For fans of fans

By Emma Liu

Which electrical fan will produce the largest velocity wind?

Abstract

The aim of the experiment was to determine the most powerful rotating arrangement and shape for blades in the mechanical fan. The blades were imitated with trapezoidal and curved shapes of equal surface area cut out of hard cardboard, attached to a thin length of wood (toothpicks) with hot glue. The other end of the wood was attached to a plywood circle. The models were attached to a motor in turn. Using a power pack set at 4 volts and a direct current, each model spun for 10 seconds. The velocity of the wind was measured using an anemometer probe, placed 10 cm to the face of the blades and 5 cm to the side of the end of the blades. Both the front and the side were measured as fans of different shapes and angles will direct wind in different directions. The range was graphed and tabulated, and the wind speed produced was compared. The results were close. However, the experiment could only test the most generic designs, and the weight of an actual blade could not be accurately represented, affecting the validity of the efficiency calculations. Despite this the results were relatively valid and fairly reliable. It was concluded that a fan with 2 curved shaped blades at an angle of 60 degrees was the most powerful, closely followed by 3 curved blades at an angle of 60 degrees. Overall, an angle of 60 degrees and 2, 4, then 3 blades all produced high amounts of wind. The shape was most indicative of the range and balance.

Introduction

Fans are necessary tools in home appliances as a short-term alternative to air conditioning, but the designs and prices range a great deal, despite all claiming to achieve high air flow, and with little noise. Which one is really worthwhile buying? How do the different designs achieve similar results? These questions are hopefully answered in this report. This experiment is important as it produces evidence that can be applied to reality, which will hopefully help most households regarding investments on appliances and saving money in general.

Within the experiment cardboard and plywood are used to imitate fans on a smaller scale. The different blades are measured to maintain the same surface area in all models and measured and cut out on cardboard, which allowed rigidity whilst being easy to manipulate. The plywood was used for the axel, however, to ensure the blades were aligned when attached to a motor, and did not move on the shaft when spun. The plywood was also heavier and thicker, serving as a more realistic representation of the mass of a fan. After trialing the experiment, the distance the anemometer probe would be placed from the model was determined in order to achieve the most valid results. A data logger was used to improve accuracy.

The experiment was altered due to some limitations. The hole cut in the centre of the axel was slightly too big and had to be stabilized using blue tack, which may have changed the mass of the model, and despite using a laser cutter, the plywood was often too thick to be cut through, delaying the experiment. Needing to complete the experiment during school hours, an inconvenient time, also meant the experiment took longer than first intended.

The research is shown in this report.

Mechanical Fans

A mechanical fan is a machine used to create flow within a fluid, typically a gas such as air. Most fans are powered by electric motors, but other sources of power may be used, including hydraulic motors and internal combustion engines.

Typical applications include climate control, vehicle and machinery cooling systems, ventilation, fume extraction, winnowing, removing dust (such as in a vacuum cleaner) and drying, although by far the most common use for fans is to cool people down. The general fan shape is also used to harness the wind, such as in anemometers and wind turbines.

These household fans are comprised of a motor run by electric current, which is attached to fan blades via a shaft. This rotor shaft is run by the motor, and turns the fan blades at different speeds depending on the speed set for the motor. The number of blades and the general revolutions per minute of the motor can vary greatly depending on the model of the electric fan, usually as a compromise between power and efficiency (Britannica.com 2015)

History

The first fan of a similar model to current mechanical fans is the punkah fan. Used in India in the early 500 BC, it was a handheld fan made from bamboo blades or other plant fiber that could be rotated. During Anglo-Indian rule, from the punkah derived the 'pankawallah', which was a large swinging fan attached to the ceiling (Wikipedia.com 2015).

During the Renaissance era, the experiments of scientists Otto von Guericke, Robert Hooke and Robert Boyle construed the principles of vacuum and airflow, allowing fans to finally be used in an industrial scene. The English architect Sir Christopher Wren, for example, designed an early ventilation system in the House of Parliament that circulated the air, which became the catalyst for later improvement and innovation. A British engineer, Hohn Theophilus Desaguliers also demonstrated a successful system to exchange stagnant air from coal mines in 1727, significantly reducing casualties to gas asphyxiation.

In the late 1700's, with the advent of practical steam power, fans could finally be used in ventilation. The pressure produced by the fans forced the incoming air in a room upward and through vents installed in the ceiling.

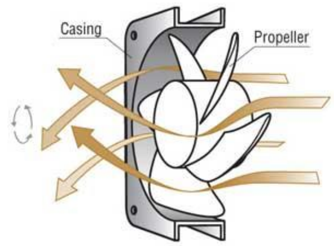
The first electrical fans were not invented until the late 19th century. Between the years 1882 and 1886, New Orleans resident Schuyler Skaats Wheeler invented a fan powered by electricity and 1882, Philip Diehl introduced the electric ceiling fan. (Fanmakers.com 2015) Heat-convection fans fueled by alcohol, oil, or kerosene were common around the turn of the 20th century (Robert Bruegmann 2015).

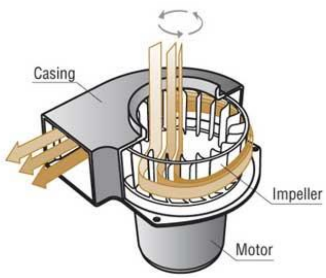
Fig. 1. Kent Electric Co. electric fan ca. 1898

Household fans however were not of popular used until the 1920's, where industrial advances allowed steel fans to be mass-produced in different shapes and sizes. Prices were brought down so more homeowners could afford them, although not long afterwards central air conditioning in the 1960s caused many companies to discontinue production of standing fans. Ceiling fans were also of popular demand in the 1970's due to their efficiency, further reducing the production of standing fans (Steve Cunningham 2015). Today, most households utilise air conditioning, although fans, being cheaper and easier to make, are still preferred as a temporary purchase.

Types of Mechanical Fans

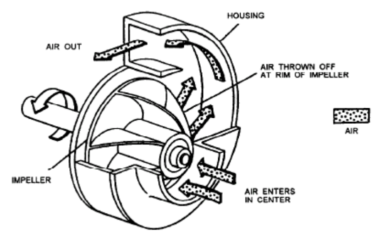
Axial-flow fans- fans which create an air stream along the axis of the fan (linearly). They have a wide range of applications, in a variety of scales, ranging from a standing/pedestal fan to large industrial fans. *Fig. 2.*





Centrifugal fan- fans which blow air at right angles to the intake of the fan, and spin the air outwards to the outlet (by deflection and centrifugal force). This design creates large amounts of air pressure, making centrifugal fans preferred for leaf blowers, inflators and other industrial purposes. *Fig. 3.*

Cross flow fan- fans which consist of an impeller with forward-curving blades spinning clockwise, to direct unmoving air through it's blades to create an airstream. *Fig. 4.*



(Orientalmotor.com 2015)

Evaporative cooling

A regular pedestal or floor fan cools people effectively by introducing movement into the otherwise still, hot air of a room, inducing the evaporation of sweat. Contrary to an electrical fan, or air conditioner, the mechanical fan does not vary the air pressure or cool the air itself, but creates a breeze which evaporates sweat faster, creating a cooling sensation (Breezair.com 2015).

Evaporation will take place when the humidity is below 100% and the air begins to absorb water. Any given volume of air can hold a certain amount of water vapour and the degree of absorption will depend on the amount it is already holding. Air is saturated when it cannot hold any more water (Clayton, V. 2015). Thus, fans may become ineffective at cooling the body if the surrounding air is near body temperature and contains high humidity.

And so, a mechanical fan can only cool those who stand in the direct air current created by the rotating blades. Moreover, mechanical fans are very inefficient. The energy expended to wave a manual fan creates heat in the body (of the fan), and the fan's air does not do enough to counteract it, bringing rise to the aim of the experiment.

Criteria for a good fan

The main purpose of an electric fan is to create airflow. So, a good fan must create a good airflow with minimal noise and moderate control over the speed. Usually a blade is moderately long, thin and bent a little up, which forces air forward and creates airflow. Usually metal/alloy blades are preferred for their rigidity and ability to withstand mechanical stress. But, nowadays, there are plastic (polymeric) blades having a comparable strength to metal blades, are used (Sawyers H. 2011)

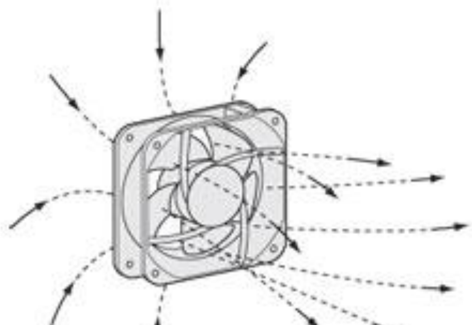


Fig. 2. Air flow of an axial flow fan

The number of blades and their shape may vary depending upon the model and aesthetic sense, but fans may have any number of blades placed at any position. However the weight of the blades must be balanced for maximum energy output. As a result, fans with only one blade are not often preferred, as the weight of the blade tends to bend the blade down and cause imbalance. To be balanced, a fan with two blades should have blades oppositely arranged to each other. Similarly in the case of having three blades, each of them must make an angle of 120 degrees with the next blade (Sawyers H. 2011)

"Absolute minimum is, of course, two blades, because with one the fan would not be symmetric. Increasing the number of blades increases efficiency, but also increases the weight of the device."-- Jerzy Michał Pawlak, PhD in High Energy Physics. Pawlak does not directly comment on power, but efficiency. As efficiency is calculated using the energy input divided by the energy output, and as the energy input is equal for each model, the energy output varies to determine the efficiency. This energy output will also be used to calculate power, so from Pawlak's comment It can be derived that the power of a fan increases as the number of blades increases.

Why I chose this experiment

When one imagines a fan, the generic image is a three-bladed pedestal or ceiling fan or a wind turbine. I have always assumed it was a compromise between cost and efficiency, so I decided to investigate further into this presumption through this experiment. I also live in a north-west facing townhouse without air conditioning, meaning we rely on fans and open windows to cool the house down in the afternoon and night, especially in the Australian summer. This investigation can help me determine whether a long-term investment into air conditioning would benefit my family cost-wise as well as comfort-wise.

Experimental report

Aim:

To determine the most powerful rotating arrangement and shape for a fan blade.

Hypothesis:

The curved blade in an arrangement of 5 and an angle of 60 degrees will be the most powerful. (B5-60)

Equipment:

- A3 Cardboard sheet
- Scissors
- Plywood
- Laser Cutter
- 15 toothpicks
- Hot glue gun
- Hot glue- glue sticks
- DC Motor
- Leads
- Power pack
- Data logger
- Anemometer probe

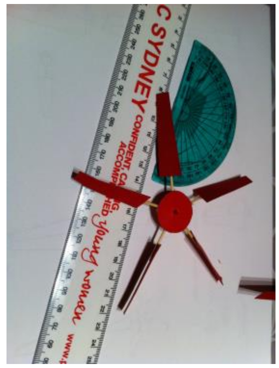


Fig. 3 and 4- Equipment used to make blades. Left- ruler, protractor. Right- toothpicks, scissors, hot glue, hot glue gun, cardboard.

Method:

Constructing the models

1. A trapezoidal blade was drawn and cut out of cardboard using scissors according to the calculated dimensions (page 10).

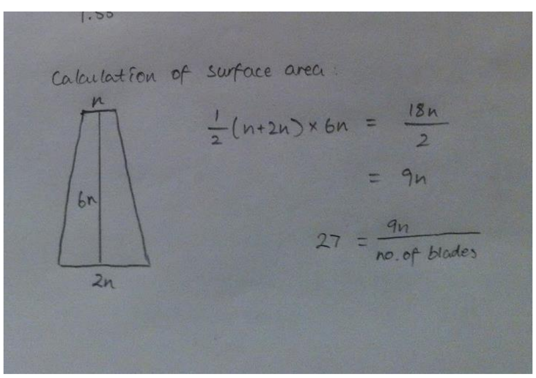


Fig. 5. Trapezoidal surface area calculations

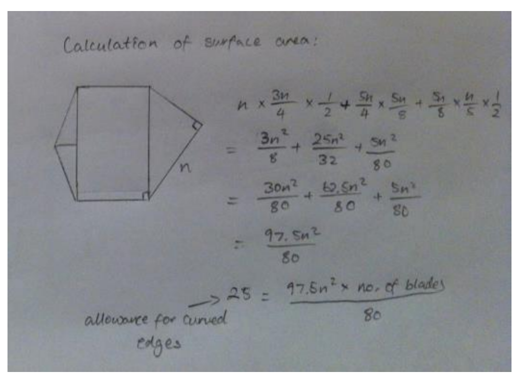


Fig. 6. Curved surface area calculations

2. The centre of the bottom of the blade was attached to the end of half a toothpick with a strip of hot glue (1cm in length approx.).
3. The other end of the toothpick was attached to a plywood axel with hot glue, leaving 1 cm of the toothpick visible from the other side.
4. Steps 1-3 were repeated with 2, 3, 4 or 5 blades. The blades are placed so they are as

far apart from each other as possible. E.g. 3 blades: 120°, 4 blades: 90°.

5. Steps 1-4 were repeated with an angle of 0, 30 or 60 degrees to the axel with a negative inclination/gradient, using a protractor.
6. Steps 1-5 were repeated with a curved blade, still maintaining the surface area (page 10).

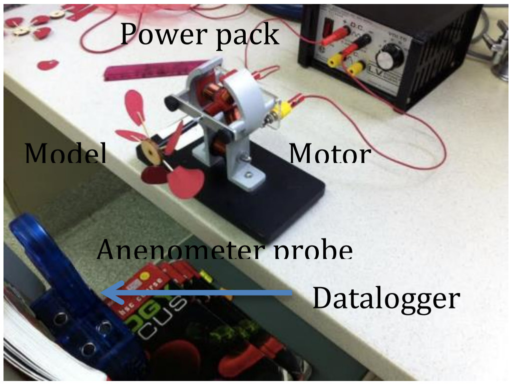


Fig. 5. Experimental set up from the front

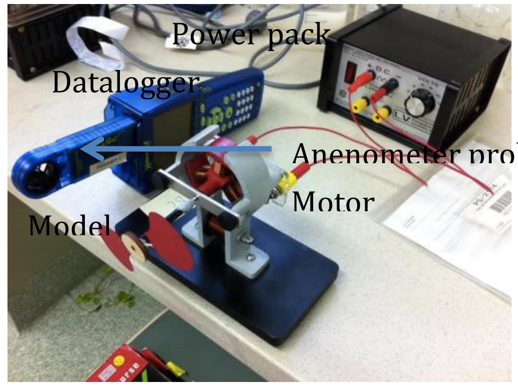


Fig. 6. Experimental set up from the side

Conducting the experiment

1. The electrical circuit was set up with the ammeter, voltmeter, leads, motor and power pack (shown in page 6 fig. 7)
2. The model A1 (1 trapezoidal blade- refer to page 10) was constructed and attached to the shaft of the motor at the axel.
3. The anemometer was set up 10cm away from the front of the model, with the sensor on the same horizontal plane as the axel, and the same vertical plane as the middle of a blade (shown in Fig. 5)
4. The circuit was turned on for 10 seconds and the wind speed range detected was recorded.
5. Step 4 was repeated another 2 times.
6. The anemometer was set up 5cm away from the tip of the blade to the side of the model (shown in Fig. 6)
7. The circuit was turned on for 10 seconds and the wind speed range detected was recorded.
8. Step 7 was repeated another 2 times.
9. The average wind speed range was calculated by adding the minimum of the 3 results and dividing by 3 and adding the 3 maximum results and dividing by 3.
10. The average wind range was calculated by subtracting the maximum and minimum results, adding them together and dividing by 3.
11. The average wind speed was calculated by finding the average of the maximum and minimum results derived from the average wind speed range (step 9)
12. The average wind speed (calculated in step 10) was multiplied by the distance the anemometer was held from the model, and then divided by 10 seconds to calculate the power of each model.

    Work= force x distance, Power= work/time

13. Steps 1-8 were repeated with the models A2- A5, A1(30)- A5(30), A1(60)- A5(60), B1-B5, B1(30)- B5(30), B1(60)- B5(60), referring to page 10.

Science Student Research Project Risk Assessment

Activity description- Testing the wind speed created by a model fan attached to a DC motor set at 4 volts.

Step 1: Identify the hazard	**Step 2: Strategies to minimise the hazard**	**Step 3: Assessment of risk (see table below)**	**Step 4: What if something goes wrong?**	**Step 5: Packing up**
Leads may be broken and framed and electrocute a person	Ensure leads are safe before plugging them into the power pack. Replace any loose leads with fitting ones.	1+2=3=MODERATE	Do not touch person who is electrocuted. Turn off power pack if possible. Consult teacher.	Turn powerpack off first. Take them out and hang them up.
The motor's spinning magnets is a hazard to fingers. There is no guard	Avoid putting fingers near the motor while on	3+2=5=HIGH	Consult teacher immediately. Call emergency contact and hospital.	Turn off powerpack off first. Remove attached fan model and store motor in box.
Spinning models can cause cuts	Avoid putting fingers near the motor while on	1+1=2=LOW	Treat cuts with antiseptic. Consult teacher.	Turn off powerpack off first. Remove attached fan model and store motor in box.
Laser cutter can diffract radiation to surroundings	Do not open the lid while the program is running and the laser is cutting	2+1=MODERATE	Program will immediately shut off. Close the lid and consult teacher.	Close off from powerpoint.

Date:………………….. Student Sign:………………………………..

How do you assess the risk? For each hazard identified in Step 1, answer A then answer B. Then add A and B together to determine Risk and Action required.

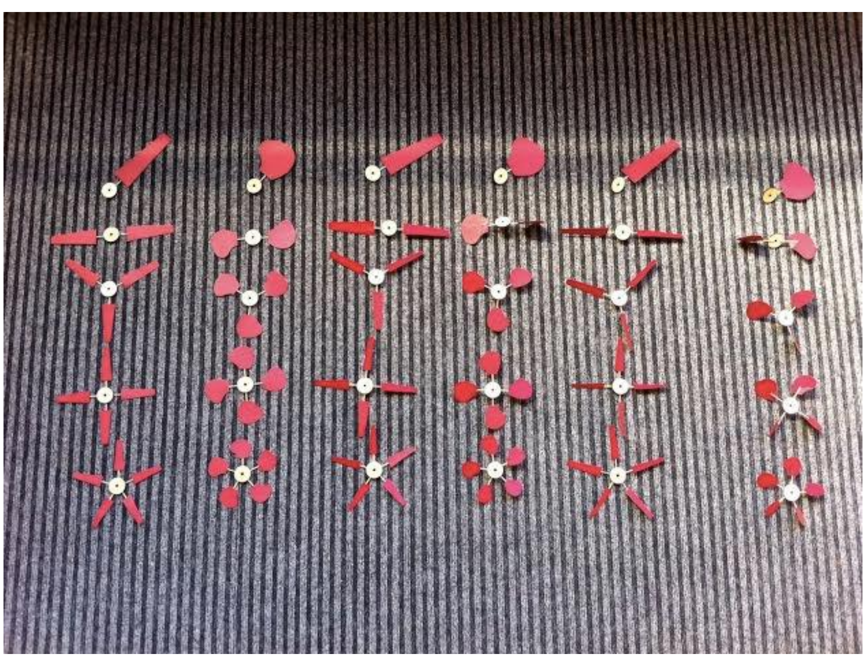
A **What is the potential impact or consequence of the hazard?**	**B** **What is the likelihood of the event happening?**	**Add the numbers in columns A and B together**	**How to assess the risk**	**Action**
1 = MINOR First Aid required with little or no lost time	1 = LOW It could happen but only rarely		1 – 2 = LOW RISK	Proceed with caution
2 = MODERATE Medical treatment required, some lost time	2 = MODERATE It could occasionally happen		3 – 4 = MODERATE	Consult with teacher
3 = SERIOUS Medical treatment required, extended lost time	3 = HIGH It could frequently happen		5 – 6 = HIGH	Reassess the need to perform practical/ consult with teacher

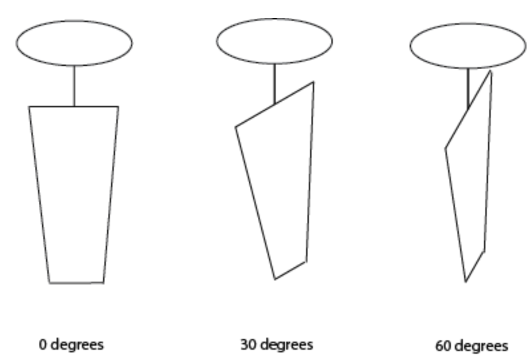
Independent variables	Dependent variables	Controlled variables
The shape of fan blades (curved or trapezoidal).	Speed of wind from the front of the model and to the side of the model fan.	The thickness and dimensions of the cardboard and plywood used.
The number of fan blades.	Range of wind from the front of the model and to the side of the model fan.	The voltage at which the circuit is powered.
The angle at which the blades are from the axel.		The approximate amount of hot glue used to assemble the models.
		The combined surface area of the fan blades.
		The distance of the anemometer from the fan.

Why this method is effective

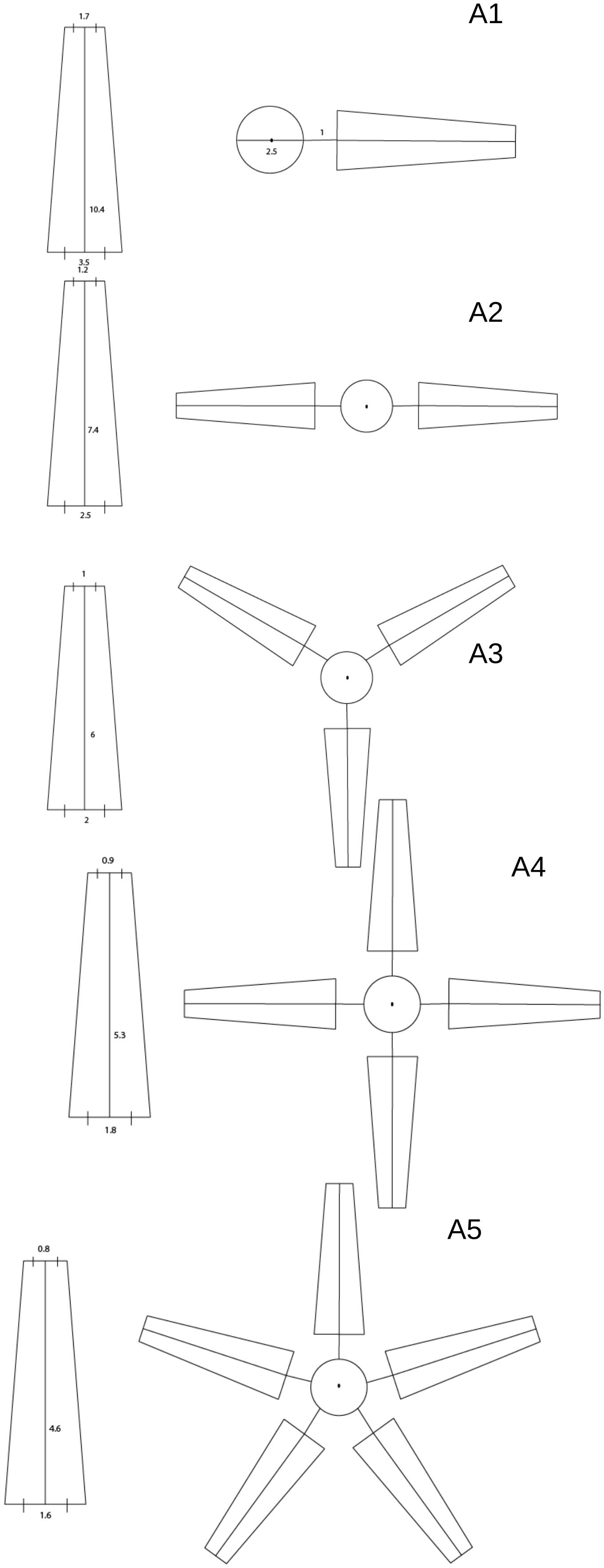
The method above will answer the aim 'to determine the most powerful rotating arrangement and shape for a fan blade', in comparing the power of all models, using scaled and suitable equipment (thick cardboard blades, a DC motor) to imitate a standing fan, controlled variables (the thickness and surface area of the fan blades, the amount of material such as hot glue the speed of the fan and the distance of the anemometer from the fan) and appropriate measuring procedures to calculate wind speed and direction. Each model is tested 3 times, to determine reliability and the correlation of the results to the general image of fans as having 3 blades.

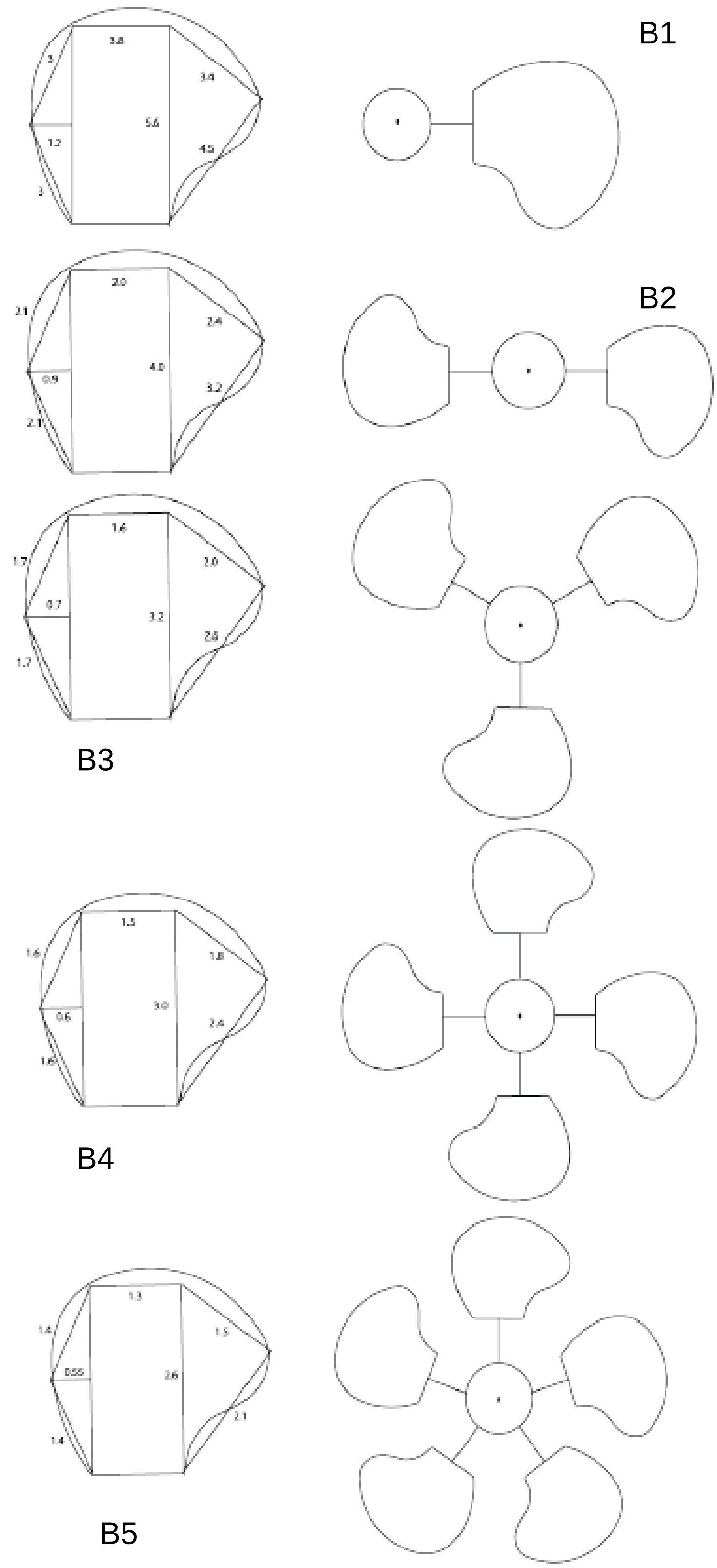
Test Models *(Fig. 7-17.)*





Left- models
Right- blade angels


A1
1.7
10.4
3.5
2.5
1
A2
1.2
7.4
2.5
A3
1
6
2
A4
0.9
5.3
1.8
A5
0.8
4.6
1.6


B1
3.8
3
3.4
5.6
1.2
4.5
3
B2
2.0
2.1
2.4
4.0
0.9
3.2
2.1
1.6
1.7
2.0
0.7
3.2
2.6
1.7
B3
1.5
1.6
1.8
3.0
0.6
2.4
1.6
B4
1.3
1.4
1.5
0.55
2.6
2.1
1.4
B5

Observation: Models with a larger radius overall (1 blade would have the largest) were the most unbalanced, often spinning itself off the shaft of the motor.

Results

The wind speed and power of each model with a 0-degree angle from the front (1dps).

	Wind speed minimum-maximum (m/s)						
Model	Trial 1	Trial 2	Trial 3	Average	Average range (m/s)	Average speed (m/s)	Average power (W)
A1	3.0-5.7	3.4- 5.5	3.4-7.9	3.3-6.4	3.1	4.7	4.7
A2	5.4-6.3	5.2-7.6	5.1-7.1	5.2-7.0	1.8	6.1	6.1
A3	5.5-6.3	6.8-8.4	5.6-6.9	6.0-7.2	1.2	6.6	6.6
A4	5.5-7.0	5.3-6.9	5.1-6.1	5.3-6.7	1.4	6.0	6.0
A5	5.4-5.9	4.7-6.7	5.1-6.3	5.1-6.3	1.2	5.7	5.7
B1	4.5-7.5	4.9-7.4	5.1-7.0	4.8- 7.3	2.5	6.1	6.1
B2	5.0-6.1	4.7-6.0	5.9-6.3	5.2- 6.1	0.9	5.7	5.7
B3	5.1-6.0	5.3-6.0	5.3-6.2	5.2- 6.1	0.9	5.7	5.7
B4	5.4-6.0	5.1-6.0	5.0-7.1	5.2- 6.4	1.2	5.8	5.8
B5	3.0-6.3	4.0-5.5	3.9-5.5	3.6-5.8	2.4	4.7	4.7

The wind speed and power of each model with a 0-degree angle and from the side (1dps).

	Wind speed minimum-maximum (m/s)						
Model	Trial 1	Trial 2	Trial 3	Average	Average Range (m/s)	Average speed (m/s)	Average power (W)
A1	5.2-9.4	5.7-8.4	5.7-8.8	5.5-8.9	3.4	7.2	3.6
A2	5.6-11.6	5.1-10.2	5.8-11.2	5.5-11.0	5.5	8.3	4.2
A3	5.7-12.8	4.2-9.6	6.4-9.4	5.4-10.6	5.2	8.0	4.0
A4	5.6-7.5	5.9-9.1	4.6-9.1	5.4-8.6	3.2	7.0	3.5
A5	5.8-7.0	4.8-9.7	5.1-8.9	5.2- 8.5	3.3	6.9	3.5
B1	5.7-8.6	5.4-7.6	5.7-10.0	5.6-8.7	2.1	7.2	3.6
B2	5.8-15.8	5.1-14.3	5.6-9.1	5.5-14.6	9.1	10.1	5.1
B3	5.7-10.1	3.2-14.3	5.3-13.7	4.7-12.7	8.0	8.7	4.4
B4	5.7-8.4	3.1-14.2	5.4-11.1	4.7-11.2	6.5	8.0	4.0
B5	5.2-6.0	5.2-6.8	5.2-10.6	5.2-7.9	2.7	6.6	3.3

The wind speed and power of each model with blades at a 30-degree angle from the front (1dps).

	Wind speed minimum-maximum (m/s)						
Model	Trial 1	Trial 2	Trial 3	Average	Average Range (m/s)	Average speed (m/s)	Average power (W)
A1-30	3.2-5.6	3.4-4.2	2.6-4.4	3.0-4.7	1.7	3.9	3.9
A2-30	5.5-17.5	4.9-10.0	4.7-25.2	5.0-17.6	12.6	11.3	11.3
A3-30	8.0-12.6	5.5-13.5	6.1-19.5	6.5-15.2	8.7	10.9	10.9
A4-30	5.4-8.4	8.5-15.4	6.1-9.6	6.7-11.1	4.4	8.9	8.9
A5-30	5.6-8.4	3.9-12.0	3.6-9.7	4.4-10.0	5.6	7.2	7.2
B1-30	2.7-13.8	2.9-7.3	2.3-6.0	2.6-9.0	6.4	5.8	5.8
B2-30	5.3-19.2	4.5-11.1	2.8-16.4	4.2-15.6	11.4	9.9	9.9
B3-30	4.0-14.7	3.7-16.0	3.2-16.7	3.6-15.8	12.4	9.7	9.7
B4-30	2.2-20.1	5.3-14.2	3.1-11.1	3.5-15.1	11.6	9.7	9.7
B5-30	4.6-19.9	4.0-9.4	3.4-16.5	4.0-15.3	11.3	9.7	9.7

The wind speed and power of each model with blades at a 30-degree angle from the side (1dps).

	Wind speed minimum-maximum (m/s)						
Model	Trial 1	Trial 2	Trial 3	Average	Average Range (m/s)	Average speed (m/s)	Average power (W)
A1-30	5.8-7.5	5.5-7.2	5.5-7.5	5.6-7.4	1.8	6.5	3.3
A2-30	5.8-16.8	5.4-8.0	5.6-11.5	5.6-12.1	6.5	8.9	4.5
A3-30	6.1-17.1	5.7- 13.0	5.7-14.9	5.8-15.0	9.2	10.4	5.2
A4-30	5.6-19.4	5.7-9.7	5.6-13.1	5.6-14.0	8.4	9.8	4.9
A5-30	5.9-13.2	4.9-12.5	5.2-9.6	5.3-11.8	6.5	8.6	4.3
B1-30	5.5-11.5	5.8-9.3	5.9-14.9	5.7-11.9	6.2	8.8	4.4
B2-30	5.2-13.6	5.4-12.1	5.3-13.2	5.3-13.0	7.7	9.2	4.6
B3-30	5.6-11.0	5.2-13.5	5.9-12.7	5.6-12.4	6.8	9.0	4.5
B4-30	5.3-13.1	5.8-11.7	5.6-12.9	5.6-12.6	7.0	9.1	4.6
B5-30	5.7-9.8	5.8-9.2	5.7-15.7	5.7-11.6	5.9	8.7	4.4

The wind speed and power of each model with blades at a 60-degree angle from the front (1dps).

	Wind speed minimum-maximum (m/s)						
Model	Trial 1	Trial 2	Trial 3	Average	Average Range (m/s)	Average speed (m/s)	Average power (W)
A1-60	13.4-23.6	16.2-20.4	12.8-19.8	14.1-21.2	7.1	17.7	17.7
A2-60	11.8-18.4	10.4-22.7	14.3-22.0	12.2-21.0	8.8	16.6	16.6
A3-60	10.7-29.2	13.8-20.3	12.0-25.0	12.2-24.8	12.6	18.5	18.5
A4-60	14.8-27.3	14.5-20.0	11.0-27.5	13.4-24.9	11.5	19.2	19.2
A5-60	15.8-21.6	15.3-33.8	11.0-18.1	14.0-24.5	10.5	19.3	19.3
B1-60	11.3-15.1	10.0-25.6	13.7-19.4	11.7-20.0	8.3	15.9	15.9
B2-60	22.3-32.1	17.7-26.5	18.5-30.3	19.5-29.6	10.1	24.6	24.6
B3-60	15.0-27.7	11.2-30.2	10.4-25.7	12.2-27.9	15.7	20.1	20.1
B4-60	14.7-26.8	16.9-28.2	19.2-23.6	16.9-26.2	9.3	21.6	21.6
B5-60	9.2-19.3	17.3-23.0	13.5-19.1	13.3-20.5	7.2	16.9	16.9

The wind speed and power of each model with blades at a 60-degree angle from the side (1dps).

	Wind speed minimum-maximum (m/s)						
Model	Trial 1	Trial 2	Trial 3	Average	Average Range (m/s)	Average speed (m/s)	Average power (W)
A1-60	5.7-12.0	5.7-13.6	5.7-17.0	5.7-14.2	8.5	10.0	5.0
A2-60	4.9-16.9	5.9-15.1	5.5-16.9	5.4-16.3	10.9	10.9	5.5
A3-60	5.7-19.8	5.8-15.2	5.7-17.4	5.7-17.5	11.8	11.6	5.8
A4-60	5.8-15.7	3.7-13.5	5.6-16.7	5.0-15.3	10.3	10.2	5.1
A5-60	5.7-16.1	4.9-16.0	5.6-14.1	5.4-15.4	10.0	10.4	5.2
B1-60	5.6-13.5	4.1-10.6	5.8-13.9	5.2-12.7	7.5	9.0	4.5
B2-60	5.5-12.5	5.6-15.3	5.4-16.8	5.5-14.9	9.4	10.2	5.1
B3-60	5.6-16.2	4.7-13.1	5.5-15.8	5.3-15.0	9.7	10.2	5.1
B4-60	5.7-14.1	5.2-15.1	5.3-15.4	5.4-14.9	9.5	10.2	5.1
B5-60	5.7-10.4	4.6-19.2	5.6-14.6	5.3-14.7	9.4	10.0	5.0

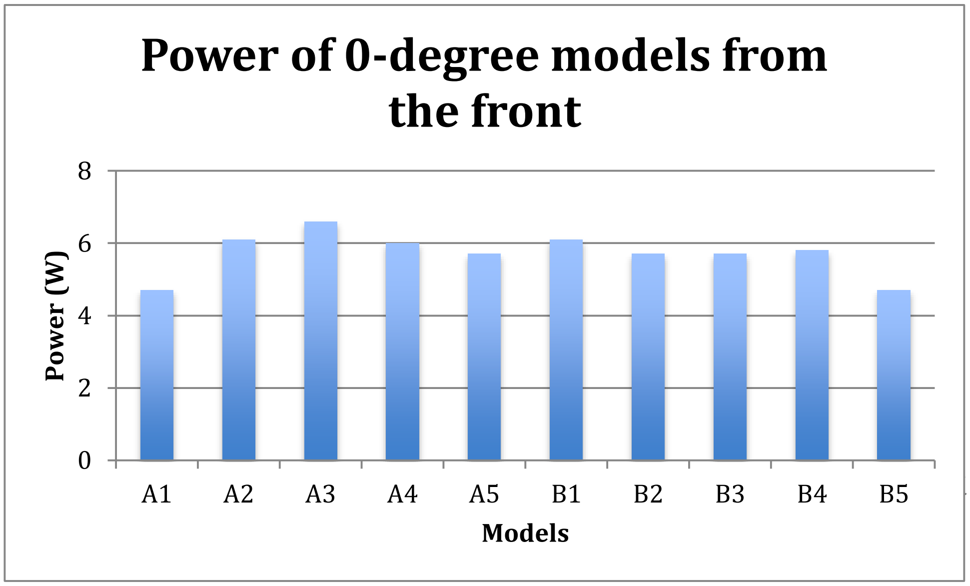


Fig.18.

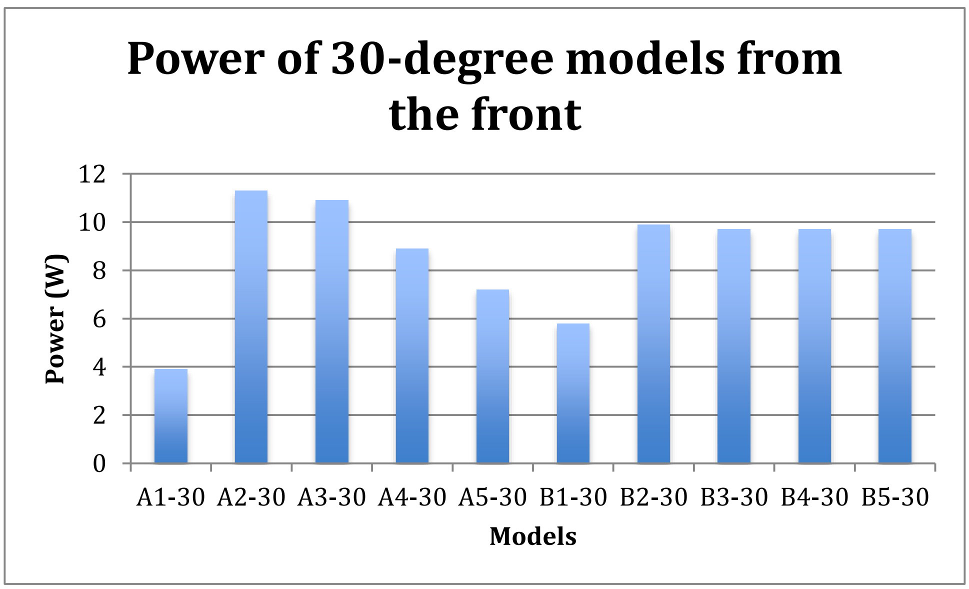


Fig. 19.

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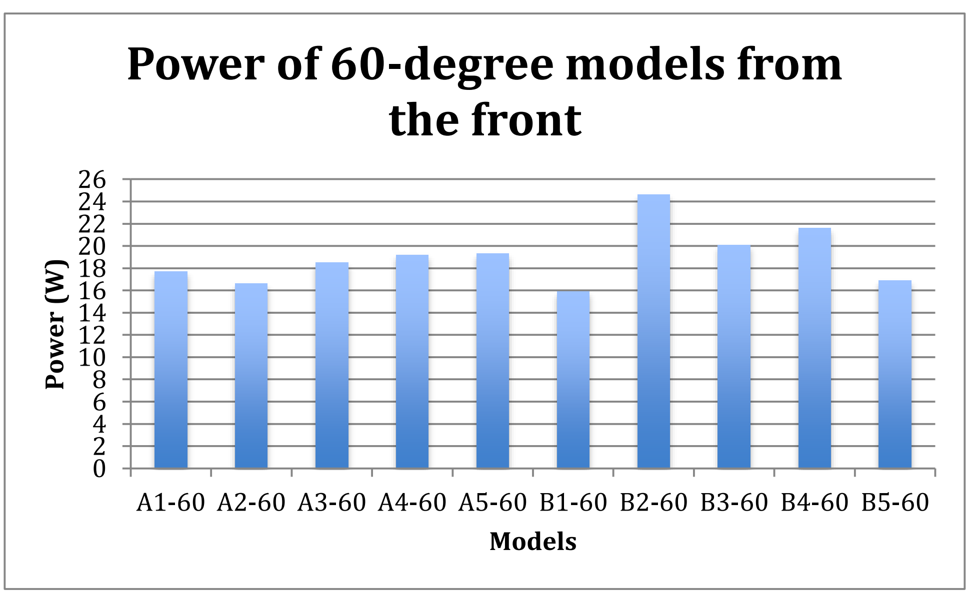

Fig. 20.

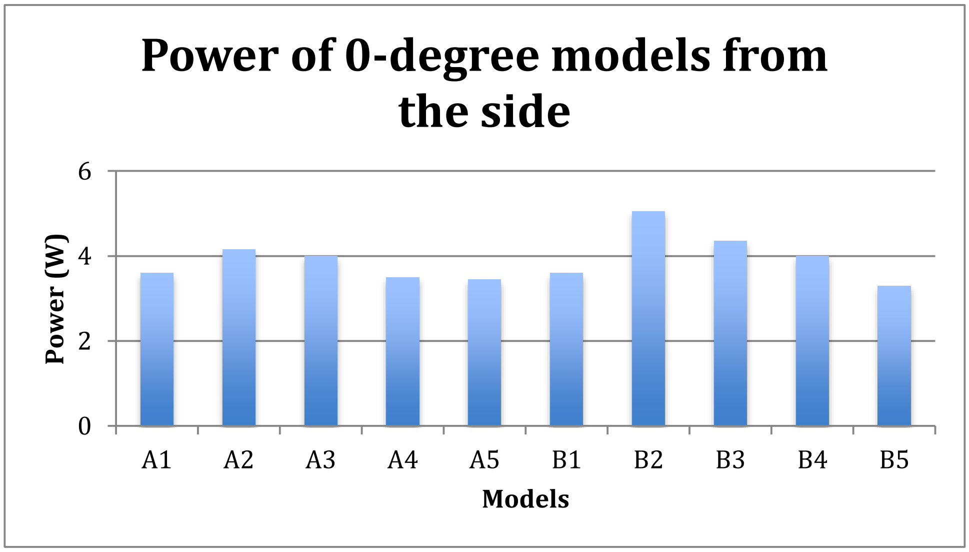

Fig. 21.

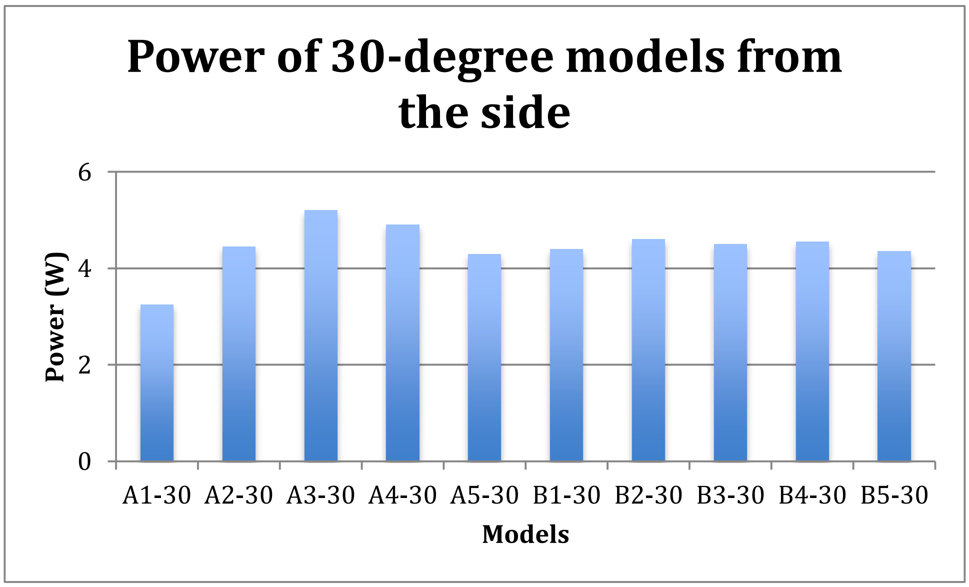

Fig. 22.

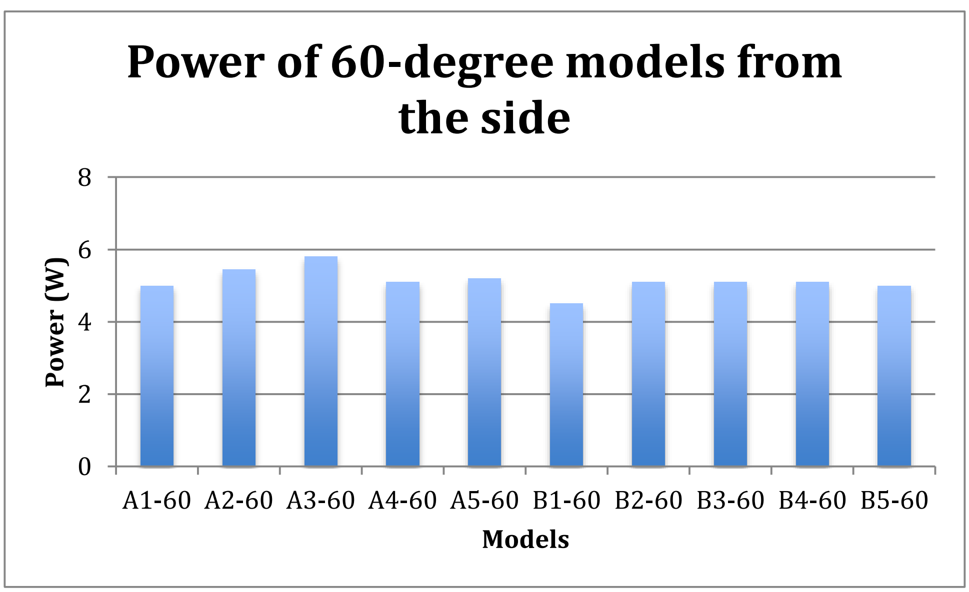

Fig. 23.

The average power produced by <u>different angles</u>

	Average power overall- Front (m/s)			Average power overall- Side (m/s)		
Angle (degrees)	0	30	60	0	30	60
A1	4.7	3.9	17.7	3.6	3.3	5.0
A2	6.1	11.3	16.6	4.2	4.5	5.5
A3	6.6	10.9	18.5	4.0	5.2	5.8
A4	6.0	8.9	19.2	3.5	4.9	5.1
A5	5.7	7.2	19.3	3.5	4.3	5.2
B1	6.1	5.8	15.9	3.6	4.4	4.5
B2	5.7	9.9	24.6	5.1	4.6	5.1
B3	5.7	9.7	20.1	4.4	4.5	5.1
B4	5.8	9.7	21.6	4.0	4.6	5.1
B5	4.7	9.7	16.9	3.3	4.4	5.0
Average	5.7	8.7	19.0	3.9	4.5	5.1

Angle (degrees)	**Front power (m/s)**	**Side power (m/s)**	**Net power (m/s)**
0	**5.7**	**3.9**	**9.6**
30	**8.7**	**4.5**	**13.2**
60	**19.0**	**5.1**	**24.1**

Therefore, models with an angle of 60 degrees have the most power, followed by models of 30 degrees and models of 0 degrees respectively.

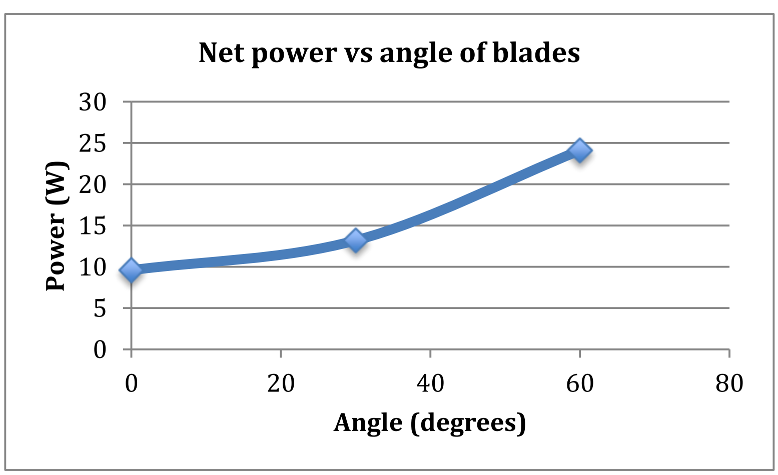

Fig. 24

The average power produced by <u>different blade shapes</u>.

A (trapezoidal)	**B (curved)**
9.9	**10.2**

Therefore, curved models produce more power than trapezoidal models, though by a slim margin.

The average power produced by each no. of blades

	Average speed overall- Front (m/s)					Average speed overall- Side (m/s)				
No of blades	1	2	3	4	5	1	2	3	4	5
A-0	4.7	6.1	6.6	6.0	5.7	7.2	8.3	8.0	7.0	6.9
B-0	6.1	5.7	5.7	5.8	4.7	7.2	10.1	8.7	8.0	6.6
A-30	3.9	11.3	10.9	11.1	7.2	6.5	11.3	10.4	9.8	8.6
B-30	5.8	9.9	9.7	15.1	9.7	8.8	9.9	9.0	9.1	8.7
A-60	17.7	16.6	18.5	19.2	15.3	10.0	10.9	11.6	10.2	10.4
B-60	15.9	24.6	20.1	21.6	16.9	9.0	10.2	10.2	10.2	10.0
Average	9.0	12.3	11.9	13.1	9.9	7.3	10.1	9.7	9.1	8.5

Number of blades	**Front power(m/s)**	**Side power (m/s)**	**Net power (m/s)**
1	**9.0**	**7.3**	**16.3**
2	**12.3**	**10.1**	**22.4**
3	**11.9**	**9.7**	**21.6**
4	**13.1**	**9.1**	**22.2**
5	**9.9**	**8.5**	**18.4**

Therefore, models with 2 blades produce the most power, but only slightly more than models with 4 blades, followed by models with 3 blades, 5 blades and 1 blade respectively.

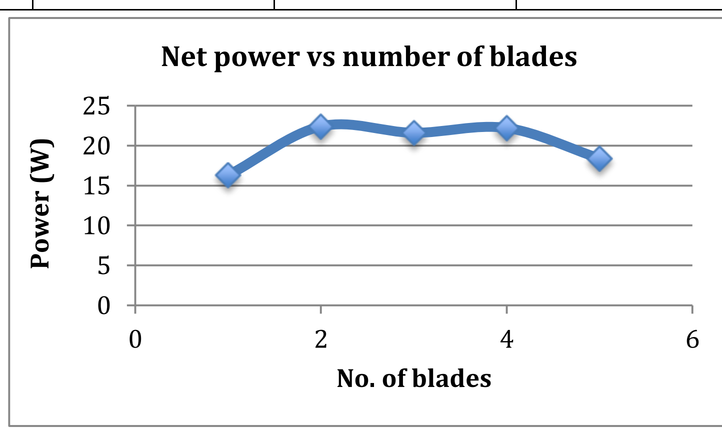

Fig. 25.

Wind speed range of models from the front

Model	Range (m/s)
A1	3.1
A2	1.8
A3	1.2
A4	1.4
A5	1.2
B1	2.5
B2	0.9
B3	0.9
B4	1.2
B5	2.4

Model	Range (m/s)
A1-30	1.7
A2-30	12.6
A3-30	8.7
A4-30	4.4
A5-30	5.6
B1-30	6.4
B2-30	11.4
B3-30	12.4
B4-30	11.6
B5-30	11.3

Model	Range (m/s)
A1-60	7.1
A2-60	8.8
A3-60	12.6
A4-60	11.5
A5-60	10.5
B1-60	8.3
B2-60	10.1
B3-60	15.7
B4-60	9.3
B5-60	7.2

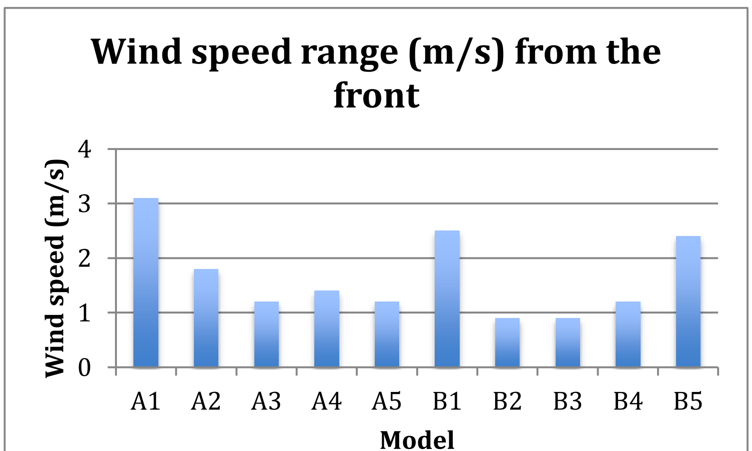

Fig. 26.

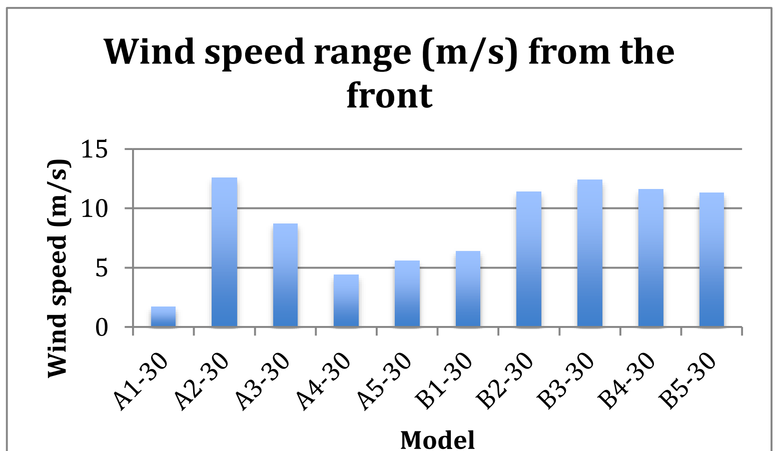

Fig. 27.

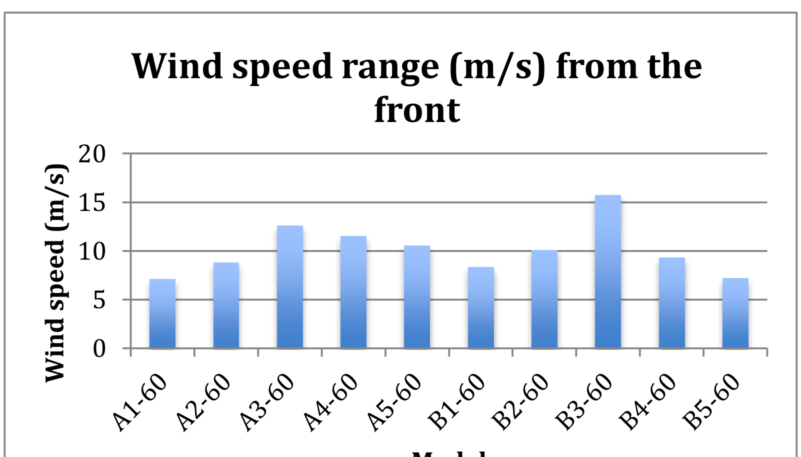

Fig. 28.

Wind speed range of models from the side

Model	Range (m/s)
A1	3.4
A2	5.5
A3	5.2
A4	3.2
A5	3.3
B1	2.1
B2	9.1
B3	8.0
B4	6.5
B5	2.7

Model	Range (m/s)
A1-30	1.8
A2-30	6.5
A3-30	9.2
A4-30	8.4
A5-30	6.5
B1-30	6.2
B2-30	7.7
B3-30	6.8
B4-30	7.0
B5-30	5.9

Model	Range (m/s)
A1-60	8.5
A2-60	10.9
A3-60	11.8
A4-60	10.3
A5-60	10.0
B1-60	7.5
B2-60	9.4
B3-60	9.7
B4-60	9.5
B5-60	9.4

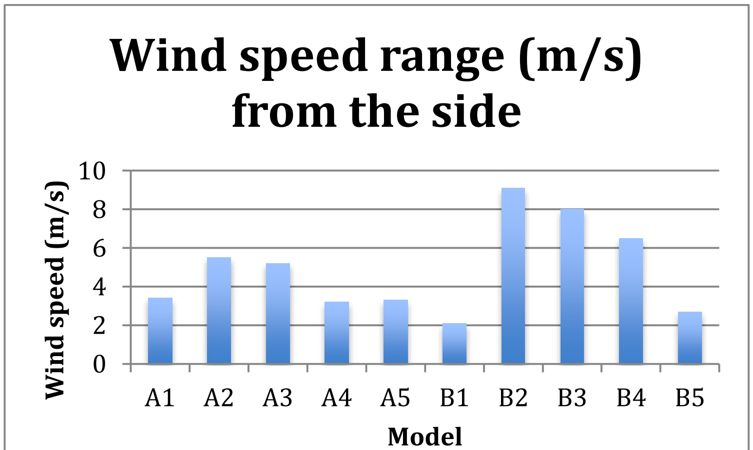

Fig. 29.

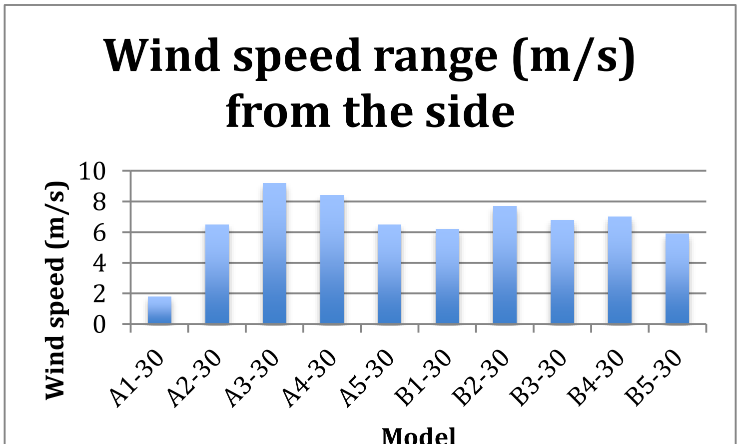

Fig. 30.

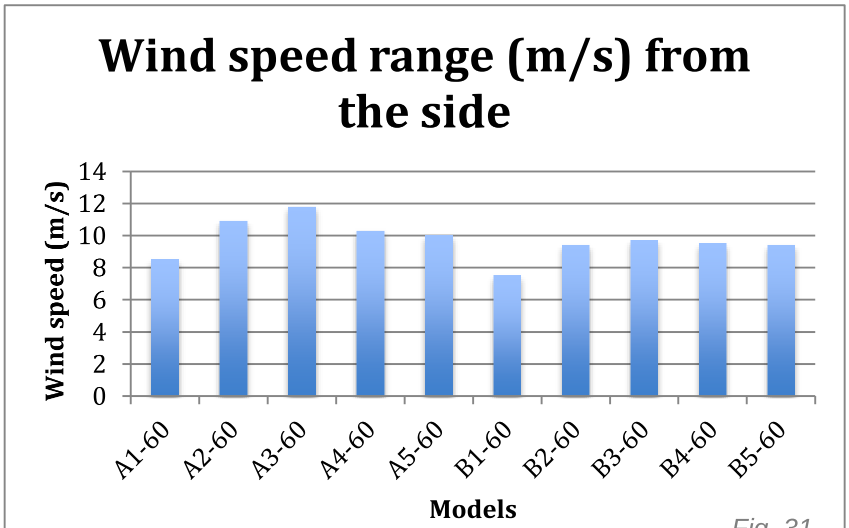

Fig. 31.

Discussion

The data presented within the results evinces that an angle of 60 degrees, with 2 curved blades (B2-60) will produce the largest net velocity wind, and the largest velocity wind to the front of the fan when surface area is kept constant, and in turn it is the most powerful. In the experiment undertaken, an angle of 60 degrees, 3 trapezoidal blades produced the highest velocity wind from the side, in turn also being the most powerful. This contrasts with the initial hypothesis, which was that an angle of 60 degrees with 5 curved blades (B5-60) would produce the largest net velocity wind. To deduce the most dynamic model, the wind speeds of different models were compared. Aspects also taken into account were the range, the balance/stability, and the net wind speed to the front and the side. Across all variables, an angle of 60 degrees, a curved shape and 2, 3, or 4 blades accumulated to the most dynamic model, producing the most power as well as (qualitively) being stable/balanced.

Between the angles of 0 degrees, 30 degrees and 60 degrees, the power was higher for 60 degrees by a large margin. As the angle increases from 0 degrees to 60 degrees, the power increases in an accelerating rate, meaning although an angle of 30 degrees is on average 4m/s more powerful than no angle, an angle of 60 degrees was almost twice as powerful than an angle of 30 degrees (see results pg. 17).

The power between 2, 3 and 4 bladed models often varied, though there was a significant drop in power for models with 1 and 5 blades, as can be seen in the graphs. When the average was taken, however, and the net power was calculated, 2, 3, and 4 blades produced 22.4, 21.6 and 22.2 m/s of wind respectively. The difference is minor, so fans with 2, 3 and 4 blades can all be effective, although models with 2 blades, from these results, are concluded as best. The main contributor to changes in power is thus the angle.

The range of each model according to the number of blades lacked a pattern that continued through all the models. The minimum wind speed was quite constant within each given angle and position (front/side), very gradually increasing as the number of blades increased, but the maximum speed varied dramatically, determining the range. Surprisingly, there was little relation of range to the period of the number of blades (based on the no. of blades- 1 blade had the largest period of 360°, 5 blades had the smallest period of 72°. In models with an angle of 0 degrees no particular trend was noticed. In models with an angle 30 degrees, 2 blades (180° period) had the largest range, which decreased as the number of blades increased. In models with an angle of 60 degrees however, 3 blades (120° period) had the largest range and models with 1 and 5 blades had the smallest range, with models with 2 and 4 blades being in between.

Through observation, an increase in the number of blades also led to a more balanced model. Models with 1 blade were not balanced and the blade swung forcibly. Models needed to have 2 blades or more to be balanced, especially in the B collection of models, which had a smaller wingspan/diameter overall, complimentary to Professor Jerzy Michal Pawlak's hypothesis.

Between the differently shaped models- trapezoidal and curved, the curved design was more powerful as the angle increased. Curved shape models produced more power and the model as a whole had a smaller radius that made it more balanced and gave a smaller range.

The results were accurate, valid, and fairly reliable. The experiment answered the hypothesis and the aim in comparing the power of all models with controlled variables. This delivered authentic and correct results, determining the validity. The surface area was as consistent as possible throughout all the models, and the models covered a large variety of possible fan designs, but a model with 6 blades (anything more than 6 is very uncommon) and more angles could have been used nevertheless, lessening the validity.

The use of suitable equipment- a motor and a well scaled model to imitate a standing fan and appropriate measuring procedures to calculate wind speed and direction also gave the experiment a high accuracy, although the centre of the axel should have been smaller so blu tack didn't have to be used to stabilise it. The use of blu tack also meant that sometimes the model spun on an angle, rather than being perpendicular to the shaft of the motor. The use of a calibrated data logger and and anemometer probe gave precise results, furthering the accuracy.

However, the ranges of wind speeds were sometimes quite varied even though the average range or power appeared to have a definite trend. The results were then not very reproducible, which decreased the reliability. To further the experiment, the anemometer probe could also be placed at an angle diagonal to the axel to further the investigation, as the wind was not only directed to the front and side.

Overall, the number of blades and the curvature affected the range, the balance and the velocity to an extent. The main contributor to wind speed was the increase in angle, with 60 degrees giving the highest power. And so, model B2-60 produced the highest velocity wind, but the wind speed varied with a minor margin regarding the number of blades, being the most dependent on the angle of the blade.

Conclusion

A fan with 2 blades, a curved blade shape and a high angle to the axel is the most powerful (B2-60).

Bibliography

Websites

Breezair.com, (2015). *How Evaporative Cooling Works Evaporative air conditioning uses only water and moving air to cool using the principles of evaporation*. [online] Available at: http://www.breezair.com/me/why-evaporative/how-evaporative-works [Accessed 9 Feb. 2015].

Clayton, V. (2015). *How Do Electric Fans Work?* | eHow. [online] eHow. Available at: http://www.ehow.com/how-does_4564463_electric-fans-work.html [Accessed 9 Feb. 2015].

Orientalmotor.com, (2015). *MOTION CONTROL 101 ~ Cooling Fans Overview*. [online] Available at: http://www.orientalmotor.com/technology/articles/cooling-fans-overview.html [Accessed 11 Feb. 2015].

Wikipedia, (2015). *Mechanical fan*. [online] Available at: http://en.wikipedia.org/wiki/Mechanical_fan [Accessed 11 Feb. 2015].

Sawyers, H. (2011). *What's Inside Your Ceiling Fan?*. [online] Available at: http://www.popularmechanics.com/home/how-to/a6735/whats-inside-your-ceiling-fan/ [Accessed 11 Feb. 2015].

Fanmakers.com, (2015). » *A short history of mechanical fans*. [online] Available at: http://www.fanmakers.com/history/a-short-history-of-mechanical-fans/ [Accessed 29 Mar. 2015].

Encyclopedia Britannica, (2015). fan | ventilating device. [online] Available at: http://www.britannica.com/technology/fan-ventilating-device [Accessed 4 Jul. 2015]

Bruegmann, R. (2015). Central Heating and Forced Ventilation: Origin and Effects on Architectural Design. 1st ed. [ebook] Chicago: Harvard. Available at: http://isites.harvard.edu/fs/docs/icb.topic753413.files/8_Engineers%20Contractors%20and%20Industrial%20Construction/Bruegmann_Central.pdf [Accessed 4 Mar. 2015].

Images

Oriental motor, (2015). *Axial Flow Fans*. [image] Available at: http://www.orientalmotor.com/products/ac-dc-cooling-fans/mdp-series-splash-dc-proof-axial-fans.html [Accessed 29 Mar. 2015].

Orientalmotor.com, (2015). *MOTION CONTROL 101 ~ Cooling Fans Overview*. *Axial. Centrifugal* [image] Available at: http://www.orientalmotor.com/technology /articles/cooling-fans-overview.html [Accessed 11 Feb. 2015].

Sparkmuseum, (2015). *Kent Electric Co. electric fan ca. 1898*. [image] Available at: http://www.sparkmuseum.com/MOTORS.HTM [Accessed 29 Mar. 2015].

Sawyers, H. (2011). *What's Inside Your Ceiling Fan?*. [image] Available at:

http://www.popularmechanics.com/home/how-to/a6735/whats-inside-your-ceiling-fan/
[Accessed 11 Feb. 2015].