Design Of Advanced Multi-Power Station Turbine Structure For Efficient Power Generation

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Abstract- *In today's world, there is a huge requirement of power and there is limited source of energy available. So we are creating a "Advanced Multi-Power Station Turbine Structure for Efficient Power Generation". In this structure we are going to use multi power station turbine structure with multiple generators which is driven by non-conventional energy resources like wind energy. The advantage of this structure is that we are getting more power due to the arrangement of single turbine with multiple generators. As compared to other structure we are getting higher efficiency. We can use this project in industrial and agricultural applications. It will more precisely work on high altitude. In this project we have modified the turbine structure due to which air impact area is more as compared to existing structures. Due to increased surface area of turbine more air is restricted due to which rotation of turbine is increased which is helpful in higher power generation.*

Keywords- Advanced Savonius unit, Main Bigger Arm, Sub 8 Arms and Multiple Generators Units.

I. INTRODUCTION

Previously till date we were aware of multiple power station and related turbines but as per future requirement of power in accordance with increasing population taken into consideration move towards a new innovation in the power generation i.e. Multi-Station power generation over single advanced Savonius turbine that means this turbine having efficiency of using Artificial as well as Natural Resources for rotation i.e. air, water, etc. This project uses a savonius structure which is very advanced and having efficiency greater that other turbines also this structure able to rotate multiple generators so that we can able to handle multiple power stations using that single unit. Now a day's power requirement is the biggest demand in the growing world. Since last decade we are using multiple turbines structure so accordingly we have succeeded to move only one generator and one station but this structure succeed to rotate multiple generators and according having capability to move multiple stations. This Advanced Multi-Station Structure unit uses 4 units i.e. Advanced Savonius unit, Main Bigger Arm, Sub 8 Arms, Multiple Generators Units so ultimately created Multi-Station Structure. This Multi-Station Structure is the demand of developing technology.

II. UNITS OF MACHINE

This savonius system uses basically 4 main systems

1. Turbine Unit
2. Generator Unit
3. Gear Arrangement Unit
4. Basement Unit Electrical Output Unit

This turbine is basically a system that means works on air flow. This system use multi station electricity generation unit. Basically it is increased RPM arrangement. This system uses arm arrangement that means with the single rotation savonius turbine the main arm rotates multiple times, with the single rotation of main arm sub arm rotates multiple times. With the single rotation of sub arm generator rotates multiple times. Finally, with the minimum rotation of turbine generator will rotates multiple times.

This system is basically a multi station electricity generation that means with the single rotation of turbine the 8 generator rotates. There 8 generator provides and run individual 8 different output. For multistation generation here used drive and driven arrangement of gear. Here used linking spur gear arrangement. Ultimately as shown in figure here used a complete gear box for rotation of multiple generators.

III. DESIGN CALCULATIONS

- **MECHANICAL POWER**

Mechanical Power (P_m)= Cp x P_{air}

But, $P_{air} = \frac{1}{2} \times mV^2$

$= \frac{1}{2}\rho AV^3$

Where, P_{air}= Power by air impact
Cp = Power coefficient
ρ = Density of air
V =Velocity of air

A = Area of rotor

Now, we know

Cp = 0.245 …… (From standard power coefficient / tip speed ratio diagram) Literature

So, Cp = 0.245

ρ = 1.225 kg/m^3 (density of air)

V = 4 to 14 m/s ……… (Assume, V = 4 m/s as per low wind speed region)

A = 0.403 m^2

Put all these value in above equation,

$\therefore P_m = \frac{1}{2}$ x 1.225 x 0.403 x 5^3 x 0.245

$\therefore$ **P_m = 4.917 watt**

- **DRAG FORCE**

Used the C_{fd} for calculating the co-efficient of drag which is used in the calculation of drag force. C_{fd} generates a graph of co-efficient of drag against the number of iterations performs. The input used in C_{fd} is the velocity of wind i.e. 5 m/s.

$\therefore F_D = \frac{1}{2}\rho A V^2$ x C_{fd}

Where, F_D= drag force

ρ = Density of air

V =Velocity of air

A = Area of rotor

C_D= co-efficient of drag

Known values,

Density=1.225 kg/m^3

Velocity = 4 m/s

Area = 0.403 m^2

Figure 6.3: Graph of co-efficient of drag

$\therefore C_D$= 3.75 ……… (Maximum value observed in above constant graph)

$\therefore$ **F_D= 14.81 N**

CENTRE FIXED SHAFT (HOLLOW)

- **Torque on shaft**

Torque = force x perpendicular distance

= Drag force (F_D) x Blade length

= 14.81 x 228.6

=3.38 x 10^3 N-mm

- **Diameter of shaft**

T = $\frac{\pi}{16}$ x d_0^3 x (1 –K^4) x Shear stress

Where, T = torque = 3.38 x 10^3 N-mm

K = d_i / d_0 = 0.8 ………….. (Assume)

Shear stress = $\frac{S_{ys}}{F.S}$

Where, Sys = 183 Mpa for SAE 1030 (Assume material

F.S = Factor of safety = 2.5 (Assume)

$\therefore$ Shear stress = 73.2 Mpa

Put all these value in above equation,

$\therefore$3.38 x 10^3 = $\frac{\pi}{16}$ x d_0^3 x (1- 0.8^4) x 73.2

$\therefore d_0$ = 7.36 mm

Increasing the diameter of shaft three times to provide it more than enough strength. Because, we are not using the frame structure. Hence the total load of whole set up will be on center shaft. So,

d_0 =3 x 7.36 = 22.08mm

$\therefore$ **d_0= 20 mm**………… (Standard diameter for shaft from design data book)

Now, d_i= 0.8 x d_0 = 0.8 x 20

$\therefore$ **d_i = 16 mm**

- **DESIGN OF BEARING**

product	Single row deep groove ball bearing 6204 with seal on both side
Dynamic load	13.5KN
Static load	6.55KN
Reference speed	-
Limiting speed	10000 RPM
Weight	0.11KG
Calculation factor(K_r)	0.1
Calculation factor(Cor)	15

Table 6.2: Technical specification of Ball bearing

Two number of ball bearing found more suitable for this application because of light radial load and it is also an anti-friction bearing. In previous session, calculated the diameter of shaft. For the shaft of diameter 50 mm, a bearing is selected.

- **Bearing Specification**

Bearing No. 6204, Bore No. 10 series 60

Bore (d) = 20 mm

Diameter (D) = 47 mm
Width (b) = 14 mm

- **Equivalent load on bearing**

Fe= (XF_r + YF_a) K_s K_o K_p K_r
Where,
F_r= Radial load in N = 23.141 N
F_a= Axial load in N = 0
X= 1, Y= 0
$K_s = 1, K_o = 0.5, K_p = 1, K_r = 1.4$
(All above data taken from machine design data book)
Put all these value in above equation,
F_e = (1 x 14.81 + 0) x0.5 x1 x1.4 x1
= 10.36 N

- **Life of Bearing**

L = $\left(\frac{C}{F_e}\right)^n$ x K_{rel}
Where,
K_{rel}= 1 = Reliability factor (Assuming 90% reliability for given system
n = 3 (for deep groove ball bearing
C = 22900 (Dynamic load factor in N)

- (All above data are taken from machine design data book)

Put all these values in above equation,
L = $(13500/10.36)^3$ x 1
L = 2.21 x 10^9 millions of revolution

- **Coefficient of friction**

μ = 0.0015 (For deep groove ball bearing) ……………(D.D.B)

- **Bearing fit type**

Fit type = g6 (for shaft stationary) ……………………..(D.D.B)

- **DESIGN OF PIPE**

Stresses in Pipe material:

Stress (σ) = $\frac{\text{Load (P)}}{\text{Area (A)}}$

Where, σ = $\frac{S_{ut}}{F.S}$ (Assuming Plastic PVC material for pipe)
For PVC plastic, Sut = 52 Mpa (From PVC website)
F.S= Factor of safety = 2.5 (Assume)
∴ Stress (σ) = 20.8 Mpa
P= Drag force = 14.81 N

Put these values in above equation,
∴ 20.8 = $\frac{14.81}{A}$
∴ A = 0.712 mm^2
Now,
A = $\frac{\Pi}{4}$(d_0^2 - d_i^2)
Let, d_i= 0.8 d_0
∴ 0.712 = $\frac{\Pi}{4}$x($d_0^2 - 0.36$ x d_0^2)
∴ d_0= 1.190 mm
∴ d_i= 0.952 mm

Keeping these dimensions of pipe is undesirable from design point of view. Hence, selecting the pipe diameter from diameter of bearing and check stresses in pipe material.
d_i of pipe=Diameter of bearing=20 mm(Assume, thickness of pipe t=3 mm as using for light *operation)*
d_o= d_i + 2t = 20 + 2x3
∴ d_0= 26 mm
Calculate stresses in pipe,
σ = $\frac{P}{A}$
Where,
P= 23.141 N
A = $\frac{\Pi}{4}$(d_0^2 – d_i^2) = $\frac{\Pi}{4}$ $(26^2 - 20^2)$ = 216.76 mm^2
∴σ = $\frac{P}{A}$= $\frac{14.81}{216.76}$
∴σ = 0.0683 mm
So, stresses in pipe material are found to be negligible. Hence, the design is safe.

- **DESIGN OF SPUR GEAR**

1. **Tooth Load (F_t)** = $\frac{Pd}{Vp}$ = $\frac{4.917}{4}$ **= 1.22 N**
Where V_p= Pitch Line Velocity, m/sec

2. **Bending Strength by Lewis Equation (F_b)** = $S_o.C_v$.b.Y.m
Where, S_o= Basic strength = 196 Mpa (From Design Data Book)

C_v= Velocity Factor = $\frac{3}{3+Vp}$ = 0.4
(From Design Data Book)
.b = Face width of gear = 20 mm
Y = Modified Lewis form factor = 0.39 (From Design Data Book)

.m =Module = 2 (From Design Data Book)
Hence, Fb= 196 x 0.42 x 20 x 0.39 x 2 = **1284.192 N**

3. **Endurance Strength (F_{en})** = S_{eb}.b.Y.m
Where, S_{eb}= Endurance strength of gear material
= 252 (From Design Data Book for steel)
Hence, Fen= 252 x 20 x 0.39 x 2 = **3931.2 N**

Above gear calculation is done for gear unit which consists of 1 larger driver spur gear having Diameter 80 mm, Thickness 20 mm and 47 Teeth by which 4 small spur gear driven having Diameter 27 mm, Thickness 18 mm and 14 Teeth.

Number of Blades for Rotor

The torque of two blade rotor is maximum than three or four bladed. But, due to low wind speed region, considering the four standard direction of wind flow i.e. north, south, east, west. The number of blade of rotor is taken such as, if wind flow in any of the above directions then turbine should easily capable to accept it, is the reason behind it.

No. of blade = 4, Blade thickness= 2 mm, Position = 90 degree

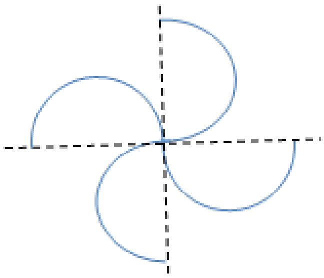

Figure 6.2: Four bladed savonius rotor arrangement (Axial)

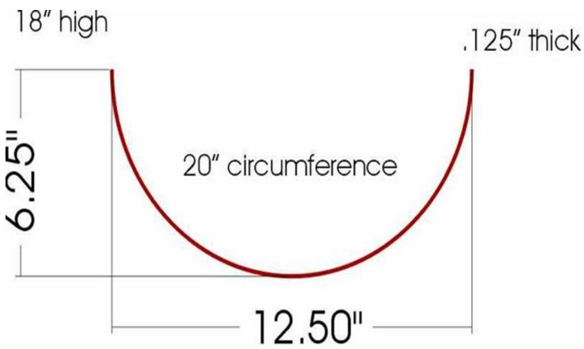

Fig. Panel Specification

Fig. Aluminum Turbine Blade

Generator Specification: -

Type: MotoArmature Control
Pole: Multi pole
RPM: 300
Shaft Length: 1 Inch
Voltage Rating: 12v
Wattage: 10 Watt

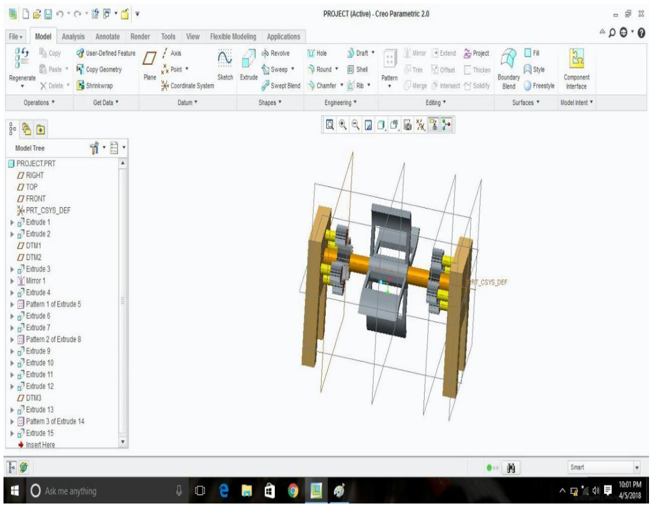

Fig. Cad model of assembly

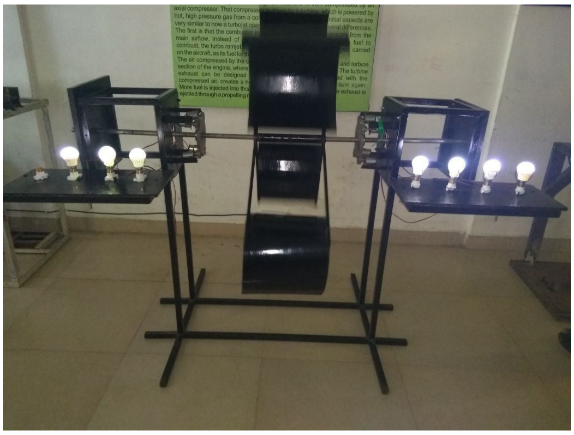

Fig. actual assembly of machine.

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