King Fahd University of Petroleum and Minerals

Aerospace Engineering Department

Senior Design Project I

(AE 411)

Air Particle Separator

SALMAN AL-FIFI

ID # 991694

ACKNOWLEDGEMENT

"In the name of Allah (God), Most Gracious, Most Merciful. Read, In the name of thy lord and Cherisher, Who created man from a [leech - like] clot. Read, and thy Lord Is Most Bountiful, He Who taught [the use of] the pen. Taught man that which he know not. Nay, but man doth Transgress all bounds. In that he looketh upon himself as self- sufficient. Verily, to thy Lord is the return [of all]. " (The Holy QURAN, Surah No. 96).

Above and first of all, I thank and pray to Allah for His guidance and protection throughout my life. Including the years of this study.

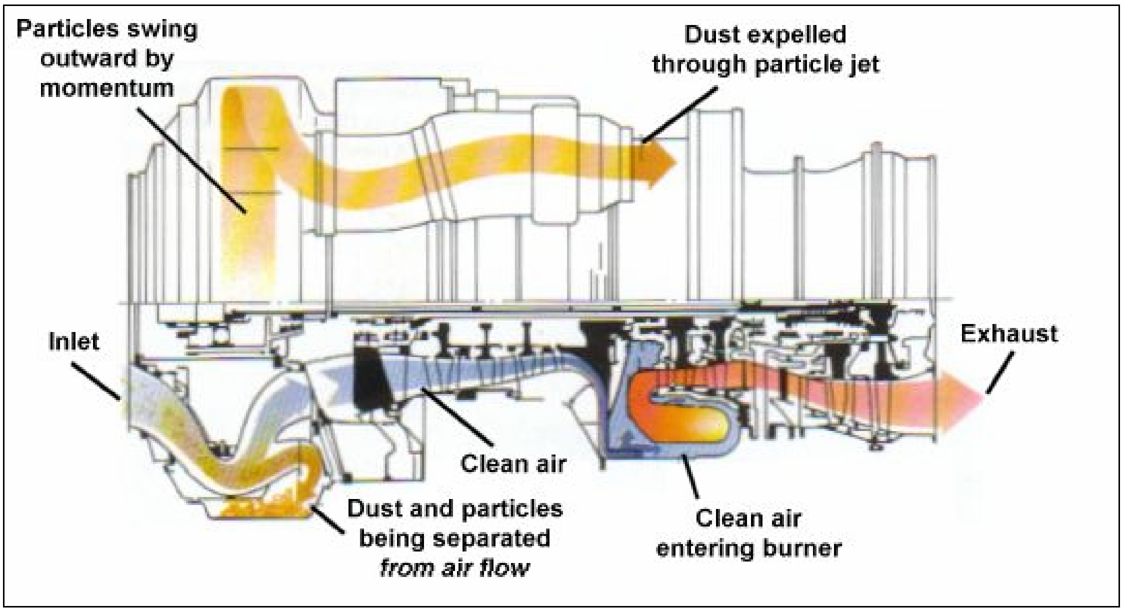
I am happy to have had a chance to glorify His name, in the sincerest way, through his small accomplishment, and I ask Him, with hope in Him, to accept my efforts. And secondary my peace upon His Prophet, MOHAMMED (salla Allah alihe wa sallam).

I would like to express my sincere thanks to my supervisor **Proof: Ahmad Z. Al - Garni** for sharing with me his knowledge and helping me through this project. I also wish to thank my direct supervisor **Mr: Mueyyet Tozan** for providing me with some sources, which deal with the air particle separator, and for his support, comments, suggestions, constructive criticism, and encouragement.

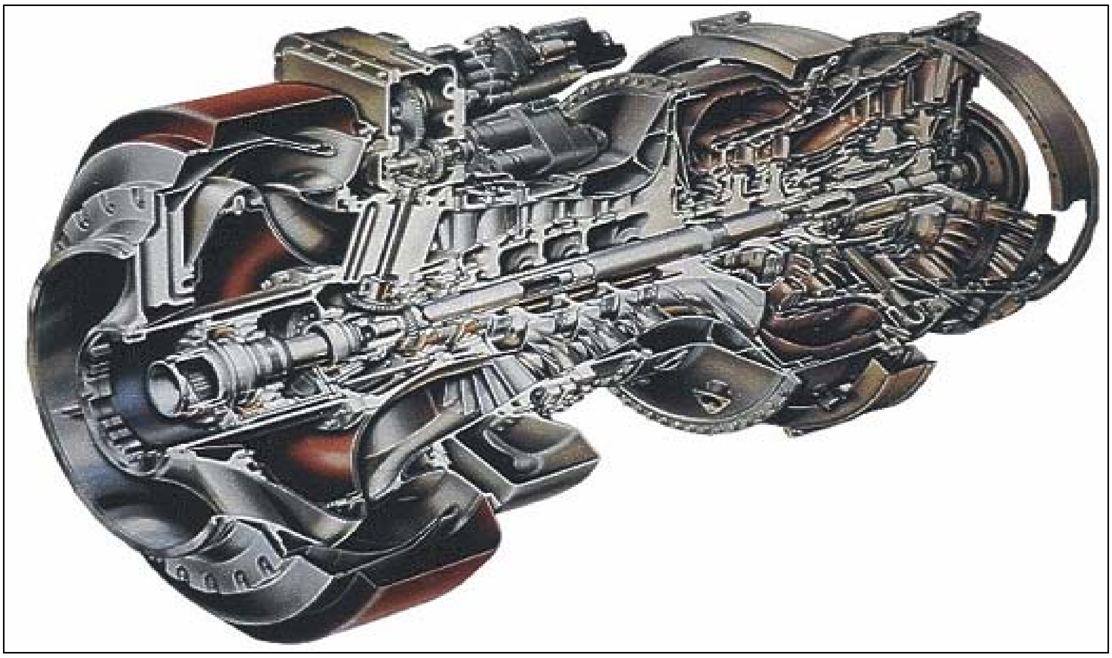
INTRODUCTION:

Flight operations in desert and sandy environments often encounter sand and dust, which have been known to create a number of operating problems for the power plant. Low altitude aircraft and helicopters are particularly vulnerable to sand and dust entering the engine due to the constant take offs and landing, and 'nap of the earth' flight operations which required flying close to the ground.

Ingestion of certain coarse sand into gas turbine engines can cause erosion (Figure 1and Figure 2) of the blades and vanes resulting in a loss of power and serge margin.
Axial compressors usually suffer from roughening of the blade surfaces, rolling of blade leading edges and the wearing of blade tips and shroud. Turbine stages can also incur similar problems.
In centrifugal compressors, wearing of the impeller leading edges and trailing edge root often result in structural failure. Ingestion of fine dust causes little or no erosion but they tend to cause other problems in the turbines where they melt in the combustion process and deposit on the turbine blades thus reducing the throat area and resulting in a mismatched engine. Erosion of the turbine by large particles can cause related problems but here the throat areas are generally enlarged. The glass like deposits can also shed causing structural damage to engine components.



(Figure 1)



(Figure 2)

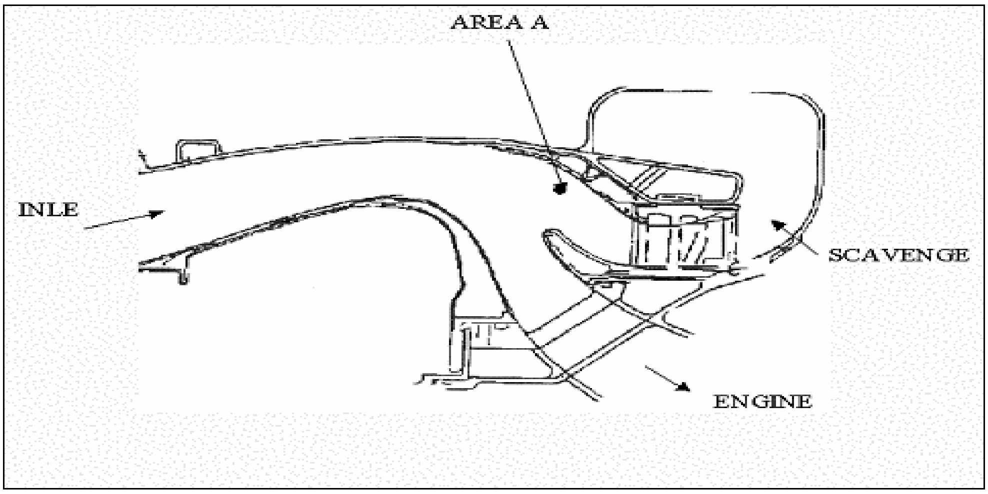
BACKGROUND:

Air particle separators operate on the principle of particle inertia; air coming into the separator is taken around a sharp bend, which the sand and dust particles, because of their inertia, are not able to turn quickly enough to follow. They are hence forced to pass into the scavenge duct and away from the engine.

As of today, every helicopter in the world fitted with an engine-mounted separator, is fitted with one, which looks and operates in exactly this way. That's a lot of helicopters and an awful lot of R&D to develop the separator technology to a mature state. In all probabilities, several tens of millions of pounds worth of R&D.

The separator, however, has a problem. it does not work very well. All of the contaminated air which passes along the scavenge duct has to be pumped. The energy required to provide the pumping force can be quite large- and on an aircraft every little bit counts. Therefore, the designs all attempt to minimize the amount of scavenge air. Unfortunately, but hardly surprising, the less air scavenged, the worse the separator performance becomes.

The fundamental problem here is that the scavenge annuals area has to be large in order to trap as many particles as possible, but on the other hand needs to be small because there is not very much flow passing through it and so that will tend to stagnate. So we will try in our own design of the air separator to compromise between all elements that give better efficiency of this separator. Figure 3 shows the shape such separator.



(Figure 3)

Environment:

Ambient air can be contaminated by solids liquids, or gases. Of these three, contamination by solids is the most common, usually the most serious situation. The quantity of solids can be defined in many ways, such as milligrams per cubic meter of air or grains per 1000 cubic feet.
A measure General Electric finds convenient is parts per million (ppm), i.e., the mass of contaminants per million units mass of air. The fact that this is a convenient measure immediately demonstrates that the quantity of dust is generally quite small compared to the mass of air. In the United States, the Environmental Protection Agency samples airborne particulates periodically at some 4000 locations. Results of annual surveys are published.
Dust loading in desert regions, particularly those subject to sand and dust storms, is much higher than those usually experienced in the United States, and this is what makes the difficulty arises here in the kingdom to overcome this problem of sands. Concentrations in sand storms may reach several hundred ppm for periods of several hours, while long-term levels may average one to five ppm. When the wind blows in these regions, the larger soil particles become airborne first, smaller particles being more adherent. When the large particles fall back to earth, they disturb the surface and ‘splash out’ fine particles. By Stokes law, fine particles settle more slowly; so they remain airborne longer. The results are that the dust concentrations are highest close to the ground, and that the particles there tend to be coarser than at higher elevations. There is no exact relationship between dust concentrations and elevation above the ground, but available data generally tend to fall within the range in (Figure 4).

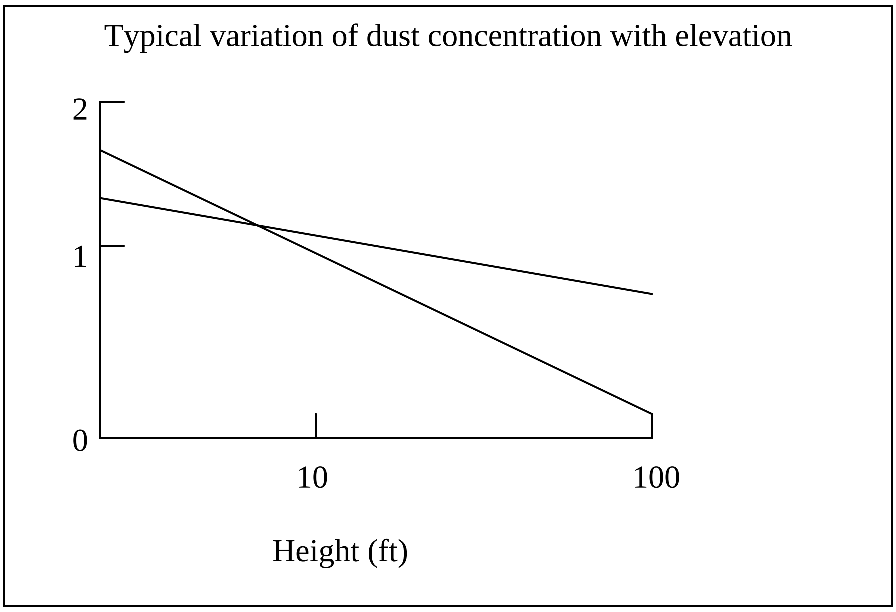


Figure 4

The size distributions of airborne dusts are variable with respect to time and place. In general, high values of dust concentrations tend to be associated with coarse dust and low values with fine dust. Large particles tend to fall quickly, while smaller particles are more likely to stay airborne. Consequently, dust samples taken near the source of contamination tend to be coarser than those samples taken at a distance.

Table 1 shows the idea of size distributions by reference to the standardized dusts, Arizona Coarse and Arizona Fine, which are widely used in the testing of air filtration devices. Table 1 shows their mass distribution as a function of particle size.

Particle size range (microns)	Nominal percentage of total mass of particles	
	Coarse dust	Fine dust
0 -5	12	39
5 -10	12	18
10 -20	14	16
20 -40	23	18
40 -80	30	9
80 -200	9	

Table 1

Types of sands and dust:

There is no single dust size, which can represent the full range of sand and dust encountered in flight operations, but the following sizes are defined as standard test dust

- MIL-E-5007C o ‘C-Spec’ sand- consists of crushed quartz with particle size from 0-1000 microns and mean diameter of about 200 microns. This type of sand is considered as highly erosive causing severe engine component damage.

- Coarse Arizona Road Dust (AC-Coarse)- has of low quartz content with particle sizes from 0-200 microns and mean diameter of about 80 microns. This type can cause erosion, glazing and clogging particularly in the hot section of the engine.

- Fine Arizona Road Dust (AC- Fine) consists of particle sizes from 0-80 microns and mean diameter of about 8 microns. Glazing and clogging particularly in the hot section of an engine are the usual phenomenon.

Inertial particle separator (IPS):

Inertial particle separators (Figure 5) are capable of moving large particles leaving the smaller ones to be trapped by the filters which greatly enhanced the life of the filter and offers maximum engine protection. The main advantage is the large installed area required for such a system thus increasing the overall intake area.

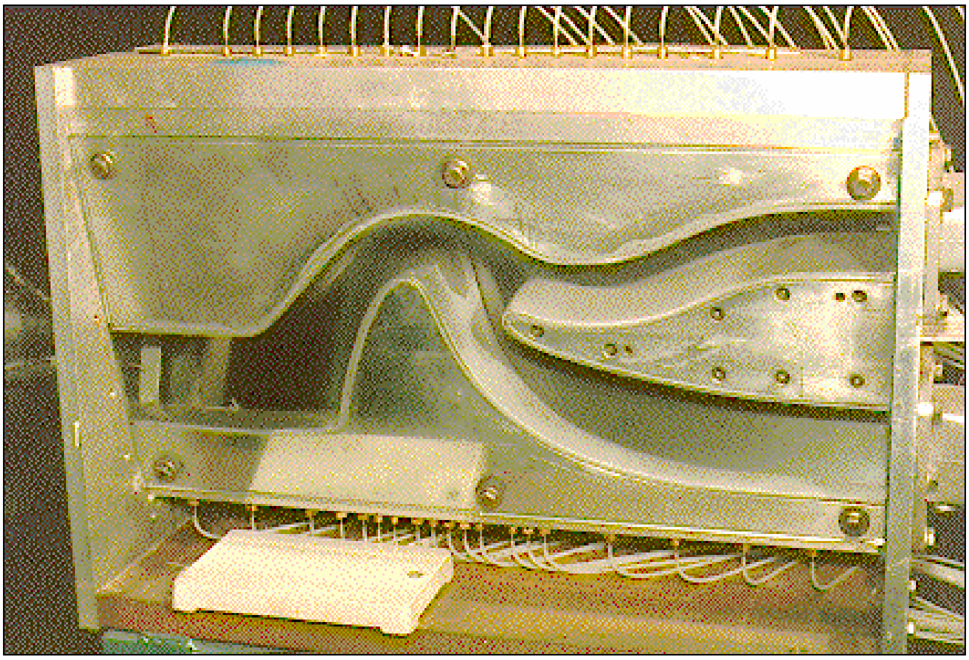


Figure 5

In this project we will manufacture our own (IPS) according to the available compressor we have with certain specifications.

The study will involve the theoreritical and experimental simulations of particle trajectories in an inertial particle separator in order to determine the sand separating efficiency for a range particle sizes. The mechanism of sand removal derives from the inertia and bounce characteristic of sand particles, which vary with the particle size, impact velocity and angle, and the target and particle materials.

A particle-air mixture is fed locally at the inlet into the (IPS) (shown left in figure 5) , which has contoured shapes to deflect sand particle into the scavenge section while only clean air enters the compressor. The sand particles used have narrow size bandwidth. The ratio of the particles colleted from the scavenge to those ingested represents the separation efficiency for the particular dust size. Optimization of the separation efficiency is carried using 3D tracking computer code, which includes the particle bounce characteristics, shape of contoured surfaces and aerodynamic performance of the separator. Figure 6 shows how the particles propagate inside (IPS)

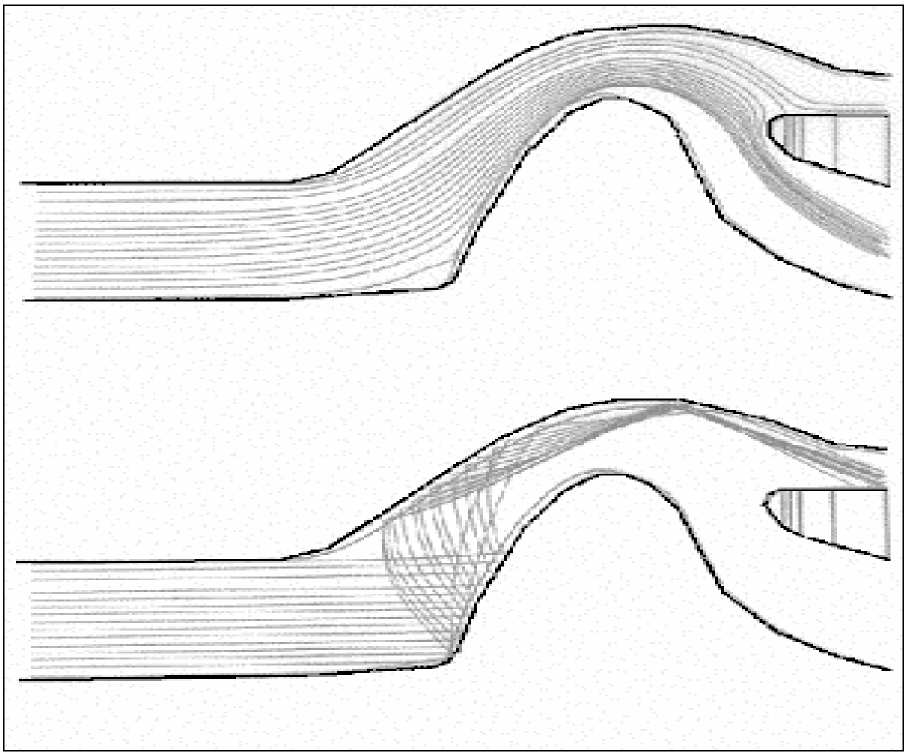


Figure 6

PRELIMINARY EXPERIMENTAL SET-UP FOR STUDYING INLET PARTICLE SEPARATOR:

We will make the set-up of our experiment as shown in figure 7 below with the following specifications:

Velocity Range	: 50-100 m/s
Sand concentration	: Variable (in mg/m3)
Model cross-section area	To be determined

Table 2

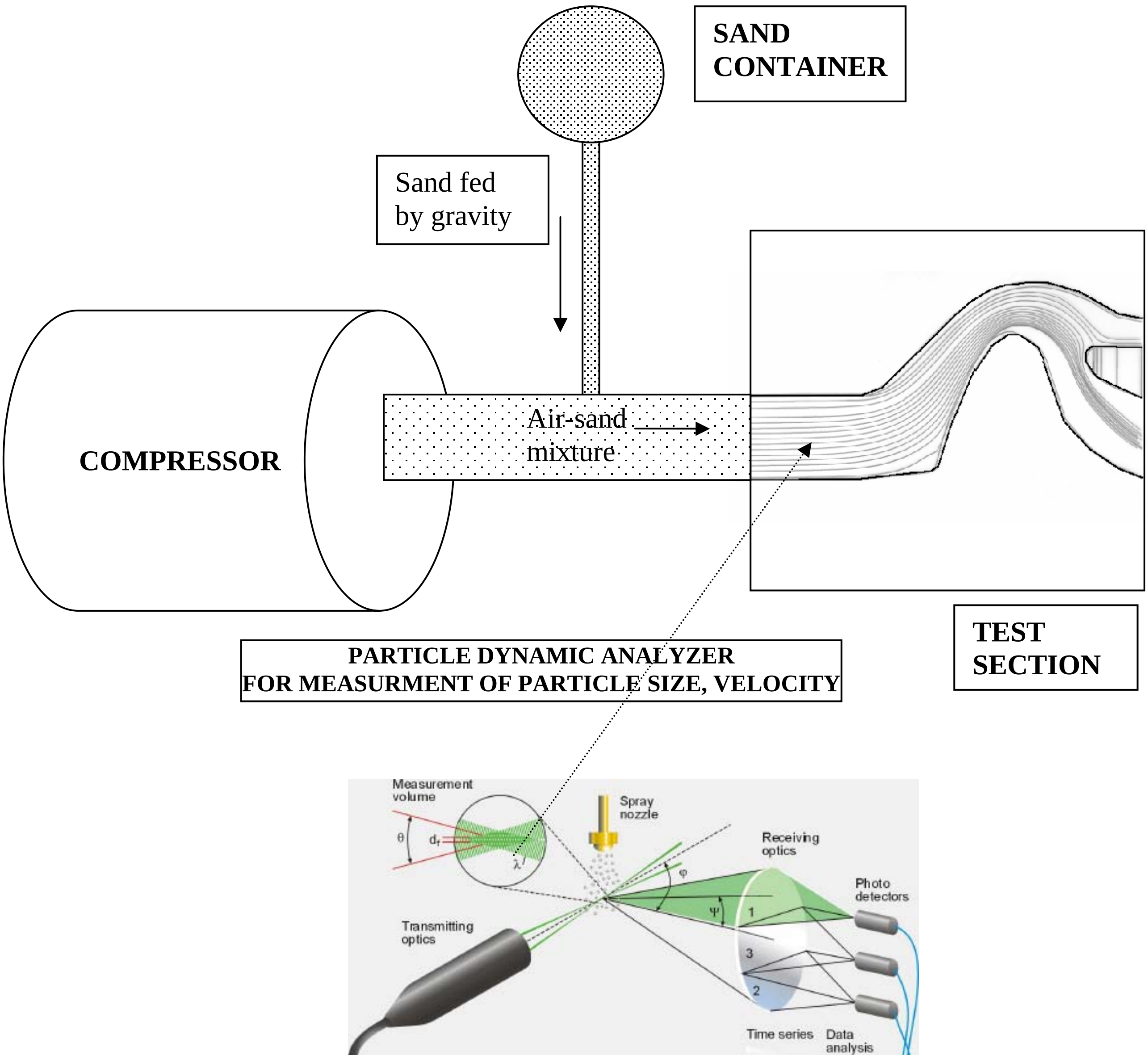


Figure 7

PRELIMINARY FINDINGS REGARDING WITH TEST SET-UP :

(1) To obtain a velocity at the range of 50-100 m/s at cross-section area of minimum (5cmx10cm) 0.005m2, a compressor should supply an airflow of 15 m3/sec min.Preliminary data collected from various compressor manufacturers indicates that 15 m3/sec. is a high flow rate that adds the cost (More than 30,000 USD). After a survey in the local market (to be conducted by Mr.Salman) and examining the available compressor in the lab, a decisison will be made in a week or so on this matter.

(2) An instrument (particle dynamic analyzer or laser anemometer) to track the particle paths is needed. Responses from some manufacturers regarding with the prices of these types of instruments are expected nowadays.

SUGGESTIONS :

It is strong probability that purchasing a new compressor and measuremet instrument is costly and probably takes time.Under this conditions followings may be suggested:

- Seek for the possibility to improve the capacity of existing compressor by some modifications.

- One of the following two ways may be chosen to go on :

    1) Project may be concentrated on ***aerodynamic performance*** i.e. experimental & theoretical investigation of flow field in the inlet particle separator without sand.This will help to develop and verify computer codes for the solution of the flow field which is needed for further steps of the project.

    2) Or, a simple set up for studying ***sand erosion*** on surfaces may be designed by using available compressor.

I. Aerodynamic Performace of Inlet Particle Separators:

Procedure in performing experiment:

(1) Obtain the drawing of an existing particle separator

(2) Build a model of inlet particle separator.

(3) Test the model in the wind tunnel to obtain pressure and/or velocity distribution along the model and to determine the ratio of pressure before and after the separator. (If sufficient time is available)

(4) Establish model for air flow in the seperator

(5) Develop computer code for solution of equations

(6) Compare results with experimental findings

II. Sand particle erosion

(1) Establish the experiment set-up with a room for further improvements

(2) Build a particle feed system that supplies variable particle flow rate (some help may be needed from industry)

(3) Conduct preliminary test to study the effect of impact angle and impact velocity on the erosion pattren.figure 8 shows Simple experimental set-up for particle erosion study.

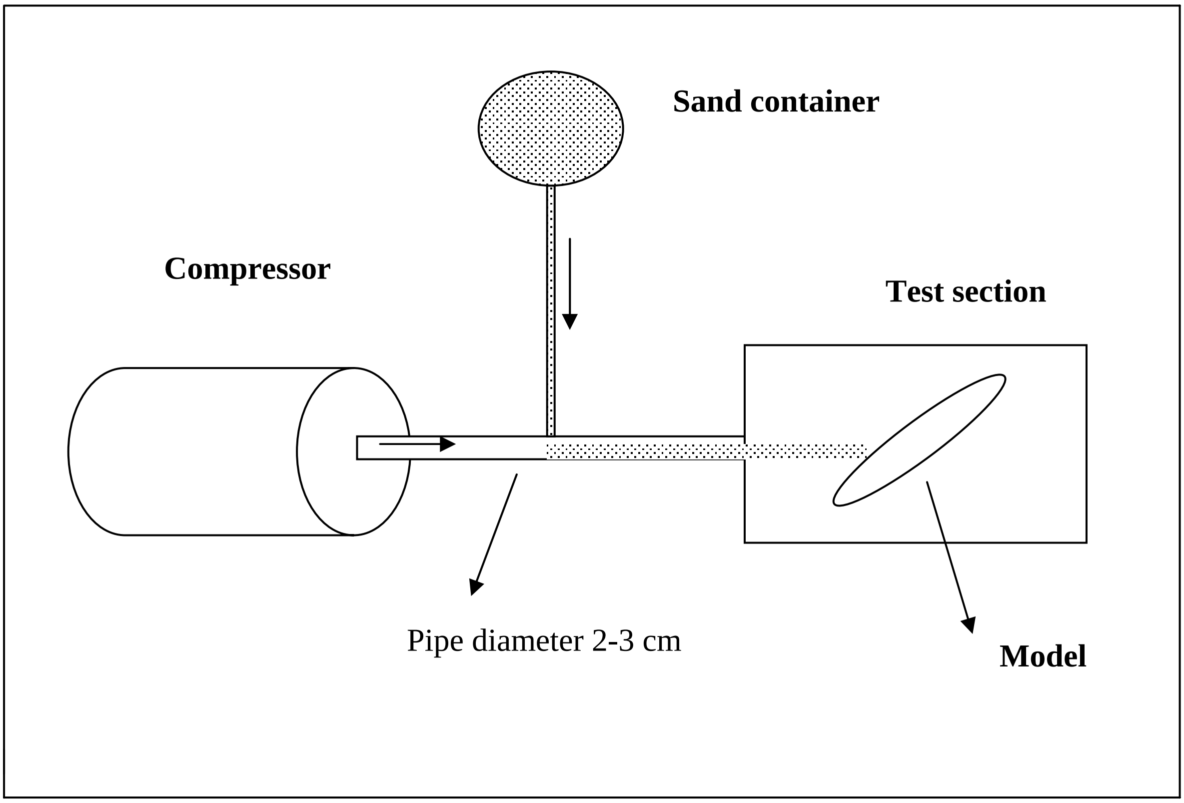


Figure 8

Remark:

Actually in this semester we will only construct a preliminary drawings of our inlet particle separator with some dimensions after we collect some information that help in design drawings ; and the rest of the project will be comletetd inshallah next semester and the final versin of the report will include all steps one by one with more specific details; and ill end up with our conclusion and resul.

DRAWINGS:

All the parts of our inlet particle separator will be drawn individually we numred these parts as hown in figure 9 below .

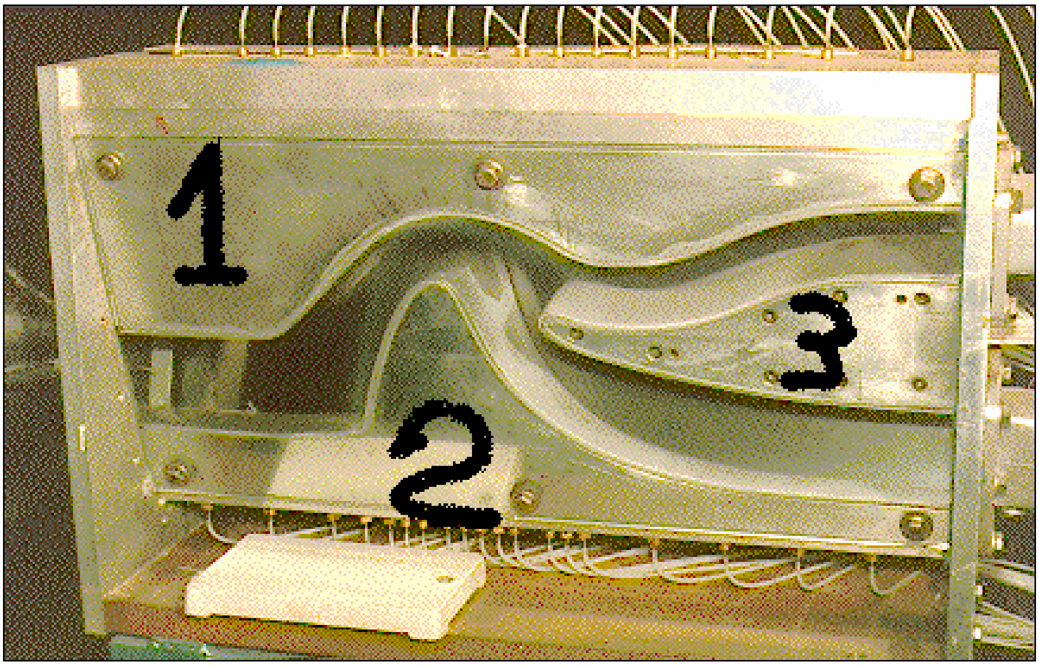


figure 9

We present the drawing of each part above as well as the assembed drawing from different faces as follows:

a) front

b) Top

c) Bottom

d) Right

e) Left

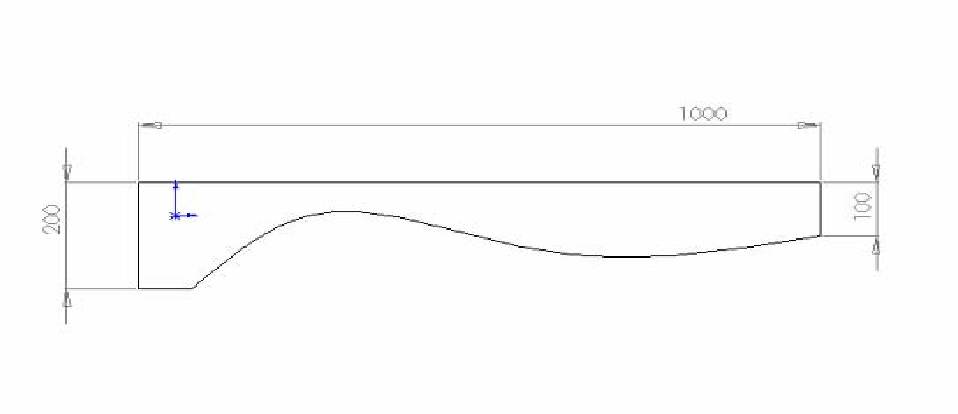
f) Isometric

g) Dimetric

h) Trimetric

Part 1:

Front



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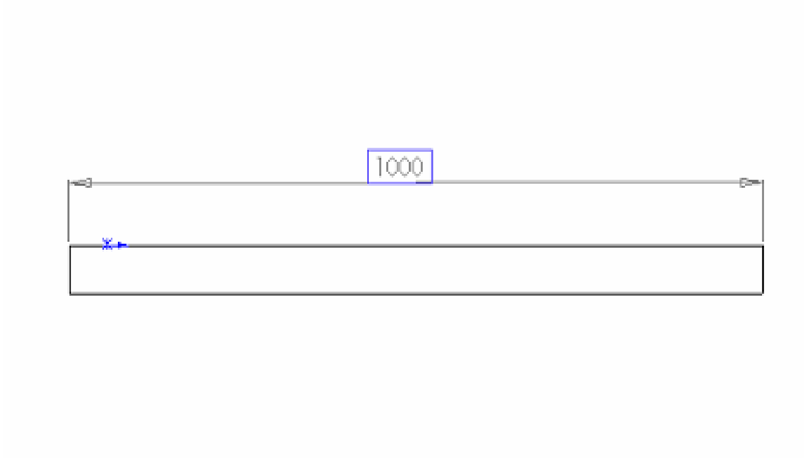

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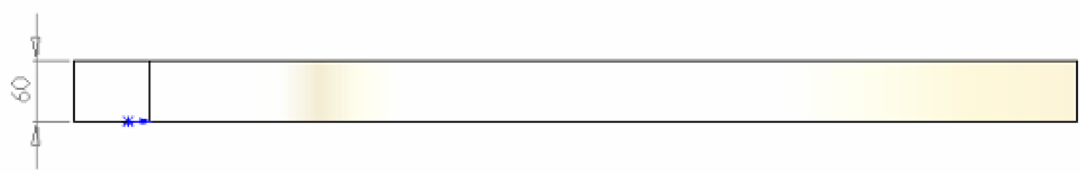
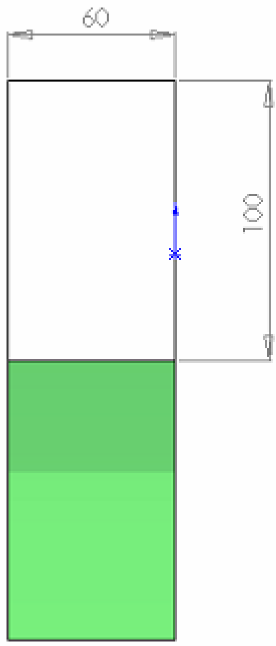


Right veiw:



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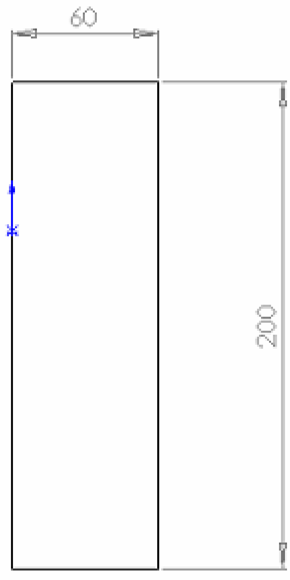

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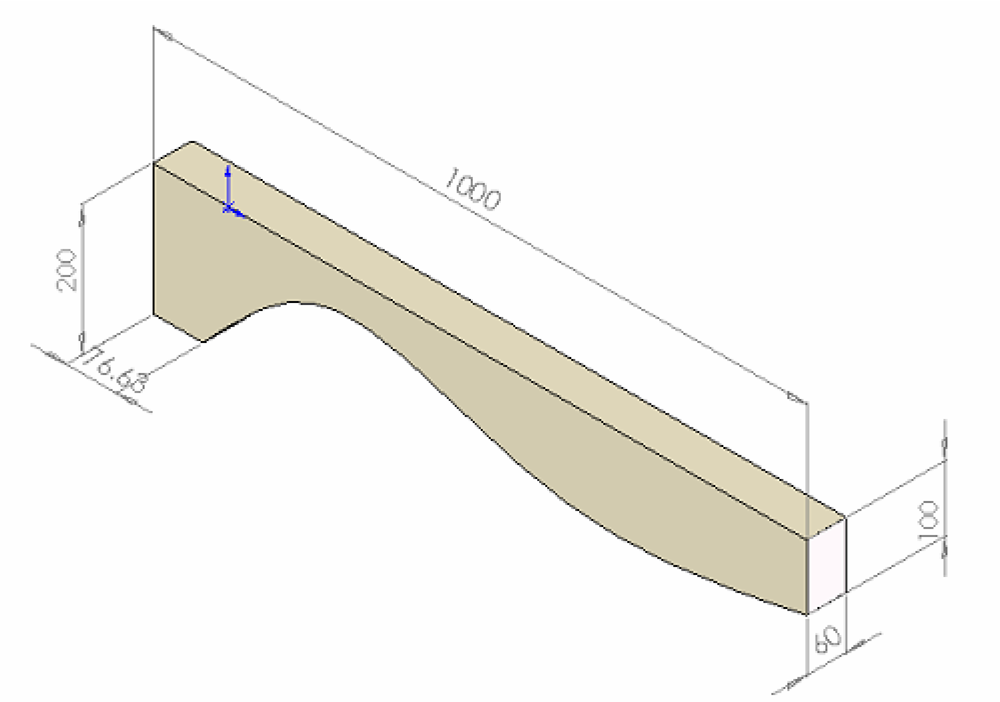

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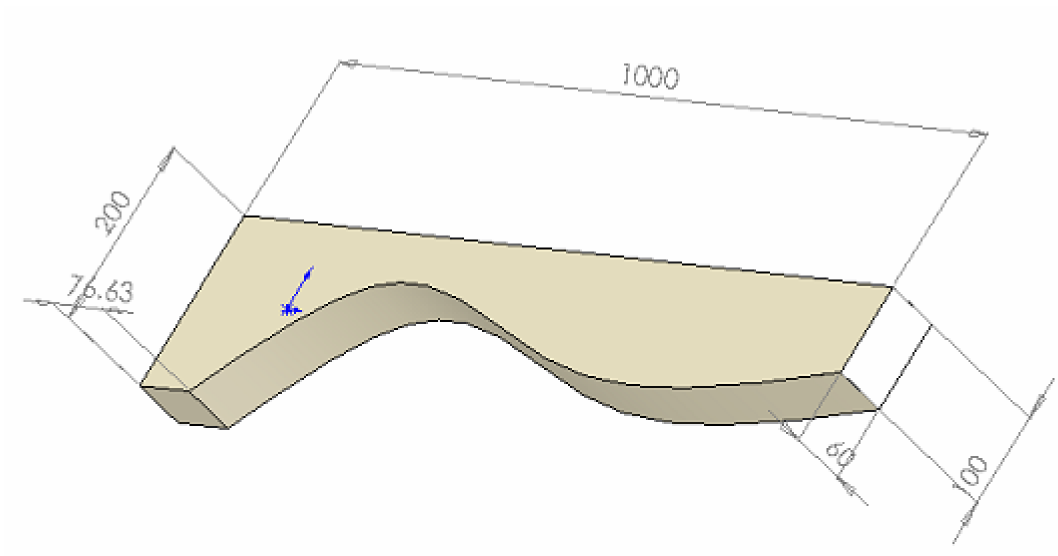

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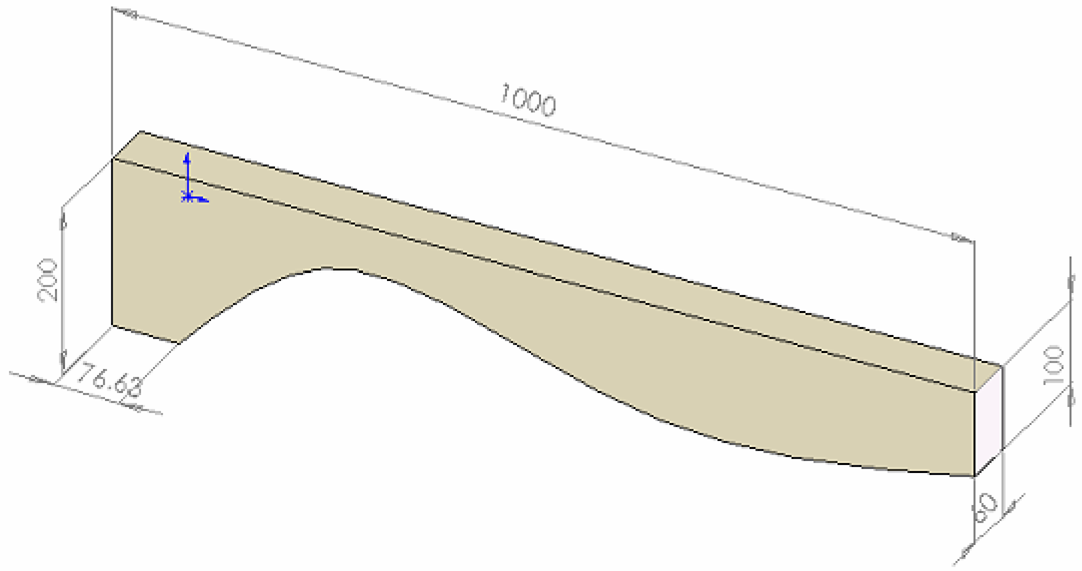
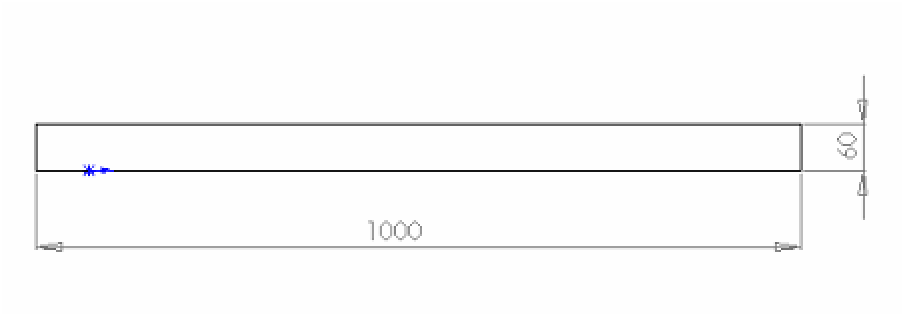


Part 2:

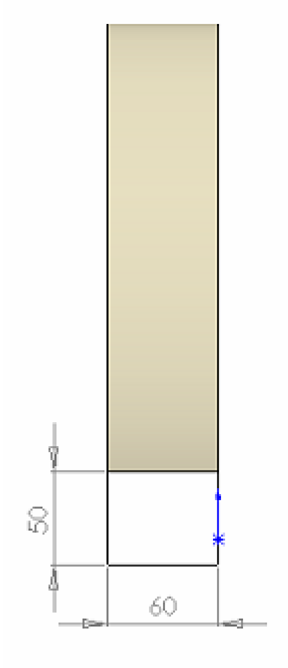
Front:

Top:

Bottom:



Right:



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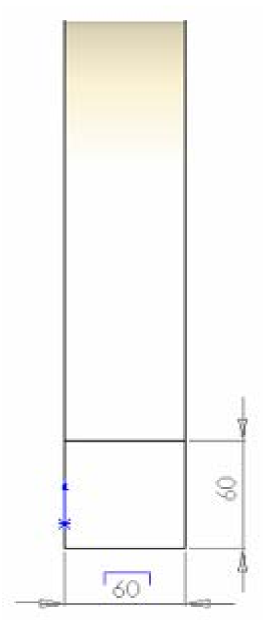
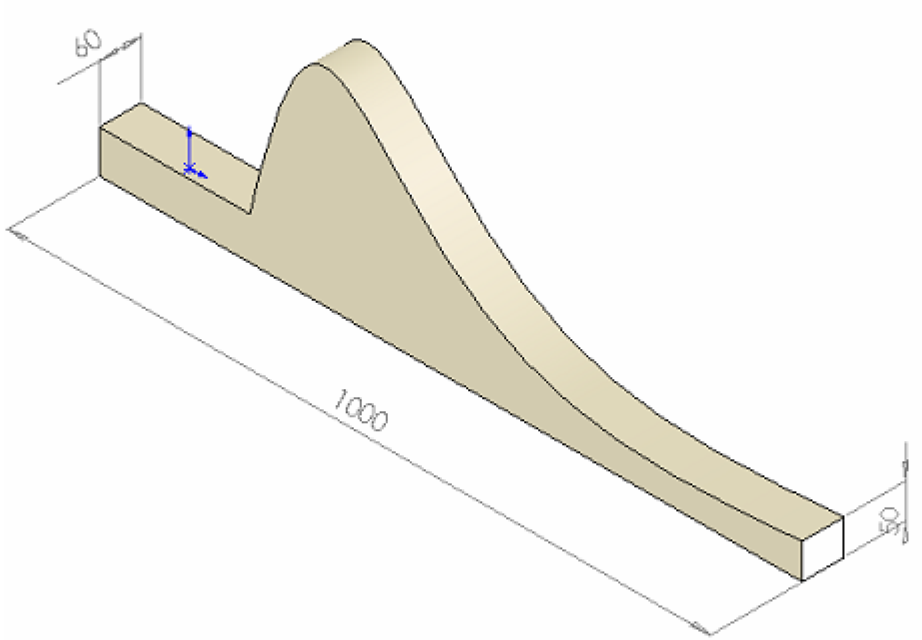


Isometric:



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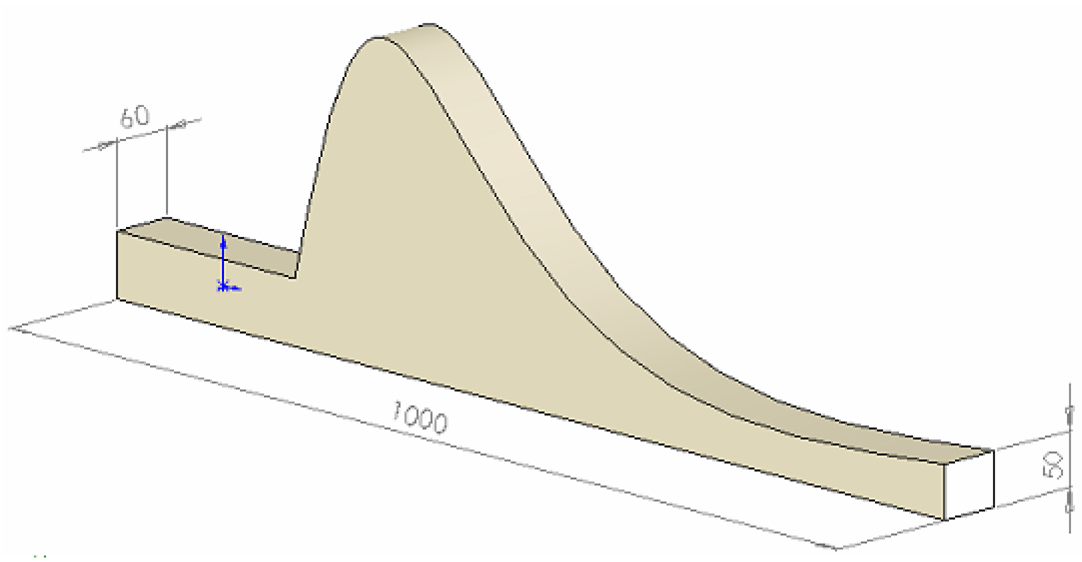

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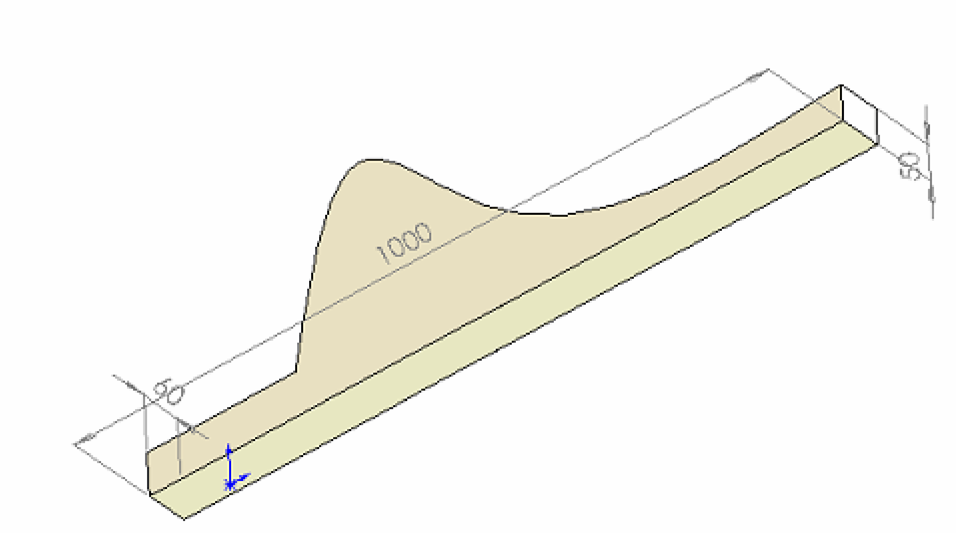
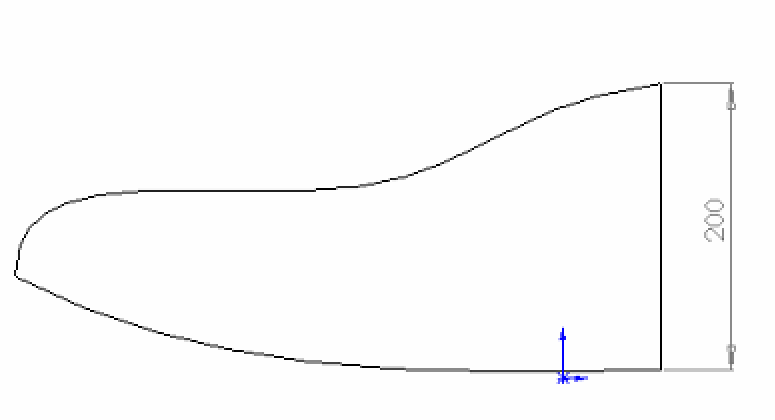


Part 3:

Front:



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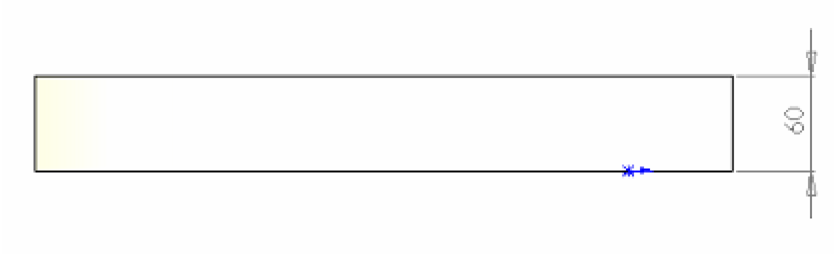

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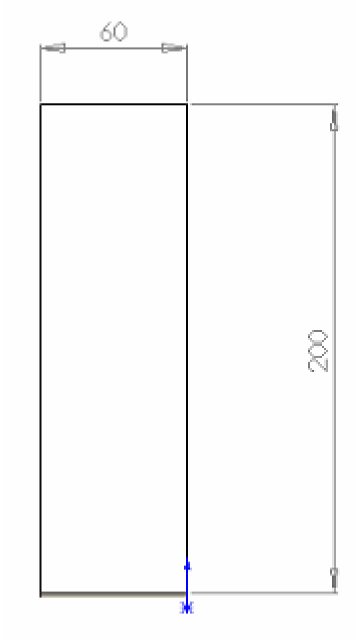

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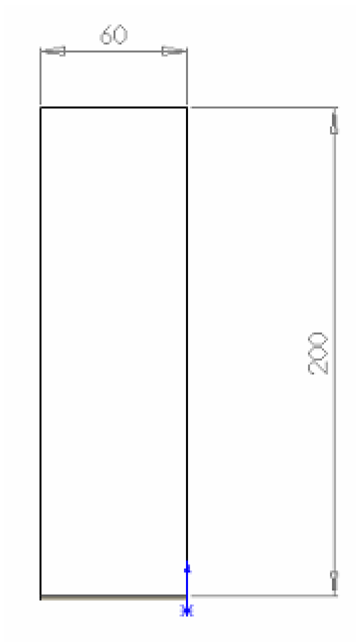

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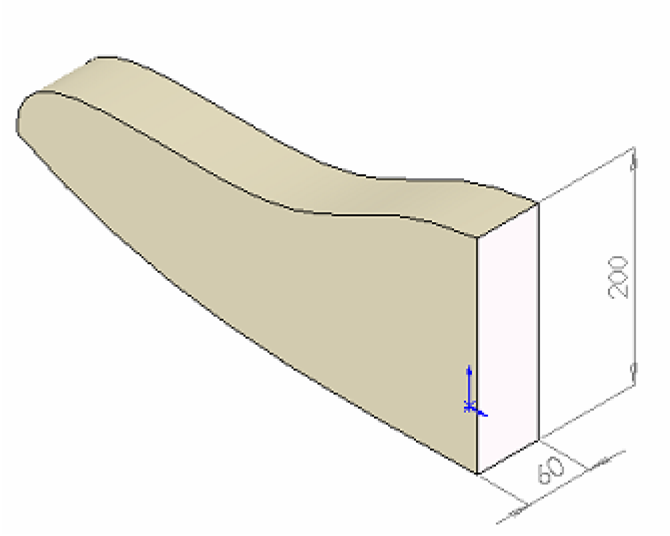

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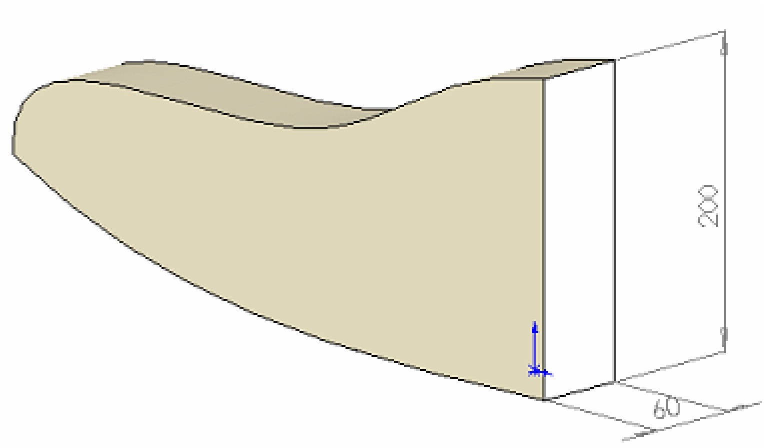

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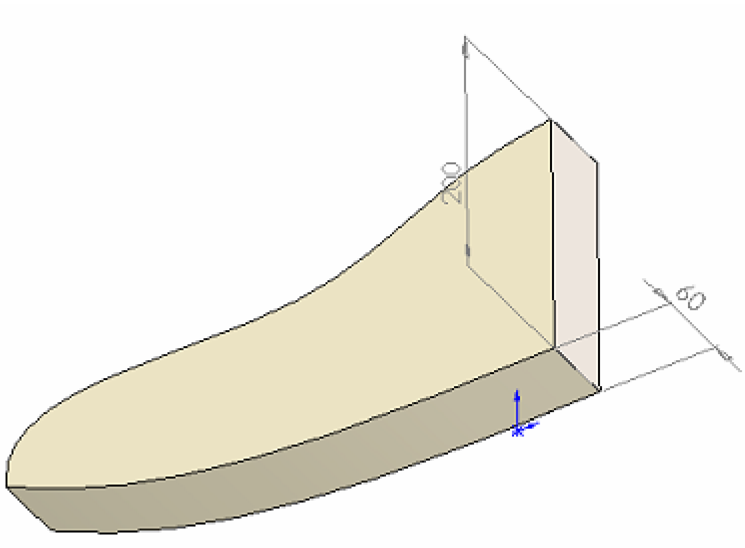
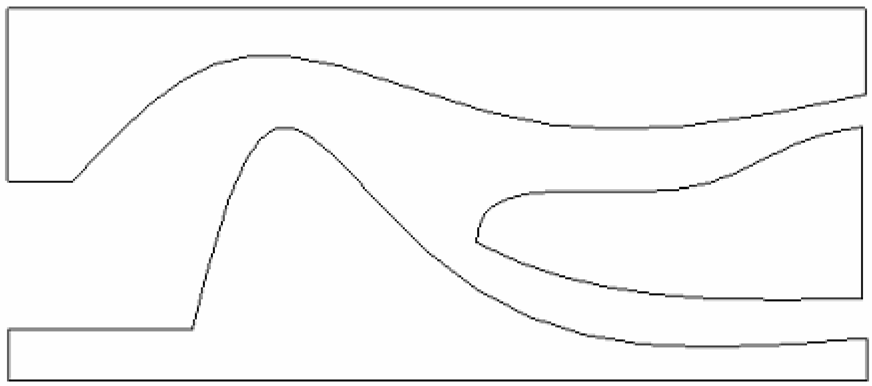


Assembly drawing:

Front:



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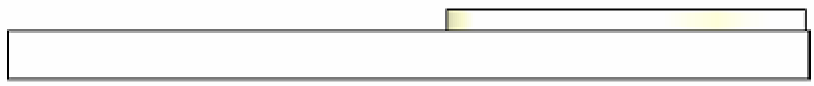

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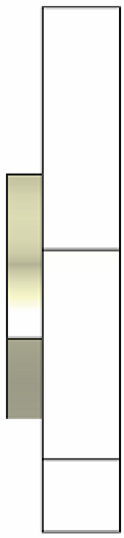

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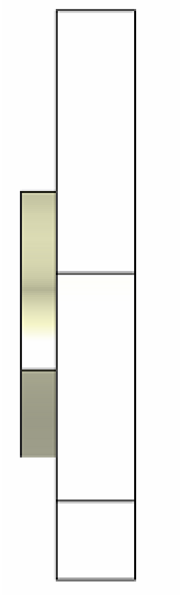

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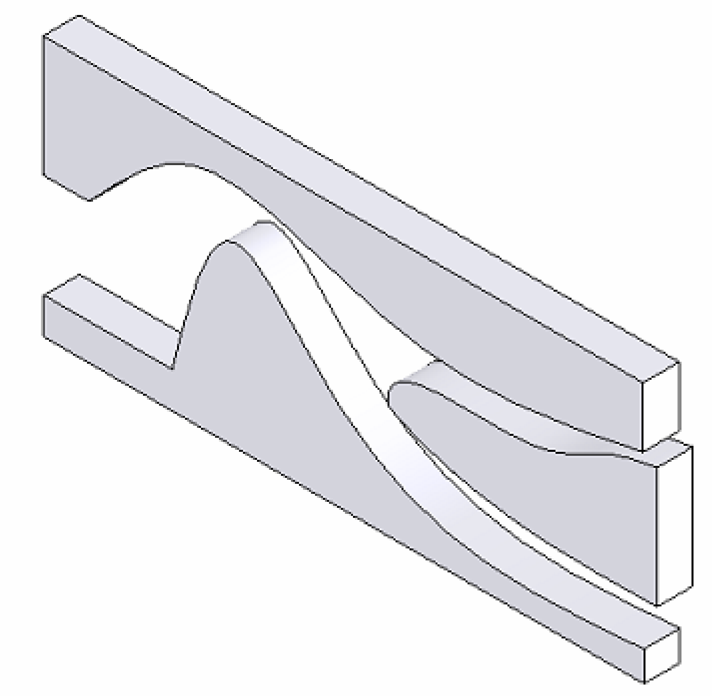

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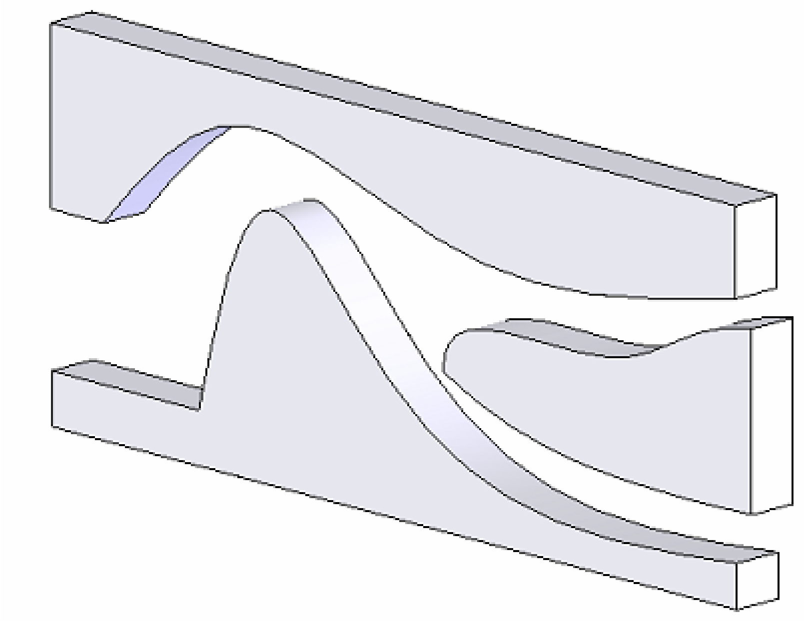

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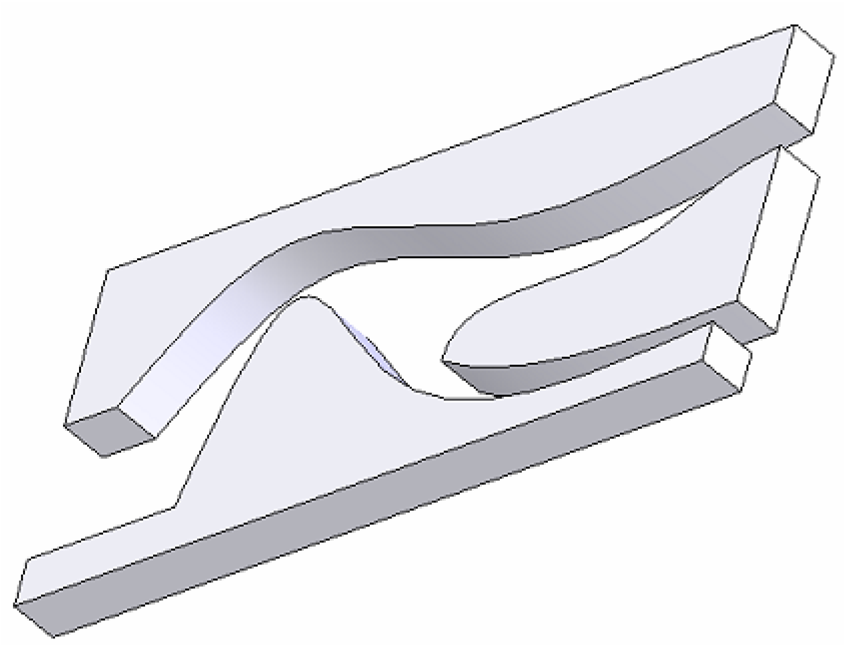

CONCLUSION:

Actually up to this level of progress of drawing the inlet particle separator parts, we finished the assigned work to us in this semester; and the rest of work will be completed inshallah next semester as assigned in the project action plan as follows:

I. Aerodynamic Performace of Inlet Particle Separators:

1) Build a model of inlet particle separator.
2) Test the model in the wind tunnel to obtain pressure and/or velocity distribution along the model and to determine the ratio of pressure before and after the separator. (If sufficient time is available)
3) Establish model for air flow in the seperator
4) Develop computer code for solution of equations
5) Compare results with experimental findings

II. Sand particle erosion

(1) Establish the experiment set-up with a room for further improvements
(2) Build a particle feed system that supplies variable particle flow rate (some help may be needed from industry)
(3) Conduct preliminary test to study the effect of impact angle and impact velocity on the erosion pattren.figure 8 shows Simple experimental set-up for particle erosion study.

Actually by now I feel that I am almost saturated of enough information and knowledge of the project nature and also I have the visualization of how the work is going to be later on. As well as I feel that this project motivated me to continue in the same field of research in higher studies inshallah.

Finally, I would like express my sincere thanks to Dr. Ahman AL-Garni and Mr. Tozan, for helping in writing this report. I also thank them for their support, patience, comments, suggestions, constructive criticim and encouragement.

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3. http://www.ifrc.co.uk/TeaBagPaper/ teabagpaper.html

4. Journal of aircraft /AIAA/journal of fluid mecaniches