Design Study of a Bladeless Fan "Air Multiplier"

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***ABSTRACT*: Here in this project I have prepared a design study of an Air Multiplier fan and it is also identified as bladeless fan that blows air from a ring with no external blades, HEPA (High Efficiency Particulate Air) Filter in its cylindrical base and it deliveries constant flow of fresh air. I have designed the Air Multiplier fan which has hidden impeller in the cylindrical base, so that is not dangerous than the conventional fan. It multiplies the volume of in taken air automatically into 15 times that travels over an airfoil through suction process.**

***Keywords*: Air multiplier, Bladeless fan, Outer ring, cylindrical base, Mixed Flow Impeller.**

I. INTRODUCTION

In recent scenario, performance and noise are the two important factors of fans that are studied and considered. Typical conventional fans have big blades which may cause some faults such as dislodged of their shaft after long working time and the efficiency of fan decrease with larger blades. These fans are noisier and may flow the dust particles into the surrounding air, which affect asthma patients and children.

Typical fans are separated into 2 types

a) Axial (large volume displacement of air)

b) Radial (stable air flow in an over pressure situation).

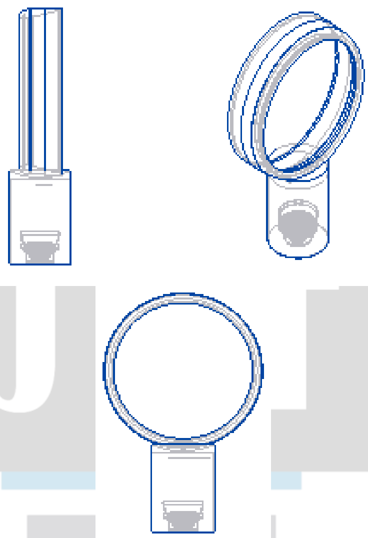


Fig 1: Line Drawing of Bladeless fan

The Bladeless fan or we can say it Air Multiplier (radial) multiplies the air that sucks in. The air pass in through holes at the cylindrical base of the fan. A DC motor runs an impeller fan pushes air to the ring through the motor and blades that smooth the airflow. At the base of the fan, the air holes is wide. But air is accelerated, induced and entrained, this is the point at which the air is multiplied. The air outlet of the tube is titled 16°, so as air is forced out through the opening i.e. surrounding air is sucked through the base. The air flow is induced the air behind the fan to be dragged and also the air around the edge of the tube along to the same direction. This results the Air Multiplier can multiplied its primary air up-to 15 times of inlet. This type of fan uses consumes less electricity and generates less noise than the conventional fan.

II. MAIN COMPONENTS

Bladeless fan comes in two parts, the outer ring part and the cylindrical base which could fit together in a matter of seconds.

Fig 2: Bladeless fan

Main Component of Bladeless fan

i. Outer ring
ii. Cylindrical base
iii. Mixed flow Impeller
iv. Brushless DC Motor

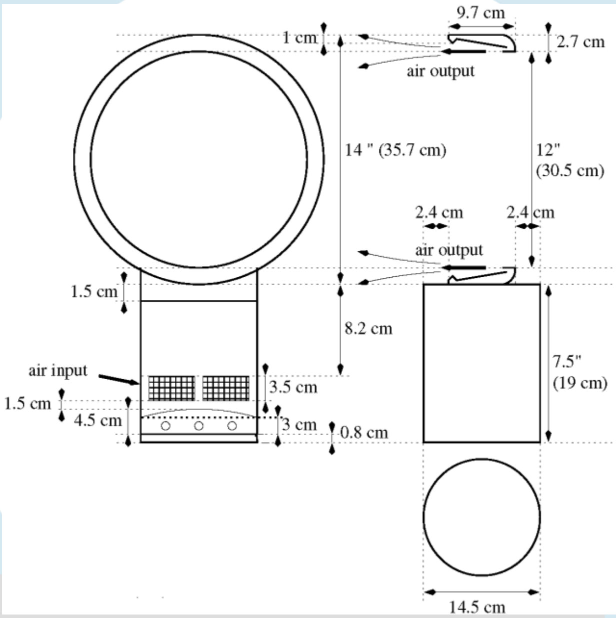


Fig 3: Line Drawing of Fan

2.1 OUTER RING

It is a nozzle including an inner passage. Nozzle contains a surface tapered away from axis, in excess of which the mouth is organized to direct air flow. The narrowing portion improves amplification properties which minimizing noise and frictional losses.

If at all possible the angle subtended between the diffuser portion and the axis is in range of 7^{o} to 20^{o} more rather about 15^{o}. It delivers more efficient air flow.

Fig 4: Outer Ring

2.2 CYLINDRICAL BASE

The air is drawn through the small holes on the body of the fan. It also comprises a lot of small holes of 1.3mm diameter.

Fig 5: Cylinder base

2.3 MIXED FLOW IMPELLER

To draw in the air necessary to generate powerful sufficient jet, in this fan a mixed flow impeller is used. It combines the technologies used in turbochargers and jet engines. It has 9 asymmetrically aligned fins with rows of small holes that reduce the friction produced by hitting high and low air pressure.

Fig 6: Impeller

Impeller is made-up using the fiber or PVC material. This is the most important product in a bladeless fan “air multiplier”, because it draw the air from the air holes and gives powerful airflow. Impeller comprises asymmetrically line up blades which is attached to the motor.

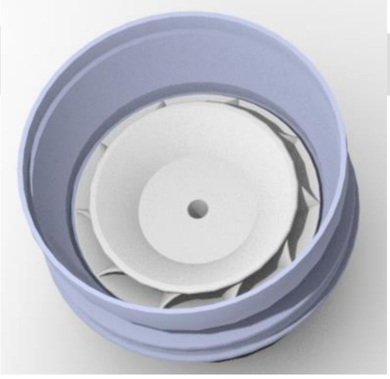


Fig 7: Impeller Assembly

2.4 BRUSHLESS DC MOTOR

For producing a jet of air and creating it powerful sufficient to function properly, the motor should be designed in a way so as to draw in more than 32 liters of air/second. It is powered by a brushless 40-Watt DC motor.

2.5 MATERIAL USED

It is created from tough Acrylonitrile Butadiene Styrene–ABS.

ABS is a tough thermoplastic used to make light, rigid and molded products.
It has shock absorbing properties and is used to make car bumpers, crash helmets and modern golf club heads.

III. WORKING & FLOW SIMULATION

Working of bladeless fan is divided into mainly four stages:-

i. Air is drawn in
ii. Air is accelerated
iii. Air is induced
iv. Air is entrained

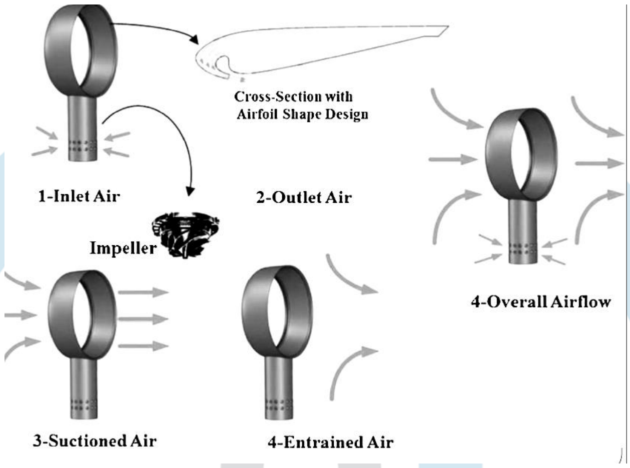


Fig 8: Air flow

3.1 AIR IS DRAWN IN

- Motor draws in nearly 32 liters of air/second.
- Air is drawn in from the small vents in base.

3.2 AIR IS ACCELERATED

- Air is enforced up into loop amplifier and is accelerated out through an annular opening generating a jet of air.
- It permits over the 16° airfoil shaped slope, which channels its direction.

3.3 AIR IS INDUCED

- As the air passes over the slope, it draws air from behind the fan, this procedure is known as inducement
- The air comes out of a 3mm slit built in the frame at a speed of 88.5139 kmph

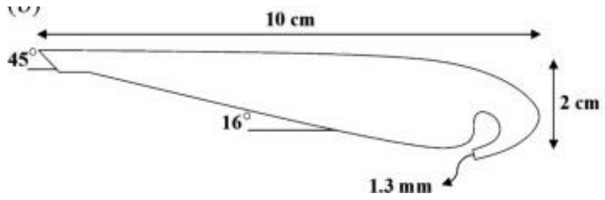
3.4 AIR IS ENTRAINED

- Air around the bladeless fan is also drawn into the air flow, through a procedure known as entrainment.

3.5 AIRFOIL SHAPE BLADE DESIGN & CALCULATION

For the new, bladeless fan, there is a development of a basic design concept in which air is drawn into the base of the unit by an impeller, accelerated through an annular hole and then passed over an airfoil-shaped slope that channels its direction.

Dimension of blade is shown



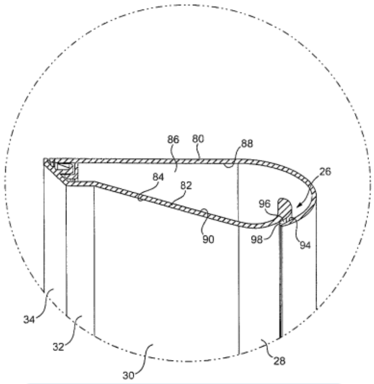


Fig 9: Airfoil blade dimension

In this work, conservation equations of mass and momentum are numerically solved to analyse the unsteady incompressible flow within the Bladeless fan. The continuity equation is described by

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i) = 0 \qquad (1)$$

Where i = 1, 2 and 3, q is the air density and ui is the velocity in direction i. The momentum equations are given by

$$\frac{\partial}{\partial t}(\rho u_i) + \frac{\partial}{\partial x_j}(\rho u_i u_j) = -\frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} \qquad (2)$$

p is the static pressure and sij is the stress tensor. The standard k–e turbulence model is used to simulate turbulent flow. The standard k–e model is a semi-empirical model. The turbulence kinetic energy, k, and its rate of dissipation, e, are described by the following equations:

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho u_i k) = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_i}\right] + G_k - \rho\varepsilon - Y_M + S_k \qquad (3)$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho u_i \varepsilon) = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_i}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}G_k - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon \qquad (4)$$

The turbulent viscosity is also evaluated as

$$\mu_t = C_\mu \rho \frac{k^2}{\varepsilon} \qquad (5)$$

and

$$G_k = \mu_t\left(\frac{\partial u_j}{\partial x_i} + \frac{\partial u_i}{\partial x_j}\right)\frac{\partial u_j}{\partial x_i} \qquad (6)$$

A second order implicit system is used for discretization of time in need of terms in the equations. Also, the second order upwind system has been used for convection terms and the central difference scheme for diffusion terms.
The geometry for simulating the bladeless fan “Air Multiplier” is the airfoil-shaped ring and the base cylinder is not taken into account. The ring is created from an airfoil-shaped 2D sketch.
This 2D sketch is then revolved 360^0 with respect to a center axis (175 mm onset in the y-direction) in order to get the shape of a ring. All the other sides and edges in the geometry are denned as no-slip Walls.

3.6 FLOW SIMULATION

The direction of air flow is controlled by the shape of fan output ring. By this shape the air flow is increased. The shapes have output side is taper and curved bend towards outside. The profile consists a tiny slot to air flow for the pushed air.

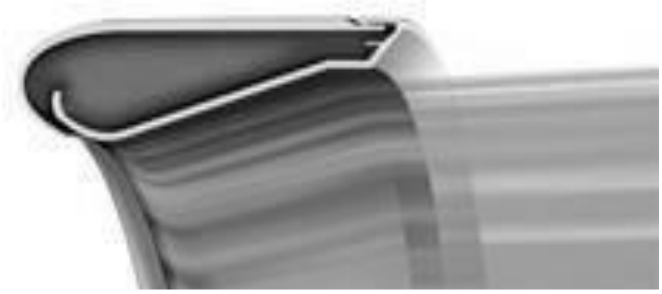
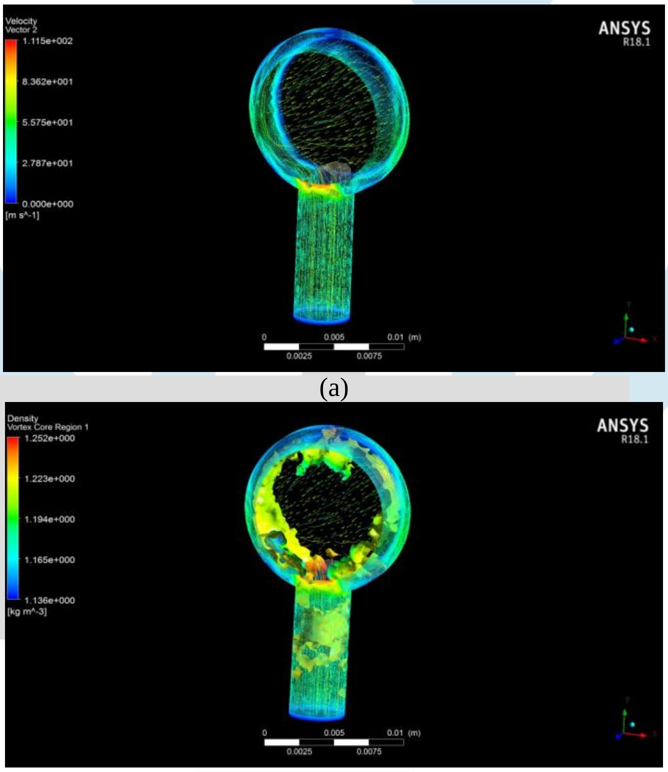


Fig 10: Airfoil Shape

The bladeless fan is created for local applications and its diameter is 30 cm. The bladeless fan could multiply volume flow rate of its intake air (about 15 times depend on geometry) by extracting air from back-up of the fan, as a result of its specific geometry. Some other advantages are low reduction, hidden impeller and more safety, easier to clean, and outlet airflow without circulation. Besides, multiplication of intake flow with respect to outlet flow and no danger for kids or pets are unique features of Bladeless fans. The mechanism of input and outlet airflow from this fan is shown in Fig. 8. At the first stage, the airflow is sucked into the fan through a revolving DC brushless motor and a mixed flow impeller. The intake air is accelerated by passing through an annular hole, and the cross section of this fan is similar to an airfoil profile. Then air is pushed out from a ring shape region and the air velocity is increased in this region. A considerable pressure difference is generated between both sides of the fan and the discharged air which can be described by Bernoulli's principle. This pressure difference draws the rear and surrounding air toward the front of fan. Therefore a Bladeless fan amplifies the intake air by drawing the air from behind and around the fan.



(a)

(b)

Fig 11: (a) Streamline (b) Vortex

IV. COMPARISSION WITH CONENTIONAL FAN

Table 1. Compression Detail

S.No	Conventional Fan	Bladeless Fan
1.	Large in structure	Effective in structure
2.	Air current produced is variable or rough	Air current is constant and amusing
3.	Noisy when in operation	No noise production
4.	Cooling effect decreases with distance	Cooling effect remains similar
5.	Reduced working area on desk	More area obtain for work on desk
6.	Difficult to clean	Easy To Clean
7.	Parts estimated outward which is less safer	No estimated parts i.e. design is safe

4.1 CONVENTIONAL FAN

The blade on conventional fans cause unpleasant buffeting because they chop the air before it hits the body.

Fig 12: Conventional Fan & Air Flow Pattern

4.2 BLADELESS FAN

Bladeless fan is done not create buffeting and it amplifies surrounding air which give an uninterrupted stream of smooth air.

Fig 13: Bladeless fan & Air flow Pattern

4.3 POWER CONSUMPTION

For Bladeless Fan

- Measured using a Kilo-watt at 120.5V:

- Lowest setting: 2-3W
- Medium setting1: 13-14W
- Highest setting: 31W
- Oscillation enabled: +2W

For Conventional Fan

Suppose the 75 Watt fan runs for 10 hours (10 P.M. to 8 A.M.) then the energy consumed is given by; E = 0.075 * 10 kWh = .75 kWh.

V. DISCUSSION

5.1 ADVANTAGES

1. Energy saving & smooth air flow
2. Durable design & Good material quality
3. Well-built looks & feels good
4. No buffeting
5. Uniform and Constant Air flow
6. One can set its off timing in advance so as to switch it off latter on its own.

5.2 DISADVANTAGE

1. Very expensive
2. Surprisingly loud at higher speeds

5.4 CONCLUSION

Thus the Design of the Ring is finalized, which provides a smooth airflow and clean air. Procedure of polypropylene bucket as the material makes it light in weight and reducing its chances of breakage. It helps to decrease the price and with the help of HEPA (High Efficiency Particulate Air) filter in its cylindrical base, the fan deliveries a constant flow of fresh air and has hidden blade in the cylindrical base and safer than the conventional fan. In conclusion the bladeless fan could amplify the volume of in taken air automatically about 15 times that travels over an airfoil through suction process.
There is no question that the Bladeless fan "Air Multiplier" is a remarkable invention. Its sleek design and innovative technology. Perhaps in the future, none of our fans will have visible blades. It is more effective than conventional fan and power consumption is also less.

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