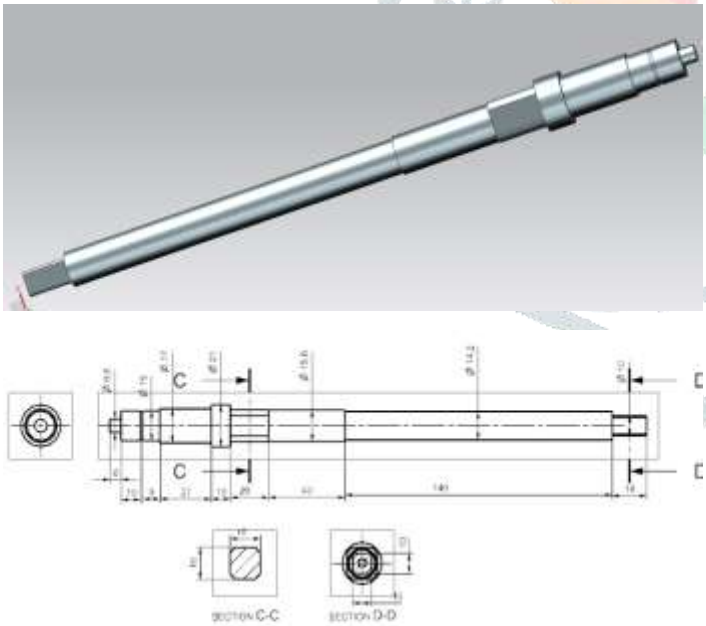


Fig. 3 : Design of Turbine Shaft

Table 1. MATERIAL SELECTION : -Ref :- PSG (1.10 & 1.24)

DESIGNATION	ULTIMATE TENSILE STRENGTH (MPa)	YEILD STRENGTH (MPa)
Aluminium 24345	480	310

As per ASME code $fs_{allowable}$= 87Mpa

Check for torsional shear failure of shaft

$$T_e = \frac{\Pi fs\, d^3}{16}$$

fs_{act} = 11.13940165 MPa As; $fs_{act} < fs_{all}$

The Turbine shaft is safe under torsional load

B. Analysis of Turbine shaft

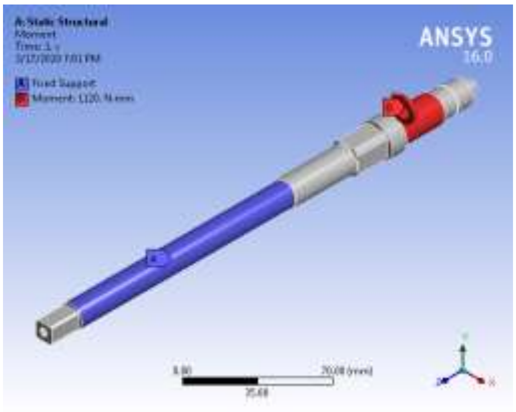


Fig. 4 : Analysis of Turbine shaft

The component geometry was developed using Unigraphix NX and step file was used as input to ansys workbench, the boundary conditions and loading was done as shown in figure above.

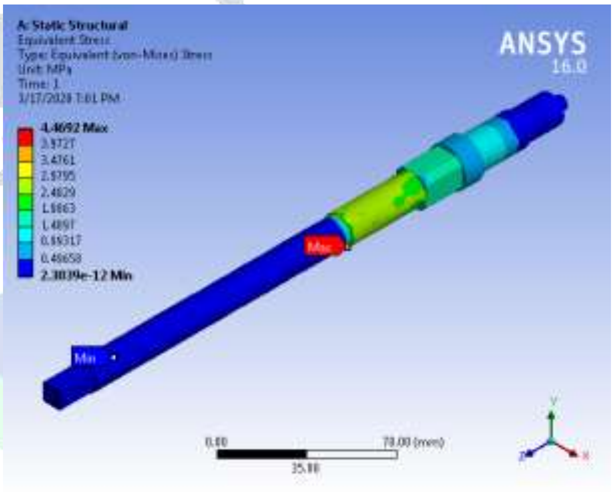
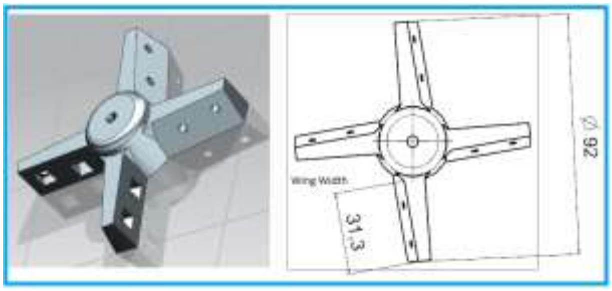


Fig. 5 :

The maximum von mises stress developed is 4.45 Mpa which is well below the allowable stress hence the turbine shaft is safe under torsional load.

III. TOP VANE HOLDER



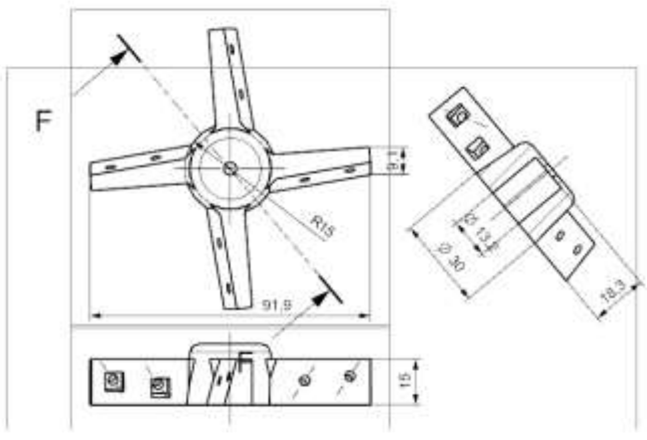


Fig. 6 : Top Vane Holder Geometry

Table 2. MATERIAL SELECTION: -Ref :- PSG (1.10 & 1.18)

DESIGNATION	ULTIMATE TENSILE STRENGTH (MPa)	YEILD STRENGTH (MPa)
ABS Polymer	66	48

As per ASME code $fs_{allowable}$= 12Mpa

Check for torsional shear failure of shaft

$Td = \Pi/16 \times fs_{act} x(D^4 - d^4) /D$

fs_{act} = 2.161575248 Mpa As; $fs_{act}<fs_{all}$

The top vane holder is safe under torsional load

C. Analysis Top vane Holder

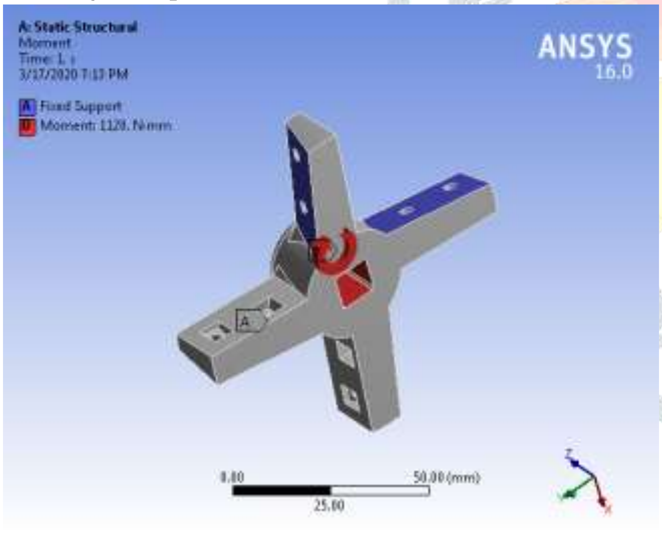


Fig. 7 : Analysis of top vane Holder

The component geometry was developed using Unigraphix NX and step file was used as input to ansys workbench, the boundary conditions and loading was done as shown in figure above.

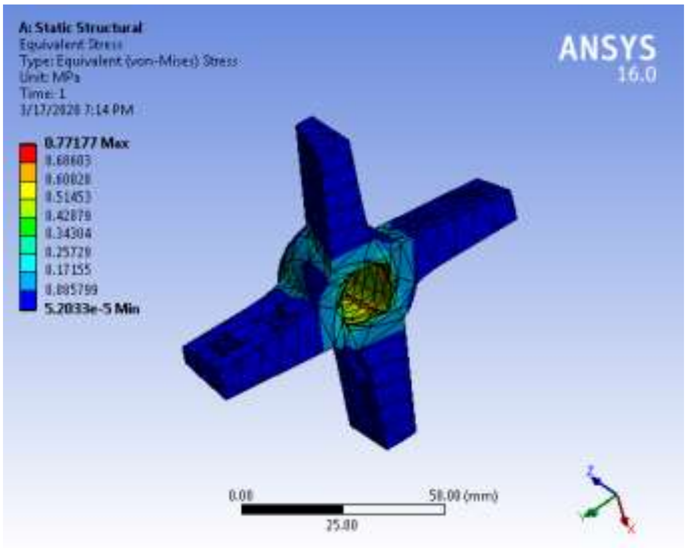


Fig. 8 :

The maximum von mises stress developed is 4.45 Mpa which is well below the allowable stress hence the turbine shaft is safe under torsional load

IV. BOTTOM VANE HOLDER

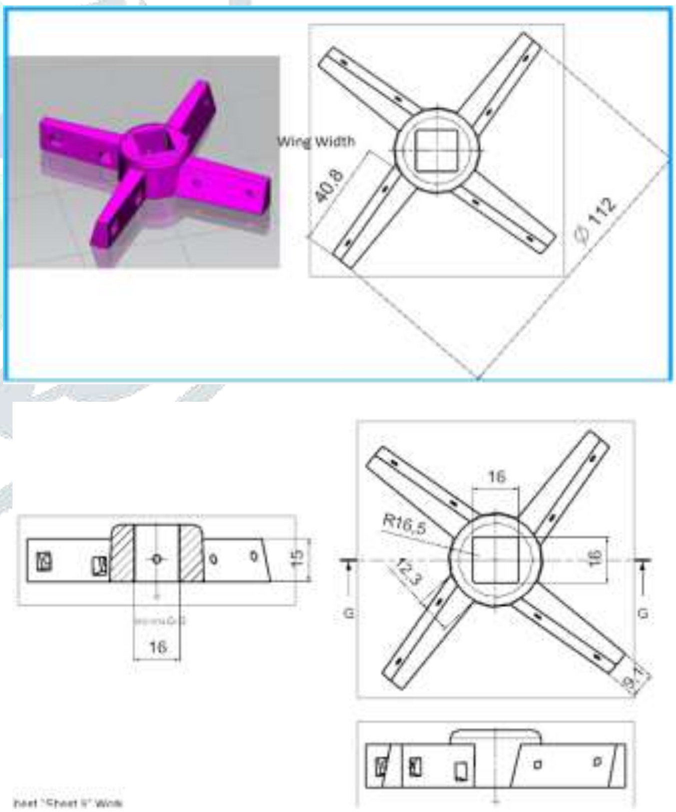


Fig. 9 : Bottom van holder

Table 3. MATERIAL SELECTION : -Ref :- PSG (1.10 & 1.18)

DESIGNATION	ULTIMATE TENSILE STRENGTH (MPa)	YEILD STRENGTH (MPa)
ABS Polymer	66	48

As per ASME code $fs_{allowable}$= 12Mpa

Check for torsional shear failure of shaft

$Td = \Pi/16 \times fs_{act} x(D^4 - d^4) /D$

fs_{act} = 2.268933353 Mpa As; $fs_{act}<fs_{all}$

The top vane holder is safe under torsional load

D. Analysis of Bottom vane Holder:

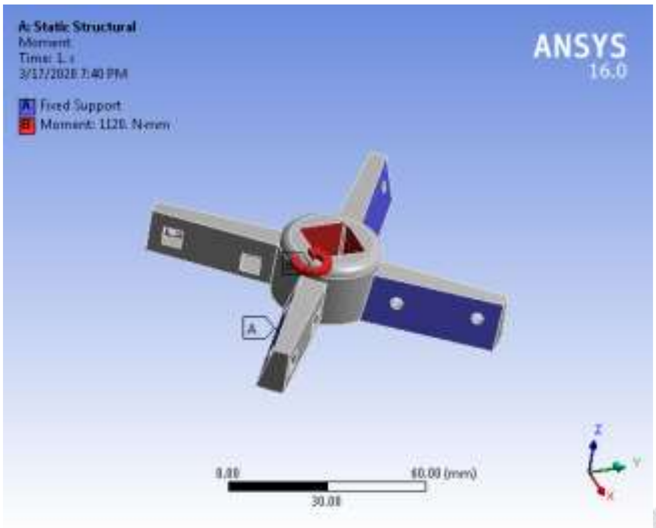


Fig. 10 : Analysis of bottom van holder

The component geometry was developed using Unigraphix NX and step file was used as input to ansys workbench, the boundary conditions and loading was done as shown in figure above.

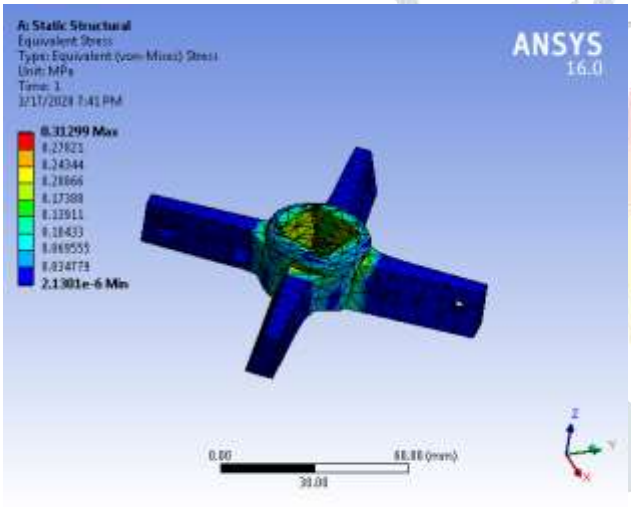


Fig. 11 :

The maximum von mises stress developed is 0.312 Mpa which is well below the allowable stress hence the turbine shaft is safe under torsional load

V. VORTEX CHAMBER

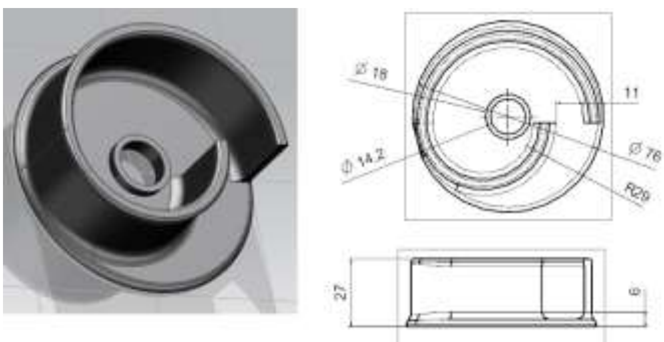


Fig.12 : Vortex Chamber

Table 4. MATERIAL SELECTION : -Ref :- PSG (1.10 & 1.18)

DESIGNATION	ULTIMATE TENSILE STRENGTH (MPa)	YEILD STRENGTH (MPa)
ABS Polymer	66	48

As per ASME code $fs_{allowable}$= 12Mpa

Check for torsional shear failure of shaft

$Td = \Pi/16 \times fs_{act} \times (D^4 - d^4) /D$

fs_{act} = 0.128668458Mpa As; $fs_{act} < fs_{all}$

The vortex chamber is safe under torsional load

E. Analysis of Vortex chamber :

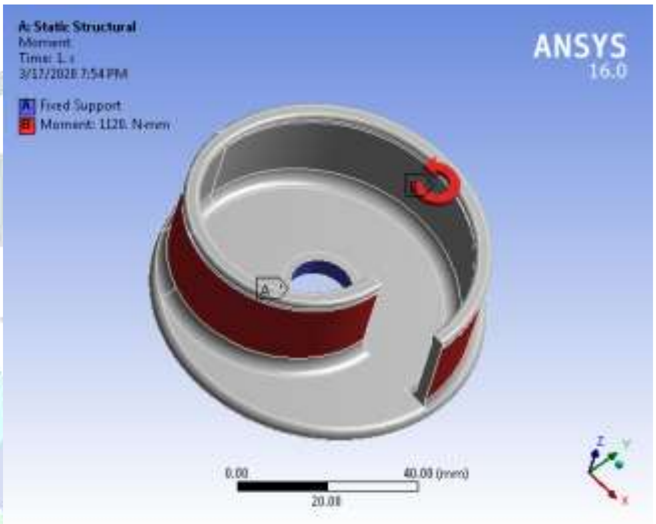


Fig.13 : Analysis of Vortex chamber

The component geometry was developed using Unigraphix NX and step file was used as input to ansys workbench, the boundary conditions and loading was done as shown in figure above.

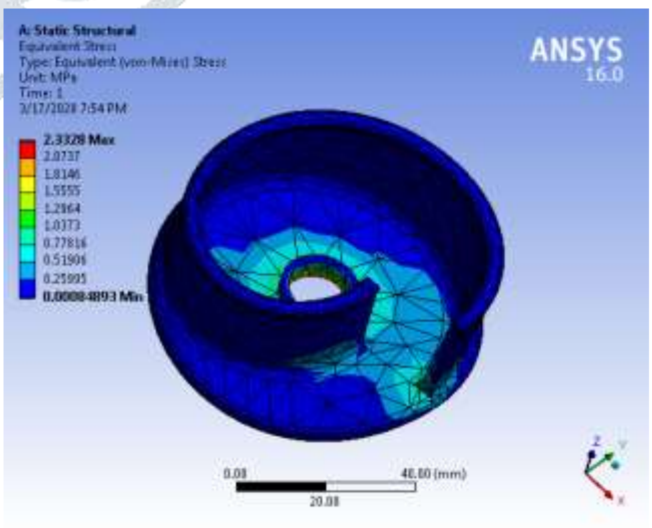


Fig.14 :

The maximum von mises stress developed is 2.328 Mpa which is well below the allowable stress hence the vortex chamber is safe under torsional load

VI. DESIGN OF COUPLER SHAFT

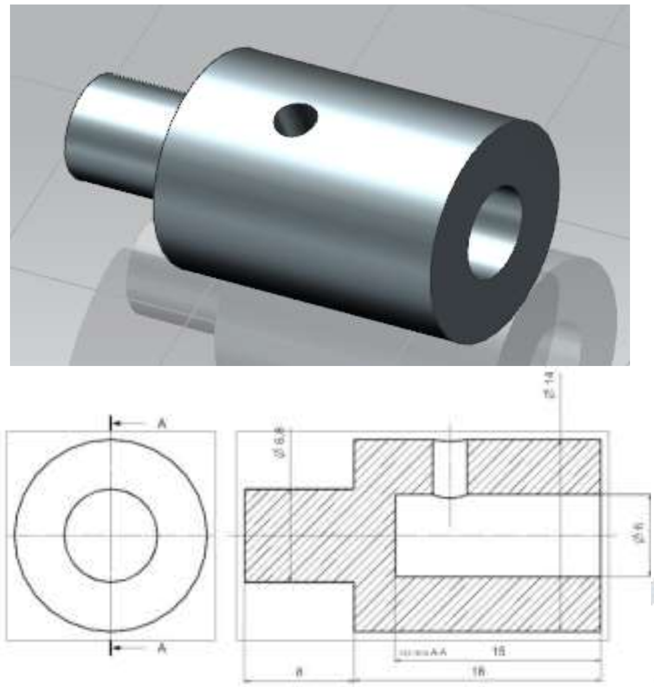


Fig.15 : Design of Coupler Shaft

Table 5. MATERIAL SELECTION : -Ref :- PSG (1.10 & 1.24)

DESIGNATION	ULTIMATE TENSILE STRENGTH (MPa)	YEILD STRENGTH (MPa)
Aluminium 24345	480	310

As per ASME code $fs_{allowable}$= 87Mpa

Check for torsional shear failure of shaft

$$Te = \frac{\Pi fs\, d^3}{16}$$

fs_{act} = 18.13865525

MPa As; $fs_{act} < fs_{all}$

The Coupler shaft is safe under torsional load

F. Analysis of Coupler shaft :

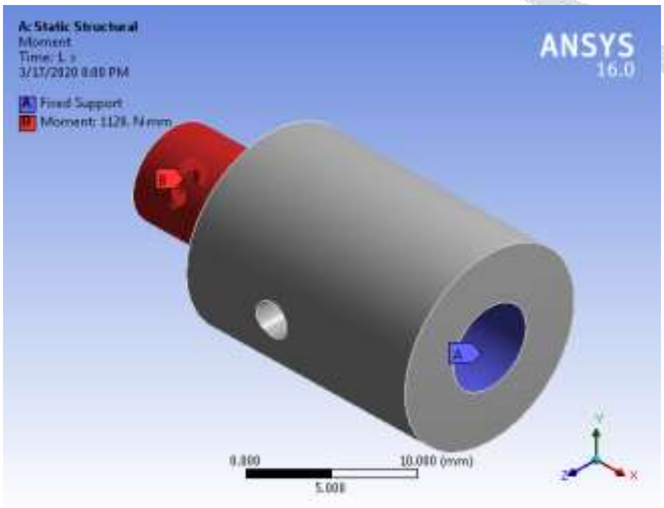


Fig.16 : Analysis of coupler shaft

The component geometry was developed using Unigraphix NX and step file was used as input to ansys workbench, the boundary conditions and loading was done as shown in figure above.

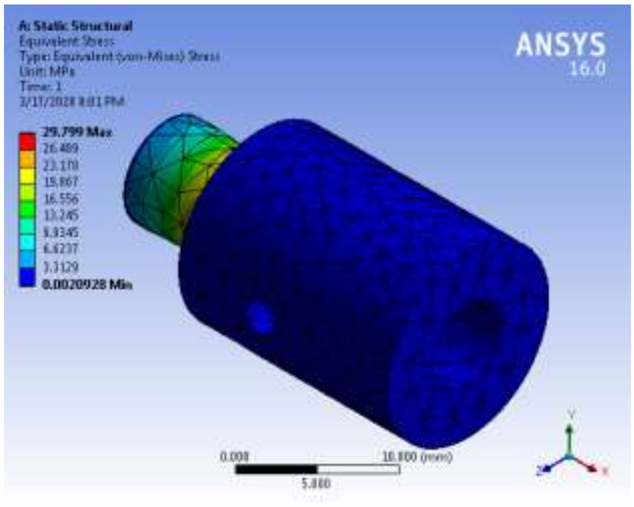


Fig.17 :

The maximum von mises stress developed is 29.29 Mpa which is well below the allowable stress hence the coupler shaft is safe under torsional load

Result and Discussion

The following results for design and analysis of critical components of the Vertical axis wind turbine

1. Maximum stress induced by theoretical method in the turbine shaft is 11.3 Mpa and the maximum Von-mises stress determined using Ansys Workbench is 4.48 Mpa , both are well below the allowable limit hence the worm shaft is safe under torsional load.
2. Maximum stress induced by theoretical method in the top vane holder is 2.16 Mpa and the maximum Von-mises stress determined using Ansys Workbench is 0.7174 Mpa , both are well below the allowable limit hence the top vane holder is safe under torsional load.
3. Maximum stress induced by theoretical method in the bottom vane holder is 2.26 Mpa and the maximum Von-mises stress determined using Ansys Workbench is 0.319 Mpa , both are well below the allowable limit hence the bottom vane holder is safe under torsional load.
4. Maximum stress induced by theoretical method in the vortex chamber is 0.126 Mpa and the maximum Von-mises stress determined using Ansys Workbench is 2.33 Mpa , both are well below the allowable limit hence the vortex chamber is safe under torsional load.
5. Maximum stress induced by theoretical method in the coupler shaft is 18.13 Mpa and the maximum Von-mises stress determined using Ansys Workbench is 29.29 Mpa , both are well below the allowable limit hence the Coupler shaft is safe under torsional load.

Conclusion

The sizing, design analysis critical components of vertical axis wind turbine is successfully done and the dimensions of the components have being determined. Estimation of the maximum stress induced in the components of the mixer have being determined by both theoretical method as well as using Ansys Work bench and the results indicate that the maximum stress values are well below the permissible limit hence the parts are safe under given system of loads.

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