Air Multiplier With Thermal Sensors

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Abstract- *Conventional fan has blades in outer portion which is often not safe for use. Also it creates noise during operation. Air Multiplier is a fan which blows air from a ring with no external blades. Adding thermal sensors in it provides variation in rate of air blown by fan. The sensors automatically regulate the speed of fan with respect to surrounding temperature. Thus, comfortable cooling is achieved. With preliminary design calculations, we have developed the optimum blades for the model. We have also developed a 3D model of this fan (outer body) and analyzed it with simulation. A model of the same has been fabricated for demonstrative purpose*

Keywords- Air Multiplier, Airfoil blades, Bladeless fan, Thermal Sensors.

I. INTRODUCTION

Fan has been used for cooling and ventilation purpose since beginning of its invention along with various engineering applications. Propeller fans were priorly used for cooling application. However, it had limitation of complete loss of circumference (tangential) component which was later overcome by axial (vane axial). Fans on desk nowadays have specific aerodynamic design (of axial blades) which provides cooling. While arrangements of fast moving blades are open and visible, it may create accidents. Also flow of air is turbulent. This limitation is solved by bladeless fan having blades hidden in fan. Bladeless fan multiplies the airflow at the same time, providing smooth airflow by creating negative pressure and applying Coanda effect.

II. PRIOR RESEARCH

2.1 NUMERICAL AERODYNAMICS EVALUATION AND NOISE INVESTIGATION OF A BLADELESS FAN (2015) *(Mohammad Jafri, Bijan Farhanieh, Hossien Afshin, Hamidreza Bozorgasareh)*

Many studies on noise investigation have been done on axial fan earlier but this paper purely focuses on aerodynamics of blades for air multiplier and noise calculation. The prior study refers the governing equations for Aerodynamic Formulation and Acoustic Computation to which validation of NACA 0012 (NACA 0012 AIRFOILS (n0012-il)- Airfoil Tools) is done by drag coefficient to the angle of attack and lift coefficient to angle of attack. The SPL (Sound Pressure Level) to the frequency graph for NACA 0012 shows the noise effect for Re= $3*10^6$. Also, the noise validation for NACA 0012 for Re=$2*10^5$ is compared. Now for the fan cross section Eppler 473 was selected among standard airfoils. The paper shows the simulation after selecting the criteria of bladeless fan i.e 30cm diameter in 4*2*2 room. The outlet volume flow rate was measured by 3 times far from fan diameter. The SPL VS HZ was plotted at 1mm in front of fan for inlet of 30L/s. The paper investigate that with increase of inlet volume flow rate, there is increase in outlet volume flow rate and the ratio for this was 21.BNS METHOD was carried out for the noise source & FW-H METHOD was applied to measure the noise level. This paper concludes that for domestic use of this fan, it requires the compromisation between outlet and inlet flow regarding the noise. Its shows that for Eppler 473 and 30cm diameter, inlet volume flow rate should not be more than 80L/s or it could be prove harmful.

2.2 SELECTION AND DESIGN OF AN AXIAL FLOW FAN (2013) *(D. Almazo, C Rodriguez, and M. Toledo)*

The paper shows the theoretical design consideration of an Axial flow fan. It is divided into Introduction, airfoil, blade twist, Number of blades and the dimensions for an axial flow fan. The first part explains the propeller and principle of axial fan. The airfoil part is explained with the help of NACA 6512 airfoil. Blade twist is important factor as per aerodynamic view. The velocity of the rotating blade is uneven, it is low near the center and increase towards the tip, this could be compensated by blade twist. Number of blades for fan should be 5 for practical solution. The dimensions for an axial flow fan show the calculation of total pressure along with minimum and maximum diameter of hub.

2.3 FINITE ELEMENT ANALYSIS OF AXIAL FLOW FAN (2015) *(M.Nagakiran, T.R.Sydanna, G.Siva Prasad, K.Sagar Kumar, M.Venkateswarlu)*

This paper shows the 3D model and design of axial fan in pro/Engineering and comparing materials and number of blades which could affect the performance of fan. Introduction of axial fan has been explained priorly i.e.

propeller, tube axial and vane axial fan. Then it shows the theoretical calculations for 10 blades axial fan. The calculation consist of Fan diameter, Hub to tip ratio, Number of blades, Blade spacing, Blades width, Blades length, Tip speed, Tip clearance, Blade passing frequency, Number of blades effect on fan noise and Fan efficiency. Now the paper initially uses Aluminum 204.0-T4. For this, Material properties like physical properties, Mechanical properties, Thermal properties, Component Element Properties are described. From the imported model from Pro/E Mesh model in Ansys, Displacement, stress, strain analysis has been done. Then same procedure was repeated for dynamic. Also the program for the same was presented. Now by replacing the Aluminum material to the E-Glass and mild steel and changing number of blades from 10 to 8 and 12, results have been performed. The paper finally concludes that E-GLASS (E-Glass Fibre- Azom.com, 2001) material with 8 blades is better in every aspect.

2.4 OPTIMIZATION OF BACKWARD CURVED AEROFOIL RADIAL FAN IMPELLER USING FINITE ELEMENT MODELLING (2012) *(M. Mohammed Mohaideen)*

The Finite Element Analysis is generated by merging individual solutions of elements, ensuring continuity at the same time. The paper shows the finite element modeling & stress analysis which is divided into three steps: (1) Pre-processing (2) Solution (3) Post processing. The Pre-processing involves the specification of material properties of forward curved radial impeller like Density, Elasticity, pressure, etc. Here free meshing is done instead of mapped meshing so that more flexibility in defining mesh area could be done. The boundary condition is also specified. The next part was Solution in which model solution task application is used. The original fan deflection plot & stress plot is mapped. The last part was Post processing in which design safety was considered. The results includes stress (kg/mm^2) and deflection (mm).The parts includes Fan impeller, Back plate(bottom), Back plate(top), Blade, Cover plate, Ring, Flange. For original and optimized fan, stress and deflection was performed for all these components and the paper conclude that by optimizing Fan impeller’s thickness, 18.5% weight could be reduce.

2.5 AN OPTIMUM DESIGN FOR AXIAL-FLOW FAN BLADE: THEORETICAL AND EXPIREMENTAL STUDIES (Cheng-Hung Huang and Chung-Wei Gau)

Designing of blades is most crucial part of fan. The study shows the designing geometry of blades. For this, four digit NACA airfoils (NACA 4 digit generator) were taken into consideration. Initially the direct problem has been addressed after which, shape generation of fan blade which includes geometrical parameters of 2D blade section of NACA and the design variable of rotor blade was shown. The shape design problem and Levenberg –Marquardt Method (LMM) minimization has been stated. The most important is Statistical analysis which would testify the reliability of predicted variable constant and in this case, it showed 99% reliable. The study then mainly focuses on the Experiment testing and results. The sensitive analysis of design parameters has been performed. For both the fans i.e. original & optimal fan, static pressure Vs air volume flow rate and RPM Vs volume flow rate was plotted. The paper suggests to manufacture the given fan in CNC machine. Results shows that for static pressure=0,for original fan airflow rate was 77.595 CFM which was increased to 84.842 CFM for optimum fan. This clearly demonstrated the advantage of optimum fan given in paper. The paper also suggests that manufacturing of this fan with the given method in study would satisfy the desired airflow to be matched and time required for redesigning the fan would be shortened

2.6 TESTING AND FABRICATION OF BLADELESS TABLE FAN (2017) *(Shivam Tyagi, Shekhar Gupta, Saurabh Khare, Dr. C.S. Malvi)*

The paper completely focuses on the manufacturing of bladeless fan with simple technique. For this Simple Apparatus like Bucket, Water drainage PVC Pipe, Adhesive, DC motor, Tin plate and cutter has been used. The design methodology has been discussed in which, what part of apparatus to be mounted on what was showed. The experimental results were shown in a tabular form comparing the normal table fan and bladeless fan in terms of distance to the velocity. The table clearly represents the advantage of bladeless fan over normal table fan for an instance at 2.0m the velocity distribution for bladeless fan was 2.05 m/s where as for normal table fan it was 1.54 m/s. The paper conclude that bladeless fan has uniform distribution of velocity compared to normal table fan and could be replace since it has more safety and less noise compared to conventional fan.

III. DESIGN, CALCULATIONS AND IMPLEMENTATIONS

3.1.1. Theoretical Design Calculation for Optimum Axial Blade by Changing Hub to Tip Ratio, Angle of Attack and Number of Blades for Maximum mass flow rate.

The Boundary condition at the inlet and at the out of the duct is set to be as the free stream pressure condition, the wall of the duct is considered as zero normal velocity, and the wall of the shaft and also the blades were set to a set of moving boundary conditions and set to zero normal velocity.

NOMENCLATURE

Q - Mass flow rate
Dfan - Fan diameter
Dhub - Hub diameter
Xb - Ration of blade radius to hub radius
H - Total head
Δ*Hth* - Theoretical head increase
Δ*Hrotor* - Rotor head drop
Ψ*fan* - Design head increase coefficient
Ψ*th* -Theoretical head increase coefficient
Ψ*rotor*- Rotor head drop coefficient
β2*k* -Fan blade angle at exit
i- Flow angle with blade at inlet
P -Pressure
t -Time
V -Flow velocity
Φ-Flow coefficient
N -Rotor rotational velocity
E-Flow rotational coefficient
u- Rotational velocity
Va- Axial flow velocity
*V*θ-Tangential flow velocity
W -Relative flow velocity
b- Number of blades

FAN ROTOR DESIGN PROCEDURE

Let us consider a specific three dimensional and temporary domain. The spatial and temporary coordinates are denoted by

$\vec{y}$= (*x*, *y*, *z*), And *t* ∈ (0, *T*).

The Navier-Stokes equations (Navier-Strokes Equations - NASA) of 3D flows:

,

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \left(\rho \vec{V}\right) = 0$$

$$\frac{\partial(\rho u)}{\partial t} + \nabla \cdot \left(\rho u \vec{V}\right) = -\frac{\partial p}{\partial x} + \rho f_x + (\Im_x)_{vis}$$

$$\frac{\partial(\rho v)}{\partial t} + \nabla \cdot \left(\rho v \vec{V}\right) = -\frac{\partial p}{\partial y} + \rho f_y + (\Im_y)_{vis}$$

$$\frac{\partial(\rho w)}{\partial t} + \nabla \cdot \left(\rho w \vec{V}\right) - -\frac{\partial p}{\partial x} + \rho f_z + (\Im_z)_{vis}$$

Here ρ ,*u*, *v*,*w*, *v*, *p*, *f* , and are the density, velocity component in the x, y, z direction, velocity, pressure, external body forces, and viscous forces respectively. For the problem under consideration, the fluid assumed Newtonian, and the flow is taken as turbulent. When taken turbulent, the dynamics viscosity of flow is modified locally using a k-epsilon turbulent model. No slipping boundary condition is exerted on the wall; also the normal velocity on external surfaces of the wall is equaled to zero. On the wall:

$$\vec{V}.n = 0$$
$$\frac{\partial \phi}{\partial n} = 0$$

Axial flow velocity in this design is needed which can be Computed from the following equation.

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

The diameter of a fan can be computed from the ratio of blade length to the shaft radius for which in this study this ratio is taken to be 0.3.

Dhub = *Dfan* × *xb*

*H*1 and *H*2 as shown in Figure are the total pressures at the inlet and at the outlet of the blade respectively in which their differences are equal to the Theoretical pressure increase and the pressure drop across the rotor.

*H*2 − *H*1 = Δ*Hth* – Δ*Hrotor*

In order to non-dimension the above equation, we need to divide the both sides by the dynamics pressure of the axial flow:

$$\frac{H_2 - H_1}{\frac{1}{2}\rho V_a^2} = \frac{\Delta H_{th} - \Delta H_{rotor}}{\frac{1}{2}\rho V_a^2} \Rightarrow \Psi_{fan} = \Psi_{th} - \Psi_{rotor}$$

In the above equation Ψfan is the design pressure increase whereas Ψth is the theoretical pressure increase across the blade and $\Psi rotor$ is the rotor pressure drop coefficient.

After calculating the non-dimension pressure increase and also the axial flow velocity then the fluid flow coefficient can be calculated from the following equation:

$$\phi = \frac{V_a}{N\frac{2\pi}{60}\times\frac{D}{2}}$$

The above coefficient is equal to the ration of axial flow velocity to the rotational velocity. In the above equation $D / 2$ is the needed ratio to evaluate the rotational velocity. The coefficients of rotation at the inlet and at the outlet of the rotor are ε1 and ε2 respectively, and can be calculated from the tangential velocities at the inlet and outlet sections.

$$\varepsilon = \frac{V_\theta}{V_a}$$

Coefficient of rotation at the inlet of the rotor is equated to zero. In turbo machines the pressure rise is calculated from the Euler equation.

$$\Delta H_{th} = \rho u(\Delta V_\theta)$$

Coefficient of rotation at the outlet of the rotor is calculated by below equation

$$\varepsilon_2 = \frac{\Psi_{th}\times\phi}{2}$$

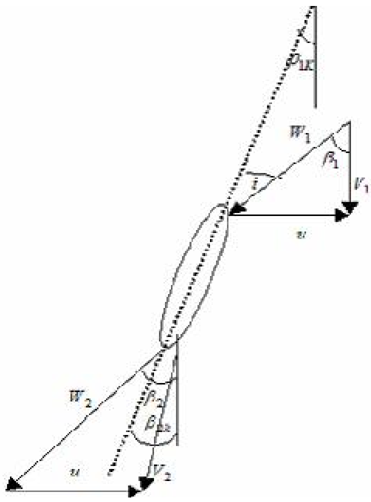
Both the flow and the rotational coefficients produce the relative flow angle at the inlet (β1) and the flow angle at the outlet (β2).

$$\beta_1 = Arc\tan(\frac{1}{\phi})$$

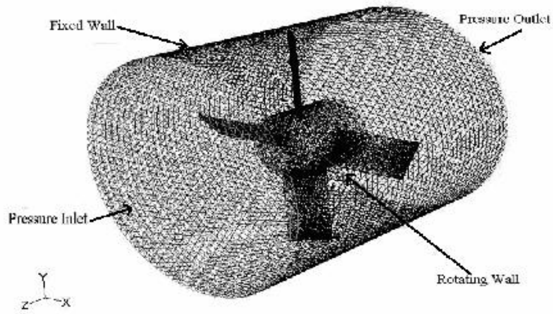
$$\beta_2 = Arc\tan(\frac{1-\varepsilon\times\phi}{\phi})$$

The blade angles at the inlet and at the outlet are β1*k* and β2*k* respectively and in this research both are equal. Flow inlet angle is equal to the difference between the relative flow angles at the inlet and at the outlet.

$$i = \beta_1 - \beta_2$$



(Figure 3.1 Blade, inlet and outlet flow velocity angles [3]*)*

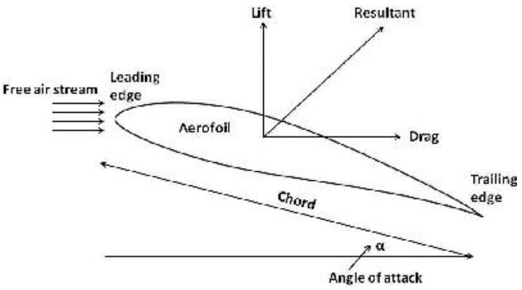


(Figure 3.2: Fluid Dynamics Meshing and node points [3]*)*

At a fixed rotational speed, we first fixed the number of blades to 2, and the angle of attack was varied from 30 to 70 degrees for a fixed hub to tip ratio. The mass flow rate was calculated for every angle of attack and saved. Then the hub to tip ratio was changed from 0.2 to 0.3, and 0.4 and then the above calculation was repeated again. Finally the sets of blades were varied from 2 to 3, 4, 5, and finally 6, and the whole numerical calculation was repeated again and again. The flow velocity pattern, the pressure variation and also the mass flow rates were calculated numerically. The conclusion is at a fixed rotational speed, at about 40 to 50 degrees angles of attack, for a four or five number of blades, and at a 0.2 hub to tip ratio we can have a maximum mass flow rate for a minimum fan cost [3]. The results are shown followed in later part.

3.1.2 CFD Analysis simulations for selecting appropriate blade profile to Improve efficiency

The forces acting on a typical aerofoil section of an axial flow fan blade are shown in below Figure. The lifting force acts at right angles to the air stream and the dragging force acts in the same direction of the air stream and is responsible for losses due to skin friction. The efficiency of axial flow fans is greatly dependent on the profile of the blade, and the aerodynamic characteristics of the fan blades are strongly affected by the shape of the blade cross section.



(Figure 3.3: Forces acting on a typical aerofoil section of axial flow fan blade [1]*)*

The cross section of fan blades is of a streamlined asymmetrical shape, called the blade's aerodynamic profile and is decisive when it comes to blade performance. Even minor alterations in the shape of the profile can greatly alter the power curve and noise level. Therefore, it is essential to choose an appropriate shape with great care, in order to obtain maximum aerodynamic efficiency. An aero-dynamic profile with optimum twist, taper and higher lift-drag ratio can provide total efficiency as high as 85–92%. The axial flow fan blades are of aerofoil sections and the idea behind using aerofoil blades is to maintain the proper stream-lining of air to reduce losses caused due to form drag as well as from strength considerations (Misra,2002). The blade performances characteristics may be predicted from the aero-dynamic characteristics such as lift and drag coefficients of the chosen aerofoil section and given by the following equations:

$$C_l - \frac{L}{\frac{1}{2}\rho V^2 A}$$

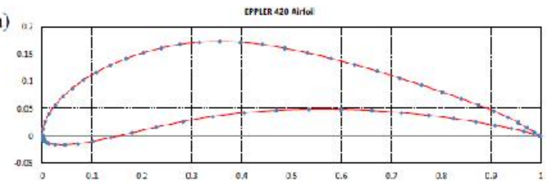
$$C_d - \frac{D}{\frac{1}{2}\rho V^2 A}$$

Where *Cl* is the coefficient of lift, *Cd* is the coefficient of drag, *L* is the lift force, *D* is the drag force, ρ is the density of air, *V* is the velocity of undisturbed airflow and *A* is the blade reference area[3]

Different profiles are selected to choose most convenient blade cross section. These includes Eppler 420, Eppler 544 Airfoil, Eppler 855 Airfoil, FX74 CL5140 Airfoil, NACA 747A315 , NACA 64(3)-418 (NACA Airfoils/NASA).

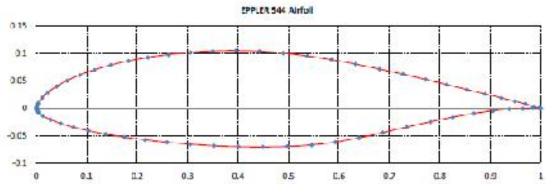
The aerofoil geometries: a – EPPLER 420, b – EPPLER 544, c – EPPLER 855, d – FX 74 CL5 140, e – NACA 747A315 and f – NACA 64(3)-418

a)



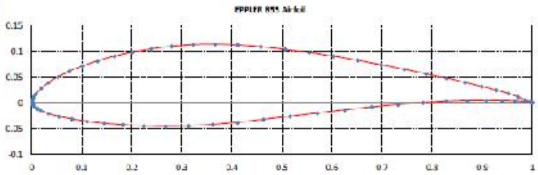
(Figure 3.4[1]*)*

b)



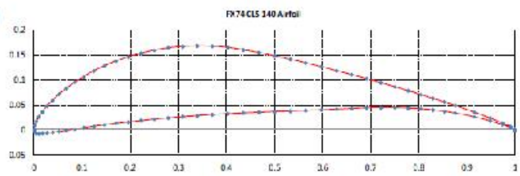
(Figure 3.5 [1]*)*

c)

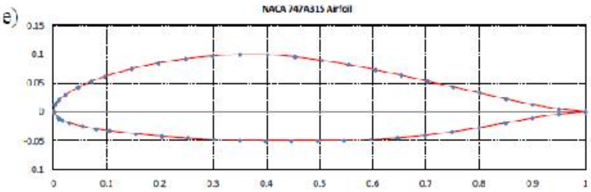


(Figure 3.6 [1]*)*

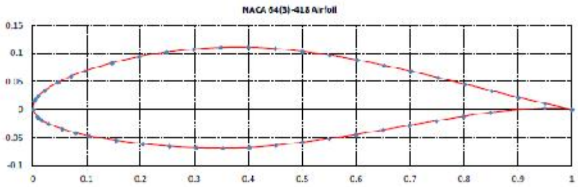
d)



(Figure 3.7 [1]*)*

e)


(Figure 3.8 [1]*)*

f)


(Figure 3.9 [1]*)*

After all the results which are shown, it is concluded that NACA 747A315 is better in efficiency for ventilation and cooling.

Results of the above design calculations i.e. for Angle of Attack, Hub to Tip ratio, Angle of Attack, and Lift to Drag ratio for Optimum Fan Design.

(Table 3.1: [1]*)*

Table 1. Summarized CFD analysis results of the aerofoil sections

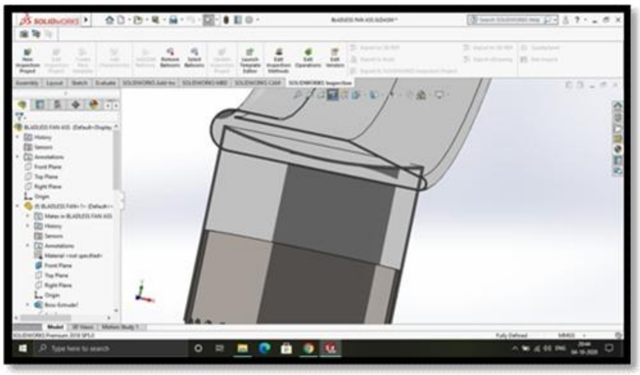
Profile ID	Angle of Attack (Degrees)	Max. C_l	Corresponding C_d	C_l/C_d ratio
E-420	15	2.553	0.551	4.633
E-544	15	2.228	0.563	3.957
E-855	12	1.934	0.408	4.740
FX-74 L5 40	12	2.667	0.549	4.858
NACA 747A315	15	1.858	0.139	13.367
NACA 64(3)418	12	1.425	0.281	5.071

From the above table its clear that NACA 747A315 is having the highest ratio of lift to drag and therefore its suitable for high efficiency.

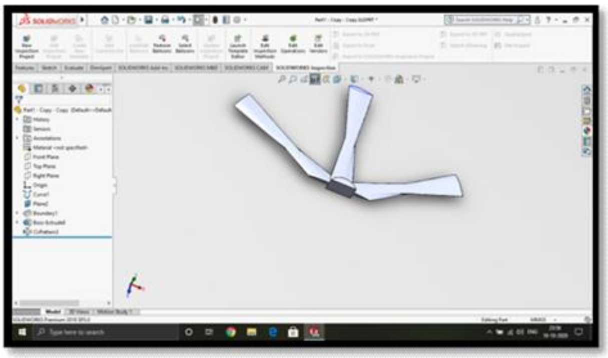
3.2 Design of Air Multiplier (Outer Body)

The main factor in the designing the of body of an Air Multiplier is Cross Section of Outlet Which is an airfoil shape and produces Negative pressure at backside and multiplies the air. We properly research this part and design the cross section accordingly.

(Figure 3.10: Outer model)



(Figure 3.11: Snapshot of cross section of Air multiplier)

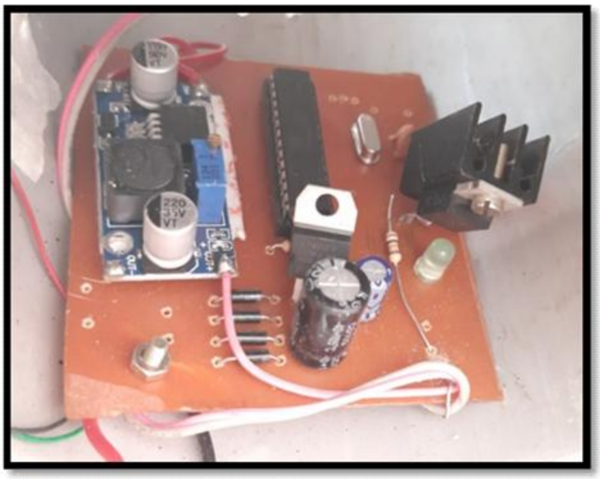


(Figure 3.12: Cross-section of NACA 747A315 with angle of attack 45 degree)

- Specification of Improvised Blades:
  - Angle of attack- 45 degree
  - Hub to tip ratio- 0.2
  - Pitch of blades- 60 degree

3.3 Internal Controller Circuit

Controller circuit consists of several components in Air multiplier. At one end it is connected to Thermal sensor forinput along with Step-down transformer and at other end it is connected to DC motor giving output.



(Figure 3.13: Controller circuit)

(Figure 3.14: Actual Model)

3.3 Thermal Sensor

LM35 is used as a sensor in model. It is a temperature measuring device having an analog output voltage proportional to the temperature. It provides output voltage in Centigrade (Celsius). It does not require any external calibration circuitry. The Alternate Current enters into Step-down transformer which converts 230V to 12V and is connected to Controller Circuit. The Controller Circuit is connected to Thermal Sensor and Fan.

(Figure 3.15: Thermal Sensor in Model)

(Table 3.2)

COMPONENT	FUNCTION
Micro controller	*Receives the signal from Thermal Sensor and give output to mosfet according to programming*
Voltage Regulator	*Keep the voltage in a circuit relatively close to a desired value*
Rectifier circuit	*Power supplies that convert an AC input voltage into a DC voltage supply that can be used to power electronic circuits.*
Capacitor	*Store the electrical energy and give this energy again to the circuit when necessary*
Bug Convertor	*Converts 12V DC to 5V DC*
Mosfet	*Vary fan speed according to the signal of Microcontroller*

IV. CONCLUSION

With all the Research, analysis & calculation we come to the conclusion that Air Multiplier is far more reliable than the conventional fan. The application of axial blades and cross-section for outlet velocity plays very important role in the performance of bladeless fan. With choosing appropriate axial blade's cross-section, more efficiency could be achieved which we have attempted here. For maximum airflow at constant speed axial blades with 45 degree of Angle of Attack with 0.2 Hub to Tip ratio and 60 degree pitch of blades (NACA 747A315), best results could be achieved. Also Bladeless fan is safer to use. Thermal Sensors further makes the system more user-friendly since it does not require any manual regulation for operation and vary speed automatically.

Advantages of these results:

- High Efficiency
- More Mass Air flow
- Less Energy Consumption
- Minimum cost
- No Buffeting
- Uniform and Constant Air Flow

V. ACKNOWLEDGMENT

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