



# **PARAG FANS & COOLING SYSTEMS LTD.**

## ***Energy Conservation with PARAG Energy Efficient Axial Flow FRP Fans***

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## INTRODUCTION:

The disruption of energy sources and resulting tenfold increase in petroleum prices has placed energy efficiency and conservation near the top of plant and institutional planning. Operators of **Cooling Towers / Industrial Ventilation and Exhaust / Radiator Cooling / Air Cooled Heat Exchangers / Humidifiers / Mine Ventilation / Withering Troughs** are constantly searching for innovative methods and equipment to lower total heat transfer cost and maintain constant process temperatures. One piece of equipment, which meets the goal, is automatically Axial Flow FRP Fans.

The reasons are -

- Lowest first cost
- Lowest Horsepower requirement.
- Lowest noise without extra cost.
- Lowest maintenance cost.

**Parag** fan designs have been under constant improvement. The Fan efficiency and pressure capabilities have all advanced significantly over the years. **Parag** Fans operate at 82-86 % mechanical efficiency as compared to 50-60 % efficiencies common with most of Aluminium Fans.

Modern Fibre Glass (FRP) fan normally enjoy quite long service time. **Parag** Fan designs incorporate aerofoil design and lesser number of blades per fan for efficiency. For each fan there is a “design point” which is established by specific airflow, total pressure, air density, fan speed and aerofoil selection. Starting with this data, it is possible to determine the one platform and twist distribution, which will accomplish the required work with minimum horsepower.

Maximum fan performance means more than just maximum airflow for minimum horsepower although that may be its most important parameters. Maximum fan performance also means that the fan achieves its expected service life with no problems. It could also mean that the fan meets its noise limitations specifications, if there is one, and that its vibration was low or met a given limit.

What follows is a discussion of how some major factors concerning the original selection; installation and operating environment also have significant impact on whether maximum fan performance is achieved.

## SELECTION OF THE FAN:

There are many fan combinations that will meet any given duty or operating requirements. The goal is to find the best one. This requires optimizing cost, horsepower and sound requirement. Horsepower is determined by a required airflow (m<sup>3</sup>/sec. or CFM), the system resistance to that airflow (called Static Pressure) and the fan efficiency.

## FAN EFFICIENCY:

There are two kinds of fan efficiency, Static and Total. It is easy to understand that the fan must work (move air) against the system resistance, which is called Static Pressure and is measured in Pascal ( $N/m^2$ ) or inches of water column (in - H<sub>2</sub>O). There is other work the fan must do is to collect air from 360° around its inlet and draw it through the fan. This work is also measured in Pascal ( $N/m^2$ ) or inches of water column (in- H<sub>2</sub>O) and is called Velocity Pressure. Velocity Pressure is not useful work and is called Parasitic Loss. The total work the fan has to do is against the Static Pressure plus Velocity Pressure. Not surprisingly this sum is called Total Pressure and the measure of how well the fan does this is called its Total Efficiency. If we consider only the useful work (Static Pressure) we consider Static Efficiency. In either case the horsepower required includes the parasitic work required to collect the air into the fan inlet. This brings up the question, which is most important to consider, Total Efficiency or Static Efficiency.

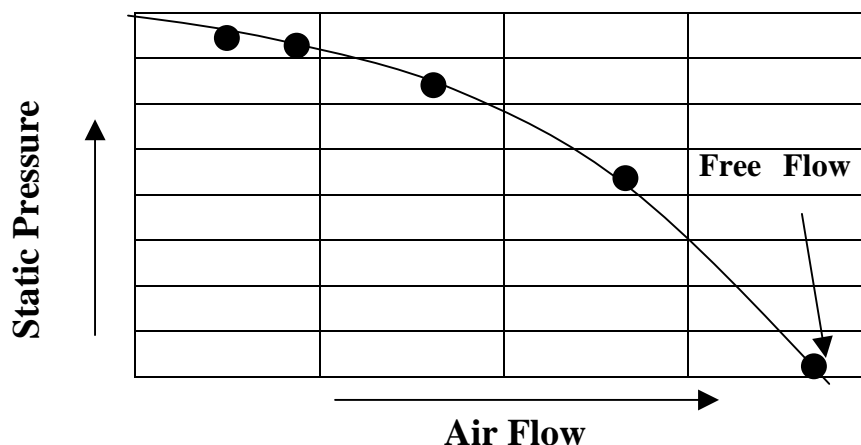
### Efficiency is calculated as below :

Total Efficiency	= $\frac{\text{Total Pressure (Pa)} \times \text{Air Flow (m}^3/\text{sec.)}}{1000 \times \text{Fan Shaft Power (kW)}}$
Static Efficiency	= $\frac{\text{Static Pressure (Pa)} \times \text{Air Flow (M}^3/\text{s)}}{1000 \times \text{Fan Shaft Power (kW)}}$

If considered their relationship by looking at a performance curve of one of the most popular fan type:

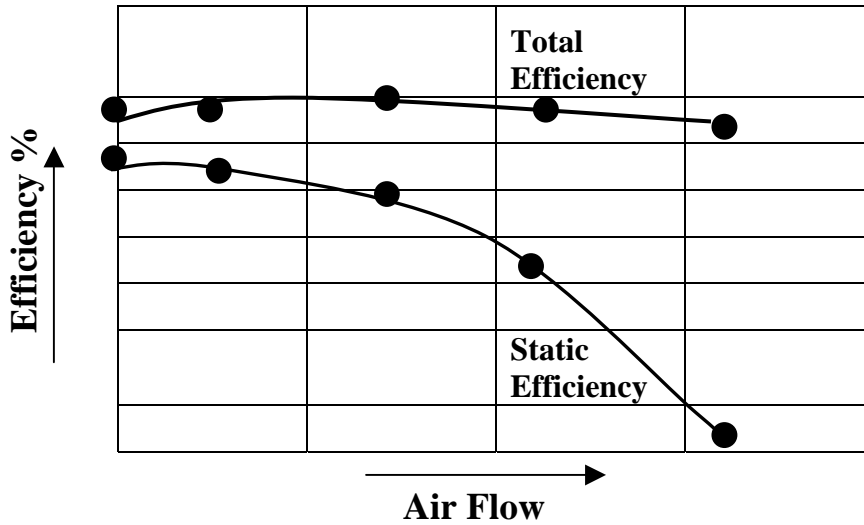
First consider how Total Efficiency and Static Efficiency vary along a pitch line. This pitch line describes the CFM and Static Pressure response of a given fan at a given density and speed.

Figure 1. shows the specific pitch performance by one fan manufacturer at five different random operating points. Note that **Static Pressure is always zero at the “Free Flow” point of the curve.** It should be because at that point Total Pressure equals Velocity Pressure and Static Pressure is zero.



**FIGURE 1**

Figure 2 shows how Total and Static Efficiency varies with increase in air flow

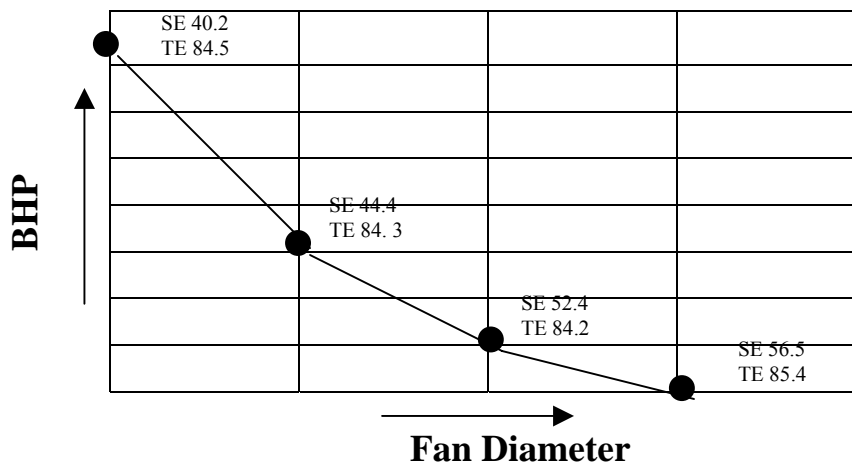


**FIGURE 2**

Note that Total Efficiency remains relatively constant, but Static Efficiency is maximum at low flow, high static pressure region. Note this optimum efficiency occurs just before fan “stall” even though the stall point may not be shown on the curve. Every axial flow fan operates on these same principles. Assume you have the Static Pressure versus CFM response for your optimum system resistance. There are many fan combinations of blade and speed variations where the fan output, in terms of static pressure and flow, meets the exact requirement of your “system”. If you have already established a duty point, what option do we have to maximize performance? We can vary the fan speed and number of blades per fan, for instance.

The most important point is that varying tip speed for a specific duty typically does not have a major effect on power for the same number of blades since the fan duty point is the same for all speeds. Blade count typically increases as we slow down to lower tip speed and decrease as we speed up. As blade count go up, efficiency generally goes down and power required goes up for a specific duty point on most fans. Optimizing fan speed can minimize this decrease in efficiency.

Figure 3 shows a dramatic change in required power at various diameters. This is because the operating point moves towards maximum static efficiency as the diameter increases, even though the Static Pressure and flow required is the same for all cases. SE and TE on curve represent Static Efficiency and Total Efficiency at each point.



**FIGURE 3**

There will also be a minor difference in horsepower as function of pitch angle and speed in the same fan. This is because some angles are more efficient than others. This will be the same for any fan.

So far, we can make some conclusions about efficiency. For a given fan:

- Static Efficiency, not Total Efficiency, indicates useful work.
- Static Efficiency peaks at high pressure and low flow for each blade pitch line.
- Efficiency varies continually along pitch line as CFM and Actual Static Pressure changes.
- The Efficiency you achieve is primarily a function of the fan selection and the operating point, which is function of the system resistance.
- About seeking lowest horsepower, varying fan speed does not have a major effect for the same blade count for a specific duty, to reduce power.
- Use the largest diameter fan possible to maximize Static Efficiency and minimize Velocity Pressure for a fixed duty. Optimizing fan speed and pitch angle for the diameter chosen can make further improvement.

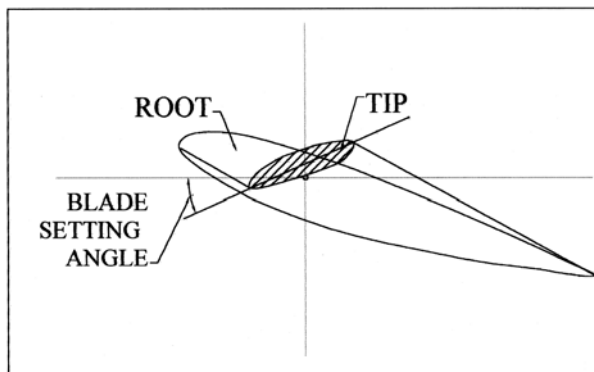
## FACTOR EFFECTING FAN PERFORMANCE:

### AIRFOIL DESIGN:

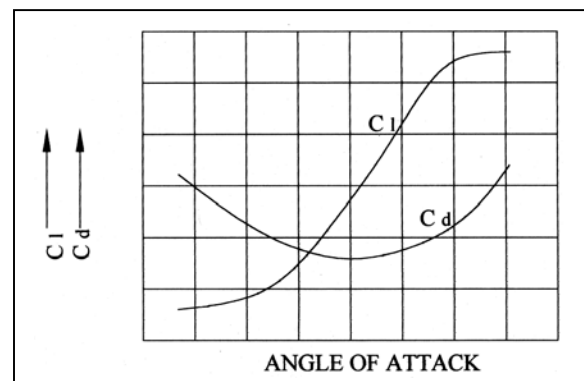
A Fan blade induces air flow by virtue of the blade surface imparting dynamic energy to the air, the more efficient the blade airfoil, the greater the air flow. The measure of how efficiently the blade is able to move air can be determined by the blade's air foil Coefficient of Lift ( $C_l$ ); the higher the  $C_l$ , the more efficient the blade. The resistance the blade offers to the air flow is determined by the Coefficient of Drag ( $C_d$ ); The higher the  $C_l$ , the less efficient the blade.

A simple way of characterizing the overall efficiency of the blade is to plot ( $C_l$ ) and ( $C_d$ ); values against various angles of attack, the airfoil with the greatest  $C_l / C_d$  value would be the most efficient

A blade profile having a greater twist and camber allows for more efficiency and uniform flow. Parag FRP Fan Blades, manufactured by a unique molding process, incorporate greater twist, camber and wider chord widths that are difficult to achieve with conventional metallic fans.



**FIGURE 4**



**FIGURE 5**

### STRUCTURAL DESIGN OF FAN BLADE:

During the course of operation, a fan is subjected to great aerodynamic and mechanical loads, and therefore must be designed to withstand such forces for the duration of its life. Due to the precise integrated fiber matrix used in Parag FRP fans, a higher fatigue strength is achieved as compared to conventional aluminium fans.

## FAN SPEED / TIP SPEED:

Noise emitted by the fan is function of tip speed 6<sup>th</sup> power (approx.) thus a small reduction in tip speed has considerable effect on noise level.

To optimize the fan performance and noise level, operating points can be worked out at various speeds, by applying the fan laws i.e.

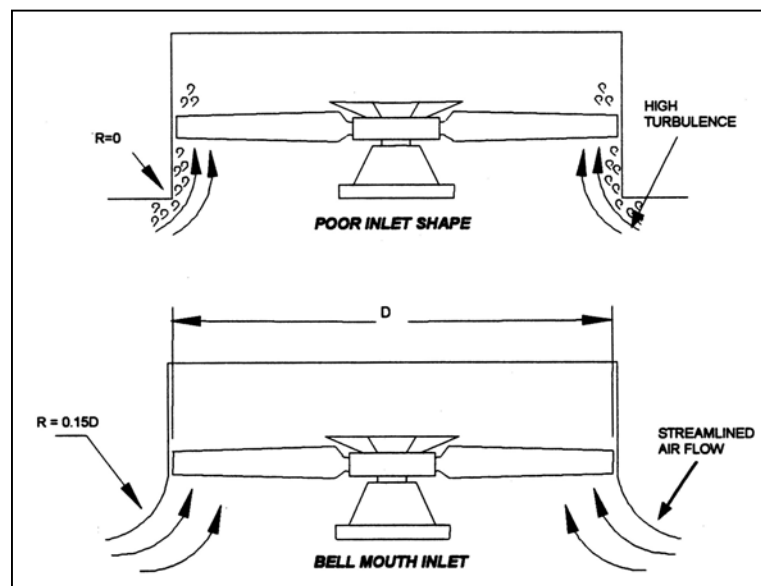
- (a) Airflow varies directly with the speed N
- (b) Total pressure varies as  $N^2$  and
- (c) Fan Power varies as  $N^3$ .

The final operating speed can be selected by making compromise in between the best efficiency point speed and available motor speeds.

Many fans have critical speed ranges; it should be always ensured that the fan operating speed does not fall within this critical range.

## INLET SHAPE & OBSTACLES:

The flow pattern in which the air flows through the inlet to the fan tip is of paramount importance. As the air is induced out of the plenum chamber beneath the fan, it tends to follow very predictable streamlines into the fan casing. As the air moves in to the casing, a vena-contracta develops. The best-suited shape of the fan casing as well as the optimum height of the fan in casing is actually based on this Vena-contracta.



**FIGURE 6**

The straight-sided inlet shape would definitely deteriorate the fan performance due to following:

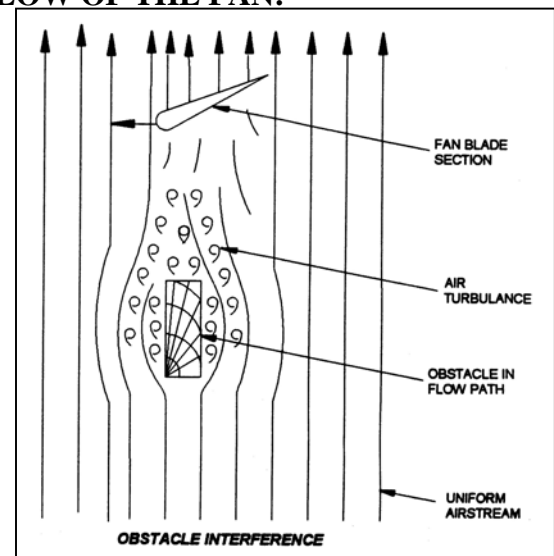
- (a) The fan blade tips are operating outside the vena contracta in a region of low airflow.
- (b) The area between the casing wall and vena contracta develops high turbulence, which further increases the pressure losses and thus reduces fan efficiency.
- (c) If the fan is located low in the casing, then the air approaching the blades attacks at an angle, causing further efficiency degradation, as the blades have to perform extra work of turning the air.
- (d) In general, the best operating results are obtained when the airflow has a smooth entry to the fan. This can be best achieved by providing an inlet bell mouth shape. The bell mouth shape reduces the turbulence, as the air enters the fan with uniform velocity. This shape also reduces the noise turbulence. The optimum bell radius is  $R/D = 0.15$  where R is the radius of bell and D is the fan diameter.

#### EFFECT OF OBSTACLES PRESENT IN THE AIR FLOW OF THE FAN:

Obstacles located in either front of back or a fan may effect the efficiency due to the turbulence caused by the interference in the air flow. Such interference in the air flow. Also tends to increase the noise level.

Obstacles in the air flow path will induce a higher velocity pressure. This is due to the reduction of 'Fan Net Free Cross Sectional Area' that the air is flowing through. The ultimate effect is a loss in static efficiency of the fan.

Although in an actual situation, it is virtually impossible to have completely obstacle free flow path, an optimum compromise can be achieved by reducing the number and streamlining the required structural members.



**FIGURE 7**

#### BLADE PITCH ANGLE :

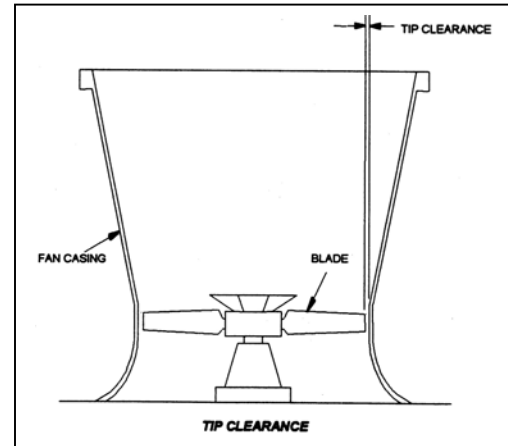
Varying the blade pitch angle has a proportional effect on the static pressure, increasing the pitch angle results in a higher static pressure and vice versa. For any specified duty, the applicable fan will have a optimum pitch angle setting pertaining to its maximum achievable efficiency. In general, it is advised that all the blade tip angles should be set at least two degrees less than the maximum permissible pitch angle to avoid a stall condition. Further , it is advisable that all the blades are set at the same pitch angle to prevent excessive noise and vibration.



**TIP CLEARANCE:**

The clearance between the tip of the blade and the fan casing influences the fan performance. Large tip clearances allow the shredding of a vortex from the upper surface of the blade back to the low-pressure area beneath the fan; this produces lowered airflow rates and reduced fan efficiency.

The smaller the fan diameter greater would be the sensitivity to changes in tip clearance since a larger portion of the smaller blade is being influenced by the tip clearance.



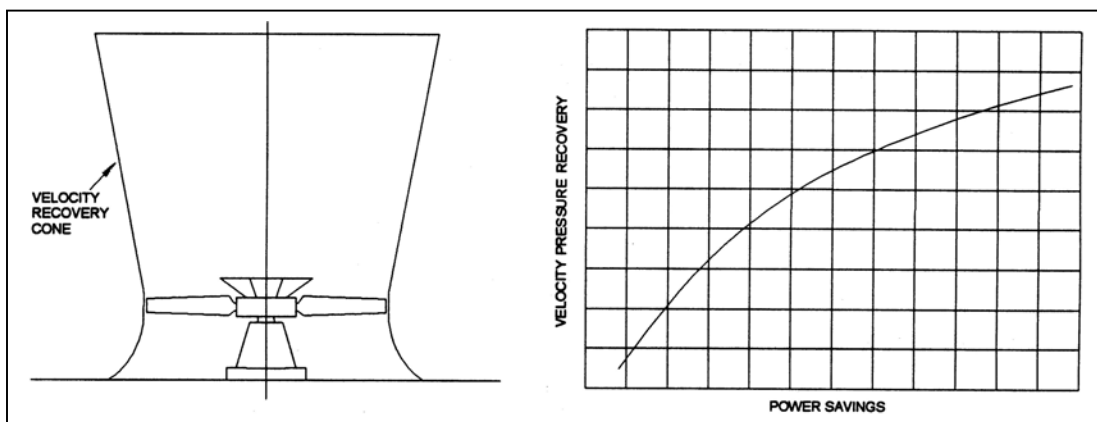
**FIGURE 7**

**ALTITUDE & TEMPERATURE:**

With varying atmospheric conditions, the air density value changes. This change directly affects the pressure and power characteristics of a fan. Pressure and power vary proportionally to the air density, however, the air flow will remain the same.

**VELOCITY RECOVERY CONE :**

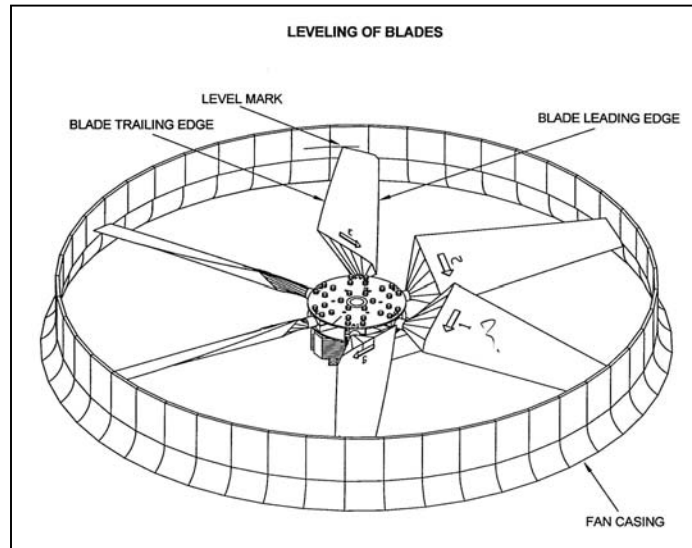
The purpose of a velocity recovery cone is to reduce the exit velocity pressure and thereby convert the velocity pressure losses into useful pressure work. It is advisable to use a velocity recovery cone in order to reduce the power consumption when the operating velocity pressure is more than 5 mm WG (0.2 in WG). The efficiency of velocity recovery is normally 60% to 80%, depending on the length of the cone to fan diameter ratio.



**FIGURE 8**

## BLADE LEVELING :

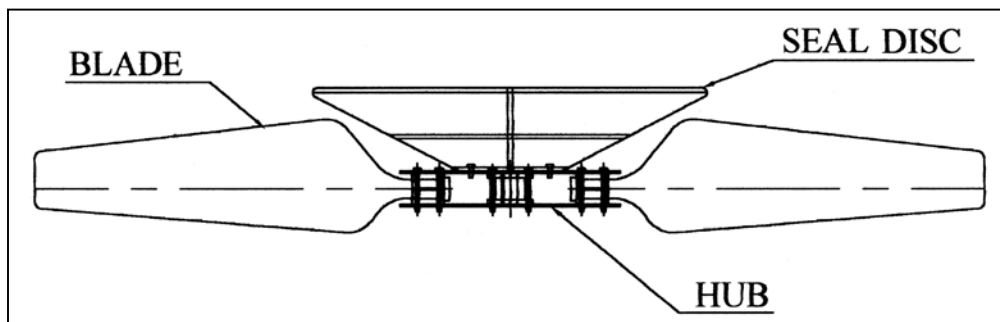
It is important that all the blades are leveled on the same plane. Difference in blade levels will result in increased fan vibration and noise. The recommended level variation between any given blade on a fan of up to 20 feet in diameter should not exceed 15 mm, and 25 mm for fans larger than 20 feet diameter.



**FIGURE 9**

## SEAL DISC :

During the fan operation, regions near the hub have a reverse air flow. The overall result is a reduction in air flow and thus the loss of efficiency. To minimize the reverse air flow, a seal disc may be mounted on the discharge side of the hub.



**FIGURE 10**

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## **ENERGY SAVING WITH PARAG HIGH EFFICIENCY FRP FANS BY REPLACING EXISTING CONVENTIONAL ALUMINIUM / FRP / GRP FANS:**

In case of Cooling Towers / Radiator Cooling / Air Cooled Heat Exchangers / Mine Ventilation / Humidification plants / Withering Troughs in Tea Industries the purpose of a fan is to move a specified quantity of air through the system, while doing so the fan has to overcome the system resistance which is defined as the pressure loss. The product of airflow & the pressure loss is air power developed / work done by the fan; this may be also termed as Fan output.

To obtain the desired output from the fan, an input in the form of electrical energy is to be provided, which is equal to 
$$\frac{\sqrt{3} \times V \times I \times \text{Cos}\Phi}{1000} \text{ kW.}$$
 Where as V = Voltage , I = Current (Amps)  
CosΦ = Power Factor

Thus it is obvious that a fan having higher efficiency will require less input power. The fan efficiency in turn is greatly dependent on the profile of the blade. An aerodynamic profile with optimum twist, taper & higher  $C_l / C_d$  ratio can provide the fan total efficiency as high as 85 – 92 %. However this efficiency is drastically affected by the factors mentioned earlier such as tip clearance, obstacles to airflow, inlet shape etc.

As the metallic fans are manufactured by adopting either extrusion or casting process it is always difficult to generate the ideal aerodynamic profiles. Whereas the FRP blades are normally hand molded which facilitates the generation of optimum aerodynamic profile to meet specific duty condition more efficiently.

Further more due to light weight FRP fans need low starting torque resulting in use of lower HP motors. The lightweight of the fans also increases the life of the gearbox, motor and bearing is and allows for easy handling and maintenance.

### **BENEFITS OF PARAG ENERGY EFFICIENT AXIAL FLOW FRP FANS**

- Optimal Aerodynamic Design of Fan impellers to provide higher efficiency for any specific application.
- Reduction in over all weight of the fan provides extended life of mechanical drive system as well as ease of handling and maintenance.
- Requires lower drive motor rating and light duty bearing systems
- Low power consumption resulting in appreciable energy savings as compared to existing metallic fans.
- FRP Fans produced by composite fabrication processes such as compression molding / resin transfer molding technique have uniform dimensions and consistent quality of fan blades.

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- Optimum aerodynamic design of blades results in considerable reduced operational noise levels.
  - Longer life of fans due to improved mechanical strength.
  - Excellent corrosion and erosion resistance
  - Vibration free operation.
  - Special Resin Systems can be incorporated for high temperature, Zero Static electricity, Phosphatic – Fluorine environments and fire retardancy.

### **IN CONCLUSION:**

Optimizing fan performance (is considered wider objective of achieving the highest possible overall performance and reliability) is a process that requires close attention to detail, from Fan design, to choice of an operating point, consideration of the fan's environment, and finally, proper installation. The reward for this close attention will be a long, trouble-free life for our fans with minimum operating costs.