Analysis of Axial Flow Fans

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Abstract: In this thesis, an axial flow fan is to be designed and modeled in 3D modeling software Pro/Engineer. Present used axial flow fan in the taken application has 10 blades, in this thesis the number of blades are changed to 12 and 8. Theoretical calculations are done to determine the blade dimensions, % flow change, fan efficiency and axial velocity of fan when number of blades is taken as 10, 12 and 8.

The design is to be changed to increase the efficiency of the fan and analysis is to be done on the fan by changing the materials Aluminum Alloy 204, Mild Steel and E Glass. Analysis is done in finite element analysis ANSYS.

I. INTRODUCTION

The axial flow fans are widely used for providing the required airflow for heat & mass transfer operations in various industrial equipment and processes. These include cooling towers for air-conditioning & ventilation, humidifiers in textile mills, air heat exchangers for various chemical processes, ventilation & exhaust as in mining industry etc.

All the major industries of the national economy such as power generation, petroleum refining & petrochemicals, cement, chemicals & pharmaceuticals, fertilizer production, mining activities, textile mills, hotels etc. use large number of axial flow fans for the aforesaid operations.

The axial flow fans are conventionally designed with impellers made of aluminium or mild steel. The grey area today is the inconsistency in proper aerofoil selection & dimensional stability of the metallic impellers. This leads to high power consumption & high noise levels with lesser efficiency

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II. TYPES OF AXIAL FLOW FANS

There are Three types of Axial Flow Fans are there, They are

A.Propeller Fans

These are a special type of axial flow fan used almost exclusively to provide cooling airflow over large finned tube heat exchangers. These fans are often several meters in diameter, they rotate relatively slowly and the blades are usually made from composite material such as Fibre-glass reinforced plastic (FRP), such as those normally used on Cooling Tower fans.

Fig no - 2.1 Propeller Fan

B.Tube Axial Fan

The simplest form of axial flow fans comprising an axial type impeller mounted in a basic cylindrical housing. The impeller is usually mounted directly on the motor shaft and the motor, in turn, is mounted on a folded metal base within the housing. In some cases the fans are belt driven with the motor mounted on a bracket outside the housing.

Tube axial fans have no provision for recovering the residual tangential component of velocity leaving the impeller and are less efficient than other types but this is offset by simplicity and low cost. They have a wide range of application in ventilation and cooling in industrial and commercial buildings, are used in both fixed locations and as portable units. A special case is the jet fan used in vehicular tunnels. In that application, the fans must be certified to continue operation for a limited time in event of a fire where they are exposed to high temperatures.

Fig no – 2.2 Tube-Axial Fan

C.Vane Axial Fan

Vane-axial fans are high efficiency machines that are unmatched in high specific speed (high volume, lower pressure) applications by other fan types. Vane-axial fans have matched downstream stator vanes that convert the tangential component of the velocity leaving the impeller to the axial direction at a higher static pressure and reduced absolute velocity. Effectively this functions as a vaned diffuser although the term is usually reserved for centrifugal machines. In addition long diffusers are often added to improve the overall efficiency, especially on large Mine fans.

Vane-axial types are the most common in higher capacity applications where highest possible efficiency (running costs) outweighs the higher initial capital cost.

Fig no-2.3 Vane Axial Fan

III THEORETICAL CALCULATIONS for 10 blades

N_b = 10 blades

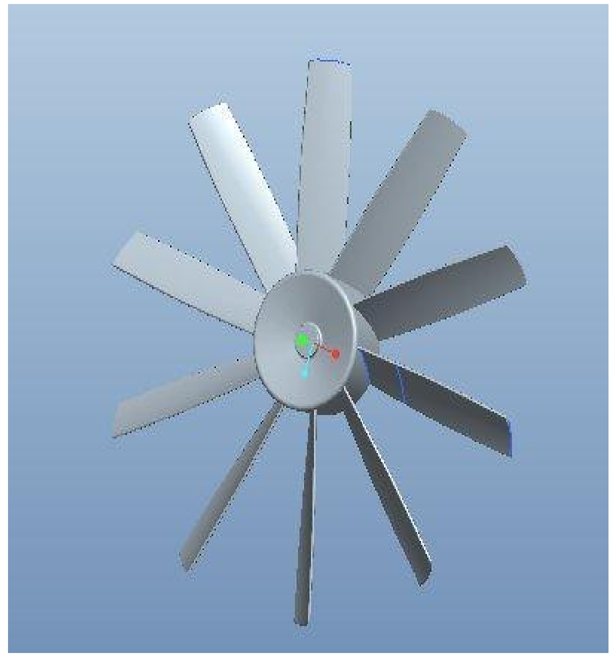


Fig no -3.1 10 Blades Model in Pro-E

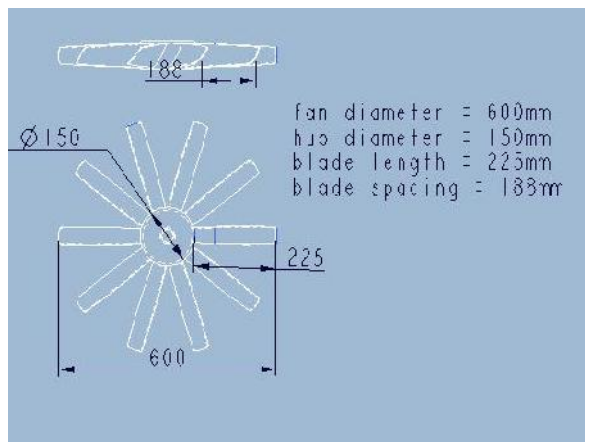


Fig no -3.2 Dimensions for 10 Blades

1) Fan diameter = 600mm Hub diameter (r_h) = 150mm Tip radius (r_t) = 120mm
2) Hub radius/tip radius r = (r_h / r_t) = 75/120

   r = 5/8 r

   = 0.625

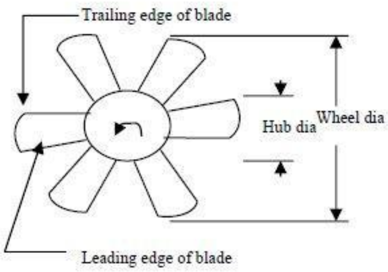


Figure 2: Basic dimensional parameters

3) Number of blades (n_b) = 6r/(1-r) Where r = 5/8

n_b = 10

4) Blades spacing (x_p) = 2πR/ n_b (or) πR(1-r)/3r

R = fan radius = 300mm

x_p = 188.4mm

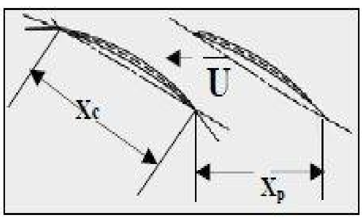
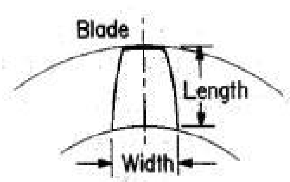


Figure 3: Chord and pitch lengths

5) Blades width = L ≤ 3.4*d/ n_b



Where d = hub diameter

n_b = no. of blades

L ≤ 3.4*150/10 = 51mm

6) Blades length = (D_{fan} – D_{hub})/2

= (600-150) /2

= 225mm

7) Tip speed (ft/min) = D*S*π/12

D = fan diameter in fts

S = speed in rpm

Assume S= 1000 rpm

T_s =512.866 ft/min

8) Tip clearance = Fan diameter/100

= 600/6 = 6

9) blade passing frequency

$F_b = \frac{N_b \times rpm}{60}$ = 10*1000/60

= 166.6Hz

10) Number of Blades Effect on Fan Noise

Blade Numbers from 9 to 30

$$\% \text{ Flow Change} = \left(\frac{N_2 - N_1}{N_1 + 222}\right)100$$

Where : N_1 = New Number of Blades

N_2 = Original Number of Blades

%Flow Change = ($\frac{12-10}{10+222}$)100 (N_1=10; N_2=12)

= 0.86

11) Fanefficiency = $\frac{\text{total pressure rise} \times \text{volumetric flow rate}}{\text{shaft power}}$

Total pressure rise = 8.56 mm of water gauge

= 8.56* 9.80664857

= 83.944Pa (1 Pa = 1 N/m^2)

Volumetric flow rate =96.94 m^3/s

Shaft power = 10.1KW (1KW = 1000W 1W = 1 Nm /s)

= $\frac{83.944 \times 96.44}{10.1 \times 1000}$ = 0.8057×100

Fan efficiency = 80.57

12) Axial velocity =V_a

$$V_a = \frac{Q}{\frac{\pi}{4}\left(D_{fan}^2 - D_{hub}^2\right)}$$

Q = flow rate

Axial Velocity = $\frac{96.94}{\pi/4((600)^2-(150)^2)}$ = 36.589*10^{-3} m/s

IV. MATERIAL PROPERTIES

ALUMINUM 204.0-T4

Physical Properties	Metric
Density	2.80 g/cc
Mechanical Properties	**Metric**
Hardness, Brinell	110
Hardness, Knoop	138
Hardness, Rockwell A	44
Hardness, Rockwell B	69
Hardness, Vickers	124
Tensile Strength, Ultimate	>= 331 MPa
Tensile Strength, Yield	>= 200 MPa @Strain 0.200 %
Elongation at Break	>= 8.0 %
Modulus of Elasticity	71.0 GPa
Poissons Ratio	0.33
Machinability	90 %
Shear Modulus	26.5 GPa
Shear Strength	199 MPa
Thermal Properties	**Metric**
Heat of Fusion	389 J/g
CTE, linear	19.3 µm/m-°C
Specific Heat Capacity	0.963 J/g-°C
Thermal Conductivity	120 W/m-K
Melting Point	529 - 649 °C
Solidus	529 °C
Liquidus	649 °C
Component Elements Properties	**Metric**
Aluminum, Al	93.3 - 95.5 %
Copper, Cu	4.2 - 5.0 %
Iron, Fe	<= 0.35 %
Magnesium, Mg	0.15 - 0.35 %
Manganese, Mn	<= 0.10 %
Nickel, Ni	<= 0.050 %
Other, each	<= 0.050 %
Other, total	<= 0.15 %
Silicon, Si	<= 0.20 %
Tin, Sn	<= 0.050 %
Titanium, Ti	0.15 - 0.30 %
Zinc, Zn	<= 0.10 %

V. STATIC ANALYSIS FOR 10 BLADES USING ALUMINUM ALLOY 204

Loads:

Pressure – 0.000083944 N/mm^2
Angular velocity – 0.121963 rad/sec

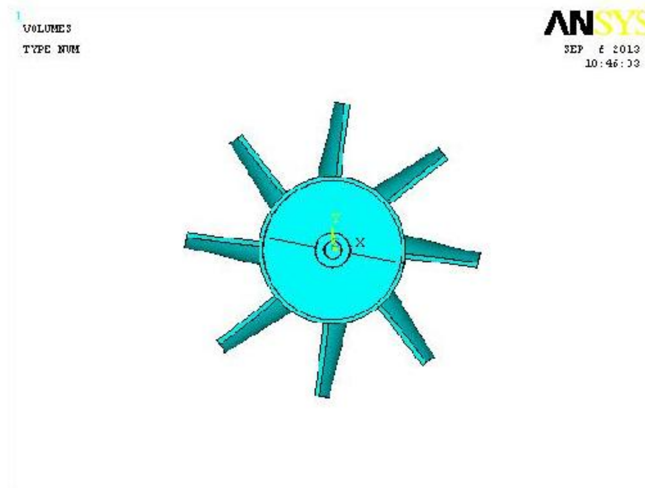


Fig no:5.1 Imported model from Pro-E

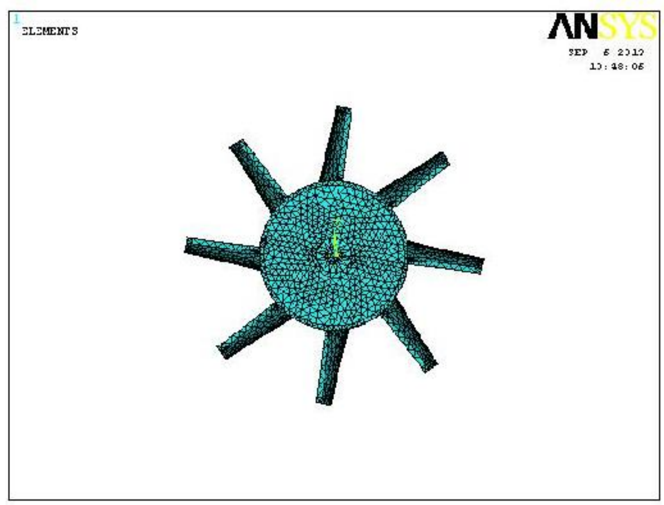


Fig no :5.2 Meshed model in Ansys

DISPLACEMENT:

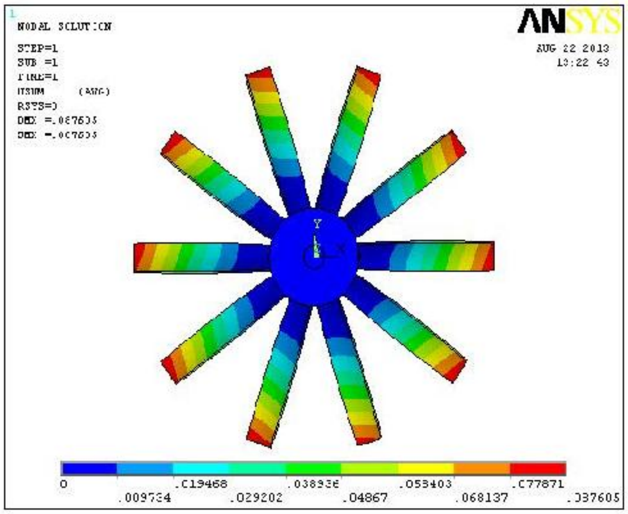


Fig no:5.3 Displacement for 10 Blades using Al material property

Stress:

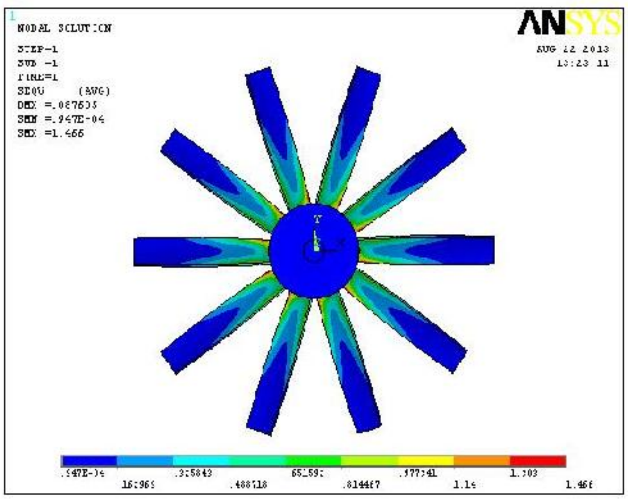
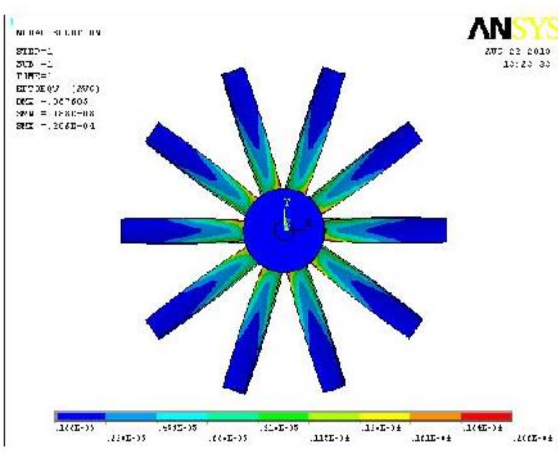


Fig no : 5.4 Stress for 10 Blades using Al material property

Strain :



Figno:5.5 Strain for 10 Blades using Al material property

VI. DYNAMIC ANALYSIS FOR 10 BLADES USING AL ALLOY 204

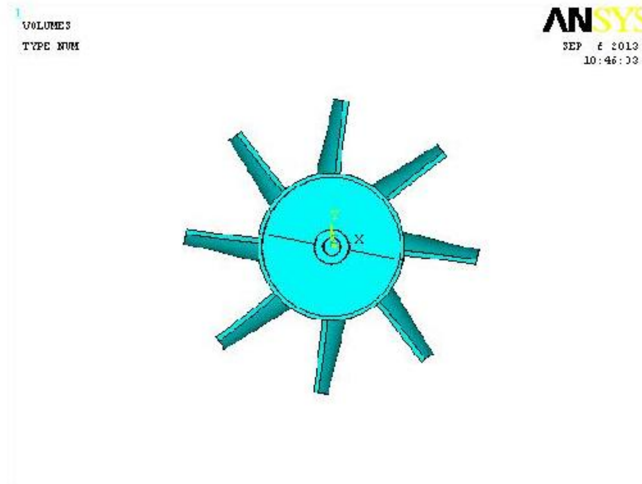


Fig no:6.1 Imported model from Pro-E

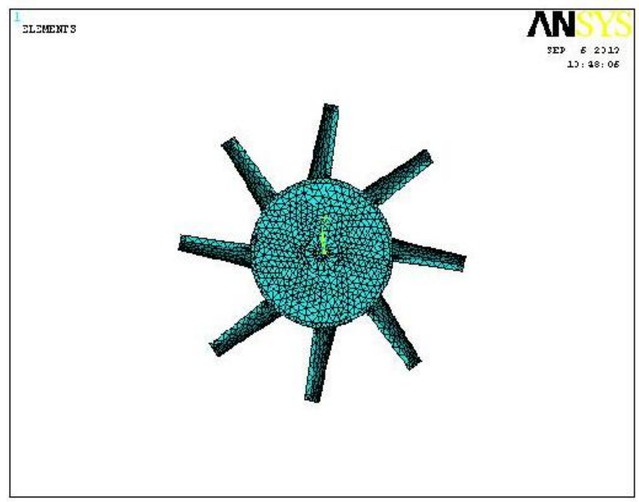


Fig no :6.2 Meshed model in Ansys

Solution

Solution- analysis type –new analysis – select transient.
Solution controls-
Define these boxes
Time at end of load step - 10
Number of sub steps - 10
Max. No. of sub steps - 10
Min. no. of sub steps - 1

Loads

Define load – apply – structural
– Displacement – on areas – select fixed area.
– Pressure – 0.000083944 N/mm^2
– Angular velocity – 0.263444 rad/sec

LOAD STEP OPTIONS

Load step options – write LS file-1-ok

SOLUTION

Analysis type - Solution controls –
Define these boxes
Time at end of load step - 20
Number of sub steps - 10
Max. No. of sub steps - 10
Min. no. of sub steps - 1

Loads

Define load – delete – all load data- all loads & opts Define load – apply – structural
– Displacement – on areas – select fixed area.
– Pressure – 0.000125916 N/mm^2
– Angular velocity – 0.263444 rad/sec

LOAD STEP OPTIONS

Load step options – write LS file-2 – OK

SOLUTION

Analysis type - Solution controls –
Define these boxes
Time at end of load step - 30
Number of sub steps - 10
Max. No. of sub steps - 10
Min. no. of sub steps - 1

Loads

Define load – delete – all load data- all loads & opts Define load – apply – structural
– Displacement – on areas – select fixed area.
– Pressure – 0.000167888 N/mm^2
– Angular velocity – 0.263444 rad/sec

LOAD STEP OPTIONS

Load step options – write LS file-3 – OK

FOR SOLVING SOLUTION

Solution – solve – from LS file – select
Start LS file number - 1
End LS file number - 3
File number increment - 1
Select –OK to begin solution

DISPLACEMENT:

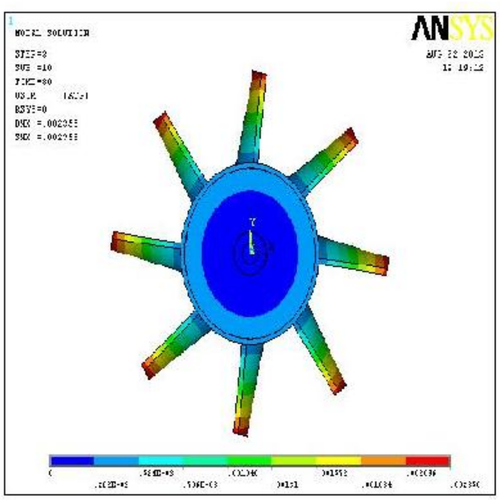


Fig no :6.3 Displacement using 10 Blades with Al Material property in Dynamic analysis

Stress:

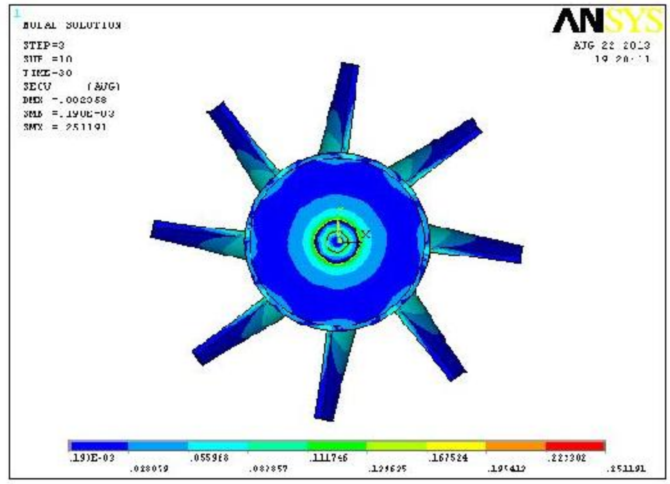


Fig no :6.4 Stress using 10 Blades with Al Material property in Dynamic analysis

Strain:

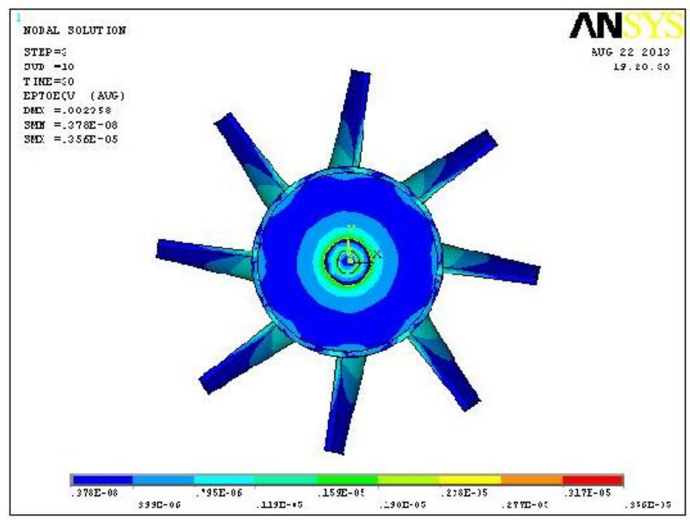


Fig no :6.5 Strain using 10 Blades with Al Material property in Dynamic analysis

Note: By using 8,10,12 Blades the Hub Diameter and Blade Length will change. For each and every Blade we are going to check with three material properties like Al.Mild Steel,E-Glass we are going to finalize the best materil for best blade with effiency.

VII. RESULTS

WEIGHT OF AXIAL FLOW FANS (Kg)

	MILD STEEL	ALUMINUM ALLOY 204	E GLASS
8 BLADES	14.63	5.07	4.71
10 BLADES	6.91	2.39	2.223
12 BLADES	48.16	16.68	15.497

THEORETICAL CALCULATIONS

	8 BLADES	10 BLADES	12 BLADES
% OF FLOW CHANGE	13.79	0.862	0.854
AXIAL VELOCITY mm/s	65.861	36.589	23.862

STATIC RESULTS

MILD STEEL:

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.737 E-03	0.29483	0.002545
STRESS (N/mm^2)	0.350563	1.492	0.400588
STRAIN	0.166 E-05	0.701E-05	0.189 E-05

ALUMINUM ALLOY 204:

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.001383	0.087605	0.007357
STRESS (N/mm^2)	0.16944	1.466	0.376155
STRAIN	0.240 E-05	0.206 E-04	0.532 E-05

E-GLASS:

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.001328	0.086858	0.00713
STRESS (N/mm^2)	0.185617	1.512	0.4046
STRAIN	0.257 E-05	0.210 E-04	0.563 E-05

DYNAMIC RESULTS

MILD STEEL:

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT(mm)	0.001066	0.059943	0.00498
STRESS (N/mm^2)	0.435849	3.095	0.921093
STRAIN	0.206E-05	0.145 E-04	0.440 E-05

ALUMINUM ALLOY 204:

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.002358	0.177895	0.014649
STRESS (N/mm^2)	0.251191	3.049	0.877972
STRAIN	0.356 E-05	0.430 E-04	0.126 E-04

E-GLASS:

	8 BLADES	10 BLADES	12 BLADES
DISPLACEMENT (mm)	0.002275	0.177883	0.01427
STRESS (N/mm2)	0.279559	3.176	0.961477
STRAIN	0.387 E-05	0.441 E-04	0.135 E-04

VIII.CONCLUSSION

By observing the analysis results, for all materials, the analyzed stress values are less than their respective yield stress values, so using all the three materials is safe under given load conditions. The strength of the composite material E Glass is more than that of other 2 materials Mild Steel and Aluminum Alloy. By observing the analysis results, the displacement and stress values are less when 8 blades are used.

So we can conclude that using composite material E Glass and using 8 blades is better.

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