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Computational and Analytical Analysis for Maximum Deflection of 18-Bladed HAWT Wind Mill Blade

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Abstract:-This paper explores the computational and analytical analysis of 18-Bladed HAWT for maximum deflection of blade. In this research article the computation of wind mill blade in ANSYS software was developed and validates those results with analytical analysis. On the basis of this result the comparison has been made between two analyses on blade and finding out the error with this method.

Keywords: - ANSYS, Blade Deflection, 18-bladed HAWT.

I. INTRODUCTION

The Wind Mill is device which is used for generation of electricity or for developing the mechanical power. In this research article the 18-bladed HAWT blade is taken into consideration. Blade is the key component to capture wind energy. It plays a vital role in the whole wind turbine. In this paper, design and analysis are conducted with layered shell elements to treat a horizontal axis 18- blade wind turbine based on ANSYS, also the analysis for wind mill blade was carried out analytically. These results are compared on basis of results obtained from ANSYS software and analytically.

II. DESIGN OF BLADE

A. Annual Energy Consumption

In this paper the blade is design by considering its power output. The energy required to pumped 1500 Liters water from a well of depth about 25 m is about 120 Watts per Day approximately.
Total annual energy consumption is = energy consumption per hour × total annual hours
Total annual energy consumption is = 120×8760

=1051.200 kwh

But this is the energy when wind will flow at rated wind speed throughout the year, which is never a case. Therefore in order to get realistic energy output, we have to multiply the above numbers by the capacity factor**.** For wind energy capacity factor is assumed to be 30 %.)

Annual Energy Production = 120× 8760 × 0.3

= 315.360 KWh

Estimation of the annual energy output of a wind machine using capacity factor is an approximate method for finding annual output. For more accurate analysis, one should know long term wind distribution.

B. Estimation of Required Windmill Power Rating

The total energy annual requirement is 1100 kwh. Then what should be the size of wind turbine that is required to be installed to meet the energy requirement.

- Annual Energy Requirement=1100 Kwh
- Coefficient of Performance = 0.40
- Wind Speed at Height of 15 meter = 7m/s
- Density of air = 1.22 kg/m^3
- Capacity Factor = 0.30 (30% of the time, wind machine is producing energy at rated power)
- No. of Hours in Year = 8760 Hours

C. Calculation of Power Density of Wind (power per unit area)

Ideal Power density of air

$= \frac{1}{2} \times \rho \times V^3$
= 0.5×1.22× (7×7×7)
= 171.5 Watt/m^2
Actual power density that will be converted to useful energy
= coefficient of performance× other losses
By considering
Other losses = 0.324
Actual power density = 171.5×0.324
= 55.55 W/m^2
Annual energy density (useful) = power density× no of hours per Year
= 55.55×8760
= 486.75 kwh/m^2
By considering the capacity factor (30%)
Real annual energy density
= Annual energy density (useful) × capacity factor
= 486.75×0.30
=146.02 kwh/m^2

D. Calculation of Rotor (Blade) Size

Area of the rotor = Total annual energy required / Real annual energy density
= 1051.200 / 146.02
= 7.199 m^2

E. Radius of Rotor (R)

$A = \pi R^2$

$7.199 = \pi R^2$

$R = 1.514\ m$

Diameter of Rotor =3 m

F. Power Rating of Windmill

= Actual power density × Area of Rotor
= 55.55 × 7.199
=399.904 watts

Lift force = $F_L = CL \times \rho \times A \times \frac{(V)^2}{2}$

$=1.3 \times 1.22 \times 0.276 \times \frac{(8)^2}{2}$

=14.00 N

Drag Force $= F_D = CD \times \rho \times A \times \frac{(V)^2}{2}$

$=0.1 \times 1.22 \times 0.276 \times \frac{(8)^2}{2}$

=**1.07754 N**

III. MODELING OF BLADE.

A. Technical Specification of Blade

The blade was modelled and design as per industry specification. The modelling of blade is carried in CATIA software. The blade design is trapezoidal in shape with size of 920×440×195.The materials for blade is galvanised iron with thickness of 1mm.The blade having the angle of incident 30^0.

Table I: Specification of Blade

Sr. No.	Parameters	Specification
1	No. of Blade	18 Nos.
2	Blade Materials	Galvanized Iron
3	Size of Blade (Trapezoidal Shape)	920×440×195mm
4	Area of Blade	0.291 m^2
5	Thickness of Blade	1mm
6	Angle of Incident of	30^0

	Blade	
7	Rotor Diameter	3 meter

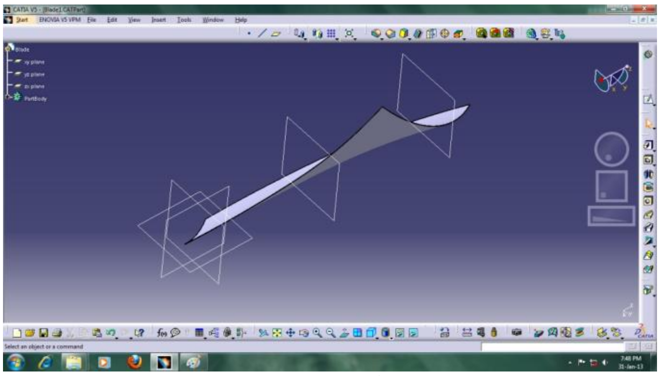

Fig: 1.Model of Blade

IV. FINITE ELEMENTS MODELING

The finite element analysis of blade is carried out in ANSYS software. The design of blade imported from CATIA software which was analyzed in ANSYS.The shell unit shell 63 was chosen to simulate structure of blade. The material properties were approximately defined as isotropic, as the blade was made of galvanized iron materials. The material number and properties were defined by the Material Models menu. The corresponding real constants were distributed to every part of the blade and appropriate grid size was set. All the areas were meshed by MASHTOOL in the way of Free Mesh. The created FEM model of the blade consisted of 810elements, 776 nodes (Fig. 3.1) shows the lamination attribute of one selected element.

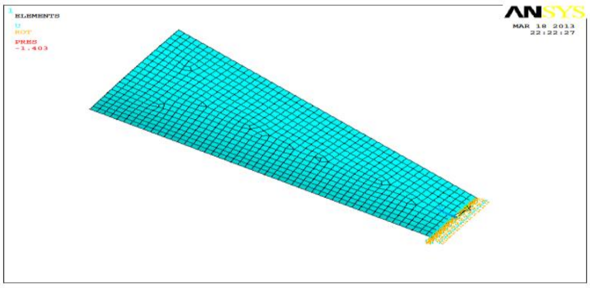

Fig: 2.Meshing of Blade

A. Structural Analysis of Blade

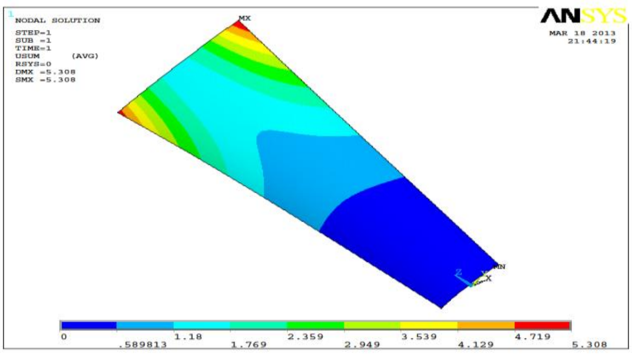

Fig: 3. Maximum Deflection of Blade

V. ANALYTICAL ANALYSIS OF BLADE

The blade was modelled as 920 mm in length, the one side of blade 195 and other is 440 mm as the blade which was modelled having trapezoidal shape. The blade is constrained at one end with uniformly distributed load acting upon its face. The blade was modelled as a cantilever with one end fully constrained and a uniformly distributed load of 1.1403 N applied on its upper surface

Available data is, E = 28.5×10^{6} Mpa, Drag force = 1.1403 N

A. **Moment of Inertia (I):**

$$I = \left\{ \left[2\left(\frac{hb^3}{36} + \left(\frac{1}{2}\times b \times h\right)\times\left(\frac{2b}{3}\right)\right)\right] + \left(\frac{hb^3}{3}\right) \right\}$$

$$I = \left\{\left[2\left(\frac{122.5\times911.80^3}{36} + \left(\frac{1}{2}\times 911.80 \times 122.5\right)\times\left(\frac{2\times911.80}{3}\right)\right)\right] + \left(\frac{195\times911.8^3}{3}\right)\right\}$$

$$I = 54.51 \times 10^9 mm^4$$

B. **Maximum Deflection (y):**

As the shape of blade is uniformly tapered from fixed end to constrained end so, we calculated the deflection by Double Integration Method.
By Double Integration Method

$$E\frac{d^2y}{dx^2} = \frac{M}{I}$$

So after solving equation we will get,

$$y = \frac{wl}{8EI}\left(-3l - \frac{7l^3}{3} - 2l^3\log_{10}2l\right)$$

$$y = \frac{1.1403\times920}{8\times54.51\times10^9\times28.5\times10^6}\left(-3\times920 - \frac{7\times920^3}{3} - 2(920^3)\log_{10}(2\times920)\right)$$

$$y = -5.34456\ mm$$

VI. CONCLUSIONS

The value of Maximum Deflection of blade by using ANSYS was found 5.308mm while the analytically it is to be 5.344mm so it is it is clear that the maximum deflection calculated analytically it is match the analysis made by analytically.

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