Analysis of Axial Flow Fans

M.NagaKiran and S.Srinivasulu

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.

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.

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.
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.

III THEORETICAL CALCULATIONS for 10 blades

\[ N_b = 10 \text{ blades} \]

1) Fan diameter = 600mm Hub
   diameter \( (r_h) = 150\text{mm} \) Tip
   radius \( (r_t) = 120\text{mm} \)

2) Hub radius/tip radius \( r = \frac{r_h}{r_t} = 75/120 \)
   \( r = \frac{5}{8} r \)
   \( = 0.625 \)

Fig no - 2.2 Tube-Axial Fan

Fig no - 2.3 Vane Axial Fan

Fig no - 3.1 10 Blades Model in Pro-E

Fig no - 3.2 Dimensions for 10 Blades
3) Number of blades \( n_b = \frac{6r}{1-r} \) where \( r = \frac{5}{8} \)

\[ n_b = 10 \]

4) Blades spacing \( x_p = \frac{2\pi R}{n_b} (or) \frac{\pi R(1-r)}{3r} \)

\[ R = \text{fan radius} = 300\text{mm} \]

\[ x_p = 188.4\text{mm} \]

5) Blades width \( L \leq \frac{3.4 \times d}{n_b} \)

Where \( d = \text{hub diameter} \)

\( n_b = \text{no. of blades} \)

\[ L \leq \frac{3.4 \times 150}{10} = 51\text{mm} \]

6) Blades length \( = \frac{(D_{\text{fan}} - D_{\text{hub}})}{2} \)

\[ = \frac{(600-150)}{2} = 225\text{mm} \]

7) Tip speed \( \text{[ft/min]} = \frac{D \times S \times \pi}{12} \)

\[ D = \text{fan diameter in fts} \]

\[ S = \text{speed in rpm} \]

Assume \( S = 1000 \text{ rpm} \)

\( T_s = 512.866 \text{ ft/min} \)

8) Tip clearance = Fan diameter/100

\[ = \frac{600}{100} = 6 \]

9) Blade passing frequency

\[ F_b = \frac{D \times S \times \pi}{12 \times 60} = 10 \times 1000 \times 60 \]

\[ = 166.6\text{Hz} \]

10) Number of Blades Effect on Fan Noise

Blade Numbers from 9 to 30

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

Where:

\( N_1 = \text{New Number of Blades} \)

\( N_2 = \text{Original Number of Blades} \)

\[ \% \text{Flow Change} = \left( \frac{12 - 10}{10 + 222} \right) \times 100 \]

\[ = 0.86 \]

11) Fan Efficiency

\[ \text{Fan efficiency} = \frac{\text{Total pressure rise} \times \text{Volumetric flow rate}}{\text{Shaft power}} \]

Total pressure rise = 8.56 mm of water gauge

\[ = 8.56 \times 9.80664857 \]

\[ = 83.944\text{Pa} \text{ (1 Pa = 1 N/m}^2\text{)} \]

Volumetric flow rate = 96.94 m\(^3\)/s

Shaft power = 10.1KW

\[ (1\text{KW} = 1000\text{W} \text{ 1W} = 1 \text{Nm }/\text{s}) \]

\[ \text{Fan efficiency} = 80.57 \]

12) Axial velocity \( = V_a \)

\[ V_a = \frac{Q}{4 \times (D_{\text{fan}}^2 - D_{\text{hub}}^2)} \]

\[ Q = \text{flow rate} \]

\[ \text{Axial Velocity} = \frac{Q}{4 \times (D_{\text{fan}}^2 - D_{\text{hub}}^2)} = 36.589 \times 10^{-3} \text{ m/s} \]
IV. MATERIAL PROPERTIES
ALUMINUM 204.0-T4

Physical Properties
Density

Mechanical Properties
Hardness, Brinell
Hardness, Knoop
Hardness, Rockwell A
Hardness, Rockwell B
Hardness, Vickers
Tensile Strength, Ultimate
Tensile Strength, Yield
Elongation at Break
Modulus of Elasticity
Poissons Ratio
Machinability
Shear Modulus
Shear Strength

Thermal Properties
Heat of Fusion
CTE, linear
Specific Heat Capacity
Thermal Conductivity
Melting Point
Solidus
Liquidus

Component Elements Properties
Aluminum, Al
Copper, Cu
Iron, Fe
Magnesium, Mg
Manganese, Mn
Nickel, Ni
Other, each
Other, total
Silicon, Si
Tin, Sn
Titanium, Ti
Zinc, Zn

V. STATIC ANALYSIS FOR 10 BLADES USING ALUMINUM ALLOY 204

Loads:
Pressure – 0.000083944 N/mm²
Angular velocity – 0.121963 rad/sec
VI. DYNAMIC ANALYSIS FOR 10 BLADES USING AL ALLOY 204

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 - 0.00083944 N/mm²
- 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/mm²
– 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/mm²
– 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](image1)

**Stress:**

![Fig no :6.4 Stress using 10 Blades with Al Material property in Dynamic analysis](image2)

**Strain:**

![Fig no :6.5 Strain using 10 Blades with Al Material property in Dynamic analysis](image3)

**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)

<table>
<thead>
<tr>
<th></th>
<th>MILD STEEL</th>
<th>ALUMINUM ALLOY 204</th>
<th>E GLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 BLADES</td>
<td>14.63</td>
<td>5.07</td>
<td>4.71</td>
</tr>
<tr>
<td>10 BLADES</td>
<td>6.91</td>
<td>2.39</td>
<td>2.23</td>
</tr>
<tr>
<td>12 BLADES</td>
<td>48.16</td>
<td>16.68</td>
<td>15.497</td>
</tr>
</tbody>
</table>

THEORETICAL CALCULATIONS

<table>
<thead>
<tr>
<th></th>
<th>8 BLADES</th>
<th>10 BLADES</th>
<th>12 BLADES</th>
</tr>
</thead>
<tbody>
<tr>
<td>% OF FLOW CHANGE</td>
<td>13.79</td>
<td>0.862</td>
<td>0.854</td>
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<tr>
<td>AXIAL VELOCITY mm/s</td>
<td>65.861</td>
<td>36.589</td>
<td>23.862</td>
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</table>

MILD STEEL:

<table>
<thead>
<tr>
<th></th>
<th>8 BLADES</th>
<th>10 BLADES</th>
<th>12 BLADES</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISPLACEMENT (mm)</td>
<td>0.737 E-03</td>
<td>0.29483</td>
<td>0.002545</td>
</tr>
<tr>
<td>STRESS (N/mm²)</td>
<td>0.350653</td>
<td>1.492</td>
<td>0.400588</td>
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<tr>
<td>STRAIN</td>
<td>0.166 E-05</td>
<td>0.701E-05</td>
<td>0.189 E-05</td>
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</table>

ALUMINUM ALLOY 204:

<table>
<thead>
<tr>
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<th>12 BLADES</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISPLACEMENT (mm)</td>
<td>0.001383</td>
<td>0.087605</td>
<td>0.007357</td>
</tr>
<tr>
<td>STRESS (N/mm²)</td>
<td>0.16944</td>
<td>1.466</td>
<td>0.376155</td>
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<tr>
<td>STRAIN</td>
<td>0.240 E-05</td>
<td>0.206 E-04</td>
<td>0.532 E-05</td>
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E-GLASS:

<table>
<thead>
<tr>
<th></th>
<th>8 BLADES</th>
<th>10 BLADES</th>
<th>12 BLADES</th>
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</thead>
<tbody>
<tr>
<td>DISPLACEMENT (mm)</td>
<td>0.001328</td>
<td>0.086858</td>
<td>0.00713</td>
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<tr>
<td>STRESS (N/mm²)</td>
<td>0.18544</td>
<td>1.512</td>
<td>0.4046</td>
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<td>STRAIN</td>
<td>0.257 E-05</td>
<td>0.210 E-04</td>
<td>0.563 E-05</td>
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</table>

DYNAMIC RESULTS

<table>
<thead>
<tr>
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<th>8 BLADES</th>
<th>10 BLADES</th>
<th>12 BLADES</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISPLACEMENT (mm)</td>
<td>0.00106</td>
<td>0.05994</td>
<td>0.00498</td>
</tr>
<tr>
<td>STRESS (N/mm²)</td>
<td>0.43584</td>
<td>3.095</td>
<td>0.92109</td>
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<tr>
<td>STRAIN</td>
<td>0.206E-05</td>
<td>0.145 E-04</td>
<td>0.440 E-05</td>
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</tbody>
</table>

VIII. CONCLUSION

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.

IX. REFERENCES: