3, 4, or 5 fan blades? Do ceiling fans with more blades give more airflow? The science behind your ceiling fan design

Recently, my family and I were looking for new ceiling fans. We would be moving into our new apartment soon, and one of our undertakings was to furnish our home with affordable ceiling fans that not only looked good, but most importantly, were also effective in moving air.

How many fan blades? How do we determine how effective these fans are in generating airflow? How do we choose our right fan? (photo from blog.sndimg.com)

The last time I went shopping for a ceiling fan – believe it or not – was when I was still a bachelor. Back then, ceiling fans were simpler, having lesser frills. But today the designs of ceiling fans have become much more varied: they look more modern, distinctive, stylish, aesthetic – and more bewildering.

So, how do we choose the right fan that can move large amounts of air? Obviously, a more powerful motor would be able to spin the fan blades faster, and the faster they spin, the more air these blades would move. But wouldn't a faster fan also be noisier and consume more energy? And what about the number of fan blades? It is today common to find ceiling fans fitted with between four to as many seven fan blades. Some ceiling fans even have two tiers of fan blades! Intuitively, more blades would "chop" more air; thus, creating more air movement, right? But where's the evidence?

3, 4, or 5 blades? More blades, the more the airflow, right? If so, why do fans like this Enigma fan from Fanimation have only, gulp, one blade? This fan moves 5,800 CFM (cubic feet per minute) of air, making this fan comparable with other fans that have more number blades. What's the science? (photo from www.fanimation.com).

A ceiling fan design must be such that the fan generates large amounts of air movement but yet performs its task quietly and consumes low amounts of energy. Since I was shopping for ceiling fans, I was curious to know the science behind the design of a ceiling fan. In other words, what makes an effective ceiling fan?

A Deka ceiling fan with two-tiers of blades! Surely this six-blade fan model would generate massive airflow, right? Hmm…perhaps not. A fan with too many blades, especially with one set of blades rotating in the upper tier and the other in the lower tier might experience too much drag and create too much turbulence to give a high or even a smooth airflow in the room (photo from deka.com.my).

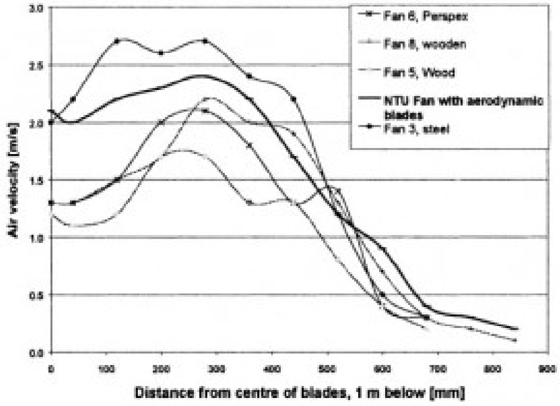
But let me however first clear one common misconception about ceiling fans. Ceiling fans, in contrast to air conditioners, do not lower air temperature or air humidity in our rooms. Ceiling fans cool us, but they do this only by increasing the air movement or airflow in the room. With increased air movement, our body sweat evaporates easier. And as our sweat evaporates, it takes away some of our body heat; thus, cooling us.

A common misconception: fans do not lower room air temperature or humidity. They increase air movement which helps to remove our body sweat faster, cooling us. Only air conditioners can lower room air temperature and humidity (photo from klimatedi.by).

Airflow profile

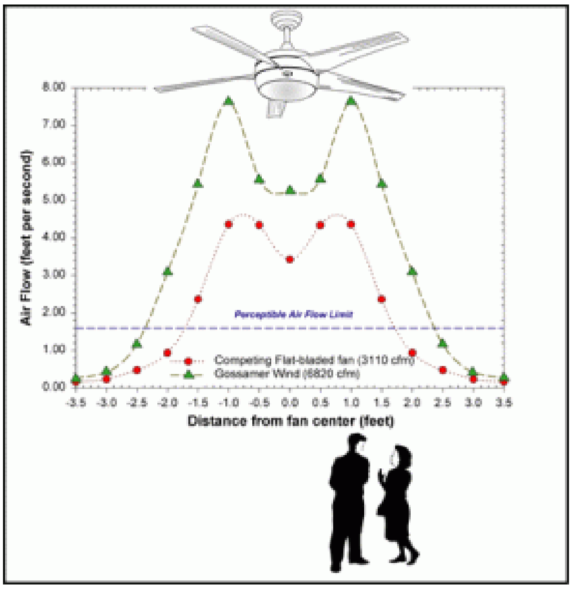
Ceiling fans do not move air in the room in a homogenous manner. Bassiouny and Korah in 2011 studied the airflow patterns in a room due to a single rotating ceiling fan. They found that airflow was the lowest at two locations: at the ceiling fan hub (*i.e.*, fan center) and at the fan blade tip. It is somewhere between the fan center and fan blade tip that airflow was the highest.

So, if we plot the airflow velocity (speed) at various distances along the fan blade length, we would observe that the airflow generated by a ceiling fan would increase from the fan center, reach maximum at somewhere midway of the fan blade length, and then decline moving towards the fan blade tip. This change in airflow velocity which rises then falls along the fan blade length is the so-called *humped* airflow profile.



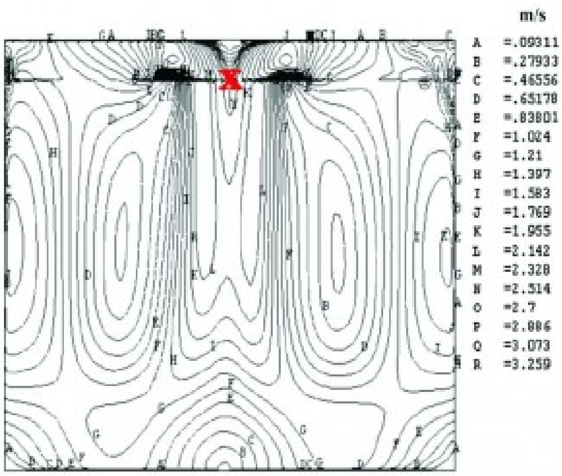
All ceiling fans display the so-called humped airflow profile, where airflow velocity increases from the fan center before reaching maximum (i.e., hump) at about midway of the blade length, then decreases farther along the blade length (Schmidt and Patterson, 2001).

This is why when we stand directly under the ceiling fan center, we would feel little air movement. But shift slightly to our left or right and the airflow suddenly picks up, particularly if we stand at a distance of about midway between the fan center and the fan blade tip where airflow here is the highest.



The humped airflow profile means if we stand directly under the fan center, we would feel little airflow in contrast if we stand somewhere in the middle between the fan center and fan blade tip, where airflow here is maximum (photo from www.gossamerwind.com).

Earlier work by Schmidt and Patterson in 2001 and Ankur and his associates in 2004 also reported similar airflow patterns.



(b) Velocity contours at the Room Mid-Plane

Computer-simulated airflow velocities (speed) in a room with a single rotating ceiling fan. The “X” marks the center of the ceiling fan. Airflow is lowest near the fan centre but increases outward up to a certain distance from the ceiling fan. Note the various “circular” airflow velocities (Bassiouny and Korah in 2011).

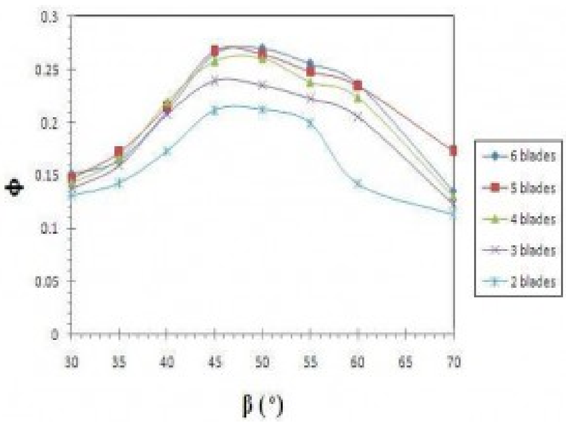
Studying the airflow patterns generated by a given ceiling fan is important because it allows us to understand how effective a ceiling fan design is in moving large amounts of air. And how effective a ceiling fan moves air depends on several factors, one of which is the fan blade characteristics.

Blade characteristics

Fan blade size and the number of fan blades do matter. The bigger (*e.g.*, wider or longer) the fan blade, the more airflow the blade is able to generate. Likewise, having more blades moving through the air would generate more airflow too. However, this ignores the effect of drag or air resistance. Whenever an object moves through air, it experiences an opposing force to motion called as drag. It is this drag that slows down motion, reduces airflow, and increases energy consumption of a ceiling fan.

Consequently, there is a tradeoff between the blade size and the number of blades to have in a ceiling fan. Having fewer blades or smaller blades may reduce drag but may also generate little airflow. But increasing the blade size or fitting more blades to a fan may not necessarily generate more airflow because of the larger drag. This increased in drag would also mean a more powerful – and presumably, a more energy-hungry (and noisier)— fan motor is required. Having more blades also adds weight to the ceiling fan and again, a more powerful fan motor is required.

Falahat is one of the few researchers who reported the effect of the number of fan blades have on airflow generation. In his 2011 study, he compared the airflow generated by an axial fan fitted with between two to six fan blades. He found that maximum airflow was generated when the fan was fitted with four blades, and the blades ought to be tilted between 45 to 55 degrees to the airflow direction. In Falahat's study, the angle of blades to the airflow direction can be regarded as the blade pitch. Blade pitch is one key factor that affects how much air a ceiling fan can move.



Falahat and his team in 2011 found

that four blades was the optimum number of fan blades, and these blades should be tilted between 45 to 55 degrees, as shown in this chart. There was little difference between 4, 5, and 6 blades in airflow generation (Falahat et al., 2011).

Imagine the fan blades as oars of a rowboat. Rowing the boat with the oars would require the oars to be slightly tilted or slanted. If the oars were parallel (horizontal) to the surface of the water (*i.e.*, 0 degree blade pitch), then very little movement would be created by rowing the oars. However, tilt the oars and they would push away more water and move the boat farther. Tilting the oars even more would move the boat even farther as more water would be pushed away. However, rowing the boat would become increasingly difficult if the oars are tilted to increasingly steeper angles.

Likewise, increasing the blade pitch would generate more airflow but at an increasing cost of having a more powerful fan motor to move these blades.

Falahat's finding of 45 to 55 degrees as optimum blade pitch range is far from that found in some commercial fans. These fans often have a blade pitch no more than about 16 degrees because after which, a more powerful fan motor would be required especially for high-speed rotations.

Falahat may have used a powerful fan motor in his study: a fan that is able to spin even six blades at high speeds. Falahat's study suggests if the fan motor is powerful enough and not treated as a factor in ceiling fan design, then the optimum number of fan blades to have is four, and these blades should be tilted between 45 to 55 degrees from vertical for maximum airflow generation.

A few ceiling fans have a curious feature where their fan blades appear to be curved or bent upward. The angle between these bent blades and the horizontal plane is called the *rake angle*.

Some ceiling fans such as this Kichler's Maiden model have their blades bent upward. Besides for aesthetic reasons, these bent blades can help to generate more airflow (photo from lumes.com).

Bending the blades upward is not just for aesthetic reasons because varying the rake angles can produce varying amounts of airflow. Afag and his associates in 2014 experimented between 0 to 10 degrees rake angle of a ceiling fan. They discovered that 6 degrees rake angle generated the most airflow, with the additional benefit that the fan motor did not have to work any harder.

Some ceiling fans even have winglets at the tip of the fan blades, similar to the winglets found on airplane wings. The purpose of these winglets is to smoothen the flow of air around the blades by decreasing the air vortices (turbulence) at the blade tip which in turn reduces the overall drag and energy use.

These winglets at the fan blade tips help to smoothen airflow around the fan blades which would lower drag and increase airflow. Also note the slanted fan blades (photo from www.modenus.com).

The material from which the fan blades are made is also another important factor because a heavier material would add weight and would require a more powerful fan motor. Schmidt and Patterson in 2001 compared the airflow generation and energy consumption of nine ceiling fans fitted with metal, wood, and plastic fan blades. They found that ceiling fans with wooden fan blades generated the least airflow and yet consumed among the highest amount of energy. But due to the lower airflow, wooden fan blades were quieter than the rest. Schmidt and Patterson further found that ceiling fans with metal blades generated the most airflow but were also among the noisiest.

Today the ceiling fan market is inundated with many modern-looking fan, some having rather complicated designs. But I suspect some if not most of these modern-looking ceiling fans have been designed more for form over function; that is, they have been designed to look good but may not move a lot of air. Developing a ceiling fan that generates a large airflow and yet is quiet and low energy is a challenge because it requires a more thoughtful design that incorporates one or more key blade design features as previously discussed.

Some efficient ceiling fans, for instance, have fan blades that are irregularly shaped. Their blades can be sharply tapered, curved, spiraled, or twisted so that the blades do not have a constant blade width, rake angle, or blade pitch. Instead, these three properties vary along the blade length. The idea is to smoothen the so-called humped airflow profile, as mentioned earlier, so that airflow velocity remains more uniform along the blade length and at the same time, lessen the drag and noise.

But it is not easy to determine how good a ceiling fan is simply by examining the fan's individual design features. It is the net or combined effect of these individual fan features that determines how much airflow can be generated. For instance, Falahat's study, as previously discussed, revealed that four blades were the optimum number of blades. However, a two-blade ceiling fan could still generate more airflow than a four-blade ceiling fan. One way is to increase the blade pitch of the two-blade fan until the pitch is large enough to generate more airflow than the four-blade fan.

For instance, I recently bought a two-blade NSB Infinity fan and a four-blade Deka fan. At their respective highest speed settings, the four-blade Deka fan spins noticeably faster than the two-blade Infinity fan – but yet, the Infinity fan generates noticeably more air movement than the Deka fan. Why? This could be because the Infinity fan has a larger blade pitch than the Deka fan.

My four-blade Deka fan has more blades and spins faster but yet generates lesser airflow than my two-blade NSB Infinity fan. Why?

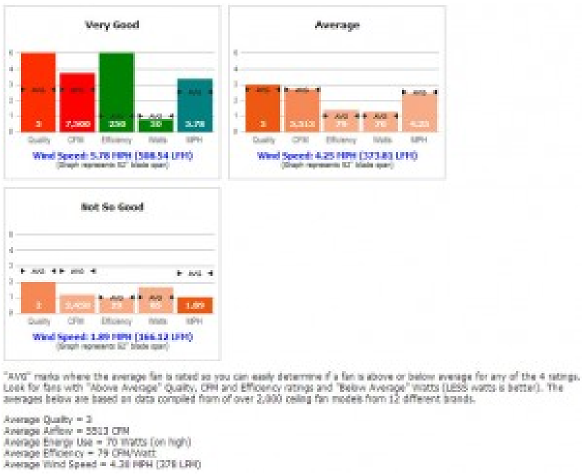
Being slower does not necessarily mean lesser airflow. Despite having only two blades, the NSB Infinity fan's larger blade pitch could have allowed this fan to generate more airflow than the faster-spinning four-blade Deka fan (photo from www.nsb.com.my).

To tell how effective is a ceiling fan, we need to make actual measurements of how much airflow can be generated by the given ceiling fan. But as ordinary consumers, we have to rely on information provided by the fan designers on how effective are their fans.

Ceiling fan efficiency: CFM and power consumption

The two most important information we need are the amount of air movement generated (represented by the unit cubic feet per minute or simply as CFM) and the power consumption (in Watts or W) by a ceiling fan.

On average, a ceiling fan has an airflow generation of about 5,500 CFM and consumes 70 W. Dividing the airflow generation by the power consumption gives the ceiling fan's efficiency. In this case, the average ceiling fan efficiency is 5,500 CFM / 70 W or about 79 CFM per W.



Averaged over 2,000 ceiling fans showed that ceiling fans typically move about 5,500 CFM of air, consume 70 W, and have a fan efficiency of 79 CFM per W. A good ceiling fan is one that has 6,000 CFM or more, consumes 30 W or less, and have an efficiency of 200 CFM per W or more (photo from www.hansenwholesale.com).

Therefore, these two information pieces give us some sort of baseline upon which we can use to determine how well a given ceiling fan can move air and yet remain energy efficient. A good ceiling fan is typically those that can move 6,000 CFM or more air, have a power consumption of 30 W or less, and have a fan efficiency of 200 CFM per W or more.

Aeratron ceiling fan has won awards for its very quiet operation and high energy efficiency. Only with three blades but with careful design (such as using winglets and twisted blades), this fan, at top speed, generates about 5,800 CFM, consumes about 15 W, and has an outstanding fan efficiency of 383 CFM per W (photo from aeratron.org).

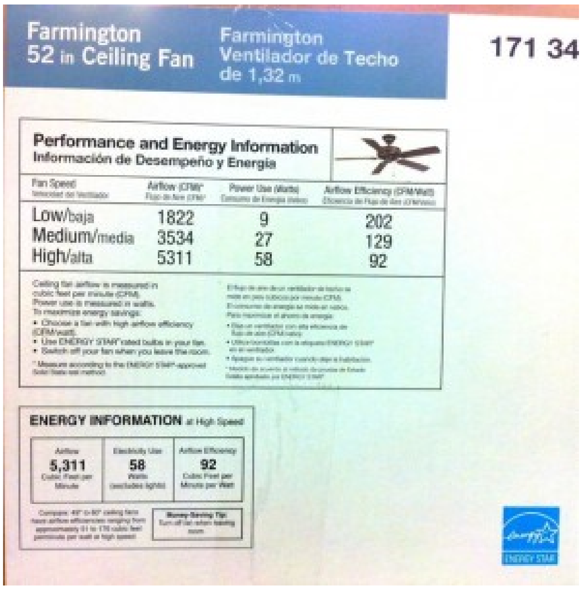
Unfortunately, information about a ceiling fan's CFM and power consumption are not always supplied or even measured by the fan designers or manufacturers. If such information are missing, it can mean that the given ceiling fan may have been designed more for looks rather than for the objectives of achieving high airflow generation, with low noise and energy consumption (*i.e.*, a case of form over function).

There are of course many other factors beside the design of the fan blades that affect airflow, some of which are the height the ceiling fan is positioned from the ceiling, fan motor, and even the room size. However, this article discusses on a topic of fan blade design that interest me the most.

Exhale fan is a unique ceiling fan because it has no blades, so it operates very quietly. Its developers claim that with Exhale fan, airflow is more uniform and gentler within the room. Exhale fans can move about 3,200 CFM, consumes 34 W, and its fan efficiency is 94 CFM per W (photo from exhalefans.com).

I have to admit that at the end of my research, I feel a little helpless. While I am now more aware on what makes an efficient ceiling fan, I am also aware that it is difficult to tell if a ceiling fan is efficient simply based on its individual design features. As mentioned earlier, these individual design features all act simultaneously to give the net outcome on whether the given ceiling fan is efficient.

Consequently, it should be a requirement that all fans be sold with information regarding the fan’s overall performance in terms of CFM and power consumption, so we would be able to make a more informed shopping decision.



Compulsory labelling. All ceiling fans sold in Malaysia should come with information about the fans' performance: their CFM, power consumption, and efficiency, so that we can make intelligent comparisons between fans (photo from www.energyvanguard.com).

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