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Dated: 13th December 2021

Award Letter for Consultancy Project on "Consultancy Project on Modification of Ceiling/Table Fan"

Dear Dr. Saurav Dixit

K R Mangalam University

Gurugram Sohna Road

Haryana

Please refer to your discussion related to Consultancy Project on Modification of Ceiling/Table Fan", we are pleased to inform you that the management of our company has approved the said project and has sanction amount of Rs. 7,50,000/- (Rs. Seven Lakh & Fifty Thousand only) towards the project implementation cost payable to your organisation "K R Mangalam University".

You are requested to initiate the process of delivering the said project.

Regards

For Kent Industries
For KENT INDUSTRIES

Authorised Signatory
Authorised Signatory

Registrar
K.R. Mangalam University
Sohna Road, Gurugram, (Haryana)

"Consultancy Project on Modification of Ceiling/Table Fan"

Introduction

The entire world essentially runs on electricity, in one form or another, and while combustibles are essential at the present time as well, their time is nearing an end. Most of the devices and appliances are run from electricity so it is present everywhere as in our bed room, kitchen, roof, in our office, in the path, in trains. A ceiling fan/table fan is a mechanical fan, usually electrically powered, suspended from the ceiling of a room that uses hub-mounted rotating paddles to circulate air. A ceiling fan rotates much more slowly than an table fan; it cools people effectively by introducing slow movement into the otherwise still, hot air of a room, inducing evaporative cooling. Fans never actually cool air, unlike air conditioning equipment, but use significantly less power (cooling air is thermodynamically expensive). Uses ceiling fans/table fans are very commonly used for circulation of air in a room to bring the cooling purpose easier. Due to circulation of air in a room, the cooling rate increases and we feel cool and less suffocation. When the air is circulated, air comes from other place and due to this the room becomes cool. The fan consists of a rotating arrangement of vanes or blades which act on the air. Unlike air conditioners, fans only move air; they do not directly change its temperature. Therefore, a mechanism can be employed in ceiling fans for reversing the direction in which the blades rotate (most commonly an electrical switch on the side of the unit) that can help in both heating and cooling. Furthermore, the efficiency of ceiling fans/table fans can be improved by using different materials with various lengths of blade. In order to attain the better efficiency, optimization of process parameters can be investigated and studied.

Training Programme Objectives

This Training will help participants to:

- Understand the concept of Ceiling/table fan working principle
- Information regarding fabrication details
- Identified the pros and cons of Ceiling/table fan
- Information about blade design and specifications
- Effect of various optimized parameters on the efficiency of fan
- Reviewed the modifications performed on ceiling/table fan.

Training Programme Outcome

By the end of this training course, the participants will be able to:

- Understand the basic electro-mechanic concept of ceiling/table fan
- Recognize the importance of blade design and direction in ceiling/table fan
- Slightly change in design input parameters can lead to tailor the efficiency of ceiling/table fan
- Economical aspects of ceiling/table fan with respect to blade material
- Extension plan in ceiling/table fan modification can lead to friendly environment of room

Prospect Participants/ Target Audience: Engineers, technical workers, Design team, and Production team.

Budget of Training Programme

S.No.	Activity	Cost
1	Trainers (2) (Rs. 20,000 per session and Total Sessions 10)	Rs. 2,00,000
2	Logistics	Rs. 1,00,000
3	Study Material for Participants	Rs. 1,50,000
4	Experimental Testing	Rs. 2,00,000
5	Refreshment and Lunch	Rs. 1,00,000
	Total	Rs. 7,50,000

Sessions of Training Programme

S.No.	Session	Activity	Duration
1	Session 1	Defining Ceiling/table fan principle	9.00 AM to 4:00 PM
2	Session 2	Technological Review	9.00 AM to 4:00 PM
3	Session 3	Technical specifications of blade	9.00 AM to 4:00 PM
4	Session 4	Blade design information	9.00 AM to 4:00 PM
5	Session 5	Effect of blade dimensions on fan performance	9.00 AM to 4:00 PM
6	Session 6	Effect of different materials on fan performance	9.00 AM to 4:00 PM
7	Session 7	Effect of process parameters on fan performance	9.00 AM to 4:00 PM
8	Session 8	Design modifications and testing	9.00 AM to 4:00 PM

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9	Session 9	Implementation of modifications	9.00 AM to 4:00 PM
10	Session 10	Optimization of process parameters and testing	9.00 AM to 4:00 PM

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Budget of Training Programme

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Details of various Sessions of Training Programme

Participants have spent the first part of the day discussing what will take place during the sessions and have an opportunity to identify their learning objectives. Based on this the following topics were covered in ceiling/table fan working principle and a complete overview has been provide to the participants on the very first day to make them accommodate for the upcoming sessions:

Session One: Introduction to the Ceiling/table fan principle.

How does a ceiling fan work?

In its most basic sense, a ceiling fan works by rotating pitched blades. The pitched blades create air flows that produce better air circulation, thus helping "cool" the body. The cooling sensation is, of course, only due to the movement of the fan. While it may enhance the effectiveness of your A/C or heating system by circulating that cooled or heated air, a ceiling fan on its own cannot actually change the temperature of a space. There are several different factors that play in a well-functioning fan. You now know how to size your ceiling fan to your room. The next few questions will teach you the different ways to control a fan, what airflow and CFM are, and why DC Motor Fans are becoming more common.

How do I control the fan?

There are three ways to operate a fan: a pull chain, a handheld remote or a wall control. Pull Chain: The pull chain is located right on the fan and provides an easy way to adjust the speed and turn a fan on and off (and its light, if it has one). Remote: The most convenient of all fan controls, handheld remotes allow for the fan to be operated from anywhere in the room. Wall Switch: Wall controls are as convenient a way to operate ceiling fans as a light switch is for a lamp. If installed next to a doorway, the chance of forgetting to turn off the fan when leaving a room is greatly reduced. In some instances, you can have the best of both worlds with a remote control and wall switch combo, or a remote control that can be wall-mounted.

What is CFM and ceiling fan airflow?

Airflow quantifies the amount of air a ceiling fan delivers and is measured in CFM which stands for cubic feet per minute. CFM measurements are taken when a fan is on high speed, then that number is divided by the watts used. This means that the higher the CFM, the more efficient the fan, and the more air it moves. 75 cfm/w is the minimum to be considered efficient, according to Energy Star requirements. The Environmental Protection Agency requires that all ceiling fan manufacturers put the following graphic on all their boxes, brochures, catalogs and such, so that you will have an exact understanding of the power behind your fan: How to find the airflow and CFM for your ceiling fan Y Lighting At a glance, this information helps you to gauge a ceiling fan's airflow and efficiency. This makes it easy to compare two or more fans of similar size.

What is a DC Motor ceiling fan, and what are its benefits?

DC motors are a new addition to household ceiling fans that generate additional torque while consuming less than 70% of the power of a typical ceiling fan. They do this by transforming electric energy into mechanical energy as they rotate. DC motor fans have a slightly higher upfront cost than regular ceiling fans since they need a more expensive electronic speed controller. However, their benefits more than make up for it. These benefits include: Virtually silent operation Much smaller motors that result in smaller, lighter fans Efficient energy use that prolongs the fan's life span Higher torque resulting in faster startup speeds The possibility for up to 6 different speeds In cases where lighting is included, DC fans typically utilize LEDs, which only add to the fan's energy efficiency. The number of ceiling blades is often an important point in deciding what type of ceiling fan to purchase, but this is becoming less of a question of function and more of personal choice with advancements in technology. It used to be the case that a five- or six-blade ceiling fan would translate into more efficiency as opposed to a three blade or four blades, but that's no longer the case. Since the CFM is the measure for a fan's airflow efficiency, the number of blades is more related to embellishing the style for your space. For example, a four or five blade ceiling fan provides a more conventional, balanced look, whereas a fan with two or three blades possesses a modern and sleek style.

Session Two: Technological Review of ceiling/table fan.

Ceiling/table flow fans are commonly used for heating, ventilating, air conditioning, tunnel and mining applications. In each form, the physical properties of the fan should be designed specifically for the application's needs. For example, in specific tunnel and mining applications, reaching the air at the operational area is vital. Therefore, the main design concern is to obtain the required pressure difference to transfer the required amount of fresh air. Moreover, in some heating applications, the flow rate becomes more critical since the heating rate is directly related to the flow rate. In that case, physical properties of the fan should be designed considering the air velocity and required heating rate of the application point. In addition to that, in some exhaust or fire applications, fan direction can be determined according to the location of the smoke. Therefore, the fan must be able to blow the air bi-directionally, and it should be designed using a proper airfoil profile which can generate flow rate in both directions. This wide-range usage calls for the utilization of different types of ceiling/table flow fans.

The subject of this thesis is the design, construction and performance evaluation of ceiling/table fan. In the design part, the commonly used empirical design methods in the literature are examined and employed. In the software implementation part; algorithm, design methodology, assumptions, database organizations and user interface are explained. Moreover, an example fan design is demonstrated using ceiling/table flow fan design software. In numerical analyses phase, Computer-Aided Design (CAD) model of the fan is generated by using the custom software and the model is analyzed by using the commercial Computational Fluid Dynamics (CFD) software with selecting the proper mesh type, boundary conditions, solution methodology and turbulence model. In the construction and experimental test part, the ceiling/table flow fan is manufactured and tested experimentally. Finally, the accuracy of the ceiling/table flow fan design software is validated with the results of the CFD analysis and the experimental tests.

General Information on Ceiling/table Flow Fans

In ceiling/table flow fans, as the name suggests, the direction of the fluid flow is in the ceiling/table direction, it means that flow is parallel to the axis of rotation or parallel to the fan shaft. Ideally, the velocity of the fluid in flow has no radial component. On the other hand, there is a tangential velocity component caused by the rotation of the impeller. It supplies the required pressure rise to the fluid flow.

In many ceiling/table flow fan applications, the air is used as a working fluid at medium- pressure and low-speed. Since the operation range of air is mostly incompressible, the change in the air density is too small compared to the change in the air pressure; and therefore, can be neglected.

Fluid compressibility depends on various physical properties of ceiling/table flow fan. Increasing the diameter of the fan and the rotational speed of the motor lead to an increase in the velocity of the fluid at the tip. Changes in the fluid density can be neglected until 0.3 of Mach number, but when the fluid velocity is over 0.3 Mach, the fluid will be compressible. So, there is a limit to the design parameters for obtaining an incompressible working fluid.

The main applications of ceiling/table flow fan are heating, ventilating, air conditioning in mines, tunnels, transportation, electronic devices, industrial applications, buildings and vehicles. In order to provide extensive range usage, there are different types of ceiling/table flow fan, and they are categorized according to their pressure rise and flow rate capabilities.

Classification of Ceiling/table Flow Fans

Propeller Fans

The first kind of ceiling/table flow fan widely used in industrial applications is propeller fans or sometimes called panel fans. These fans have a low-pressure rise and high flow rate capabilities. They are generally used for exhausting air from a room or a factory. The hub-tip ratio for these fans is generally less than 0.3, and they have low production cost.

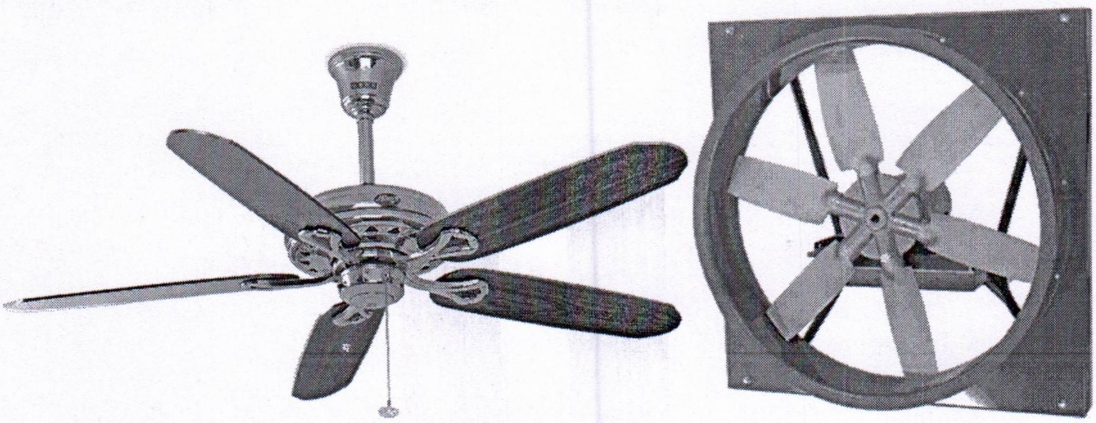

Figure. Propeller Fan in Direct-Drive Arrangement

Propeller fans are generally mounted on the walls or windows of the buildings. They can be used with other propeller fans on the same wall and operated in parallel to obtain a higher flow rate. Propeller fans have two types of drive arrangements, namely belt-drive or direct-drive arrangement. In the direct-drive arrangement, the electric motor is directly mounted to the rotor of the fan. The production cost is lower compared to belt-drive arrangement as a belt and pulleys are not used. Moreover, the direct-drive arrangement is more efficient than belt-drive since no losses are stemming from friction and transmission. A propeller fan in a direct-drive arrangement is shown in figure.

In belt-drive arrangement, the rotational motion of the electric motor is transferred using a belt and pulleys. Since the reduction ratio of the pulley can be adjusted, the rotational speed range of belt-drive arrangement is more comprehensive that of the direct-drive arrangement. This speed control feature allows the use of belt-drive arrangements in larger size propeller fan applications. A propeller fan in belt-drive arrangement is shown in Figure .

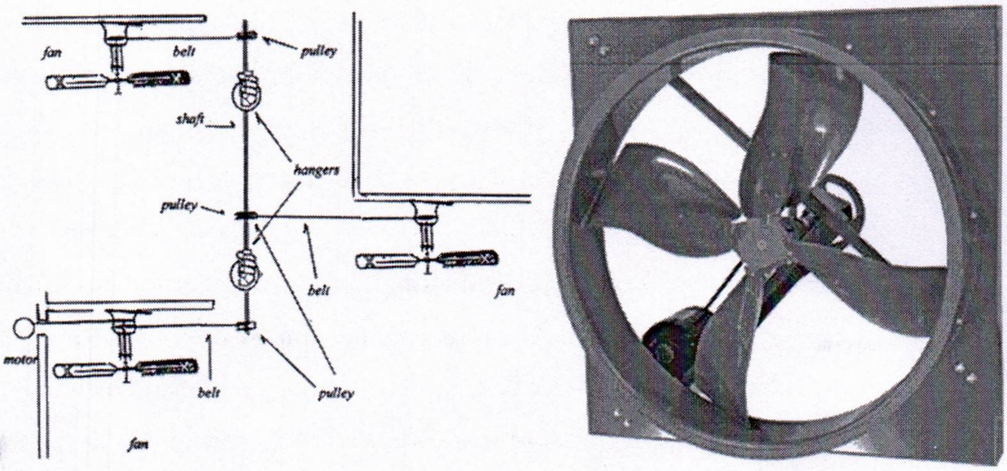

Figure. Propeller Fan in Belt-Drive Arrangement

The focus of most of the studies on the ceiling/table flow fans is regarding the design methods. These are generally about the fan blade and the ceiling/table flow fan design methods. In the blade design methods, isolated airfoil approach versus cascade airfoil approach is mostly compared. In ceiling/table flow fan design methods, the differences between the design steps are compared and analyzed.

Design methods are compared with respect to numerical and experimental studies. In the numerical studies, analyses are performed using Computational Fluid Dynamics (CFD) tools and other mathematical models. The turbulence models used in the CFD tools are compared according to their performances. In experimental studies, performance curves of fan are obtained experimentally, and the results are compared with numerical ones. Additionally, airfoil types are also compared. In this case, the impellers of the ceiling/table fans constructed by using different airfoil types are compared. Castegnaro studied the differences in the design methods for low-speed ceiling/table flow fans. The choice of the airfoil and the solidity distribution, the computation of the stagger angle of the blade elements and the determination of the number of blades are the methodological differences among the classical design methods. Three tube-ceiling/table flow fans and two types of airfoil, C4 and NACA 65, are used in this work. The purpose of the first fan is to find out the best airfoil and obtain the most accurate formula for the stagger angle. The second fan is used in determining the convenient solidity distribution. In the last fan, Reynolds number effect on the flow deflection is examined. The results show that C4 airfoil is the most convenient airfoil type for the ceiling/table fan applications and recommended formula for the stagger angle due to the achievement in the required flow deflection and the fan pressure. In order to get the optimum solidity distribution, two blade types are used, and results show that the blade designed according to a linear diffusion factor criterion has higher efficiency than criterion-based blade. Lastly, it is found in the third fan that the flow deflection reduces about 12% when the fan works at 1000 rpm instead of 2000 rpm for the same propeller.

In another study of Castegnaro, the cascade and the isolated airfoil approaches on the blade design are analyzed. It is stated that the cascade approach is valid for high solidity isolated airfoil approach is valid for low solidity and for medium solidity modified isolated approach is generally used. The aim of this work is to compare the performances of the modified isolated airfoil approach, modified cascade approach and their mixed form on the medium solidity blades. In the scope of the study, two rotor-only ceiling/table flow fans are tested experimentally and numerically. The airfoil type using in the blade profile of both fans is chosen from NACA 65 series. In the CFD model, the model of Wilcox is applied in the solution. The analyses are performed on the commercial code CD- Adapco StarCCM+©. The experimental results show that the modified isolated approach is an effective design method for blade design; while it is proven that the mixed approach is the most accurate approach for medium solidity values. Moreover, the cascade approach is found not enough to supply the required flow deflection for low-solidities. Ahmed et al. examine the effects of solidity ratios, and stagger angles on the flow field around NACA 0012 airfoils numerically using the turbulence model. The flow separation on the training edge of the airfoil for different angles of attack is predicted for solidity ratios and stagger angles. The angles of attack are varied from 0 to 24 degrees, and the stagger angle is varied from 10 to 30 degrees while the solidity is ranged from 0.55 to 0.83; and the resulting pressure, lift and drag coefficients are recorded. The results show that the decrease in the solidity ratios causes to start the flow separation earlier. Boundary layer thickness increases with the increase in the angle of attack but increasing rate comes down with the decrease in the solidity ratios. Pressure coefficient at the suction side increases with the decrease in the solidity. The lift coefficient decreases when the flow separation starts and it is observed that the lift and drag coefficients increase with a reduction in the stagger angle at high incidences. Masi et al. study on the design criterion for high efficiency for tube-ceiling/table fans. In the tube-ceiling/table fans, the desired pressure rise requirements may not be achieved in the application due to not having guide vanes or straightened. It is stated that this problem may be overcome by the knowledge of the design constraints such as maximum size and rotational speed. Thus, one of the aims of this work is to give a suggestion about the sizing for high-efficient tube-ceiling/table fans. The second aim is to help the fan designer to give efficiency diagrams, and therefore, the designers can check whether their fan is acceptable or not. Two design scenarios are used in the experiments. The design objective of the first scenario is to obtain maximum efficiency, and it is called unconstrained design scenario. The design objective of the other scenario is to obtain maximum efficiency with fixed rotational speed and external diameter, which is called as a design under constraints on fan size and rotational speed. The analysis shows that the fan efficiency depends on the trade-off between ceiling/table diffusion losses and the swirl velocity at the rotor outlet, and the fan sensitivity improves with the increase in the volumetric flow rate. It is suggested that hub-tip ratio should be as low as possible since the fans having a low hub-tip ratio are less sensitive with respect to the application types. If it is not possible, the tail cone diffuser is suggested for utilization. Venter et al. study the tip clearance effect on the performance of an ceiling/table flow fan. In the study, a new approach where not only changes in the static fan pressure and fan static efficiency are evaluated but also volumetric flow rate changes are employed, is used. The test code used in the study is BS 848: 1980: Type A, which implies that free inlet and free outlet conditions prevail. The fan used in the application is 8-bladed 1542 mm of diameter ceiling/table flow fan. Six different tip clearances are used, and their sizes are varied between 3.0 mm to 10.5 mm. The analysis shows that an increase in the tip clearance ends up with a decrease in the static pressure, the static efficiency, the power consumption and the volumetric flow rate of the fan. Moreover, it is also found that the type of the application and size of the rotor have an impact on fan performance. Pogorelov et al. also study the effects of tip clearance on the flow field in an ceiling/table flow fan. Numerical analysis is performed by using large-eddy simulation. Compressible Navier-Stokes equations are used in the solution. The purpose of the numerical analysis is to find out the impact of the clearance width on the overall flow field, and it is observed that decreasing the tip clearance

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completely affects the flow field: First of all, the blade-wake interaction is removed. Secondly, the amplitude of the tip clearance vortex, and lastly, the noise-level decreases with decreasing tip clearance. Yilbas et al. study the numerical simulation of flow field developed around a cascade of NACA 0012 airfoils. Two-dimensional incompressible Navier-Stokes equations are used in the numerical solution of the flow field. Turbulence effects are also included in the solution by using model. Lift, drag and pressure coefficients are calculated for different angles of attack varying between 0 and 24 degrees and different solidities swept between 0.55 and 0.83. According to the results, it is concluded that the pressure coefficient of the suction side of trailing edge increases with decreasing solidity. However, it is predicted that the lift coefficient drops suddenly when the flow separation starts, and no drastic reduction in the lift coefficient is observed. It is also seen that the increase in the solidity causes the incidence angle to increase at which maximum lift occurs. Moreover, the effect of rotation of leading edge on the drag coefficient is also examined and it is concluded that the rotation causes the drag coefficient to decrease, increase the lift coefficient.

Session Three: Technical specifications of blade of ceiling/table fan.

The first thing to consider when deciding your ceiling fan size is the size of the room in which it will go. The square footage of a room dictates how big the ceiling fan will need to be because a fan that is too small or big for a space will not circulate the air properly. If you don't know it already, you can measure a ceiling fan's size by recording the diameter of its blade sweep, or from the tip of one blade to another straight across from it. If your fan has an odd number of blades, then measure from the tip of one blade to the center of the fan and double that number for your measurement. Once you know how large your ceiling fan's size is, you will need to measure the size of your room.

Ceiling Fan Size Guide:

Fan Size	Room Size	Room Type
29″ or less	less than 50 sq. ft.	Hallway, Laundry Room, Walk-In Closet
36″	up to 75 sq. ft.	Breakfast Nook, Large Bathroom

42″	up to 100 sq. ft.	Bedroom, Office, Kitchen
52″	up to 225 sq. ft.	Master Bedroom, Dining Room, Patio Area
56″	Up to 400 sq. ft.	Large Living Room, Great Room

In larger spaces, depending on the shape of the room, another option can be to go with two smaller fans. When sizing a ceiling fan to your room size, you want a minimum of 18″ to 24″ of clearance on all sides of the fan.

Session Four: Blade design information.

The number of ceiling blades is often an important point in deciding what type of ceiling fan to purchase, but this is becoming less of a question of function and more of personal choice with advancements in technology. It used to be the case that a five- or six-blade ceiling fan would translate into more efficiency as opposed to a three blade or four blade, but that's no longer the case. Since the CFM is the measure for a fan's airflow efficiency, the number of blades is more related to embellishing the style for your space. For example, a four or five blade ceiling fan provides a more conventional, balanced look, whereas a fan with two or three blades possesses a modern and sleek style. This guide enables architects, designers, and engineers to maximize the many benefits of integrating ceiling fans into building systems. It introduces the advantages of using ceiling fans, describes how ceiling fans work, provides guidance and resources for designing spaces with ceiling fans and specifying ceiling fan products. This widespread applicability stems from the many benefits that ceiling fans can provide in interior environments. The key benefits of ceiling fans are as follows:

- Thermal Comfort
- Improved Air Distribution
- Improved Perceived Air Quality
- HVAC First Cost Savings
- Energy Savings

The following subsections describe each of these benefits in more detail.

Thermal Comfort

Simply stated, thermal comfort is an occupant's satisfaction ("comfort") with the perceived temperature ("thermal sensation") of their environment. For centuries, humans have been using fans to help regulate. thermal comfort. The reason for this is simple: in warm conditions there is generally less heat lost from the skin than in cooler conditions, and so people are at risk of warming up (the science of thermal comfort is described in more detail below). Increased air movement across the skin carries away more heat from the body (via convection and evaporation), and thereby restores comfort. Since the advent of mechanical HVAC systems, building designers have largely focused on a single factor of thermal comfort: air temperature. However, modifying other factors of thermal comfort, such as air speed, changes how a particular air temperature is perceived. Occupants near a ceiling fan will feel cooler than they would at the same temperature in still air, similar to the phenomenon of “wind chill”, though the wind chill index is typically used for higher air speeds and colder temperatures than occur indoors. Similarly, when the air temperature is warmer, occupants near a fan will feel more comfortable than they would in still air conditions.

Improved Air Distribution

In addition to the thermal comfort benefits of increased air speeds, ceiling fans can also improve air distribution, working in concert with the HVAC system to provide the desired thermal conditions more consistently throughout a space. When correctly designed and operated, ceiling fans support the HVAC system to minimize temperature gradients within a space, providing more consistent temperature and air quality conditions throughout a space. This improved air distribution can be effective for both heating and cooling scenarios. For example, ASHRAE Standard 62.1 – Ventilation for Acceptable Indoor Air Quality lists a ventilation effectiveness of 0.8 for ceiling-supplied warm air systems (due to stratification of the warm air near the ceiling), but adding ceiling fans in this scenario brings the ventilation effectiveness back to 1.0, or fully mixed condition, reducing the amount of outside air required.

Improved Air Quality

By increasing air movement and improving air distribution in a space, ceiling fans also improve air quality. The increased air movement prevents the sensation of stale or stuffy air, and can help dissipate odours. One recent study has also documented a measurable air quality improvement from ceiling fans by dissipating CO_2 and other exhaled pollutants that would otherwise gather near occupants in still air conditions. Large-scale studies of occupant survey data indicate that occupants would prefer more air movement than they have, especially in conditions where occupants report feeling warm, as illustrated in figure below.

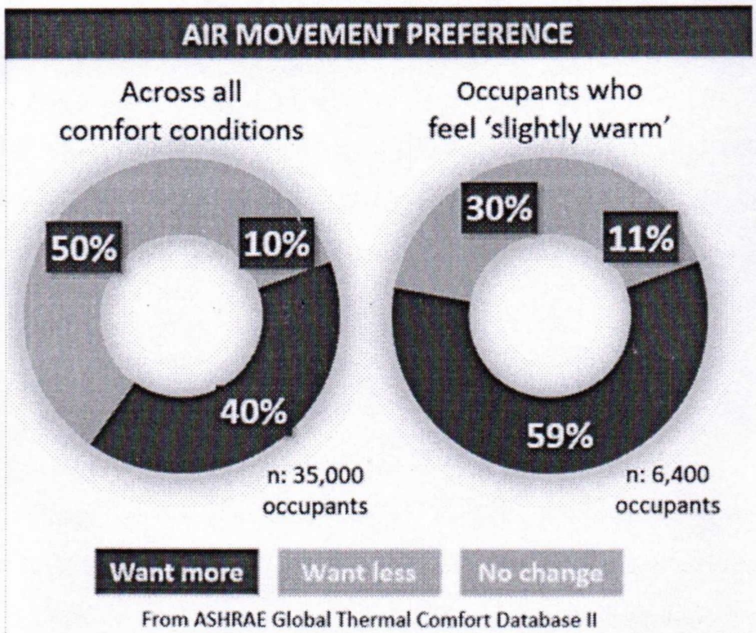

Figure: Occupant preference for more air movement

First Cost Savings

The benefits described above—thermal comfort, improved air distribution, and improved air quality— achieve more than just increased occupant satisfaction, they can also help reduce first costs for HVAC systems. Using ceiling fans to more effectively distribute air throughout a space can reduce the extent of distribution ductwork and diffusers required to serve a zone. Additionally, if the same zone is designed to a slightly higher cooling setpoint due to the comfort cooling effect provided by the fans, this can also reduce the required latent and sensible cooling capacity of the HVAC system, providing first cost savings to equipment and ductwork.

Energy Savings

Perhaps most importantly, when implemented effectively as an integral component of a building's thermal comfort strategy, ceiling fans can also result in significant energy savings by reducing the demand on the HVAC system. Although ceiling fans consume energy, the potential HVAC savings outweighs fan energy use, typically by a factor ranging between 10 and 100 times. The primary energy saving derives from thermal comfort benefits of ceiling fans, keeping occupants comfortable at higher temperatures and allowing for increased cooling set points. Effectively, a room with ceiling fans is thermally comfortable over a wider range of temperatures than a room without ceiling fans. This wider range of temperatures reduces the cooling and fan energy consumption of the HVAC system. Counter intuitively, this wider range of temperatures also reduces heating energy consumption because when a space is warmer, it will take longer to cool down to the heating set point. Lastly, when ceiling fans are used to provide air distribution, Ceiling Fan Design Guide 2020 Page 8 reducing the extent of distribution ductwork and diffusers, they also help reduce HVAC fan energy by reducing the pressure drop in the air system. The section on Modelling, Simulation and Estimating Energy Savings discusses these effects in more.

Session Five: Effect of blade dimensions on fan performance.

Blade shape, number of blades, and blade pitch are important factors in increasing energy efficiency while maximizing air flow through the fan blades. There are two main types of blades shapes shown in Figure below. Blade shapes have evolved over time from flat to airfoil-style blades to become more energy efficient and maximize air movement. As the name implies, flat ceiling fan blades are flat panels mounted at a fixed angle, whereas airfoil blades are similar to airplane wings in section. Similar to the cross-section of an aircraft wing, the curvature of the airfoil blades helps increase air flow through the ceiling fan, minimizing air turbulence at the trailing edge of the blade common to flat blades. Airfoil-style blades are thus typically more efficient and also quieter than flat blades. However, flat blades are cheaper to manufacture. Note that flat blades will perform equally whether the fan is operating in the forwards (blowing down) or reverse (blowing upwards) direction. In contrast, airfoil blades will not operate as efficiently in reverse, and will typically have a lower airflow when doing so. Some fan models have blades that can be manually attached in inverted position, or can mechanically invert the blade while it is attached to the fan, which allows for improved efficiency when operating in reverse.

The number of blades is an important factor in increasing airflow of ceiling fans. Although increasing the number of blades will increase airflow, the increased weight and drag due to the blades can cause a loss in energy efficiency. Standard fans typically have between 3 and 5 blades, though some models have as few as 2 blades or up to 6 blades. Large-diameter fans typically have 6 or 8 blades, though some models have as few as 3 blades. Similarly, increasing the blade's angle may also increase airflow at the cost of energy efficiency. Academic modelling studies have found the optimal blade angle to be 8-10° for residential fans. Manufacturers recommend 12-15°. Some airfoil-style blades also vary the blade angle over the length of the fan blade, with steeper angles toward the centre of the fan to maximize air flow for the low blade speed in this region, and reducing to shallower angles toward the tips where the blade speed is high in order to limit drag and maximize energy efficiency.

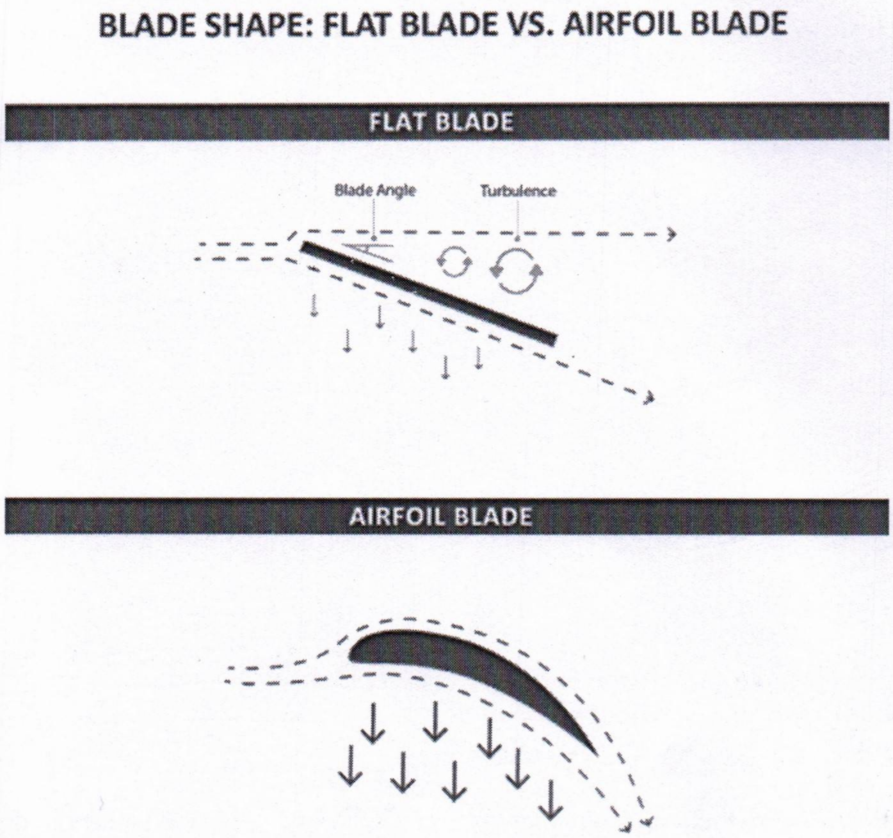

Figure: Ceiling Fan Blade Types.

Fan Selection, Sizing, and Layout

The following sections provide guidance on how to understand fan performance metrics, and recommendations for fan size, spacing, and location.

Understanding Fan Metrics

A number of factors determine a fan's performance, as well as its suitability to a given application. Some of the most critical factors are described in the following sections.

Diameter and rotational speed

Ceiling fans are available in a wide range of diameters, from very small fans approximately 18 inches in diameter to very large fans up to 24 feet in diameter. Determining the appropriate fan diameter depends largely on the dimensions of the space and the application, as discussed in more detail later in this guide. The California Energy Commission maintains the Modernized Appliance Efficiency Database System (MAEDbS), which contains a large dataset of information on ceiling fans as well as many other types of appliances. For context, this dataset shows that the majority of fan models on the market today are between 4 and 5 ft in diameter, and presumably therefore aimed at the residential market, as illustrated in Figure below.

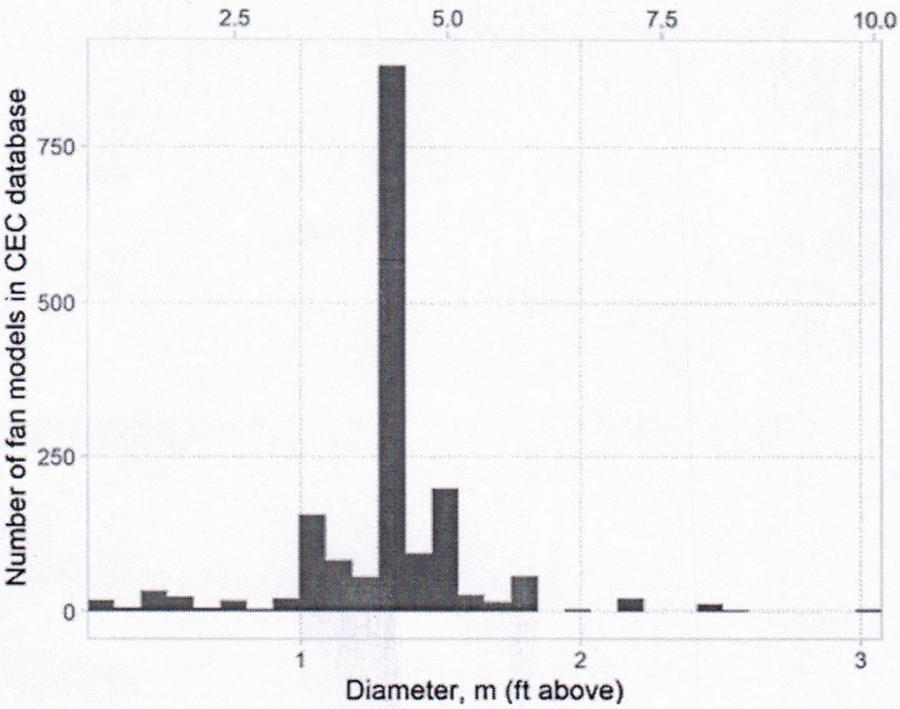

Figure: Distribution of fan diameters in a random sample of the fans in the CEC MAEDbS appliance database.

All other factors being equal, a larger diameter fan will produce greater airflow through the fan than a smaller diameter fan at the same rotational speed. Figure below shows a range of example fans of varying diameters and the range of possible airflows and rotational speeds at which those fans can operate. In general, higher airflow through the fan generally results in higher average air speeds in the space. Additionally, larger fan diameters increase the uniformity of air speeds throughout a space. Lastly, larger diameter fans increase the depth of the boundary layer of air moving along the floor in the spreading zone outside the fan blades. This figure also highlights the differences between fan models even if they have the same diameter. Comparing the Type G and Type F fans, of equal diameter (8 ft), it is clear that the range of performance varies by fan type. The Type G fan has a higher maximum airflow, a lower minimum airflow, and a higher rotational speed for any particular airflow point. For any particular fan, airflow is linear with rotational speed, as Figure also shows. Additionally, the air speed at any point in the space is also directly linear with fan rotational speed. So, if a point in the room measures 100 fpm when the fan is rotating at 80 rpm, it will measure approximately 50 fpm at 40 rpm. This relationship begins to break down at very low air speed, very low rotational speeds, or where the fan blade height is unusually far from the floor (e.g. > 10 ft).

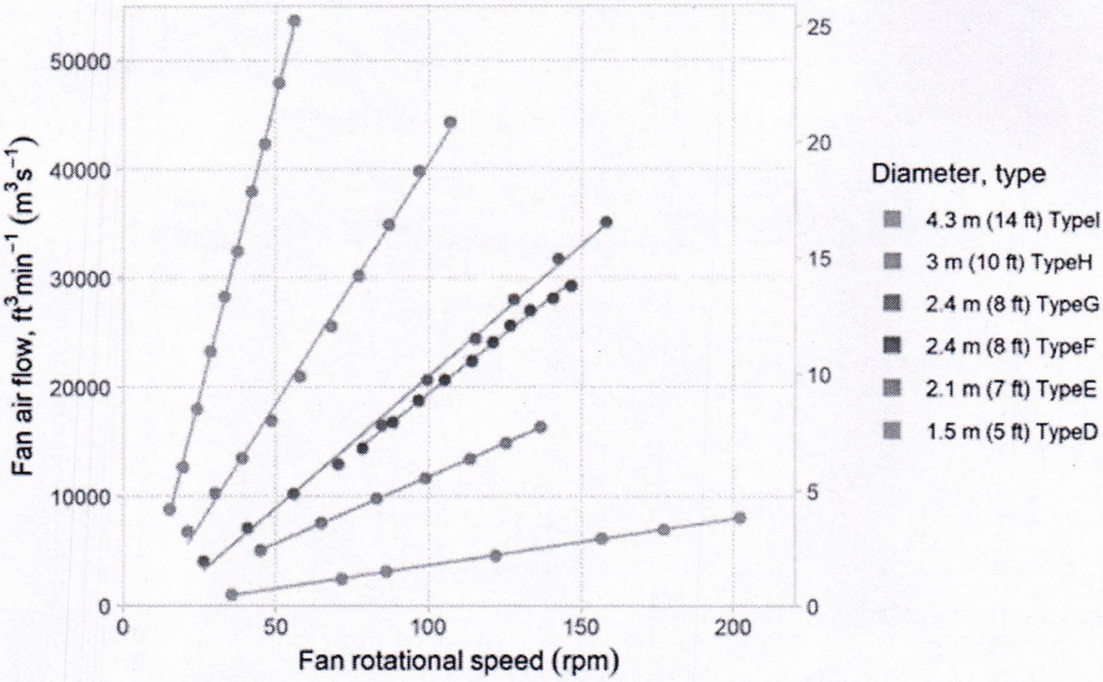

Figure: Fan rotation speed and fan air flow for fans of varying diameters.

Power and fan efficacy

The power consumed by a fan increases in proportion to the cube of its rotational speed, while the airflow generated by the fan increases linearly with its rotational speed. Thus, fan efficacy - or the airflow per unit power consumed - decreases as fan speed increases. However, in many fan models, motor efficiency is poor at lower speeds, partially counteracting this effect. In the MAEDbS dataset, the typical (median) fan efficacy at the lowest operating speed of each fan is 165 cfm/W, while it is 79 cfm/W at highest operating speed. Note that the only way to make a direct energy performance comparison between one fan and another is to compare it under the same conditions - the same diameter and the same power (or the same airflow). This is because fans with lower-rated maximum airflows will have a better-rated efficiency even if they consume more power to provide the same airflow. Note that the US Department of Energy and Energy Star criteria – and the metric that shows up on the Energy Guide label - calculates the ceiling fan airflow efficacy using an average of the efficiency at different operating speeds, weighted according to the amount of time the fan is expected to operate at those speeds, including a standby power loss. This does not account for different maximum and minimum airflows between fans of the same diameter, so it can be misleading. As before, fans with lower maximum airflow will generally perform better in this efficiency metric. Figure 16 below highlights the issue, where three fans have the same 234 CFM/W efficacy, but there is a clear difference in performance between the fans due to the different range of airflows provided. The fan represented by the curve furthest to the left (least efficient, lowest maximum airflow) is rated as having the same overall efficacy as the fan furthest to the right (most efficient, highest maximum airflow).

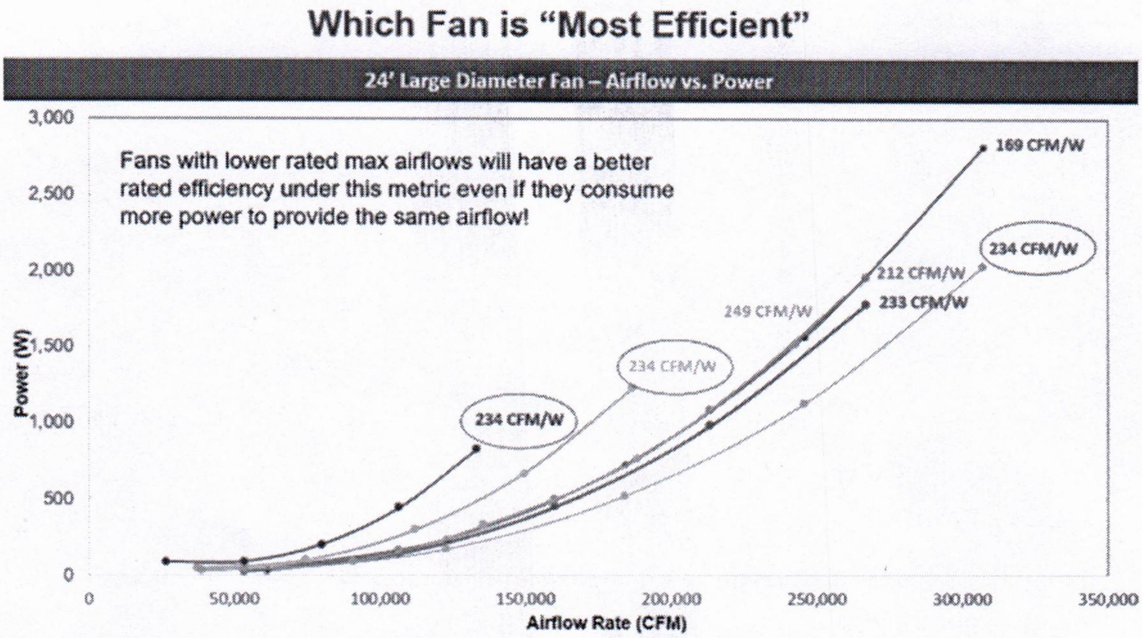

Figure: Fan efficacy versus total air flow and power

Fans that can turn down to a low rotational speed and maintain good motor efficiency at that speed can operate very efficiently under those conditions. There are a number of fans on the market with an efficacy of over 1000 cfm/W at their lowest operating speed. Other fans typically have a relatively high minimum speed, and often also have poor motor efficiency at that speed, and these fans benefit less from speed reduction. Generally, the ability of a fan to operate efficiently at lower speed improves as the diameter increases, as the Figure below demonstrates.

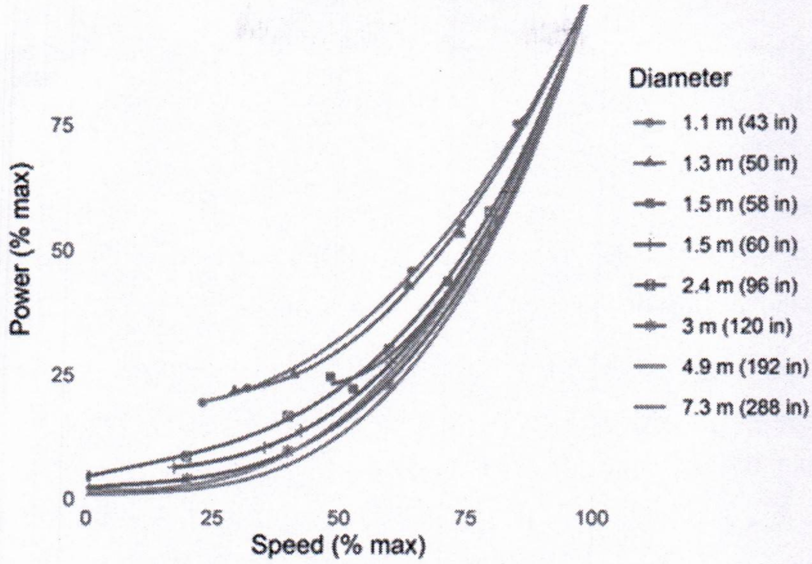

Figure: Relationship of power and fan speed settings for eight fans of different diameters (data from a selection of fans from MAEDbS)

However, there is considerable variation in performance between models of fans with the same diameter, as Figure shows. This also demonstrates that there is a wide range of turndown ratios (minimum speed divided by maximum speed) among different fan models at the same diameter. Some fans can operate at or below 20% of their maximum rotational speed, while others cannot run below 50% of their maximum rotational speed.

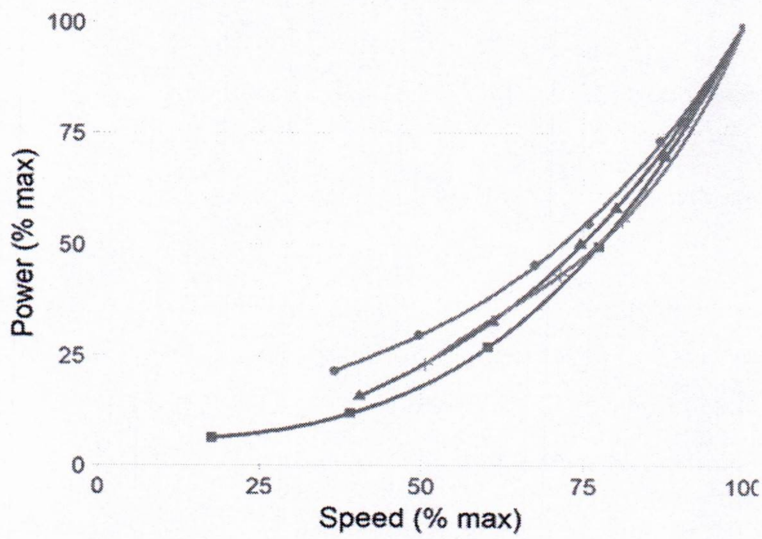

Figure: Relationship of power and fan speed settings for four different 5 foot (1.5m) diameter fans.

Airflow

The test methods for rating the airflow of these fans is federally regulated under 10 CFR 430 Appendix U. For standard fans, the rating is determined by a modified Energy Star method,

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which infers airflow from an anemometer traverse below the fan. For large diameter fans (above 7ft), the rating is determined by the AMCA 230-15 test method, which infers airflow from a load cell measurement of fan.

Fan air speed

The fan air speed is calculated by dividing the rated airflow of the fan by its diameter. It represents the average airspeed that passes through the circle swept by the fan blades. Thus, as with rated airflow, fan air speed varies linearly with fan rotational speed. Fan air speed is a useful metric as it is more directly representative of the air speeds that will occur in the space. For example, the maximum airspeed at any location and height in the room will typically be within 1.3 to 1.5 times the fan air speed, and it will occur below the fan blade tip, slightly inside the fan blade diameter. That applies regardless of fan diameter. Unlike fan rotational speed, airflow, or power consumption, the concept of fan air speed is also very useful as it allows designers to directly compare fans with different diameters to one other. Fans with higher maximum fan air speeds will yield higher maximum air speeds in the room regardless of fan diameter.

Session Six: Effect of different materials on fan performance.

Choosing the finish for your ceiling blades will largely be dependent on what room it's going in and what your budget is. The four main blade materials and their unique advantages are:

Medium Density Fiberboard (MDF)

With medium density fiberboard (MDF) blades, sawdust and other wood remnants are compressed together with a hardening material. Then, a laminate (a sticker) is put over it to protect it and give its finished look. This type of blade is the least expensive and so is generally used for inexpensive fans, but not always. It does not hold up well outside; if there's any moisture, the blade will start to droop fairly quickly after being installed. But in dry indoor locations, these kinds of blades work great.

Plastics

ABS plastic is used in a lot of fans, mainly because it is easy and inexpensive to manufacture. Plastic can be moulded into almost any shape and can be finished to look like real wood. And ABS blades hold up well outside. (Note on reversible finishes: Blades that offer two different wood finishes are usually able to do so because of two different laminates being applied on either side. That being said, ABS blades can also be made with two different finishes. So, while reversible blades are most likely made out of MDF, it's not a hard and fast rule).

Wood

Wood is best for indoor applications, but it will also work for outdoor damp. Sourcing and processing natural wood into fan blades takes more effort and cost than other materials. So generally, when a fan has "real wood" blades, it is a premium fan. Most wood blades are balsa wood–which is solid, but lightweight and aerodynamic–although other types can be used as well. Visually, real wood blades tend to have a carved look, with a thicker profile than standard flat blades.

Metal

Metal is best for large spaces where the fan is high above the floor. By code, they are supposed to be hung at 10′ or higher. Metal fan blades are also good for outdoor damp and outdoor wet applications. That said, anywhere near the ocean and they will rust. Even a "marine grade" version will eventually rust. (However, customers who live in this environment usually know this!) Metal is also a popular blade choice with smaller oscillating ceiling, wall and portable fans. For safety purposes, assuming they could be within reach, these are usually equipped with a protective cage.

Session Seven: Effect of process parameters on fan performance.

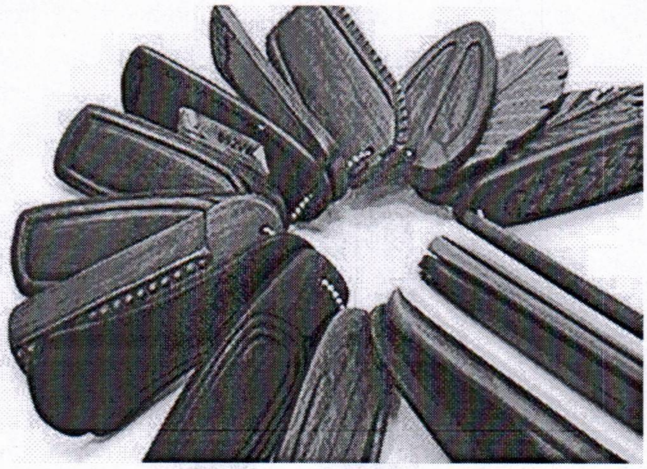
Blades may not be the first thing you think about when shopping for a new fan, but you may be surprised by how much blades affect both the aesthetics and performance of a ceiling fan. Whether you are looking for a new ceiling fan or want to replace an existing fan's blades, there are several factors to consider. Some blades are created to withstand outdoor environments, while others are meant to lower energy costs inside your home. By understanding the importance of ceiling fan blades, their types, and in which rooms they are suitable, you can make your home's ceiling fan work for you—and even reduce your cooling costs in the process.

Blade Span

Blade span refers to the width of a fan, from blade tip to blade tip. The most common ceiling fan blade spans are 52 and 42 inches. Longer blades work best for larger rooms and create softer, more comfortable airflow. Shorter blades offer more direct airflow and are ideal for smaller rooms. The volume of air is not determined by blade span, but by the motor. A motor with smaller blades will move a greater quantity of air than the same motor with larger blades.

Blade Types

General, in-home use, many ceiling fan blades are made from particleboard or medium-density fiberboard (MDF). High-quality ceiling fan blades, on the other hand, are made from furniture-grade, real hardwood, many with hand-carved intricate designs. Regardless of the material from which they are made, blades come in a wide variety of colors, patterns, and styles to match any room's décor. If you are shopping for a fan that will be used outdoors, you will want to look for fans with damp or wet-rated ceiling fan blades



Consider Your Ceiling

The type and size of your ceiling makes a big difference when choosing a fan for your home. Low ceilings that are less than 8' high need what is referred to as a flush mount or "hugger" ceiling fan. These allow enough head room while still providing good airflow. Ceilings that are 8' or higher are ideal for fans with down rods that allows them to hang at the optimal 8' to 9' from the floor. You can also install a ceiling fan on a steeply vaulted ceiling with a special mount and a down rod that is long enough to allow the ceiling fan blades to turn without striking the ceiling.

Ceiling Fans and Energy-Efficiency

Just about every homeowner wants to go "green" and save on their monthly heating and cooling costs. Ceiling fans are a great way to lower energy costs for the winter and summer months, but only if they are constructed properly. According to Energy Star, the pitch of the ceiling fan's blades helps, but it is only part of the equation 2. For some ceiling fan models, higher pitch does not mean more savings, especially if the unit has a lower-efficiency motor installed. Higher pitches move more air throughout the room, but the motor's speed and design, blade design, length, and material all impact how effective it is as a whole.

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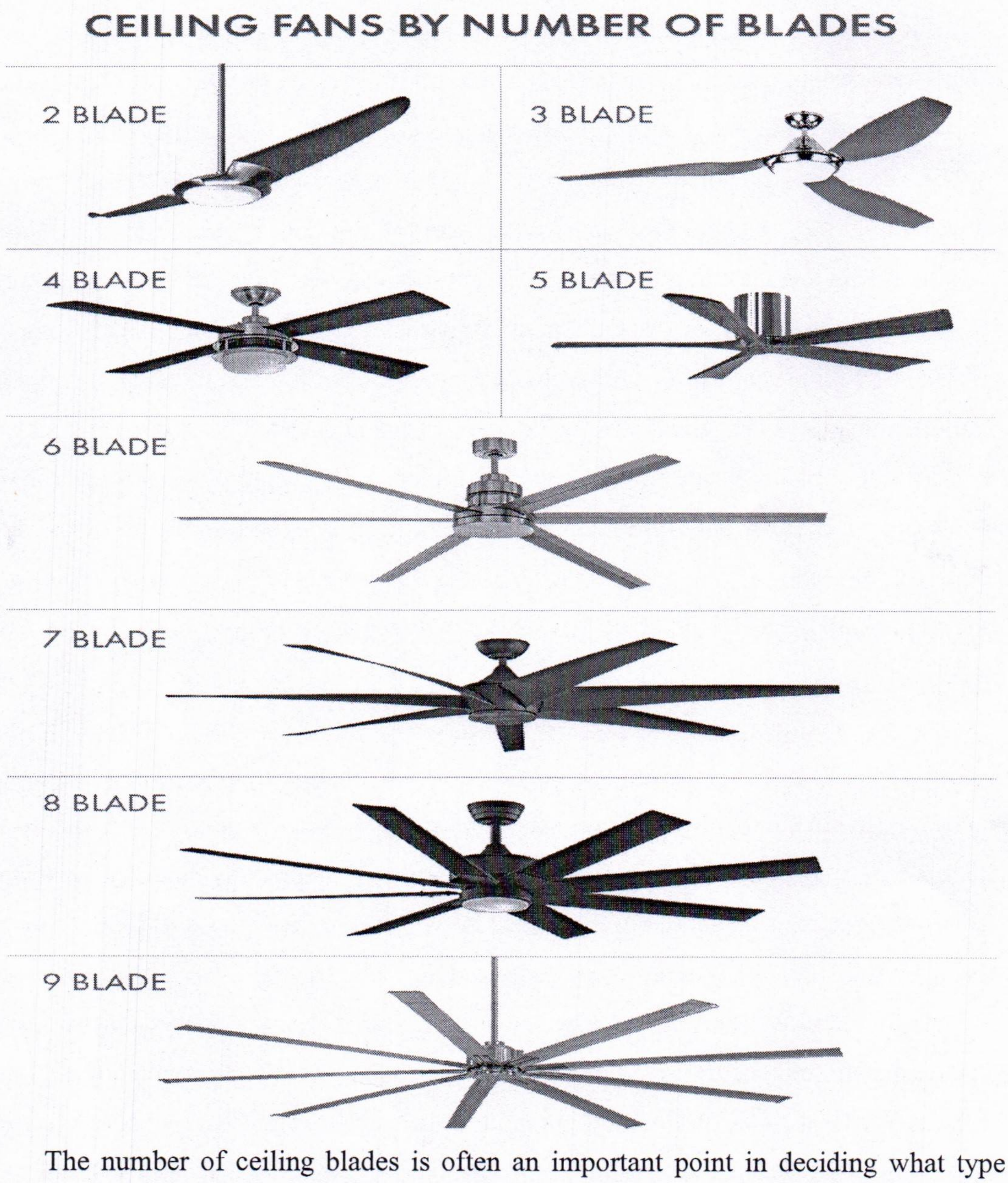
How Many Blades?

There is a common misconception that five ceiling fan blades work better than four or even three blades. Homeowners assume that five blades means better air movement, circulation, and less cooling costs, but in reality, all five blades do is add aesthetic appeal. According to Energy Star more blades do not move more air [1] – even one, two, or three bladed fans can be extremely efficient — what matters is the strength of the motor powering the fan.



The number of ceiling blades is often an important point in deciding what type of ceiling fan to purchase, but this is becoming less of a question of function and more of personal choice with advancements in technology. It used to be the case that a five- or six-blade ceiling fan would translate into more efficiency as opposed to a three blade or four blades, but that's no longer the case. Since the CFM is the measure for a fan's airflow efficiency, the number of blades is more related to embellishing the style for your space. For example, a four or five blade ceiling fan provides a more conventional, balanced look, whereas a fan with two or three blades possesses a modern and sleek style.

Session Eight: Design modifications and testing.

Creating a breeze in a space is necessary to enhance convective heat transfer and accordingly body heat dissipation. In most tropical countries fan are extensively used to create indoor breeze, improve the space air distribution and hence enhance the feeling of comfort. The fan speed, diameter, number of blades, blade angle and location, all play an important role in determining the induced flow pattern features in the space. Analytical calculations are performed to calculate the coefficient of performance, estimate the net air flow per unit power input for four different blade materials namely steel, aluminium, GFRP composite and PVC. The ceiling fan model is created in CREO elements/Pro 5.0 and the whole geometry is imported into ANSYS CFX. Profile GM 15 airfoil is selected for the blade analysis. The ceiling fan simulation is done for the entire fan model including blade behaviour due to aerodynamic lift and drag forces which also accompanied by bending stresses and deflection. The comparisons for the combined loads are studied for better stability and performance of the blade for different materials. ANSYS APDL software is used to do the structural and modal analysis.

To produce cooling effect ceiling fan utilize hub-mounted rotating blade in the respective surrounding. Ceiling fans are made up of a few basic parts: the base plate, the motor (with housing) and blades. The blades are usually made up of steel, aluminium, wood, etc. Ceiling fans are commonly found in abundant in most tropical countries which experience very high level humidity and a hot weather condition where heat dissipation through convection is essential due to the high temperature and humidity level such as Malaysia and other countries with high humidity level . It comprises of 3 to 5 paddles or blades to circulate the air. Ceiling fan are cheap reliable and easy to install. They are use a relatively low amount of energy in comparison to the air-conditioning units; they suffer from significant level of electricity loss due to their inefficiencies. The unreasonably high consumption of electrical energy by the conventional ceiling fan is due to high losses at the blades of it, as they are not designed for the optimum aerodynamic performance.

Methodology

Creo Elements/Pro 5.0 is used to model the ceiling fan using GM-15 airfoil sketch. Meshed CAD model of ceiling fan with twisted blade, 3-D view and Model of ceiling fan for CFD simulation is shown in Figure 1. The structural and aerodynamic analysis is done in ANSYS (CFX) 14.0 Software.

Characteristic of Airflow around fan blade

For analyzing the air flow around the fan blade, some characteristics of the air should be defined like

- Reynolds number: As this problem is an external stream case, the Reynolds number for airflow should not be larger than 500,000.If it's going beyond this then flow will become turbulent which is not desired in our case.
- Mach number: The Mach number is defined as the ratio of local flow speed to the local speed of sound. In fluid Flow, when Mach number less than 0.3 is treated as compressible while any value beyond this will be regarded as incompressible. For calculating the Mach number the maximum blade speed and speed of sound are required.

Coefficient of Performance

The general definition of Co-efficient of performance, COP is the ratio of desired effect to the power required to produce the desired effect. In case of a ceiling fan the desired effect is the flow of air and it is represented in volume flow rate per unit time (cubic meters per minute).

Assumptions for calculating COP:

- Flow regime is laminar.
- Flow is incompressible i.e. the Mach number of flow is less than 0.3

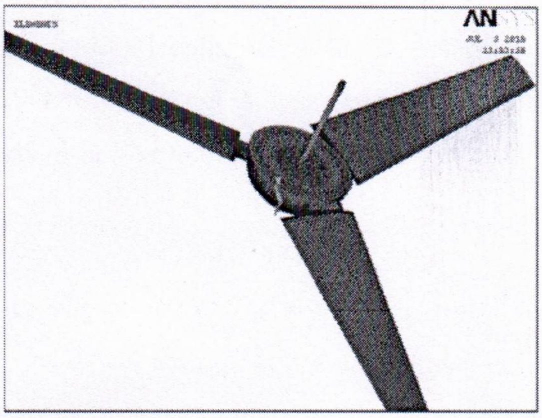
Algorithm to calculate coefficient of performance:

- Input design constants example the width & length of blades, air properties, material properties etc.
- Calculate area of fan blade span, volume of blade and thus the mass of blade.
- Calculate moment of inertia of the blade to obtain the radius of gyration and then the total mass moment of inertia.
- Depending upon the maximum revolutions per second of the fan calculate the angular velocity.
- Assuming a certain time required by the fan to reach its maximum angular velocity calculate angular acceleration.

- Calculate torque required by the fan from inertia and angular acceleration and then the power required.
- Depending on the blade design calculate the vertical component of velocity with which air will be forced. (As fan is a low velocity operating device thus the average velocity of blade and thus the air is taken to be in range of one third to its maximum speed, this result is concluded for our profile by reading the paper and performed simulation).
- Finally for different velocities the airflow rate and thus the COP are calculated.

Finite Element Analysis

The structural and aerodynamic analysis is done using ANSYS software. The element used for the analysis of ceiling fan blade is 8 node 185. Solid185 is a lower order 3-D 8-noded solid element that exhibits quadratic displacement behaviour. The element is defined by 8 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. After meshing the total number of nodes and elements are 16309 and 65432 respectively.



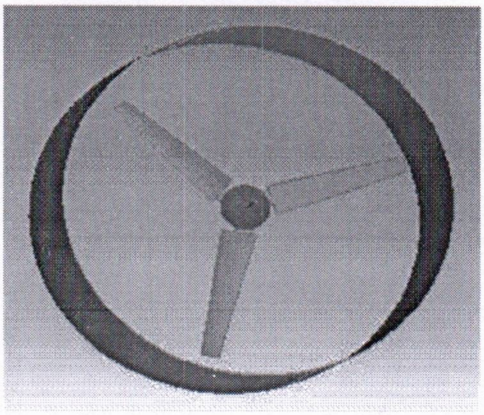


Figure 1Meshed CAD model of ceiling fan with twisted blade and Model of ceiling fan for CFD simulation

The 'K-Epsilon" model is used for turbulence (fluid domain). The following assumptions are taken for defining boundary condition.

- Steady state condition
- No leakage losses
- Friction between walls and fluid is neglected.

For inlet boundary static pressure is specified as input parameter, value of static pressure is equal to the atmospheric pressure. Wall of room is taken as smooth and no slip wall. Figure 2 shows the applied boundary condition. After giving the boundary condition we need to decide the no. of iteration depending upon value of convergence criteria. The residual target is set to 10^{-6}.

Session Nine: Implementation of modifications

This training address a wide range of topics from fundamental human subject studies to new product design. They also focus on the removal of barriers to fan implementation in design practice, and comfort and energy standards. The human-subject laboratory tests examined fan-related comfort at a fundamental level. Several types of fan configurations were tested. The projects establish air temperature and humidity comfort thresholds for spaces with fans, obtain subjects' preferred air speed at different ambient conditions, and test for whether air movement causes dry-eye discomfort. They also examine whether the comfort model for elevated air movement in ASHRAE Standard 55 is applicable to realistic environments with fans. The model assumes that the entire body is exposed to uniform low-turbulence air movement, while actual air movement is only on parts of the body, and with varying levels of turbulence. The numerous results of this project are all promising for the advancement of air movement cooling as an important energy efficiency strategy. They show that comfort can be provided by fans drawing 2-8 watts per person, up to 30C (86F) and 60% RH (relative humidity) ambient conditions.

Real buildings and occupancies contain features that cannot be tested in laboratory studies. The field studies investigated human responses to fans under long-term exposures. The results show that occupants like building with fans, and fan provides comfort under warm environments. Most people (75% in DPR and 70% in UW) felt that thermal comfort in their buildings enhanced their ability to get their job done. However, the Oakland school study showed that when using fans with automatic controls in designs, occupants should be trained how to interact with the controls.

The team explored ways to integrate fans into ceilings. We incorporated oscillating floor fans into the ceiling. We also proposed a design solution that eliminates the heat transfer reduction from radiant ceilings caused by suspended acoustical panels. Acoustical panels have been a major barrier for radiant ceilings.

This design solution increases total heat transfer to 150% of the original heat transfer without acoustical panels. The team also designed two versions of an occupant-tracking fan, which have resulted in a provisional patent. The occupant-tracking fan overcomes the disadvantage of ceiling fans which in fixed position only project air movement to a limited floor area. It actively recognizes and tracks the occupants and permits continuous airspeed at the occupant's location, even if they move about within their workplace. This new idea will encourage various types of occupant-tracking fans in the future.

Fans providing comfort in warm environments save HVAC energy in air-conditioned building by allowing the set points to be controlled over wider ranges of temperature. Energy Plus simulations show that each 1F increase in cooling set points corresponds to about 5% of total HVAC air-conditioning energy use.

To confidently use fans in buildings, designers need better information from fan manufacturers to select them and space them. Current fan specifications do not provide much design guidance, and are not based on an appropriate evaluation index. Our laboratory studies suggest that there may be simplified approaches to developing a new fan evaluation index, based on airspeed and comfort rather than volumetric flow. The development of a fan performance test method and index has been approved.

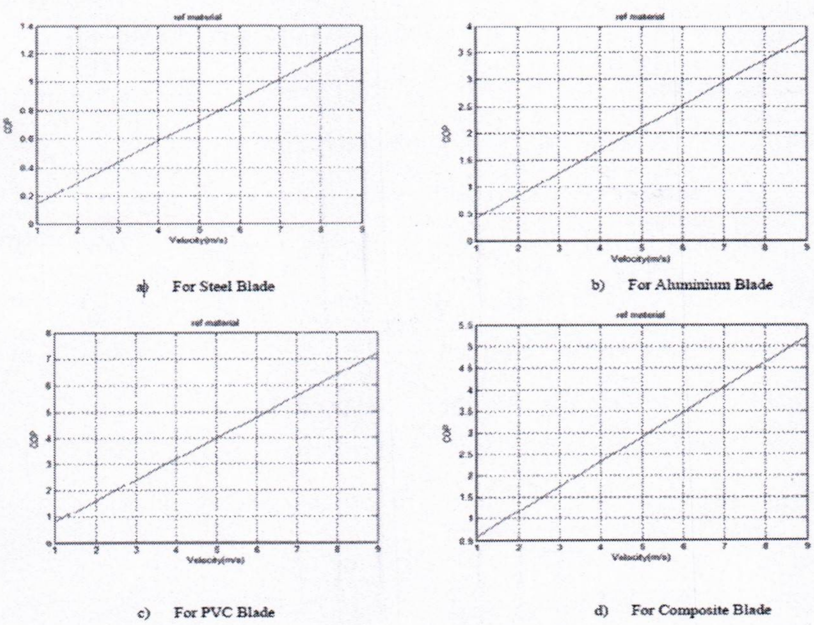
We will assist this committee and use the findings from this study to help formulate a good test method and index. The team also did a great deal of work under this contract to implement our work in the new code-compliant ANSI/ASHRAE Standard 55-2013. The air movement sections were improved over 55-2010, and are one of the major contributions to the new standard. Members of the team were also selected to prepare the new User's Guide to Standard 55. This guide will provide detailed design information for the use of air movement for cooling occupants in buildings. One of the provisions of the new standard is useful for design of indoor fan systems. The 'air speed' affecting comfort is now defined throughout Std 55 as 'average air speed', formally defined as the arithmetic average of three heights (ankle, midbody, and neck). This averaging has the effect of allowing the fan system to include higher maximum local airspeeds in the occupied zone, since flows from fans are rarely equally high at all three levels. The designer of a ceiling fan system now has more flexibility than in the past when a single-point maximum speed was in place, since airflow maxima at a point are difficult to predict.

Furthermore, in this study, the design, construction and performance evaluation of ceiling/table flow fans are performed. The design process of ceiling/table flow fan is examined in detail, and the experiences gained in the design are presented. It is observed that designing of a ceiling/table flow fan is a complicated process. The detailed design takes a long time, and it is possible to make a calculation error during the design process. In addition, there are a lot of empirical graphs used in the design process. Reading of the design parameters from the empirical graphs can also trigger to make mistakes in the design. In order to get rid of design mistakes, to reduce the allocated time to the design and to obtain an accurate ceiling/table flow fan, a ceiling/table flow fan design software is developed. In the code of the software, the suggestions, the design rules and the empirical graphs regarding the ceiling/table flow fans are embedded. In the airfoil selection of the implemented software, the experiences gained in the industry are used. An airfoil database is created to increase the diversity of the airfoil profiles used in the ceiling/table flow fan design. Moreover, a ceiling/table flow fan is designed by using design software, and it is manufactured. In order to observe the aerodynamic characteristics of the fluid flow inside the fan and to prevent re-work processes in the manufacturing process, CFD analyses of the designed fan are performed before the manufacturing process. According to the results of the CFD analyses, the accuracy of the implemented software is found enough to start the manufacturing process. In order to obtain the performance curves of the manufactured ceiling/table flow fan, a test setup is prepared by obeying the rules in the testing standards. The tests are performed for three different rotational velocities of the AC motor, 800 rpm, 1000 rpm and 1500 rpm. The total and static pressures are recorded by the help of located Pitot tubes in the test tube. The performance curves of the fan are plotted, and a sample calculation is presented. Implementing design software takes the most of the labor force, which is spent on this thesis. All the design rules and experiences learned from the literature and the industry are combined to generate a design code. All the empirical data in the design procedure is digitized to use in the code. Designing of a ceiling/table flow fan is an iterative process. The initial and the final values of the lift coefficient and the hydraulic efficiency are compared, and a proper airfoil is selected in each iteration. These iterations are repeated with respect to the number of selected diametric slice points to obtain an airfoil data along the span length of the blade. Therefore, it turns to a complicated process. As a result, in order to supply ease of use, a user interface is developed. App Designer tool of the MATLAB is used for this process. The user-interface is prepared and connected to the design code with App Designer. Then, in order to increase the accuracy of the designs, the number of airfoils used in the database is increased. The data produced is used in this process. There are suggestions regarding the type of airfoil at the result screen of the interface. These airfoils are selected in the generated database. In the CFD analyses part, the simplified geometry of the fan is analyzed. The main objectives of using CFD are to observe the aerodynamic characteristics of the fluid flow and to prevent re-works in the manufacturing process. Because of not being a CFD based study, the allocated time for the analyses is limited, and therefore, the simplifications are made in the analyzed model of the fan. Typically, there is a one- diameter long inlet tube and a ten-diameter long outlet tube at the inlet and the outlet of the fan model, respectively. The diameter of the fan is calculated as 1.5 meters, and therefore, the suggested length of the fan model for the analyses is computed as 15 meters. The CFD analyses of this kind of a big and detailed fan model take a long time. On the contrary, the allocated time for the analyses is limited due to the timely delivery of the produced fan. As a result, the simplified geometry of the fan model is drawn. The small ineffective details such as nuts and screws are deleted in the model. Moreover, the size of the mesh file is adjusted with the help of the mesh independency study. The constructions and experimental tests are performed. All parts used in the fan assembly except AC motor are constructed in the workplace of the company. The blades are produced by using an aluminum casting process. It is a critical process since the air bubbles in the blades lead to crack. In order to observe the quality of the molded blades, a non-destructive testing method is used. After the production process is completed, the test setup is prepared. There are some testing methods for fans to find their performance ratings.

Session Ten: Optimization of process parameters and testing.

Co-efficient of performance

MATLAB program is developed to calculate Co-efficient of performance for different blade materials. Figure 3(a-d) shows the variation in COP of fan when it runs at varying speed for different materials.



a) For Steel Blade

b) For Aluminium Blade

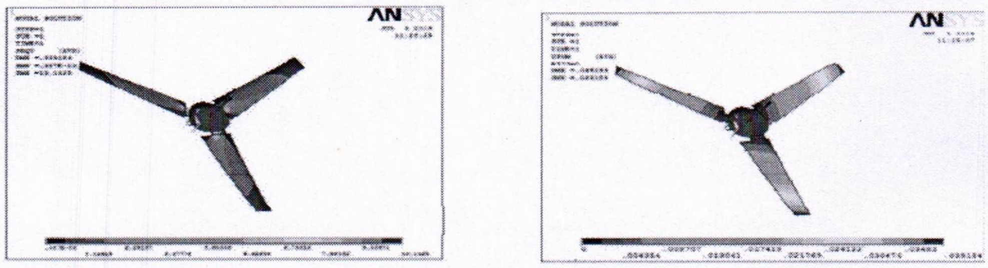
c) For PVC Blade

d) For Composite Blade

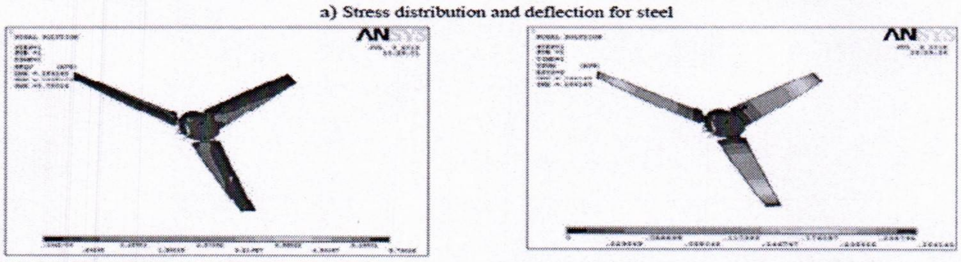
Figure1 .Variation of COP with velocity for different materials

Validation

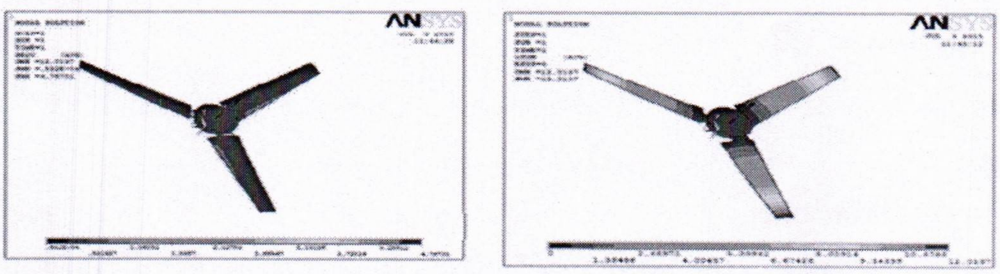
For validation, the forces on the blade of fan due to its rotation and aerodynamic are calculated by analyticalcalculation which is validated from the result of Ansys CFX as shown in Table 1. ANSYS results shows goodarrangements with Analytical results.



a) Stress distribution and deflection for steel



b) Stress distribution and deflection for aluminium



c) Stress distribution and deflection for PVC

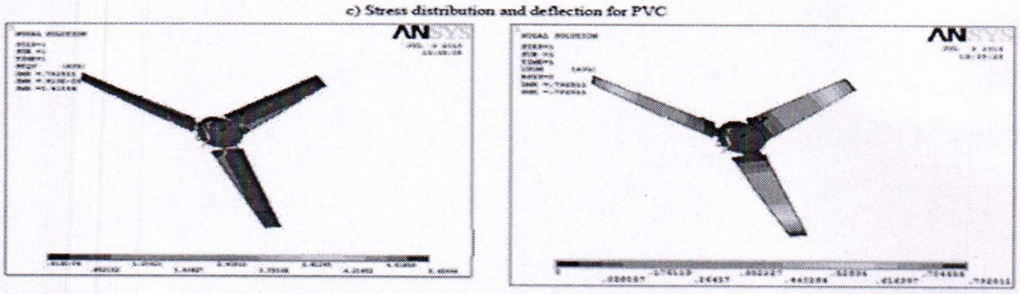


Figure 2 (d) Stress distribution and deflection for **GFRP composite**

The obtained value of stresses and deflection are compared with analytical results and they are found to be in permissible limit. The results obtained are-

- Trailing edges of the blades near root are under maximum stresses than the tip whether maximum deflection is found at the tip of each blade.

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Sohna Road, Gurugram, (Haryana)

- The stress at root and deflection at tip is observed as maximum, because the blades of the fan are fixed with the hub and hence act as a cantilever beam. This is loaded by the aerodynamic forces and by its own weight.
- The stresses produce in Steel is more than that of others and least in PVC.

Stresses in increasing order

PVC < Composite <Aluminium< Steel

The modal analysis of fan blade is done for 5 different modes as shown in figure 3.

Table 1 Comparative result of stress and maximum deflection

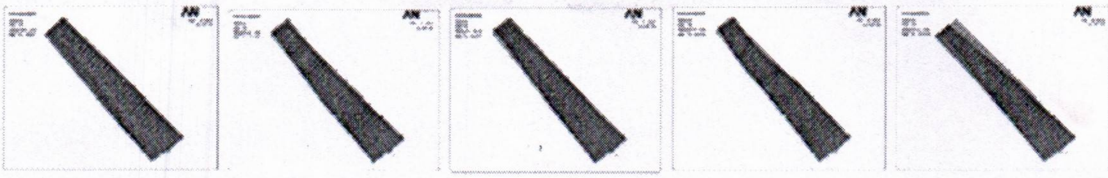
Blade Material	Moment (M)	Bending stress (σ) MPa	Axial stress (σ) MPa	Y_{ansis} (mm)	$Y_{Analytical}$ (mm)
Steel	0.117	0.04	1.74	0.03	0.013
Aluminum	1.056	0.37	0.60	0.264	0.34
PVC	1.35	0.47	0.31	12.01	2.03
GFRP Composite	1.261	0.44	0.40	0.79	1.1

From Table 4 the weight determined in all cases it is clear that blade of PVC is much lighter in weight than others. The power consumed by the steel, aluminium, composite and PVC blade ceiling fan is compared with each other and the monthly, yearly unit consumed are presented in Table 3 and Table 2.

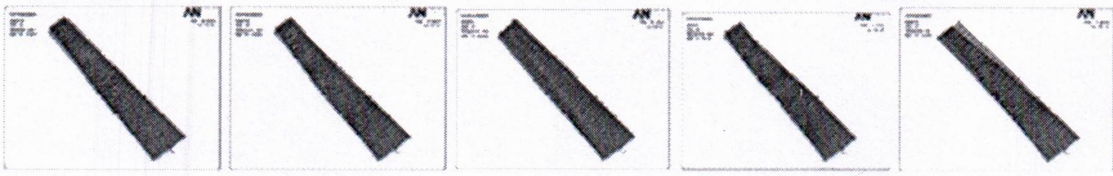
Table 2 Power needed to drive three blades

Blade Material	Steel	Aluminum	PVC	Composite
Total mass M.O.I	0.268	0.0925	0.048	0.062
Torque	3.484	1.202	0.624	0.808
Power	91.21	31.46	16.33	21.1

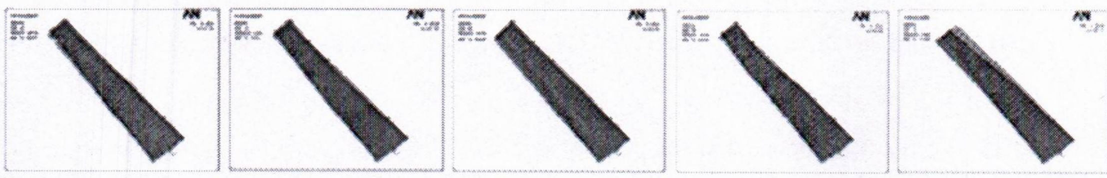
For steel -



For aluminum -



For PVC –



For GFRP Composite –

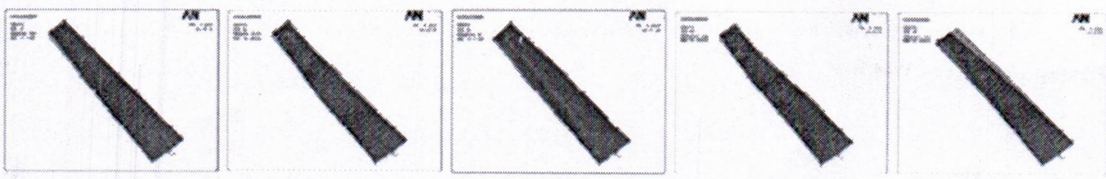


Figure 3 Different 5 modes shapes of different blade materials

Table 3Yearly power Consumption with respect to various blade materials

Parameters	Blade Materials			
	Steel	Aluminum	PVC	Composite
Time(hr)	10.96	31.78	61.23	47.39
Unit/hr	0.091	0.031	0.016	0.021
Unit/month (Run 8hr. a day)	21.84	7.55	3.84	5.04
For 1 year (Unit consumption)	262.08	90.6	46.08	60.48
Cost @ 8/unit(Rs.)	2096.64	724.8	368.64	483.84

Table 4Characterization of blade on the basis of density mass and volume

Blade Material	Density	Volume	Mass of 1 Blade
Steel	7800	0.0884×10^{-3}	0.689
Aluminium	2700	0.0884×10^{-3}	0.238
PVC	1800	0.0884×10^{-3}	0.123
Composite	1400	0.0884×10^{-3}	0.159

Complete analysis of ceiling fan is done for four different blade materials. Structural analysis and aerodynamics analysis is done using ANSYS software. COP analysis is done using MATLAB Program and weight and power consumption analysis is also presented. From the results obtained from the present work, it can conclude that the ceiling fan having blade of PVC material results in higher COP than the blade of other material within the taken range of speed. Fan having blade of PVC material is capable of reducing the power consumption than the other blades leading to higher efficiency of fan and is energy saving. By structural analysis we can say that the deflection of all blade at their tip are maximum, in which PVC blade undergoes more deflection than blade made of other material though PVC blade has maximum deflection but is in limit, the stresses generated in it is less than others. By reducing the weight of blades, the power needed for operating the ceiling fan will be decreased.

Re: Consultancy/Training proposal: K R Mangalam University, Gurgaon

Dr. Saurav Dixit <saurav.dixit@krmangalam.edu.in>

Thu 16-Dec-21 5:38 PM

To: Deepak Agrawal <deepak.agrawal@kentbharat.com>

Cc: chirag.gupta@kentbharat.com <chirag.gupta@kentbharat.com>

Dear Sir,

Greetings!!

PFA herewith the Consultancy Project on **"Modification of Ceiling/Table Fan"** for your kind review and further processing.

The main objectives covered by this consultancy project are:

- Understand the concept of Ceiling/table fan working principle
- Information regarding fabrication details
- Identified the pros and cons of Ceiling/table fan
- Information about blade design and specifications
- Effect of various optimized parameters on the efficiency of fan
- Reviewed the modifications performed on ceiling/table fan.

Looking forward to hearing from you the feedback of the training and the report submitted by Prof Kaushal Kumar, and Prof Jarnail Singh.

Thankfully,
Best regards,

Dr. Saurav Dixit, PhD
Associate Dean Research and Director International Collaboration
M +919289021467; t +9101242867800 (extension-1046)
e- saurav.dixit@krmangalam.edu.in
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ORCID: http://orcid.org/0000-0002-6959-0008
ResearchGate: https://www.researchgate.net/profile/Saurav_Dixit
Google Scholar: https://scholar.google.com/citations?user=uTmnqJIAAAAJ&hl=en
Publons: https://scholar.google.com/citations?user=uTmnqJIAAAAJ&hl=en

K. R. Mangalam University, Sohna Road, Gurgaon, India, 122103
https://www.krmangalam.edu.in

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From: Deepak Agrawal <deepak.agrawal@kentbharat.com>
Sent: Monday, December 13, 2021 12:29 PM
To: Dr. Saurav Dixit <saurav.dixit@krmangalam.edu.in>

Registrar
K.R. Mangalam University
Sohna Road, Gurugram, (Haryana)

Cc: chirag.gupta@kentbharat.com <chirag.gupta@kentbharat.com>
Subject: Re: Consultancy/Training proposal: K R Mangalam University, Gurgaon

Dear Sir,

As discussed over the phone, please find the attached attached letter for your reference.

Regards,
Deepak

On Sat, Dec 11, 2021 at 9:54 PM Dr. Saurav Dixit <saurav.dixit@krmangalam.edu.in> wrote:

> Dear Sir,
>
> Greetings of the day, I hope this email finds you well!!
>
> As per our conversation and discussion in your office on dated 11th Dec 2021, PFA herewith the consultancy project tailored especially considering your needs and your workforce requirements for your kind perusal and approval.
>
> Looking forward to hearing from you.
>
> Best regards,
>
> **Dr. Saurav Dixit, PhD**
> **Associate Dean Research and Director International Collaboration**
> M +919289021467; t +9101242867800 (extension-1046)
> e- saurav.dixit@krmangalam.edu.in
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> **ORCID: http://orcid.org/0000-0002-6959-0008**
> **ResearchGate: https://www.researchgate.net/profile/Saurav_Dixit**
> **Google Scholar: https://scholar.google.com/citations?user=uTmnqJIAAAAJ&hl=en**
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Sohna Road, Gurugram, (Haryana)

From: Deepak Agrawal <deepak.agrawal@kentbharat.com>
Sent: Thursday, December 9, 2021 11:35 AM
To: Dr. Saurav Dixit <saurav.dixit@krmangalam.edu.in>
Cc: chirag.gupta@kentbharat.com <chirag.gupta@kentbharat.com>
Subject: Re: Consultancy/Training proposal: K R Mangalam University, Gurgaon

Dear Mr. Manish,

Thanks for your proposal.

With reference from your above email, please visit our office on 11.12.21 in the first half to discuss the proposal in person and to get some more information about your proposal.

Office address:

Kent Industries
K-721, Ashoka house, ashoka crescent, Mandi road, Sultanpur, New Delhi-110030 (INDIA)
Near Dus quarter mandir

For any other query, please feel free to contact undersigned.

Regards,
Deepak Agrawal
+91-9650031301

On Wed, Dec 8, 2021 at 5:40 PM Dr. Saurav Dixit <saurav.dixit@krmangalam.edu.in> wrote:

> Dear sir,
>
> Greetings of the day, I hope this email finds you in good health!!
>
> I Dr Saurav Dixit, currently working as Associate Dean Research at K. R. Mangalam University, Gurgaon, India. We are having an efficient and dynamic team of professionals and researchers who have previously worked on feasibility study projects, providing training and consultancy services for industries, and working on joint collaborative research and consultancy projects at national and International level.
>
> We would like to propose consultancy and training module titled " **Consultancy Project on Modification of Ceiling/Table Fan**" for your firm attached herewith for your kind review and perusal.
>
> Kindly spare 15-20 minutes to discuss this further in detail as per your convenience.
>
> Looking forward to hearing from you.
>
> Thankfully,
> Best regards,
>
> **Dr. Saurav Dixit, PhD**
> **Associate Dean Research and Director International Collaboration**
> M +919289021467; t +9101242867800 (extension-1046) ,

Registrar
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e- saurav.dixit@krmangalam.edu.in
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ORCID: http://orcid.org/0000-0002-6959-0008
ResearchGate: https://www.researchgate.net/profile/Saurav_Dixit
Google Scholar: https://scholar.google.com/citations?user=uTmnqJIAAAAJ&hl=en
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From: Dr. Saurav Dixit <saurav.dixit@krmangalam.edu.in>
Sent: Wednesday, December 8, 2021 5:36 PM
To: deepak.agarwal@kentbharat.com <deepak.agarwal@kentbharat.com>; chirag.gupta@kentbharat.com <chirag.gupta@kentbharat.com>
Subject: Consultancy/Training proposal: K R Mangalam University, Gurgaon

Dear sir,

Greetings of the day, I hope this email finds you in good health!!

I Dr Saurav Dixit, currently working as Associate Dean Research at K. R. Mangalam University, Gurgaon, India. We are having an efficient and dynamic team of professionals and researchers who have previously worked on feasibility study projects, providing training and consultancy services for industries, and working on joint collaborative research and consultancy projects at national and International level.

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Kindly spare 15-20 minutes to discuss this further in detail as per your convenience.

Looking forward to hearing from you.

Thankfully,
Best regards,

Dr. Saurav Dixit, PhD
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M +919289021467; t +9101242867800 (extension-1046)
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ORCID: http://orcid.org/0000-0002-6959-0008
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To

Mr. Chirag Gupta/ Mr. Deepak Aggarwal

M/s Kent Industries

K-721, Ashoka house, Ashoka Crescent

Mandi Road, Sultanpur,

New Delhi - 110030

Invoice No. : 006/2021-22

Invoice Date : 20/12/2021

Invoice for Consultancy Project

Particulars	Amount (Rs.)
Invoice for services rendered in relation to the consultancy and training module titled "**Modification of Ceiling/Table Fan**".	7,50,000
Net Amount Payable	7,50,000

(Rupees Seven Lakh & Fifty Thousand Only)

Please make the payment of the invoice by NEFT/RTGS/IMPS as per Bank Detail:

Beneficiary Name : K.R. Mangalam University
Account No. : 091101000622
IFSC CODE : ICIC0000911
Bank : ICICI Bank Ltd.
Branch : Sohna Bus Stand, Gurgaon

PAN : AAJCS3143G

For K. R. Mangalam University

Registrar
K.R. Mangalam University
Sohna Road, Gurugram, (Haryana)

(Authorised Signatory)