Universidad de Valladolid

ESCUELA DE INGENIERÍAS INDUSTRIALES

UNIVERSIDAD DE VALLADOLID

ESCUELA DE INGENIERIAS INDUSTRIALES

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Design of a ventilation system for fan testing

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TÍTULO: Design of a ventilation system for fan testing

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1 Introduction and objectives.

The aim of this project is to design and build a low budget didactic stand for testing fans and ventilation systems.

It needs to be a compact and easy to transport, in the same way, it must be safe and firm because it is going to be used by students in the laboratory.

The project will be based on the study of the properties and applications of the fans, as well as general theoretical knowledges about fluid mechanics and fluid machinery.

2 Abstract.

Ventilation systems are present in many aspects of our lives, our own houses, hospitals, cars, factories, etc.

So it is important to know how they work, the machine needed to boost the fluid or the type of duct necessary for it.

Therefore, this document will discuss the types of fluid machines that exist, how we will know the energy we would need depending on our system and our fluid, and how we can measure certain important parameters.

In particular we will focus on fans, and we will try to design a didactic system that can be used to understand these concepts.

At the time of carrying out the project, we count with a limited budget, so it is tried to use recycled or low cost pieces.

To design the system we will use computer-aided design software such as CATIA V5 and Solidworks. There will also be some machinery available to use in the university: 3d printer and laser cutter. For these operations we will also use the software: Repetier Host V 1.6.2.

3 Description of fluid machinery.

A fluid machine is a system exchanging mechanical energy with a fluid flowing through it. Fluid machines do a variety of jobs and are applied in hydro and thermal power stations, in aircraft as propulsive devices, in ships as propellers, in automobiles, and earth moving machinery. Fluid machines serve in enormous array of applications in our daily lives, and they play an important role in modern world.

4 Classification of fluid machines.

Before describing ventilation systems and fans, it is needed situate them in the general scheme of fluid machines.

Fluid machines can be classified depending on

-Direction of energy exchange between the machine and the fluid.

-The degree of compressibility of the fluid.

-Operating principle.

4.1 Direction of energy exchange.

According to this criteria, there can be found either power absorbing machines or power producing machines.

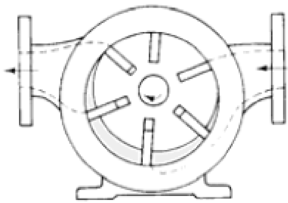
The power absorbing machines transmit energy to the fluid. Consequently, it increases his specific energy between inlet and outlet of the machine.

Examples of this kind of machines are pumps, compressors and fans. Pumps and compressors increase

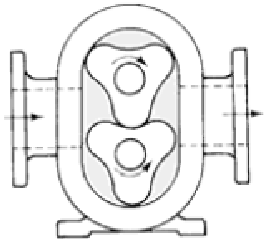
the energy of the fluid and may be positive displacement or rotodynamic.
A pump is a turbo machine wherein the fluid is liquid and power is given by an electric motor to raise pressure of the fluid.
A compressor transmits power to a gas to raise pressure but with small increase in velocity.
A fan imparts motion to gas with small change in pressure.
A fan blower increases the velocity of gas with small pressure. Fans are always rotodynamic.
In power absorbing machines the driver is usually an electric motor but it can be also an internal combustion engine or a gas turbine.

The power producing machines extract energy from the fluid. Some examples are steam, hydraulic (Pelton, Francis or Kaplan) and gas turbines.
In hydraulic turbines the working fluid is water or oil and it is incompressible. They can be classified in impulse and reaction turbines. Impulse turbines are driven by one or two high velocity jets. Each jet is accelerated in a nozzle external to the turbine wheel known as turbine rotor.

In steam turbines expansion of high pressure and temperature is expanded in fixed and moving blades of a turbine. Steam is produced in high pressure boiler and after expansion steam condensed in condenser.
The gas turbine is similar to a steam turbine except that air is used instead of water as working fluid. The exhaust gases after expansion go into the atmosphere.



Pallet machine of positive displacement



Machine of positive displacement of three lobes.

4.2 The degree of compressibility of the fluid.

Depending on the compressibility of the fluid that is going through the machine, they can be classified in hydraulic machines or heat engines (compressible flow machines).

In hydraulic machines specific volume variations experienced by the They fluid through the machine are negligible. This occurs when the fluid is a liquid, or when a gas undergoes minor variations in pressure, as in the case of the fans.

In compressible flow machines, variations of density experimented by the fluid are not insignificant. The mechanical and thermal decoupling of the equations is not possible and it is necessary to establish a balance of total energy.

4.3 Operating principle.

Fluid machines can be also classified as:

- Positive displacement machines
- Rotodynamic machines.

In positive displacement machines fluid is drawn into a finite space bounded by mechanical parts, then sealed in it, and then forced out from space and the cycle is repeated. The flow is intermittent and depends on the dimensions of the space (chamber). Gear pumps, vane pumps are all positive displacement pumps.

In rotodynamic machines there is free passage between inlet and outlet of the machine without intermittent sealing taking place. In these machines there is a rotor which is able to rotate continuously and freely in the fluid. The transfer of energy is continuous resulting the change of pressure or momentum of the fluid. Centrifugal blower, centrifugal pumps and hydraulic turbines are some examples of rotodynamic machines.

5 Balance of mechanical energy in a hydraulic machine.

In order to establish the integral balance of mechanical energy in a hydraulic machine, we will consider this as a black box with just one input and output. From each way we will only know the energy that it is exchanged with the environment.

Hydraulic machines are incompressible flow machines so there is a decoupling between the mechanical and thermal equations in the general equations of fluid mechanics.

$$\left(\frac{p}{\rho}+\frac{v^2}{2}+U\right)_o-\left(\frac{p}{\rho}+\frac{v^2}{2}+U\right)_i=\frac{W}{G}-\frac{\emptyset}{G}$$

Where:

$\left(\frac{p}{\rho}+\frac{v^2}{2}+U\right)_{output/input}$ → Specific mechanical energy between the output and the inlet of the machine.

$\frac{W}{G}$ →Specific mechanical energy that is provided or extracted in the machine shaft.

$\frac{\emptyset}{G}$ → Specific energy degraded due to viscous dissipation.

If we apply this equation to a fan, we can obtain the increase of energy between the inlet and outlet as follow:

$$\Delta P=\left(P+\frac{v^2}{2}\rho+\rho gz\right)_o-\left(P+\frac{v^2}{2}\rho+\rho gz\right)_i$$

Unless there is a significant difference of level between the input and the output of the fan we can suppose that (z_o-z_i) ≈ 0. Moreover, the air velocity upstream of the aspiration, where the atmospheric pressure is present, is zero, so:

$$\Delta P = P_o - P_{atm} + \frac{1}{2}\rho_o v_o^2 = \Delta P_s + \Delta P_d$$

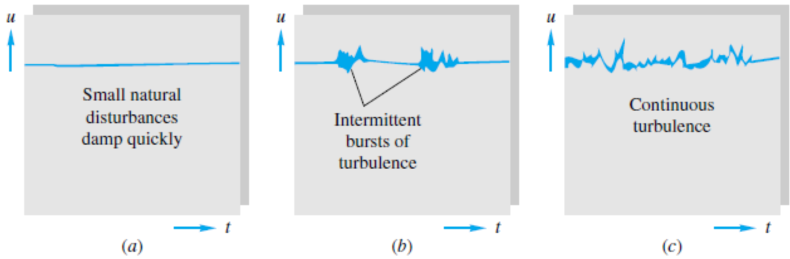
$$Static\ pressure\ jump: \Delta P_s = P_{output} - P_{atm}$$

$$Dynamic\ pressure\ jump: \Delta P_d = \frac{1}{2}\rho_o v_o^2$$

6 Turbulence or laminar (viscous flow in tubes).

An important problem when we are designing piping systems is what type of flow we desire to have inside the ducts. However, there are no general analysis of fluid motion yet. We can only find some particular solutions, some rather specific digital computer solutions, and there are a great many experimental data.

Turbulent or laminar flow is due to a profound change in fluid behavior occurs at moderate Reynolds numbers. We can talk about laminar flow when it is smooth and steady, but might become agitated and fluctuating and we will call it turbulent flow. The changeover is called transition to turbulence.



Three regimes of viscous flow

Transition depends upon many effects like wall roughness or fluctuations in the inlet stream, but the primary parameter is the Reynolds number.

Reynolds number is defined as:

$$Re = \frac{U\rho L}{\mu} = \frac{UL}{\vartheta}$$

Where *U* is the average stream velocity and *L* is the width, or transverse thickness, of the shear layer.

If the flow is laminar, there may be occasional natural disturbances which damp out quickly .If transition is occurring, there will be sharp bursts of turbulent fluctuation. At sufficiently large Reynolds, the flow will fluctuate continually and is called fully turbulent.

When talking about piping systems the laminar parabolic flow profile becomes unstable at approximately Re = 2300 and begins to form slugs or puffs of intense turbulence.

These are representative ranges which vary somewhat with flow geometry, surface roughness, and the level of fluctuations in the inlet stream

·$0 < Re < 1$: highly viscous laminar “creeping” motion.

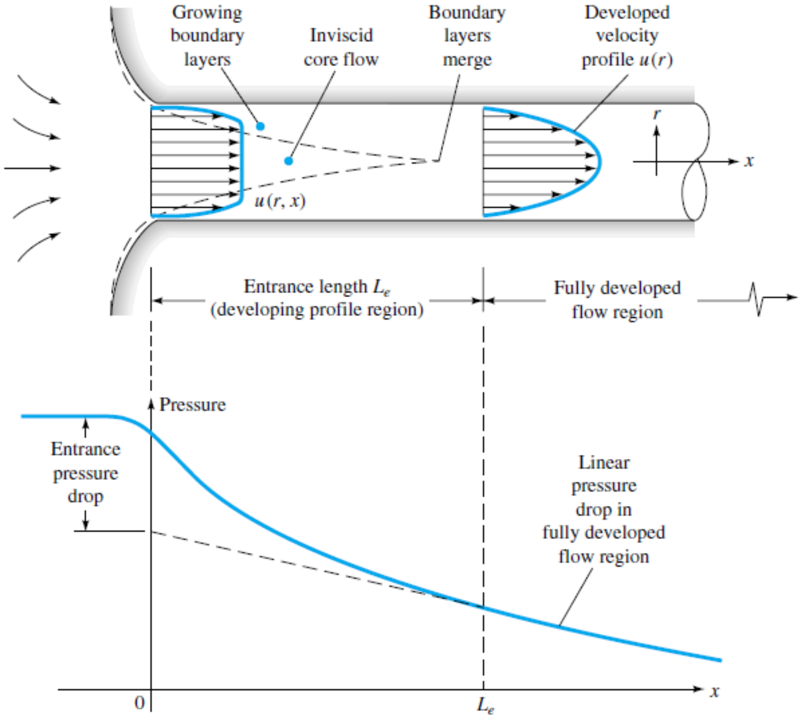
·$1 < Re < 100$: laminar, strong Reynolds-number dependence.

·$10 < Re < 10^3$: laminar, boundary-layer theory useful.

·$10^3 < Re < 10^4$: transition to turbulence.

·$10^4 < Re < 10^6$: turbulent, moderate Reynolds-number dependence.

·$10^6 < Re < \infty$: turbulent, slight Reynolds-number dependence.



Developing velocity profiles and pressure drop in a duct.

7 Devices to measure pressure and flow.

7.1 Pitot.

A pitot tube is used in wind tunnel experiments and on airplanes to measure flow speed. It's a slender tube that has two holes on it. The front hole is placed in the airstream to measure what is called the stagnation pressure. The side hole measures the static pressure. By measuring the difference between these pressures, you get the dynamic pressure, which can be used to calculate airspeed.

A flow can be considered incompressible if its velocity is less than 30% of its sonic velocity. For such a fluid, it is possible to apply the Bernoulli equation along a streamline and describe the relationship between pressure and velocity. So in the case of the Pitot tube, we consider:

$$\frac{v_1^2}{2g} + z_1 + \frac{P_1}{\rho g} = \frac{v_2^2}{2g} + z_2 + \frac{P_2}{\rho g}$$

All terms on the left side represent the stagnation point (entrance of the pitot tube) where P1 is the stagnation pressure and V1=0 is the velocity of fluid in the pipe at point 1. All terms on the right side refer to point 2, a point upstream from the pitot tube. The two points that are being evaluated are at the same height, so z1 and z2 drop out

$$P_1 - P_2 = \frac{1}{2}\rho v_2^2$$

The equation for the difference in pressure in a manometer is substituted into the simplified Bernoulli equation:

$$\Delta P = g \cdot \Delta h \cdot (\rho_m - \rho)$$

$$\frac{1}{2}\rho v_2^2 = g \cdot \Delta h \cdot (\rho_m - \rho)$$

This equation can be rearranged and used to solve for fluid velocity or difference in height of the fluids in the manometer:

$$\Delta h = \frac{\rho \cdot v_2^2}{2 \cdot g \cdot (\rho_m - \rho)}$$

$$v_2 = \sqrt{\frac{2 \cdot g \cdot (\rho_m - \rho)}{\rho}}$$

Here P_2 is the static pressure of fluid in the pipe, ρ and ρ_m are the densities of the fluid in the pipe and manometer fluid, g is the gravitational constant and Δh is the difference in height of the manometer fluid.

Pitot tube sensors, flow nozzle or Venturi tubes are classified as flow measuring devices which utilize differential pressure to measure volumetric flow, but to use this devices some conditions need to be achieved.

The fluid has to completely fill the pipe so that the measured differential pressure is representative of the volumetric flow. Fluids in partially filled pipes can only be measured if a full pipe can be arranged (e.g. by means of a siphon)

The fluid must be single-phase. Two-phase fluids (e.g. water-air mixtures) cannot be measured.

8 Mechanical fan

A fan is a machine used to create flow within a fluid, typically a gas such as air. The fan consists of a rotating arrangement of vanes or blades which act on the fluid. The rotating assembly of blades and hub is known as an impeller, a rotor, or a runner. Usually, it is contained within some form of housing or case. This may direct the airflow or increase safety by preventing objects from contacting the fan blades. Most fans are powered by electric motors, but other sources of power may be used, including hydraulic motors and internal combustion engines.

Fans produce flows with high volume and low pressure (although higher than ambient pressure), as opposed to compressors which produce high pressures at a comparatively low volume. A fan blade will often rotate when exposed to a fluid stream, and devices that take advantage of this, such as anemometers and wind turbines, often have designs similar to a fan.

Typical applications include climate control and personal thermal comfort (e.g. an electric table or floor fan), vehicle and machinery cooling systems, ventilation, fume extraction, winnowing (e.g. separating chaff of cereal grains), removing dust (e.g. in a vacuum cleaner), drying (usually in combination with heat) and to provide draft for a fire. While fans are often used to cool people, they do not actually cool air (if anything, electric fans warm it slightly due to the warming of their motors), but work by evaporative cooling of sweat and increased heat convection into the surrounding air due to the airflow from the fans. Thus, fans may become ineffective at cooling the body if the surrounding air is near body temperature and contains high humidity.

9 Types of fans

Revolving blade fans are made in a wide range of designs. They are used on the floor, table, desk, or hung from the ceiling. They can also be built into a window, wall, roof, chimney, etc. Most electronic systems such as computers include fans to cool circuits inside, and in appliances such as hair dryers and portable space heaters and mounted/installed wall heaters. They are also used for moving air in air-conditioning systems, and in automotive engines, where they are driven by belts or by direct motor. Fans used for comfort create a wind chill by increasing the heat transfer coefficient, but do not lower temperatures directly. Fans used to cool electrical equipment or in engines or other machines do cool the equipment directly by forcing hot air into the cooler environment outside the machine. There are three main types of fans used for moving air, axial, centrifugal (also called radial) and cross flow (also called tangential). The American Society of Mechanical Engineers Performance Testing Code 11 (PTC) provides standard procedures for conducting and reporting tests on fans, including those of the centrifugal, axial, and mixed flows.

9.1 Axial-flow fans

Axial-flow fans have blades that force air to move parallel to the shaft about which the blades rotate. This type of fan is used in a wide variety of applications, ranging from small cooling fans for electronics to the giant fans used in wind tunnels. Axial flow fans are applied in air conditioning and industrial process applications. Standard axial flow fans have diameters from 300–400 mm or 1800 to 2000 mm and work under pressures up to 800 Pascal. Special types of fans are used as low pressure compressor stages in aircraft engines. Examples of axial fans are:

- Table fan: Basic elements of a typical table fan include the fan blade, base, armature and lead wires, motor, blade guard, motor housing, oscillator gearbox, and oscillator shaft. The oscillator is a mechanism that moves the fan from side to side. The armature shaft comes out on both ends of the motor, one end of the shaft is attached to the blade and the other is attached to the oscillator gearbox. The motor case joins to the gearbox to contain the rotor and stator. The oscillator shaft combines to the weighted base and the gearbox. A motor housing covers the oscillator mechanism. The blade guard joins to the motor case for safety.

- Ceiling fan: A fan suspended from the ceiling of a room is a ceiling fan. Most ceiling fans rotate at relatively low speeds and do not have blade guards. Ceiling fans can be found in both residential and industrial/commercial settings.
- In automobiles, a mechanical fan provides engine cooling and prevents the engine from overheating by blowing or drawing air through a coolant-filled radiator. The fan may be driven with a belt and pulley off the engine's crankshaft or an electric motor switched on or off by a thermostatic switch.
- Computer cooling fan for cooling electrical components: Variable-pitch fan: A variable-pitch fan is used where precise control of static pressure within supply ducts is required. The blades are arranged to rotate upon a control-pitch hub. The fan wheel will spin at a constant speed. As the hub moves toward the rotor, the blades increase their angle of attack and an increase in flow results.

9.2 Centrifugal fan

Often called a "squirrel cage" (because of its similarity in appearance to exercise wheels for pet rodents) or "scroll fan", the centrifugal fan has a moving component (called an impeller) that consists of a central shaft about which a set of blades, or ribs, are positioned. Centrifugal fans blow air at right angles to the intake of the fan, and spin the air outwards to the outlet (by deflection and centrifugal force). The impeller rotates, causing air to enter the fan near the shaft and move perpendicularly from the shaft to the opening in the scroll-shaped fan casing. A centrifugal fan produces more pressure for a given air volume, and is used where this is desirable such as in leaf blowers, blow dryers, air mattress inflators, inflatable structures, climate control, and various industrial purposes. They are typically quieter than comparable axial fans.

9.3 Cross-flow fan

The cross-flow or tangential fan, sometimes known as a tubular fan, was patented in 1893 by Paul Mortier, and is used extensively in the HVAC industry (heating, ventilating, and air conditioning industry)

The fan is usually long in relation to the diameter, so the flow approximately remains two-dimensional away from the ends. The CFF uses an impeller with forward curved blades, placed in a housing consisting of a rear wall and vortex wall. Unlike radial machines, the main flow moves transversely across the impeller, passing the blading twice. The flow within a cross-flow fan may be broken up into three distinct regions: a vortex region near the fan discharge, called an eccentric vortex, the through-flow region, and a paddling region directly opposite. Both the vortex and paddling regions are dissipative, and as a result, only a portion of the impeller imparts usable work on the flow. The cross-flow fan, or transverse fan, is thus a two-stage partial admission machine. The popularity of the crossflow fan in the HVAC industry comes from its compactness, shape, quiet operation, and ability to provide high pressure coefficient. Effectively a rectangular fan in terms of inlet and outlet geometry, the diameter readily scales to fit the available space, and the length is adjustable to meet flow rate requirements for the particular application. Common household tower fans are also cross-flow fans.

One phenomenon particular to the cross-flow fan is that, as the blades rotate, the local air incidence angle changes. The result is that in certain positions the blades act as compressors (pressure increase), while at other azimuthal locations the blades act as turbines (pressure decrease).

10 Uncommon types of fan.

There are some other kind of fans that are not widely used but still exist and we have to mention for thoroughness reasons. These are the following:

- Bellows
- Convective
- Electrostatic

11 Noise

One aspect that few people consider when choosing a fan is the noise produced by the fans operation. Fans generate noise from the rapid flow of air around blades and obstacles, and sometimes from the motor. Fan noise has been found to be roughly proportional to the fifth power of fan speed; halving speed reduces noise by about 15 dB.

Once our project ventilation system is mainly consists of axial flow fans; further analysis on the design of those fans should be done.

12 Axial fan design.

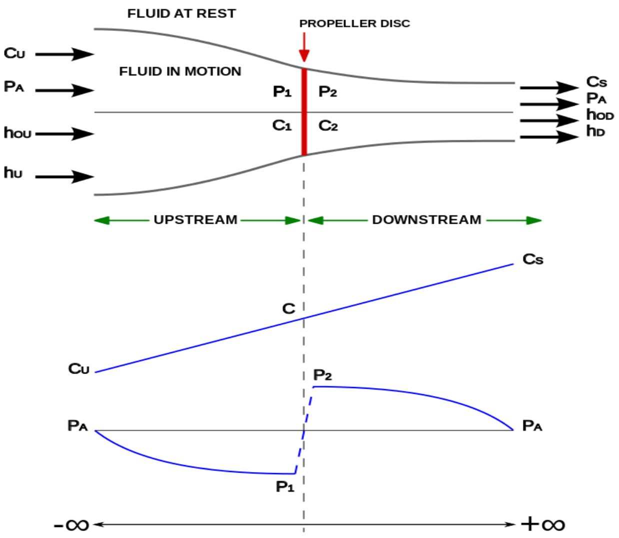
An axial fan is a type of a compressor that increases the pressure of the air flowing through it. The blades of the axial flow fans force air to move parallel to the shaft about which the blades rotate. In other words, the flow is axially in and axially out, linearly, hence their name. The design priorities in an axial fan revolve around the design of the propeller that creates the pressure difference and hence the suction force that retains the flow across the fan. The main components that need to be studied in the designing of the propeller include the number of blades and the design of each blade. Their applications include propellers in aircraft, helicopters, hovercraft, ships and hydrofoils. They are also used in wind tunnels and cooling towers. If the propeller is exercising propulsion, then efficiency is the only parameter of interest and other parameters like power required and flow rate are considered of no interest. In case the propeller is used as a fan, the parameters of interest include power, flow rate, pressure rise and efficiency.

An axial fan consists of much fewer blades i.e., two to six, as compared to ducted fans. Axial fans operate at high specific speed i.e., high flow rate and low head and hence adding more blades will restrict the high flow rate required for its operation. Due to fewer blades, they are unable to impose their geometry on the flow, making the rotor geometry and the inlet and outlet velocity triangles meaningless. Also the blades are made very long with varying blade sections along the radius.

12.1 Calculation of parameters

Since the calculation cannot be done using the inlet and outlet velocity triangles, which is not the case in other turbomachines, calculation is done by considering a mean velocity triangle for flow only through an infinitesimal blade element. The blade is divided into many small elements and various parameters are determined separately for each element. There are two theories that solve the parameters for axial fans:

- Slipstream Theory
- Blade Element Theory



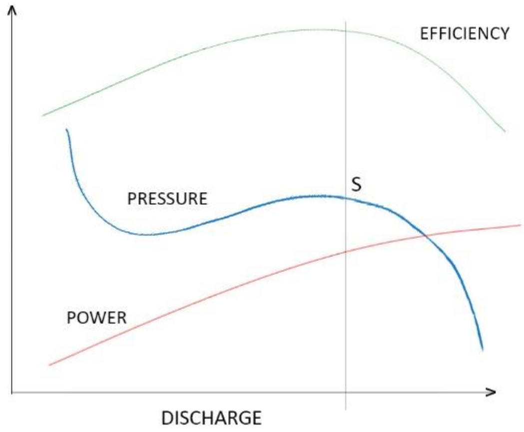
Variation of pressure and velocity of flow.

12.2 Performance characteristics

The relationship between the pressure variation and the volume flow rate are important characteristics of fans. The typical characteristics of axial fans can be studied from the performance curves. The performance curve for the axial fan is shown in the following figure. (The vertical line joining the maximum efficiency point is drawn which meets the

Pressure curve at point "S"). The following can be inferred from the curve:

- As the flow rate increases from zero the efficiency increases to a particular point reaches maximum value and then decreases.
- The power output of the fans increases with almost constant positive slope.
- The pressure fluctuations are observed at low discharges and at flow rates (as indicated by the point "S") the pressure deceases.
- The pressure variations to the left of the point "S" causes for unsteady flow which are due to the two effects of Stalling and surging.



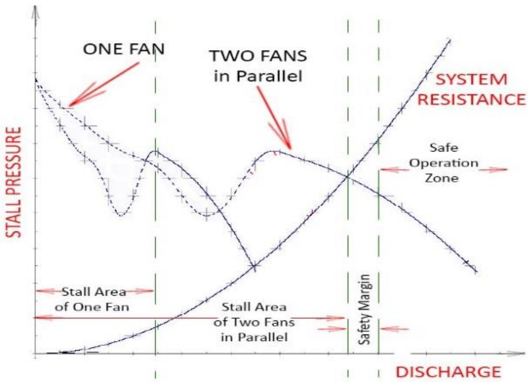
Performance curve for Axial Flow Fan. 1

12.3 Causes of unstable flow.

Stalling and surging affects the fan performance, blades, as well as output and are thus undesirable. They occur because of the improper design, fan physical properties and are generally accompanied by noise generation.

12.4 Stalling effect/Stall.

The cause for this is the separation of the flow from the blade surfaces. This effect can be explained by the flow over an air foil. When the angle of incidence increases (during the low velocity flow) at the entrance of the air foil, flow pattern changes and separation occurs. This is the first stage of stalling and through this separation point the flow separates leading to the formation of vortices, back flow in the separated region. For further the explanation of stall, rotating stall refer to compressor surge. The stall zone for the single axial fan and axial fans operated in parallel are shown in the figure.



Stall zone 1

This figure shows the Stall Prone Areas differently for one fan and two fans in parallel.

The following can be inferred from the graph:

- For the fans operated in parallel, the performance is less when compared to the individual fans.
- The fans should be operated in safe operation zone to avoid the stalling effects.

Many Axial fan failures have happened after controlled blade axial fans were locked in a fixed position and Variable Frequency Drives (VFDs) were installed. The VFDs are not practical for some Axial fans. Axial fans with severe instability regions should not be operated at blades' angles, rotational speeds, mass flow rates, and pressures that expose the fan to stall conditions.

Surging effect/Surge

Surging should not be confused with stalling. Stalling occurs only if there is insufficient air entering into the fan blades causing separation of flow on the blade surface. Surging or the unstable flow causing complete breakdown in fans is mainly contributed by the three factors:System surge,fan surge and paralleling.

System surge

This situation occurs when the system resistance curve and static pressure curve of the fan intersect have similar slope or parallel to each other. Rather than intersecting at a definite point the curves intersect over certain region reporting system surge. These characteristics are not observed in axial fans.

Fan surge.

This unstable operation results from the development of pressure gradients in the opposite direction of the flow. Maximum pressure is observed at the discharge of the impeller blade and minimum pressure on the side opposite to the discharge side. When the impeller blades are not rotating these adverse pressure gradients pump the flow in the direction opposite to the direction of the fan. The result is the oscillation of the fan blades creating vibrations and hence noise.

Paralleling.

This effect is seen only in case of multiple fans. The air flow capacities of the fans are compared and connected in same outlet or same inlet conditions. This causes noise, specifically referred to as Beating in case of fans in parallel. To avoid beating use is made of differing inlet conditions, differences in rotational speeds of the fans, etc.

Methods to avoid unsteady flow.

By designing the fan blades with proper hub-to-tip ratio and analyzing performance on the number of blades so that the flow doesn't separate on the blade surface these effects can be reduced. Some of the methods to overcome these effects are re-circulation of excess air through the fan, axial fans are high specific speed devices operating them at high efficiency and to minimize the effects they have to be operated at low speeds. For controlling and directing the flow use of guide vanes is suggested. Turbulent flows at the inlet and outlet of the fans cause stalling so the flow should be made laminar to prevent the effect.

13 Project development.

In this section we will discuss about all the ideas we had during the development of this project, with the final aim to select the better one and put it into practice.

First designs.

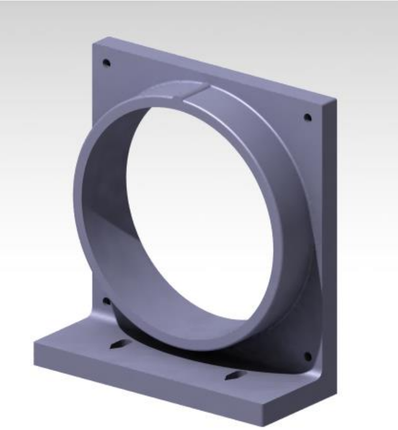
As it is said in the introduction of this document, the aim of this project is to make an easy and didactic stand to test fans. The idea is to create ducts through which the air will be driven by the fans. It is intended to develop a system in which fans can be tested in series and in parallel.

The machines we are supposed to use are two 3D printers and a laser cutter, besides basic tools as screwdrivers, bolts etc.

Several alternative designs are presented and evaluated according to the given criteria, and then the better design selected.

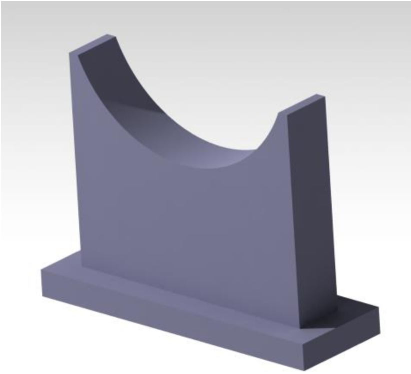
Thus, the first idea was to create a piping system with PVC tubes. However, this design was turned down because it is not easy and quick to assemble and dissemble if you want to change the layout. Furthermore it would be necessary to construct a support structure to fix the pipes. This layout is called as 'Piping design' when comparing.

A simple piece was designed to fix the fan between the pipes:



It contains four holes in the front side to fix the fan and two more in the bottom to be attached on the bench.

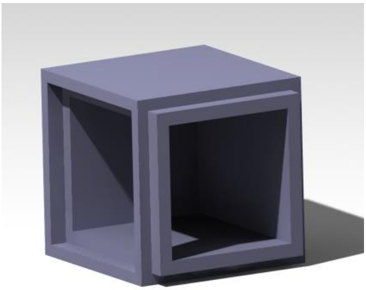
We would also need several pieces to support all the pipes. As shown in the next picture, it is a simple base that properly distributed would hold up all the system.



Support

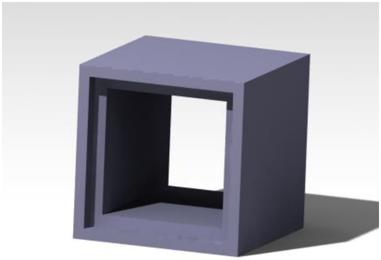
Modular design.

After this first design, a modular layout was thought. It consists of cubes of 110 mm side with male and female connections. This will be called ‘Modular design A’ in order to compare with the other ideas.



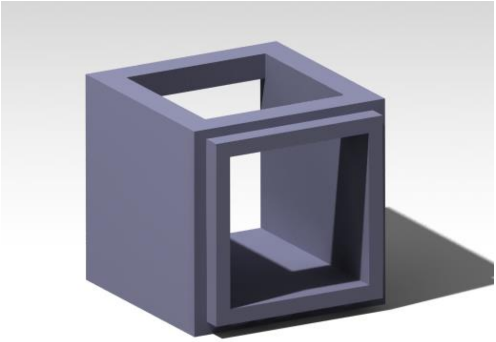
90 degrees module

This design contains straight, corner (90 degrees), 'T' connections and another box more with a cover to insert the fans.

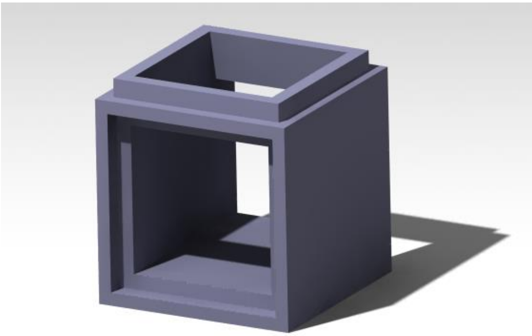


Straight module

The problem in this case was that it was difficult to print because the 3D printer would have needed a lot of support material to build the layers. It also would have increased the printing time and the cost of the system due to the big amount of material needed.



Fan module.



`T` module

To avoid the excessive use of the 3D printer, with the increase of the cost that entails, an idea mixing the laser cutter and the printer was thought. We will call this idea 'Modular design B'.

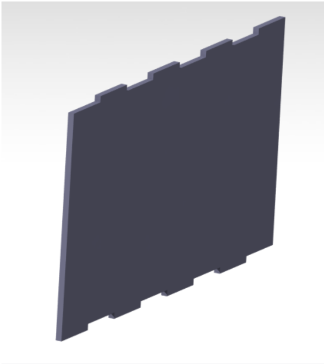
It consists in creating the less pieces possible to build the system just combining them.

The main piece is the interface showed in the following picture:

Interface

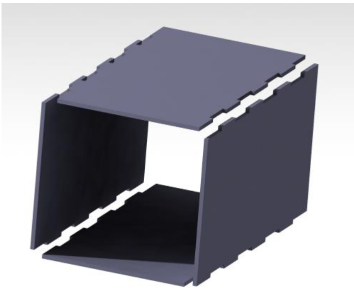
It is designed to connect the tubes regardless of whether it is straight, elbow or ‘T’. With two of these interfaces you can make a straight tube or a ‘T’ leaving one side open; with two interfaces and a cover you can make a corner.

To make the connectors between the interfaces, we are going to create a square pipe with four PVC sheets that will join together.



Sheet to build the square pipe.

Four sheets will be put together by using the tabs they have, forming a tube of square section.

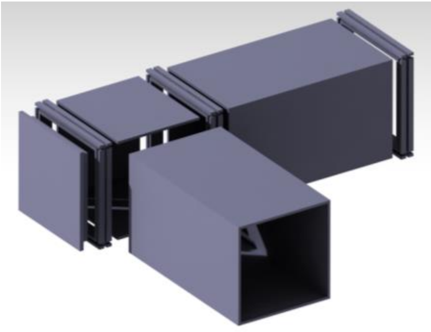


Tube assembly

The parts will be secured by the interfaces on both sides.

To make the corner, two interfaces are used, joined by three PVC sheets that will leave one side free. The other part of the interface will be closed with a cover as shown in the following image.

The functioning of the system can be better understood when looking at the exploded drawing.



Realization of a corner.

Measurements and proportions can be checked in the section of plans.

14 Calculations.

In this section it is going to be calculated an estimated cost of printing one piece of each idea, to see which one would be the most suitable to make the project the cheapest way, not only in money but also in time.

The material used by the 3D printer is a plastic usually called PLA (polylactic acid). An approximately density for this material is 1,25 g/cm^3 . So the method to calculate the cost of printing is based on calculate the mass of material needed for each piece. Knowing the volume (it can be obtained from the CAD software used to make the 3D models) and the density of the material the mass is easy to calculate.

However, we have to make some approximations concerning this method, because the pieces we print are no totally full of material. This is due to the 3D printer, which puts layers forming 90 degrees, so it leaves some holes between the lines. But, as all the pieces are made with same printer, all the pieces will have the same spaces. Having this note in mind, the real density of the pieces would be lower than the one we will calculate with the theoretical density of the plastic. In our case, we are just going to compare them, so it will not suppose a mistake, although we have to keep in mind that the numbers we will obtain are not totally exact.

For the piping design, several supports would be necessary to fix the pipes on the ground. In this case the volume would be 0,000168 m^3.

In the second idea, that we have called ‘Modular design A’ the volume would be 0,000627 m^3.

And the design with the interface, called ‘Modular design B’ the volume would be 0,000052 m^3.

At this point a clarification should be done regarding the number of pieces of each type.

In the first (piping design) and the third (Mod. Design B) ideas the number of pieces are going to be similar because they will be the support parts of the system. However, in the modular design with only cubes (Mod. Design A) there would be many more pieces that need to be printed because in this layout the cubes themselves are the support of the system. So this design could be turned down without any calculations.

After these explanations, we can start with the calculations. The steps to follow are: having the volume and density it is easy to calculate the mass of each piece, and with the mass we can calculate how many meters of PLA would be necessary. After this we can estimate the cost.

$$\rho_{PLA} = 1{,}25\frac{g}{cm^3} = 1{,}25 \cdot 10^3 kg/m^3$$

Piping design.

$$V_1 = 0{,}000627\, m^3$$

$$m_1 = 1{,}25 \cdot 10^3 \cdot 6{,}27 \cdot 10^{-4} = 0{,}210\, kg$$

Modular design A

$$V_2 = 0{,}000168\, m^3$$

$$m_2 = 1{,}25 \cdot 10^3 \cdot 1{,}68 \cdot 10^{-4} = 0{,}784\, kg$$

Modular design B

$$V_3 = 0{,}000052\, m^3$$

$$m_3 = 1{,}25 \cdot 10^3 \cdot 5{,}2 \cdot 10^{-5} = 0{,}065\, kg$$

15 Conclusions.

After the for and against arguments said about the designs presented in the previous sections we can add some more assessments and obtain certain conclusions.

If we discuss about the ease of use and the system functionality the best option might be the PVC piping system because the connections between tubes are the stronger which means the losses are almost null. Nevertheless, buying each PVC pipe would increase the budget and the assembly and disassembly capacity in this case is low because to change the layout of the system you might use specific tools.

So, concerning the ease of assembly and disassembly the best options are the modular designs, in which you can change the system only using your hands.

In the section ‘calculations’ we have made an estimation about the mass needed to print a piece in the 3D printer. The cost of printing will be proportional to the mass, or in the same words, the meters of PLA filament.

Another point to keep in mind is the printing time for each piece. This time will be calculated by the software that generates the code for printing. The time of printing and the cost (in a qualitative way) are included in the following table:

	Printing time	*Cost of printing*
Piping design.	4h 25min	↑↑↑
Modular design A.	17h 33min	↑↑↑
Modular design B.	4h 28 min	↑

The Modular design A is turned down, not only for the reasons given before, but also because a printing time of approximately 17h is unfeasible. So, between the two options with a reasonable printing time, we will select the one with less cost.

With these assessments and calculations we can conclude that the most appropriate design that meets the objectives required is the Modular design B.

16 Extension and further study.

Further studies could be made in this project. Of course several factors should be taken into consideration.

First and foremost, the concept of this project was to construct it with a low budget, so the idea of using parts out of old computers was ingenious. The more difficult the modifications that could be made are, the higher the cost would be. One easy way to modify the system is by adding some filters, valves, heaters or coolers etc, and taking as much data as it is possible. In addition a smoke creator device can be placed in order to visualize the flow.

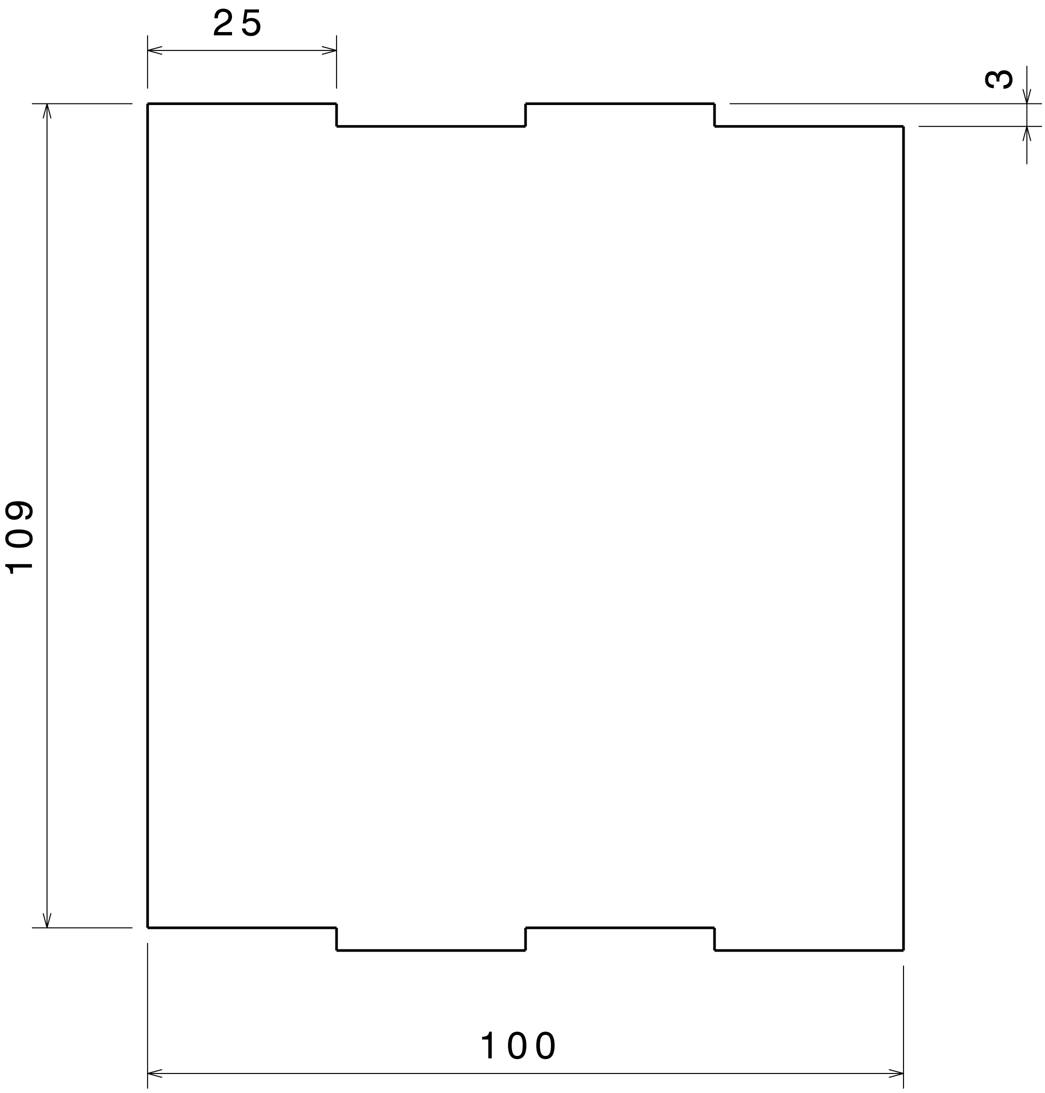
One of the first idea was to create a system in which you can test fans whether in series or in parallel. This design could be accomplished in an easy way with the right materials.

A step further, is to scale up the system and try to simulate a wind tunnel. The bigger the tunnel, the greater the results would be!

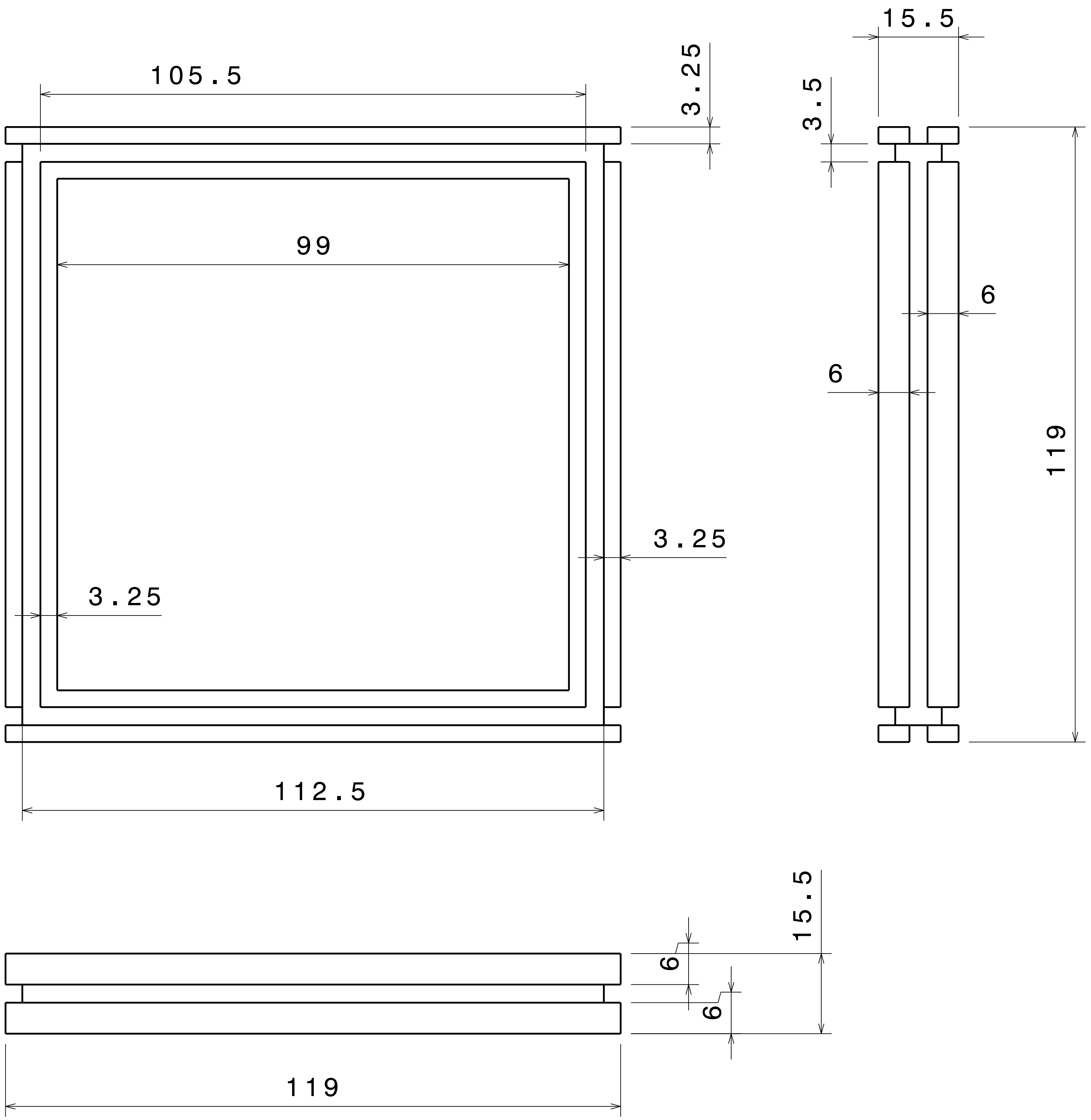
Furthermore, a real model such as a car or a wing could be placed, and it would be a good experience to study the flow around it. Put some smoke inside the wind tunnel to take clear point of you of the flow.

In conclusion, optimize the model's shape to achieve the best aerodynamic result possible. By changing the model you can make numerous tests so the possibilities of exploiting the system are endless.

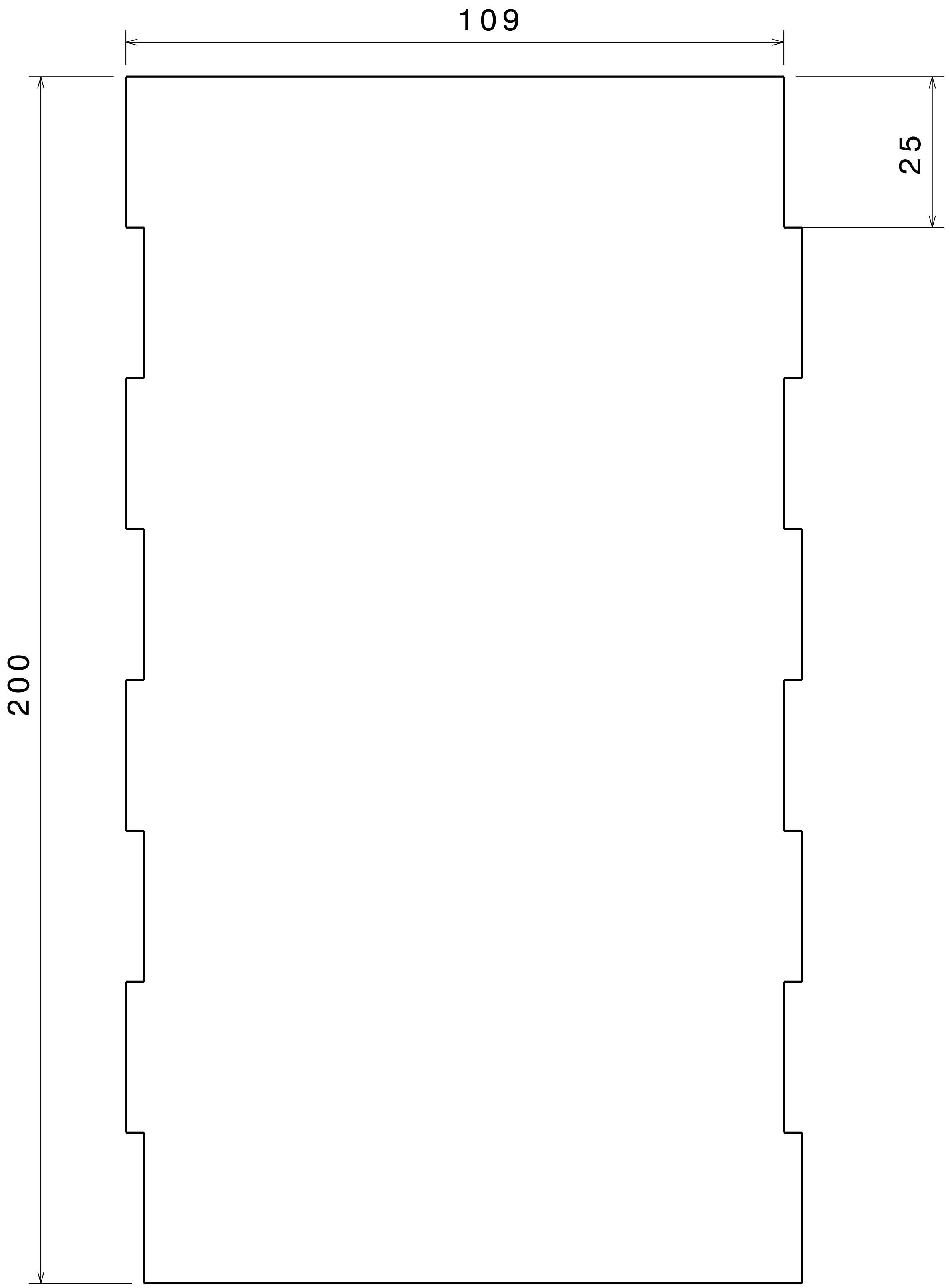
17 Drawings.



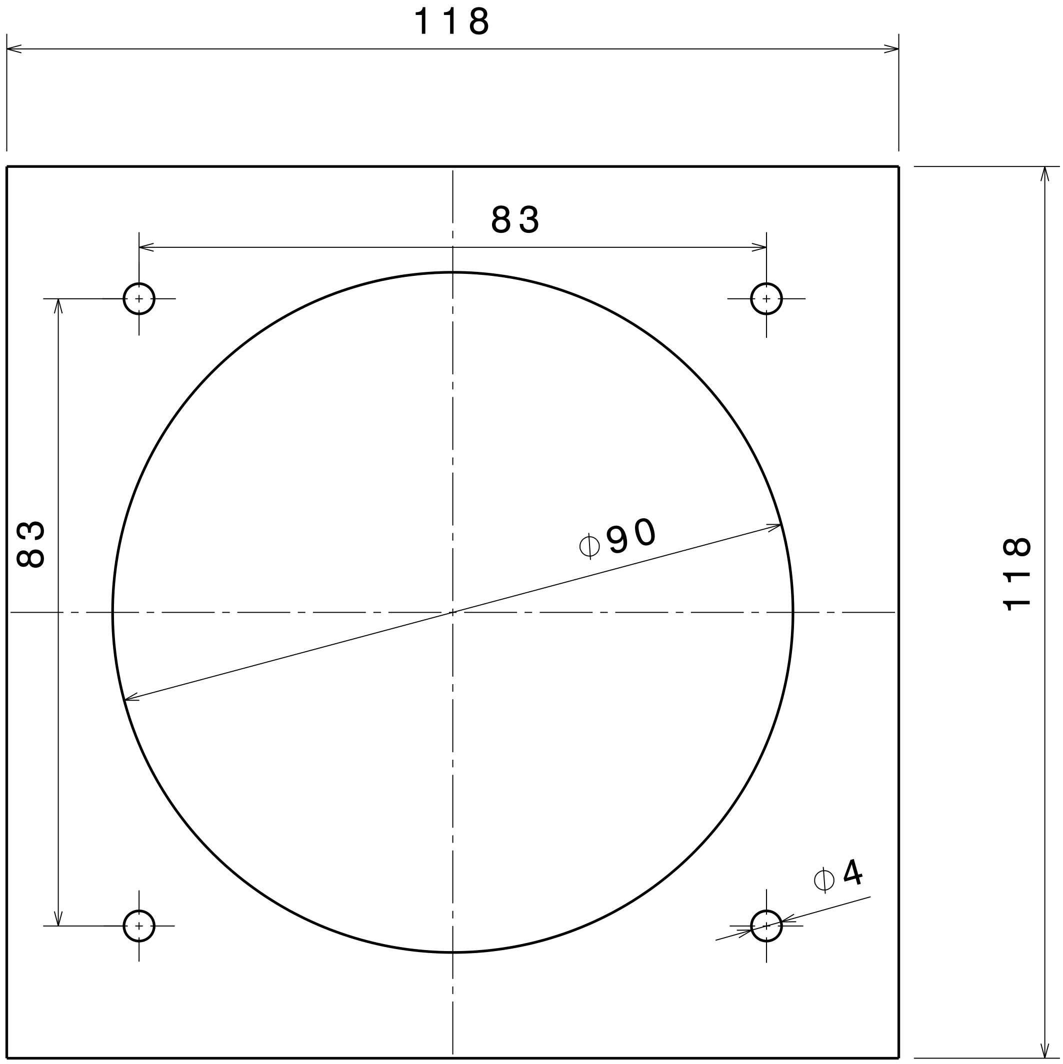
DESIGN OF A VENTILATION SYSTEM FOR FAN TESTING		
VIVES UNIVERSITY COLLEGE Industrial Sciences and Technology IWT		
Scale 1:1	SHEET TO ASSEMBLY (SMALL)	Plane No. 1
Lecturer	FURNIERE, GEERT	Date / Signature Dec 2016
Students	FADRIQUE RUANO. GONZALO KOKKINORIS,KONSTANTINOS	Date / Signature Dec 2016



DESIGN OF A VENTILATION SYSTEM FOR FAN TESTING		
VIVES UNIVERSITY COLLEGE Industrial Sciences and Technology IWT		
Scale 1:1	MODULAR INTERFACE	Plane No. 2
Lecturer	FURNIERE, GEERT	Date / Signature
Students	FADRIQUE RUANO. GONZALO KOKKINORIS,KONSTANTINOS	Date / Signature



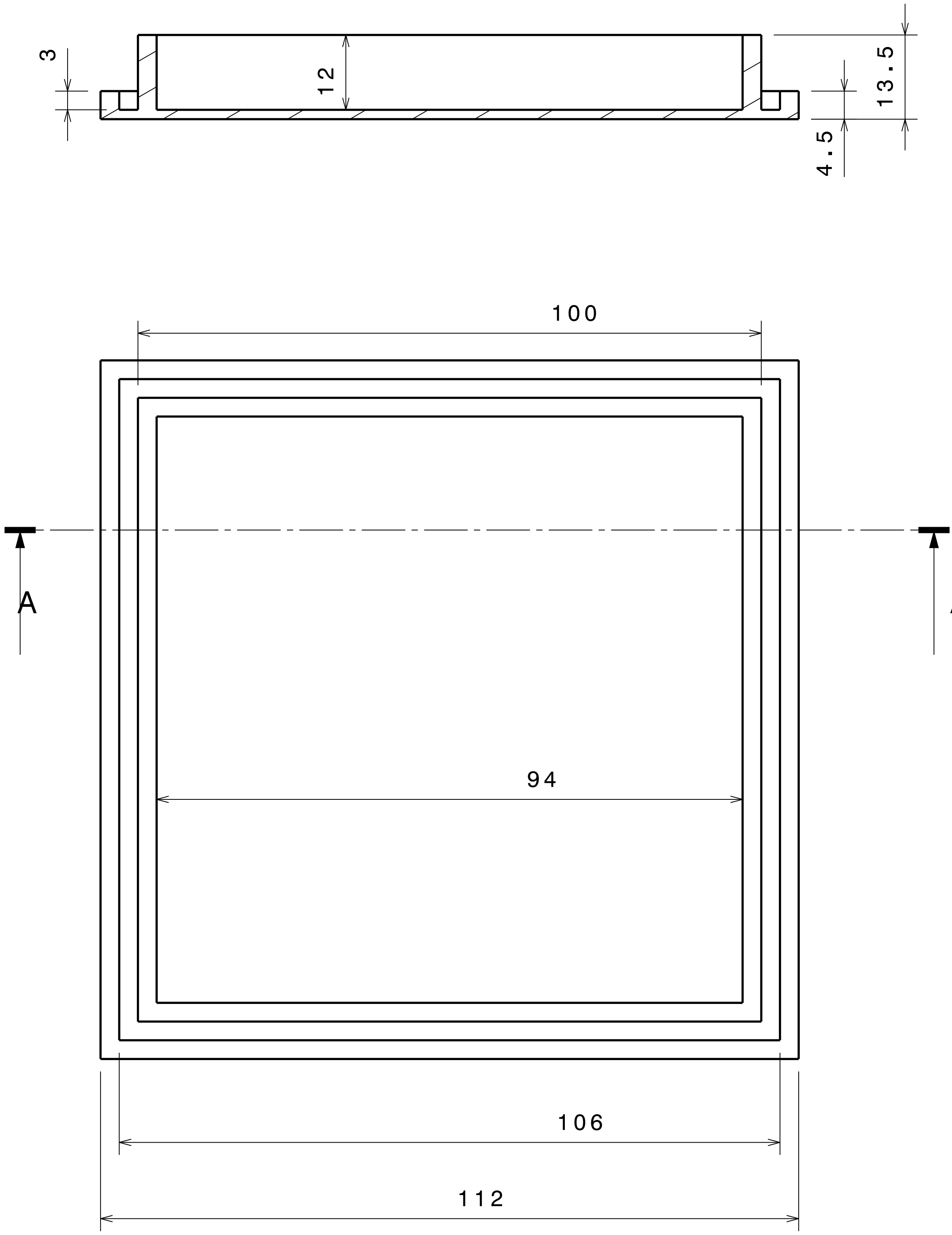
DESIGN OF A VENTILATION SYSTEM FOR FAN TESTING			
VIVES UNIVERSITY COLLEGE Industrial Sciences and Technology IWT			
Scale	1:1	SHEET TO ASSEMBLY	Plane No. 3
Lecturer	FURNIERE, GEERT		Date / Signature
Students	FADRIQUE RUANO. GONZALO KOKKINORIS,KONSTANTINOS		Date / Signature



DESIGN OF A VENTILATION SYSTEM FOR FAN TESTING

VIVES UNIVERSITY COLLEGE Industrial Sciences and Technology IWT

Scale 1:1	FAN SUPPORT		Plane No. 4
Lecturer	FURNIERE, GEERT		Date / Signature
Students	FADRIQUE RUANO. GONZALO KOKKINORIS,KONSTANTINOS		Date / Signature



DESIGN OF A VENTILATION SYSTEM FOR FAN TESTING

VIVES UNIVERSITY COLLEGE Industrial Sciences and Technology IWT

Scale	1:1	COVER	Plane No. 5
Lecturer	FURNIERE, GEERT		Date / Signature
Students	FADRIQUE RUANO. GONZALO KOKKINORIS,KONSTANTINOS		Date / Signature

18 Bibliography.

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· *Competition Car Aerodynamics*, Simon McBeath 2006 Haynes Publishing ISBN 978 1 84425 230 5

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·http://www.intel.com/content/www/us/en/support/boards-and-kits/desktop-boards/000005560.html

19 Annex.

19.1 Practical information about PC fans.

Once all our fans come from old PCs we have to mention some of their characteristics and how they improve the performance of any computer.

The vast majority of PCs has at least one of them. They carry the heavy load to keep the PC's temperature cool and functional, either by providing fresh air in the box, or by forcing the hot air to leave a hot surface by pushing cool air. It is more than obvious that a PC fan is not rotated from a simple DC motor. It has the permanent magnets fixed on the rotor, the stator carrying the coils, no brushes exist and it has a controller; it is of course a brushless motor. (More information about brushless motors are given later).

As long as the motor is concerned, all PC fans use brushless motors. There are several reasons that a brushless motor should be used, among them is the reliability, the power efficiency and the rpm feedback. So the motor type would not be the proper way to categorize PC fans. Instead, to make things easier to remember the categorization will be done with the most obvious characteristic: their connector.

There are actually three different types of PC fans:

- those with a 2-pin connector
- those with a 3-pin connector
- those with a 4-pin connector

19.1.1 Two-wire PC Fans

These are the oldest and most simple PC fans. Only two wires come out of the fan controller, the positive and the negative. Giving power to the fan, it will rotate at full speed. The internal diagram of a typical two-wire fan is the following:

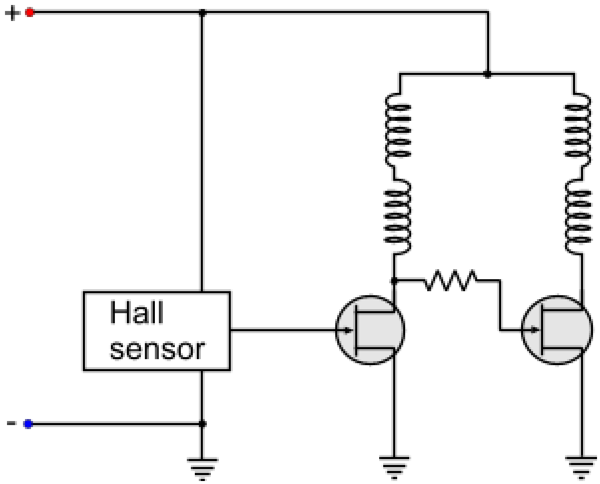


Diagram of a two wire fan

The connector of a 2-wire fan has usually a red and a black cable. The red cable goes to the positive of the power supply and the black to the negative. Usually, for more flexibility, they have a male-female 4-wire molex power connector. In one end of the connector the fan is connected in parallel with the 12V. Therefore, the fan is powered normally and the cable of the PSU can be used to power another device.

19.1.2 Three-wire PC Fans

A very common type of PC fan. These fans introduced the "tacho" for the first time. The first two wires are the power supply of the fan. The third wire, comes directly from the output of the Hall sensor. This output generates 2 pulses per one revolution of a fan. The fan is then connected to the motherboard. From the third wire, the motherboard can "read" the tacho of the fan and see if the fan is running and with how many RPMs! It is a great innovation! If the motherboard sees no pulses or very low rpm, then the characteristic buzzer sounds to inform the operator that something goes wrong. The internal diagram of a typical three-wire fan is as follows:

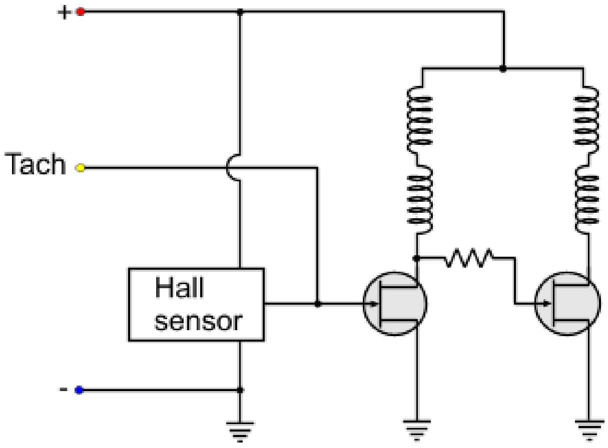
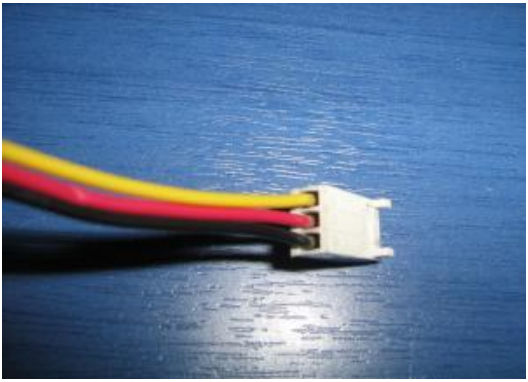
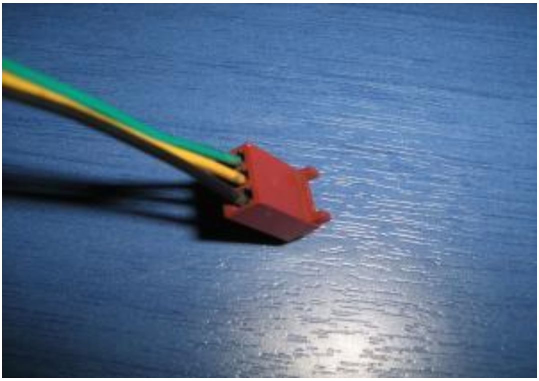


Diagram of a three wire fan

It is very common that, the manufacturers do not have the same wire provider, or their wire providers do not have the same colored-plastic provider... Two fans with 3-wire connectors may not have the same wire colors. Thus, instead of using the colors to distinguish the function, better go with the connector that is standard. No matter what color the cable is, it will be plugged in the same motherboard connector!



BLACK:Negative RED:Positive YELLOW:Tacho



BLACK:Negative YELLOW:Positive GREEN:Tacho

19.1.3 Four-wire PC Fan

This is the most modern type of PC fan. This fan is designed to be controlled with a PWM signal and increase or decrease its RPM. All fans actually can be controlled with

PWM, but this particular type can also provide tacho feedback simultaneously, something that the 3-wire fan cannot do -under normal circumstances. The 3-wire fan powers the Hall sensor and the controller from the same line that the coils are powered. Thus, if someone tries to send PWM pulses to the coils of a 3-wire fan, the same pulses will arrive at the controller. The controller will then malfunction, because it needs constant current to operate. As a result, the third wire will not provide correct readings.

Unlike the 3-wire fans, the 4-wire fans have a slight change that eliminates this problem. The controller and the Hall sensor are always powered with constant current. A transistor (fet) is placed before the coils. The base of the transistor is actually the fourth wire. So, the PWM pulses are driving the transistor. The coils receive these pulses through the transistor, but the controller along with the Hall sensor are not affected at all. This change can be seen in the internal diagram of a typical 4-wire fan:

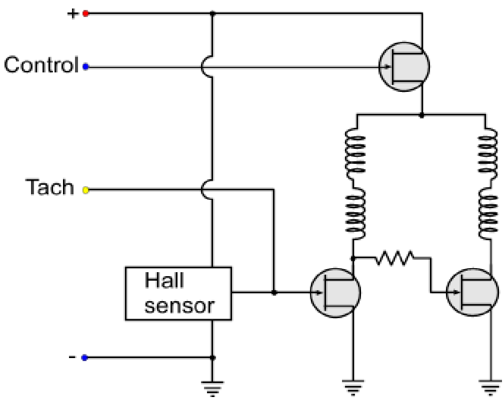
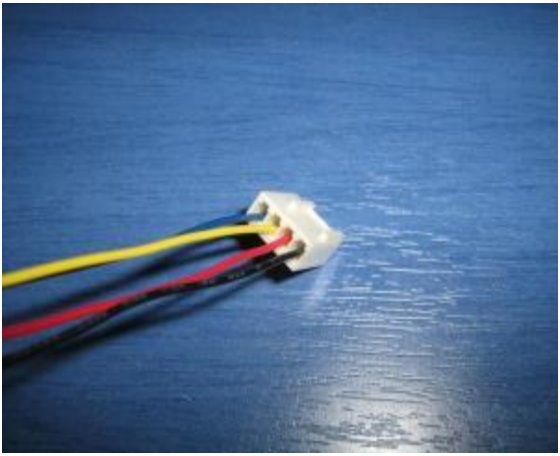


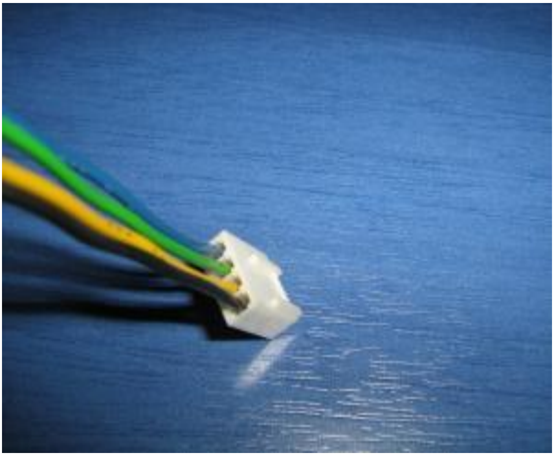
Diagram of a four wire fan

Usually, the diagram is more complicated than this one. But it can be used to give an idea about the principle of operation of the PC PWM Fans (as used to be called).

The controller actually checks the PWM input pulses and sends pulses to the transistor accordingly. If the PWM Duty cycle is bellow a threshold value, then the fan either shuts down, or it remains in a stable 'LOW" rpm. There are also fans that even with 0% duty cycle, they keep on running at this 'LOW' speed. This is usually done in critical applications that even if the external controller fails to operate, the internal fan controller will bypass the signal and will keep the fan running.



BLACK:Negative RED:Positive YELLOW:Tacho BLUE:PMW



BLACK:Negative YELLOW:Positive GREEN:Tacho BLUE:PMW

19.1.4 Three wire fan to a four wire connector header

Based on Intel's website article ID: 000005560 and last reviewed: 11-Mar-2016 'Chassis and processor fans use either a three-wire or four-wire connector. The three-wire connectors are for small chassis fans with lower power consumption. The four-wire connectors are for processor fans with higher power consumption.'

Strange as it may seem it is possible to connect a three wire fan to a four wire connector! The first three pin outs of the fans are the same for the 3 and 4 wire fans. Also, the keys are the same for both connectors. The 4-wire connector has smaller back-key to accept the smaller 3-wire fan connector keys. The fan will always run at full speed (as the control pin will not be used), but the rpm feedback (tacho) of the fan will operate normally and the motherboard will read the rpm normally.

Conversely, a 4-wire fan can be connected to 3-wire connector to a 3-wire connector! The connector is larger but the keys of the 4-wire fan have still the same distance as the 3-wire connector. The fan will operate at full speed all the time, as the 4th wire from the PWM control will be on air. The motherboard will normally read the rpm feedback from the fan tacho. This means that the PWM control line must have an internal pull-up resistor, so that when the pin is unconnected, the control FET will be kept always ON.

19.2 Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics or abbreviated CFD is a technique that has only really been around the 1970s because that was the time that computer's performance needed became available. As the title implies, CFD is a technique that uses computers to provide simulations of fluid flow problems. It is analysis of systems involving fluid flow, heat transfer and associated processes (chemical reactions) through the use of computer-based simulations. Although the results taken are very pretty and insightful the mathematics that goes on in the background is highly complex. In any specific case the user has to insert the same unknowns to run the study; which are:

- Fluid velocity in the three directions indicated as x, y and z.
- Pressure.

· Density.

· Temperature.

Theoretically speaking, any fluid dynamic problem can be solved using the equations of the underlying basic principles:

· The principle of Conservation of Mass.

-The principle of Conservation of Momentum.

· The principle of Conservation of Energy.

However, obtaining exact solutions in more complex studies is not possible and only certain types of 'ideal' flow can be accurately predicted.

19.2.1 Process of CFD

There are five steps that need to be accomplished in order to obtain the requesting data. First a CAD (computer aided design) model should be made that will represent the system that we want to study. This model can be in 2D if 2D CFD or 3D if maximum realism is required. By this way an electronic digital model is generated .Then it is imported into a "preprocessing" package in which the relevant conditions are set up.

Afterwards, a procedure called “meshing’ is performed. Meshing is the generation of a three dimensional grid defining possibly millions of “cells” in which calculations are carried out. The “solver” then performs the CFD calculations on the meshed model. During this process the information related with each cell is correlated to each other and the forces and mass flow is balanced across the whole flow “domain”, until a solution is reached.

”Post-processing” is the last step in which analysis of various results such as pressures and velocities on and off the surfaces of the body being tested. In this point it should be stated that in the “meshing” procedure hexahedral (six-sided cells) are the most common cells and are mainly used in not complexed surfaces. As a result, they give the most accurate mesh type.

Of course, numerous complex shapes can be created to define an unusual surface. Such a shape is tetrahedrals having four triangular shaped sides which in turn create more numerical diffusion and hence errors.

19.2.2 Solidworks FlowXpress Report

SOLIDWORKS FloXpress is a first pass qualitative flow analysis tool which gives insight into water or air flow inside your SOLIDWORKS model. To get more quantitative results like pressure drop, flow rate etc, you will have to use SOLIDWORKS Flow Simulation. Please visit www.solidworks.com to learn more about the capabilities of SOLIDWORKS Flow Simulation.

Model

Model Name: Test tube.SLDPRT

Fluid

Air

Environment Pressure 1

Type	Environment Pressure
Faces	Face<1>@Boss-Extrude4
Value	Environment Pressure: 101325.01 Pa Temperature: 293.20 K

Environment Pressure 1

Type	Environment Pressure
Faces	Face<2>@Boss-Extrude6
Value	Environment Pressure: 101325.00 Pa Temperature: 293.20 K

Results

Name	Unit	Value
Maximum Velocity	m/s	0.130

19.3 Parts we have

In the library that part of the study was performed and all of the components were extracted can be found some other parts that may be used in future projects. Unfortunately, it wasn't possible to find all the information and data sheets of the parts once the extracted items came out of old machines like computers and projectors.

Here you can find the exact nomenclature of each part we had in our possession and some information about them. It is obvious that each part characteristic can be correlated with another newer if precise study would be done.The extracted components are the following:

1)Intel C91968-002 N 5401D I1 F09A-12B3S1 01AC1H2 DC12V 0.42A NIDEC CORP.

Note: Found in datasheets: Intel C91968-003 Socket-775 Aluminum Cooler, Nidec P/N: F09A-12B3S1

2)Intel C91968-003 Socket-775 Aluminum Cooler, Nidec P/N: F09A-12B3S1 Intel C91968-003 (C91968003)

3)Nidec N 5409D and P/N: F09A-12B3S1 01AC1H2

DC 12V 0.42A 4-Pin / 4-Wire Connector

4)AVC FAN

Note: Information for this fan can be found in the pdf from the link:

---

http://www.avc-europe.eu/cms/upload/pdf/Fan_Catalogue.pdf

---

3)DC BRUSHLESS D12SL-12 DC12V 0.30A YATELOONELECTRONICS

Note: There are no datasheets for this fan so further study should be made to figure out their characteristics which is out of the borders of this project.

Further datasheets can be obtained from the following link:

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http://category.alldatasheet.com/index.jsp?sSearchword=AVC%20FAN%20&sPage=10
