CFD OF A SCREW BLADE FOR STANDALONE MICRO HYDRO GENERATOR

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Report submitted in partial fulfillment of the requirements for the award of
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EXAMINERS APPROVAL DOCUMENT

UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

I certify that report entitled 'CFD of a screw runner blade for standalone micro hydro generator' is written by SugaGaneshan a/l Kalaichalbanwith matric number MA09048 .I have examined the final copy of this report and in my opinion, it is fully adequate in terms of language standard, and report formatting requirement for the award of the degree. I herewith recommend that it be accepted in fulfillment of the requirements for the degree of Bachelor Engineering.

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SUPERVISOR DECLARATION

I hereby declare I have checked this report, which written by SugaGaneshan s/o Kalaichalbanand in my opinion, this report project is adequate in terms of scopes and quality for the award of the degree of Bachelor of Mechanical Engineering.

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Date: 20 JUNE 2013

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own, except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any other Degree and is not concurrently submitted for award of other degree.

SugaGaneshan S/O Kalaichalban
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Date: 20 JUNE 2013

DEDICATION

Dedicated to my beloved mother Kamala Devi, father Kalaichalvan, sister Suga Priya and Parijatha Letchumi, brother Yathavan, cousins and to all my family, friends and to my beloved Ghaneshinee. Hereby, I would like recommend thousand of thanks to my supervsisor, En Muhammad Ammar Bin Nik Mutasim for helping me along this project.

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First of all, I would like to express my highest gratitude to God for blessing me in finishing this project. With his permission and his guidance me to do what I can. I have been trying to get this thesis with the language simple, clear and easy to understand for all levels of society.

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ABSTRACT

Archimedean screw is one of the oldest hydraulic machines. Previously, this screw runner is used to lift water from lower part to upper part. In this modern era, Archimedean screw is used to generate electricity using the reverse concept of the old Archimedean screw. The efficiency of the screw blade is depend on the parameters of the screw blade. The main aim in this paper is to determine the efficiency of the Archimedean screw at different inclination angle and angle of attack of the blades. Re-inversed concept of the old Archimedean screw was used and using k-epsilon turbulence method was applied to study the fluid flow behavior. Comparison between theoretical design and CFD was done to obtain the most effective inclination angle and angle of attack between blades. Results show the inclination angle 23.58º and angle of attack 75º was the most reasonable design. In future can be more determine on the orientation angle for future research in Archimedean screw.

ABSTRAK

Archimedes skru adalah salah satu mesin hidraulik yang tertua. Sebelum ini, Archimedes skru digunakan untuk mengalirkan air dari bahagian bawah ke atas. Manakala pada zaman sekarang, Archimedes skru digunakan untuk menjana tenaga elektrik melalui konsep yang bertentangan dengan skru Archimedean lama. Tujuan utama dalam kertas kerja ini adalah untuk menentukan kecekapan skru Archimedean pada sudut kecenderungan yang berbeza dan sudut antara bilah. Konsep bertentanggan dari konsep skru Archimedean lama digunakan dan kaedah k-epsilon pergolakan telah digunakan untuk mengkaji kelakuan aliran cecair. Perbandingan antara reka bentuk teori dan CFD telah dilakukan untuk mendapatkan kecekapan skru yang paling berkesan antara sudut kecenderungan dan sudut antara bilah. Keputusan menunjukkan sudut kecenderungan 23,58^o dan sudut antara bilah 75^o adalah reka bentuk yang paling munasabah. Penyelidikan dalam sudut orientasi pada masa depan dalam Archimedean skru lebih menetukan.

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LIST OF SYMBOLS

F	Fore
V	Velocity
P	Power output
β	Angle of attack
α	Orientation Angle

LIST OF ABBREVIATION

CFD	Computational Fluid Dynamic

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Malaysia has many potential renewable energies such as mini / micro hydro, biomass energy, solar energy, wind energy, geothermal energy and ocean energy. For micro hydro, it use the potential of the water to rotate the turbine and generator then convert into electrical energy. In Malaysia the average of water resource potential has a higher discharge and low head, so it is suitable to develop a low head turbine in Malaysia.

In this, a research on Archimedes screw is been done. The Archimedean screw is still new to be developed in Malaysia. This screw operates with low rotation speed and can generate electricity up to 500kW. The Archimedes screw has many advantages such as; do not require special control system, environmentally friendly and easy in construction.

It has been discovered that the performance of the screw if affected by the parameters of the screw. It is important to determine the parameters in order to get high performance of the screw. By this, a research is been carried on Archimedes screw in the aim to determine the effect of angles between the blades and orientation angles of the screw blade in the performance of the Archimedes screw in generating a small-scale of electricity.

1.2 PROBLEM STATEMENT

Developing Archimedean screw is very important in today's micro hydro system world. Archimedean screw is very easy to install and very low maintenance is required.Developing Archimedean screw in rural areas can generate small amount of electricity which can be used for wide purpose. Unfortunately, the efficiency of the Archimedean screw differs in different parameters. The efficiency changes at different angles, the horizontal angles between the land and the angles between the blades, cause an investigation need to be done before install the Archimedes screw.

1.3 OBJECTIVE

The objectives of the project are as follows :

i. To design three screw blade model using CAD.
ii. To study the screw blade characteristics at steady flow using Ansys CFX.
iii. To validate obtain result with experimental method from other researcher.
iv. The best design which as better efficiency is chosen as a base model.

1.4 PROJECT SCOPES

The scopes of the project are as follows :

i. Design three designs of screw blade with different parameters for comparison.
ii. Setup suitable boundary conditions for the simulation. Assume the fluid flow as steady flow.
iii. Run analysis using CFD application which isAnsys CFX to obtain results.
iv. Compare the obtained computational results with experimental results.

1.5 SIGNIFICANT OF STUDY

Computational Fluid Dynamics (CFD) is done to save cost and time of a project.From this research the efficiency of the screw blade can be analysed and the output scale of a screw blade can be can be calculated. This research will help to increase the importance of usage of computational results to analysis a certain experiment with high cost and long duration.

CHAPTER 2

LITERATURE REVIEW

2.1 COMPUTATIONAL FLUID DYNAMICS (CFD)

Computational fluid dynamics (CFD) is a computer simulation that analyzes systems for fluid flows, heat transfer, and phenomena such as chemical reactions. The rapid development of computational power and CFD technique becomes more and more relevant to the industrial applications, and this method has been applied in the area of the aerospace industry , meteorology (weather prediction), and external environment of buildings (wind loads and ventilation) commonly. CFD has many advantages over experiment-based approaches, such as reduction of lead times and costs of new designs, study systems under hazardous conditions, systems that are impossible to study with controlled experiments and, the unlimited level of detail of the results.

There are also problems with CFD. The physics are complex and the result from CFD is only as good as the operator and the physics embedded. With today's computer power, there is a limitation of grid fineness and the choice of solving approach (DNS, LES and turbulence model). This can result in errors, such as numerical diffusion, false diffusion and wrongly predicted flow separations. The operator must then decide if the result is significant. While presently, CFD is no substitute for experimentation, it is a very helpful and powerful tool for problem solving.

When working with CFD a number of different steps are followed. These steps are illustrated in figure 2.1.

Figure 2.1: The CFD process flow

The first step is to create geometry (with CAD). This is often already done by other departments or done by scanning a model. The geometry cannot have any holes, it has to be airtight, and unnecessary things in the CAD model that do not affect the flow has to be removed to save computer power. This is called CAD cleanup. The next step is to generate a mesh and this is often done automatically by a meshing program. Then the flow is simulated by a solver. After the simulation is ready, it is time for post processing. Post processing involves getting drag and lift data, and analyzing the flow.

2.2 CFD METHODS

There are many models in CFD such as laminar, k-omega, transientand more. The models used for turbulence will be k-epsilon and k-omega. K-epsilon is one of the most common models used for turbulence models. K-epsilon has two transport equations which represent the turbulence flow properties which mean it is a two equation model. The transport variable has two, the turbulent kinetic energy and turbulent dissipation.

K-EPSILON

For turbulent kinetic energy k

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + P_k + P_b - \rho\epsilon - Y_M + S_k \qquad 2.1$$

For dissipation ϵ

$$\frac{\partial}{\partial t}(\rho\epsilon)+\frac{\partial}{\partial x_i}(\rho\epsilon u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\epsilon}\right)\frac{\partial\epsilon}{\partial x_j}\right]+C_{1\epsilon}\frac{\epsilon}{k}\left(P_k+C_{3\epsilon}P_b\right)-C_{2\epsilon}\rho\frac{\epsilon^2}{k}+S_\epsilon \quad 2.2$$

The k-epsilon that were using in CFD for this study is called the renormalized group k-epsilon. Yakhot and Orszag are the first to investigate the renormalized group analysis of turbulence in 1986. In 1992, by removing the smallest scales of turbulence, a turbulence model was developed that gives improvement in modeling turbulence at high Reynolds number (Schleicher, 2012).

2.3 HISTORY OF ARCHIMEDEAN SCREW

The screw pumps we are using today were to be the oldest pumps for the carrier of water. In the 3rd century, Archimedes, the Greek mathematician and physicist, invented the original screw pump.He named it upon his name called the "Archimedian Screw". It was a hand operated, spiraled tube set at an incline. The main purpose of the screw is to carry the water from lower part to upper part.

In the 4th century, the Romans started to use the water supply systems. For this they applied the archimedian Screw in their highly advanced systems.The Romans also used the archimedian screw pumps for irrigation and drainage work. Screw pumps also found use in ore mines in Spain.Before the Archimedes screw is employed, the Roman’s driven man and animals to run the system.

In the 14th century, screw pumps reappeared as a means of conveying liquid and constituted the first rebirth of Archimedes' ancient pump. Historical records refer to its use with artificial fountains. This rebirth was short-lived with the development ofreciprocating plunger pumps which had their heyday during the 19_{th} century and were used in the development of public water supply systems. Reciprocating plunger pumps were later replaced with centrifugal pumps.

Screw pumps with their ability to pump relatively large quantities of water at low lifts still found one obvious application as adrainage pump in low-lying areas, such as the reclaimed land areas of the North Sea and Baltic Sea. During this era the screwswere constructed of wood and were powered by use of wind force with windmills.

Present rebirth of the modern day screw pump dates back to the 1920's where their primary use was drainage pumps. In1930 there were some 300 screw pump installations in use in the Netherlands for draining low-lying ground. It wasn't until afterWorld War II that screw pumps were seriously applied for handling wastewaters. Since this time, their use has grown rapidly.

In present, the Archimedean screw is used to generate electricity from the fluid flow. The concept used is the reverse of the actual Archimedes screw, which is first used to lift water, from bottom to top.In the new era, the water flow downwards which means from top to bottom. The water flow is then rotates the screw blade where the kintic energy is thenconverted to electrical energy by using the generator (Berk, 2009).

2.4 TYPES OF HYDRO TURBINES

There are many types of hydro turbines. The type of turbine used for particular application depends on the head and flow rates seen by the turbine. Types of turbines commonly used in today’s world are Kaplan, Pelton and Francis turbines. Pelton turbines used for application at high head and Francis turbine at mid head.Kaplan and Archimedean screw used in the choice at low head. Figure below shows head, flow rate and power output that can be generate by each hydro turbines.

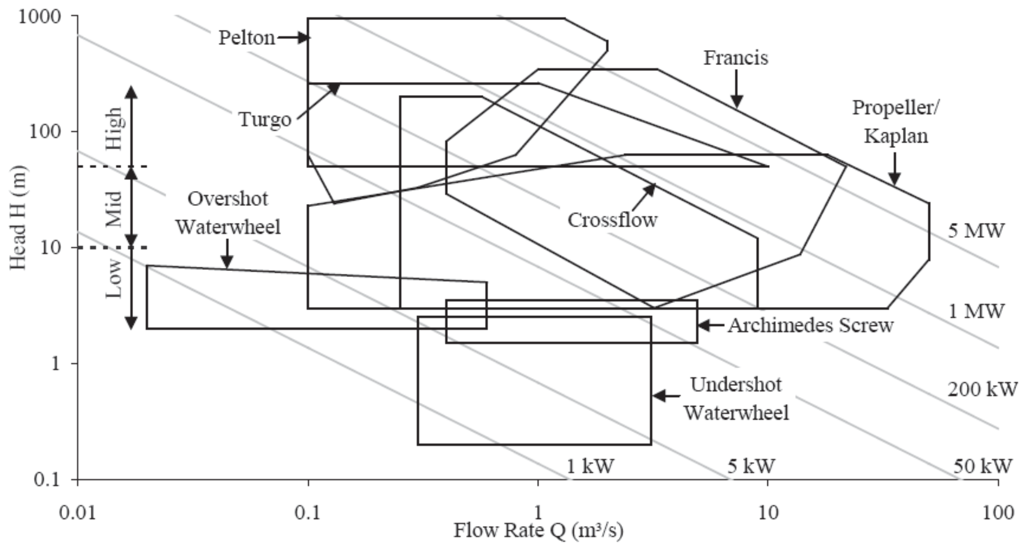


Figure 2.2 : Hydropower turbine application range chart

Source: Stergiopoulou et al., 2009

2.5 ADVANTAGES OF USING ARCHIMEDEAN SCREW

There are many advantages in using Archimedean screw as hydrodynamic screw. The most important features are :

2.5.1 High efficiency

Because of the flat efficiency curve the efficiency is high in a wide range of flows. Varying flowsand water heads have a small influence on the efficiency. The archimedean screw generator does not need a grease pump for the lower bearing which further increases efficiency (Babcock, 2010).

2.5.2 Simple and Reliable

The Archimedean screw generator, consist of a few wear parts. The screw generator has a low rotational frequency resulting in low wear. Since its not complex it is not hard to handle and can last for a longer time (Babcock, 2010).

2.5.3 Fish Friendly

Several test showed the fish friendliness of the Archimedean screw. In Holland, Canada, USA and other countries the Spaans Archimedean screw is used as a fish ladder by pumping fish (Babcock, 2010).

2.5.4 No screen is necessary

Only a simple 100-120mm bar screen is used to prevent large items enters the screw generator. This saves costs, prevent head loss and allow fish passage (Babcock, 2010).

2.5.5 Low Maintenance

Due to the simple and robust design, Archimedean screw generator installations require minimum maintenance (Babcock, 2010).

2.5.6 No Cleaning Service Required

Cleaning of the screw generator is not necessary. The generator is self-cleaning. No efficiency loss due to dirt builds up in the intake area (Babcock, 2010).

2.6 TYPES OF TROUGH FOR ARCHIMEDEAN SCREW

The Archimedean screw generator can be supplied with various trough types. The choice is depending on the existing civil structure. Below the two most common types are shown. The choice can also be a combination because every unit can specifically be designed to suit existing civil layouts.

2.6.1 Concrete Trough

The trough is in this case made out of concrete, by using the screw to form it's own trough. The concrete trough is the classic design. A trough roughly 50 mm larger than the outer diameter of the screw pump body is initially formed. After completion of installation of the screw and grouting of the bearings and drive base plates the required trough diameter is obtained by rotating the screw with a temporary screed bar fitted, slowly rotating and applying a concrete screed until the correct trough profile has been achieved. Figure 2.3 are example of Concrete trough (Babcock, 2010).

Figure 2.3 : Concrete Trough

Source: Spaans Babcock, 2010

2.6.2 Steel Trough

In certain circumstances the construction of a screwed concrete trough is not practical and a prefabricated steel trough liner can be provided. Anchors are attached to the back side of the trough and after positioning and fixing of the trough mass concrete is applied to form the final construction. Both the concrete trough and steel trough liner options require the provision of a separate drive mounting. This trough construction gives a medium amount of civil costs but a little higher mechanical cost. Figure 2.4 below show the examples for steel trough (Babcock, 2010).

Figure 2.4 : Steel Trough

Source: Spaans Babcock, 2010

2.7 HEAD AND FLOW

Wherever there is a flow of water falls from a higher level to a lower level, hydraulic power can be generated. This may occur where a stream runs down a hillside, or a river passes over a waterfall or man-made weir, or where a reservoir discharges water back into the main river. The vertical fall of the water, known as the “head”, is essential for hydropower generation; fast-flowing water on its own does not contain sufficient energy for useful power production except on a very large scale, such as offshore marine currents. Hence two quantities are required: a Flow Rate of water Q, and a Head H. It is generally better to have more head than more flow, since this keeps the equipment smaller. The Gross Head (H) is the maximum available vertical fall in the water, from the upstream level to the downstream level. The actual head seen by a turbine will be slightly less than the gross head due to losses incurred when transferring the water into and away from the machine. This reduced head is known as the Net Head. Sites where the gross head is less than 10 m would normally be classed as “low head”. From 10-50 m would typically be called “medium head”. Above 50 m would be classed as “high head”. The Flow Rate (Q) in the river, is the volume of water passing per second, measured in m3 /sec. For small schemes, the flow rate may also be expressed in litres/second where 1000 litres/sec is equal to 1 m^3/sec (The British Hydropower Association, 2005).

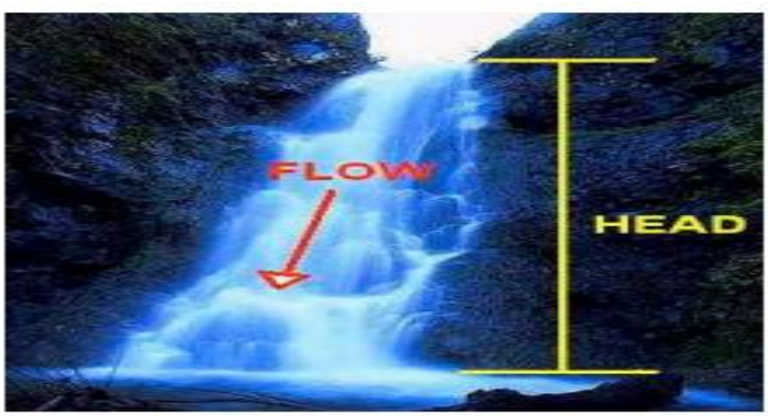


Figure 2.5: Head and Flow of a river

Source: The British Hydropower Association, 2005

2.8 EXTERNAL PARAMETERS

The external parameters determine how much water is to be lifted and usually determined by the location of the screw blade. External parameters are the outer radius, length and slope. This parameters determined the performance of the screw.

2.8.1 Outer Radius

The outside diameter, D of the screw pump in combination with the diameter of the centre tube are essential factors for the capacity of the pump. For long screw pumps a larger centre tube will be required to control the deflection, but this will have an effect on the effective capacity (Gerald Muller, Simplified Theory, 2009).

Outer radius of the screw blade determines the size of the screw. The larger the screw, the larger the volume of water that it can pass and the greater the quantity of energy that it can generate. The diameter of the screw play an important role in determines the rotational speed of the screw runner. The smaller the screw blade, the higher the rotational speed rpm (Kibel et al., 2011).

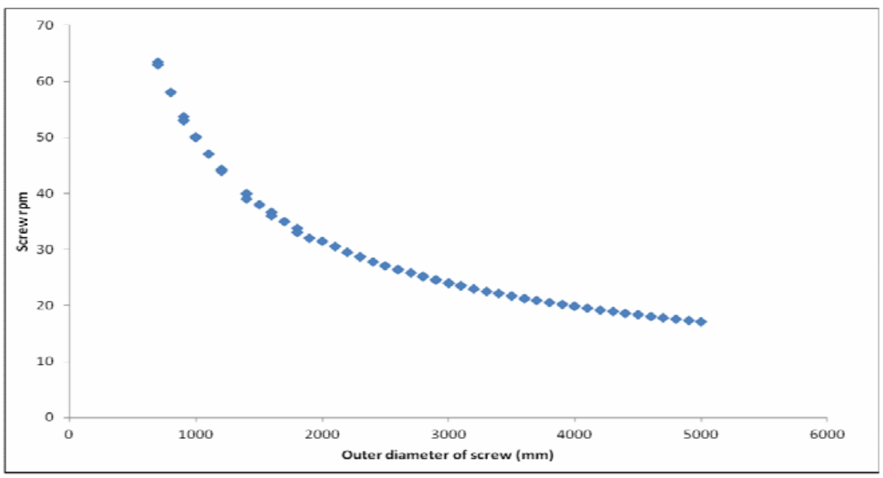


Figure 2.6 : Relationship between screw diameter and rotational speed rpm of a screw turbine

Source: Kibel et al., 2011

2.8.2 Orientation Angle

The angles play the main role in determining the efficiency of the screw blade. The main factor that rotates the screw blade is the weight of the water. When the water flow down through the screw blade, the gravitational force which exert on the water pull the water down causing the weight of the water rotates the screw blade.Based on theory, been stated that the efficiency of the screw blade increases as the angle decreases (Muller, 2009).

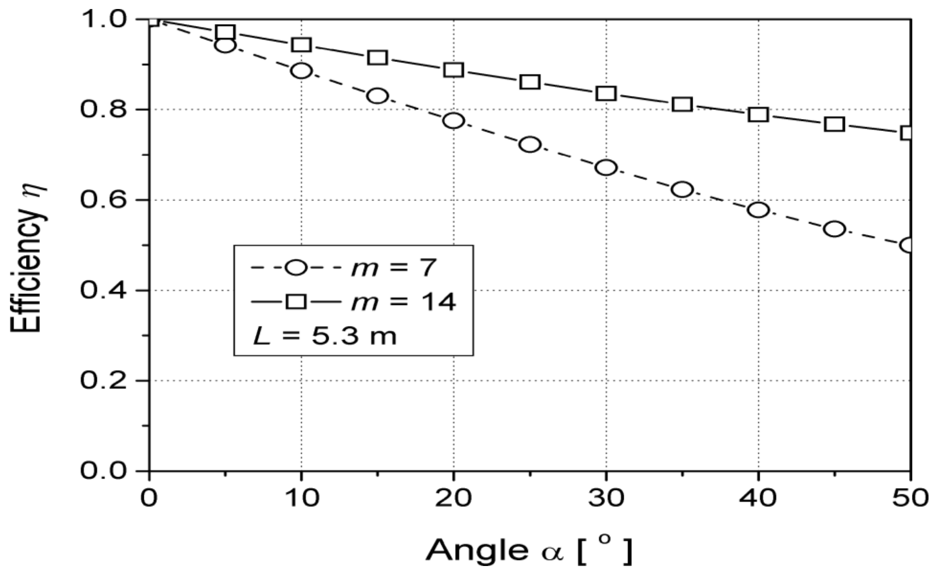


Figure 2.7 : Efficiency of screw runner against orientation angles

Source: Muller, 2009

From Journal of Environmental Science and Engineering 2012, stated that the best orientation angle for Archimedean screw is between 22^o and 33^o. In this angle the efficiency of the screw blade is assume to be high.

The figure 2.8 below shows the outer radius, D, the length, L, inner radius, D_H, height, H, and the orientation angle which is α .

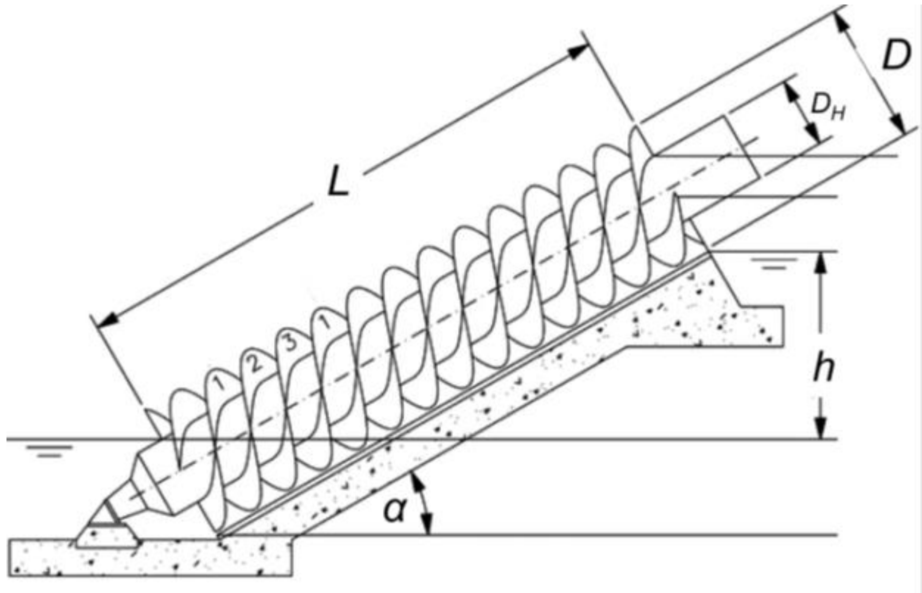


Figure2.8: Parameters of a screw blade

Source: Muller, 2009

2.9 INTERNAL PARAMETERS

The internal parameters defined as the inner radius, number of blades and pitch of the blades. Internal parameters are free to be chosen as in order to optimize the performance of the screw runner.

2.9.1 NUMBER OF BLADES

The number of blades determines the number ofchannels through which the material can flow in the screw blade. With an increase in the number of blades, a greater volume of water flows into the screw blade. This increases the pressure of the material in the screw blade and consequently increases the volume dispensed (Santos et al., 2000).

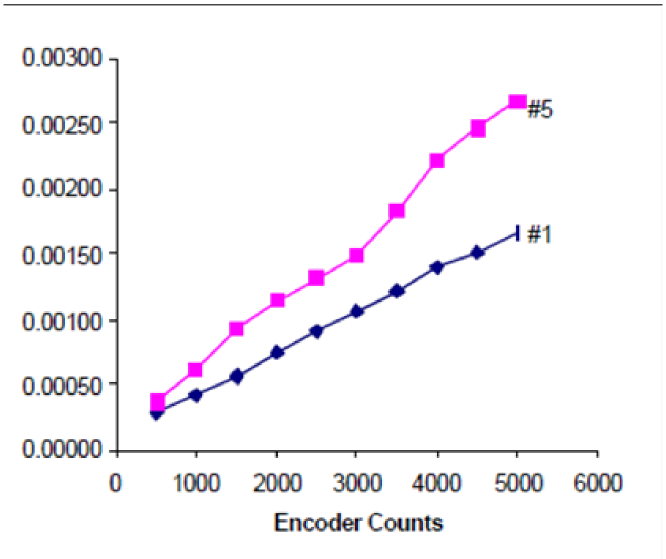


Figure 2.9 : Effect of number of blades on weight of water

Source: Santos et al., 2000

With more blades on the screw runner, higher volume of water can be handled and greater quantity of energy can be generated. The journal also states that there is a particle operational limitation between the interaction of the outer radius and number of blades. Figure 2.7 below shows the relationship between the screw size and rotational speed rpm of a screw runner for 3, 4 and 5 blades (Kibel et al., 2011).

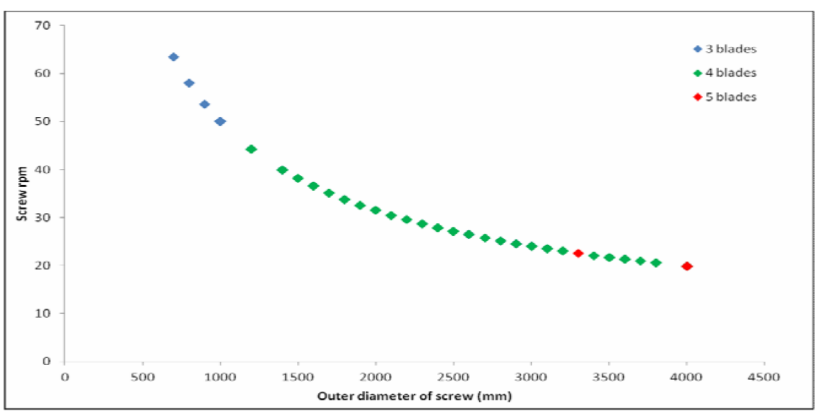


Figure 2.10: Relationship between screw diameter and rotational speed rpm of a screw turbine for number of blades at 3, 4 and 5

Source: Kibel et al., 2011

2.9.2 Pitch Of Blades

The pitch is another parameter which will affect the capacity of the pump.The present study on micro-pump showed different transient flow patterns when the screw pitch was modified. The screw has a diameter d and the pitch = $\pi d tan\theta$ where $\theta$is the helical angle and dis constant for all cases. When the screw pitch is increased, the pump requires less time to reach the steady state flow rate. This is due to the pressure gradient along the screw axis which increases with decreasing the pitch. The velocity of the fluid fluctuates, because the velocity decreases periodically as a result of the shape of the screw. Thus, the oscillations are high during quasi-steady state (Santos et al., 2000).

2.10 FISH TRIALS THROUGH ARCHIMEDEAN SCREW

Fish passage trials performed on Archimedean screwshave shown that no significant damageis caused to fish that enter and pass through these turbines. In the UK, this has beendemonstrated for salmonids naturally passing down an Archimedean screw and artificially introduced (Kibel, 2007; Kibelet al., 2008), (Kibelet al., 2008), coarse fish (Kibel, Coe and Pike, 2009) and lampreys (Luca, 2010).

In addition, studies performed in other countries have shown that Archimedean screws do not cause serious damage to fish passing through them (Spah, 2001; Vis Advies, 2007).

The first assessment of fish passage through Archimedes turbines was conducted by Spah (2001). The turbine tested had a diameter of 1.4 m and processed 615 litres of water per second. 158 fish of nine species were passed through the turbine and netted at the outflow. 4.4% of the fish suffered limited damage, mainly scale loss that was deemed to be minor and generally recoverable. Chub and roach were the only species to suffer any damage; eels that traditionally experience problems passing through turbines suffered no damage at all. Table 1 summarizes the results.

Table 1.1: Summary of results from Spah (2001), showing the number that passed through of each species and the lengths of fish affected, Kibel, 2011.

Species	No. Tested	Length Range (cm)	No. fish Injured	Injuries
Eel	22	36-58	0	
Grayling	3	20-36	0	
Brown trout	31	8-35	0	
Perch	19	14-18	0	
Chub	63	8-43	5	Scale loss, haematoma
Gudgeon	8	12-14	0	
Bullhead	3	11-14	0	
Dace	1	21	0	
Roach	8	16-21	2	Scale loss, haematoma

2.11 PROBABILITY OF DAMAGE OCCURING

The chance of fish contacting the leading edge increases with the rotational speed of thescrew, although not necessarily with the number of blades. This increase in rotational speed is typically also accompanied by a reduction in the size of the screw. In terms of the tip speed of the leading edge, this reduction in size compensates for the increase in rotational speed, such that smaller screws with high rotational speeds have slower maximum tip speeds than larger screws with low rotational speeds.This relationship means that while the probability of a fish contacting the leading edge is higher for a small screw, the likelihood of physical damage occurring is reduced, due to their lower tip speed. Tip speed has previously been shown to be a key determinant of whether injury occurs when a fish is struck by a turbine blade (Turnpennyet al., 2000; Ploskey and Carlson, 2004).

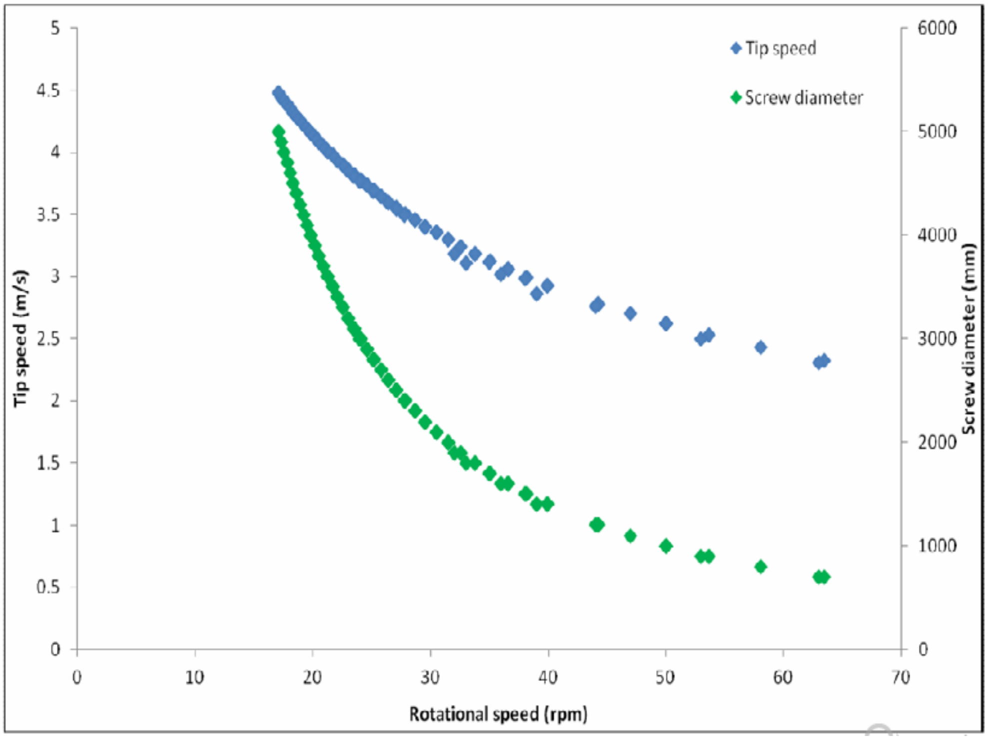


Figure 2.11: Tip speed of a range of commercially available Archimedean screw turbines, depending on screw diameter and rotational speed

Source: Kibel, 2011

2.12 MATHEMATICAL MODEL

Governing equations

The equations of continuity, momentum at steady state can be written as follows described by :

- Continuity equation ***:***

$$\tilde{V} \text{ x } u = 0 \qquad 2.3$$

- Momentum equation ***:***

$$\tilde{V} \text{ x } \rho uu = \tilde{V} \text{ x } (\mu_{eff} \tilde{V}) - \tilde{V}_p + S \qquad 2.4$$

- The transport equations for κ and ε are

$$\tilde{V} \text{ x } (\rho \text{ u} \kappa) = \tilde{V} \text{ x } (\frac{\mu_{\text{eff}}}{\sigma_{\text{k}}} \Delta \kappa) + G - \rho\varepsilon \tag{2.5}$$

$$\tilde{V} \text{ x } (\rho \text{ u} \varepsilon) = \tilde{V} \text{ x } (\frac{\mu_{\text{eff}}}{\sigma_{\varepsilon}} \Delta\varepsilon) + (C_1 G - C_2 \rho\varepsilon) \frac{\varepsilon}{\kappa} \tag{2.6}$$

Where C_1 = 1.44, C_2 = 1.92, σ_{κ} =1.0, σ_{ε} =1.3.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The project will analyze the effect of blade and slope on the fluid flow of the screw blade using Computational Fluid Dynamic (CFD).CFD will be used to analyze the fluid flow of the screw blade. This software will make the objectives to be achieved successfully. To solve all the problem, first thing to do is to determine all the flow works with the duration oftime, the Gantt chart and flow chart is a recommended method to use. It is important so that all the flows work with the description of task carried out to meet the date line.

First, a rough sketch of screw blade is done. Then the screw blade is designed in solidwork, CAD. The actual dimension of the screw blade is taken from other researchers study. The design is then generate into CFX Ansys FLUENT to do meshing and run the simulation to obtain results.

3.2 FLOW CHART

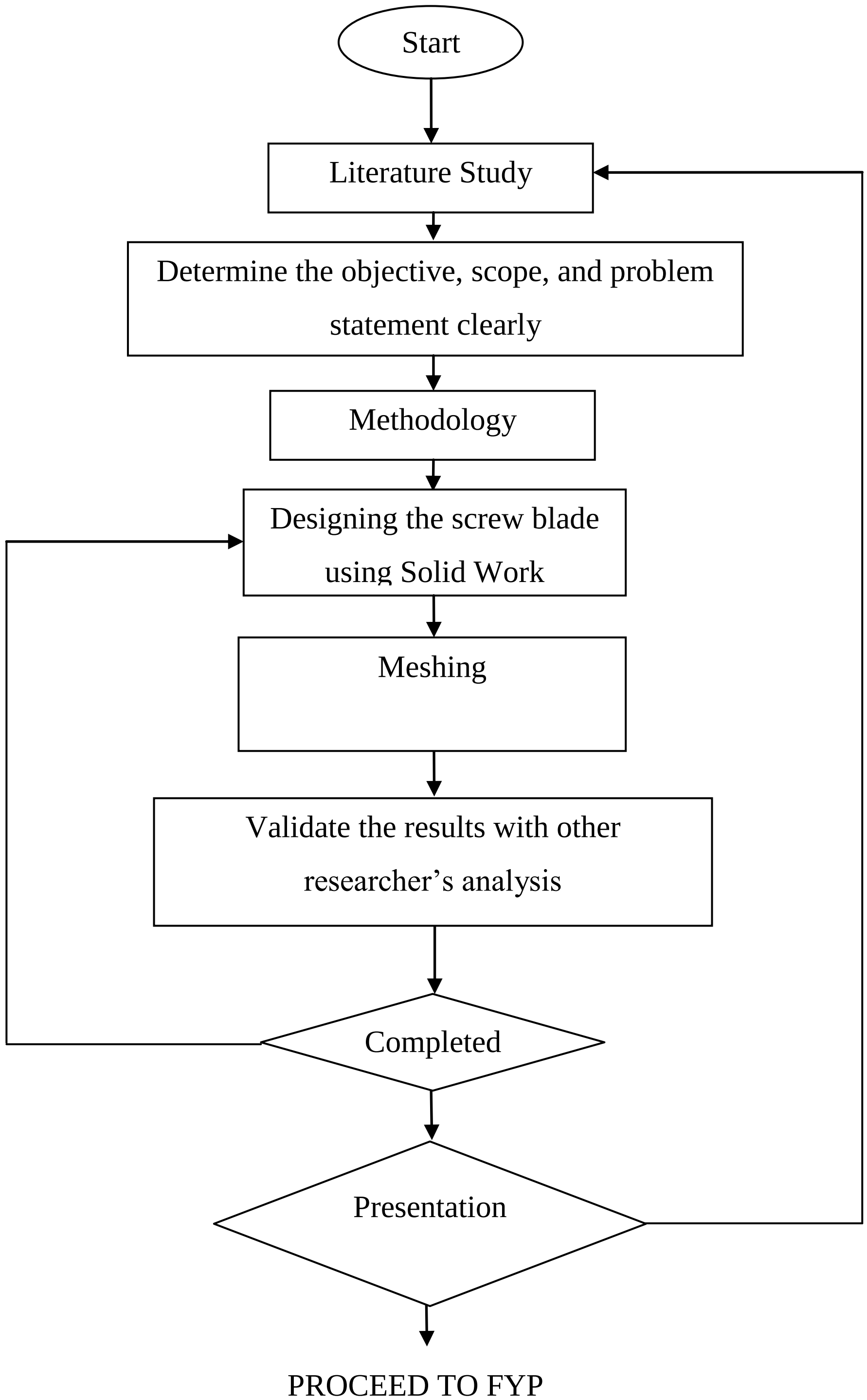


Figure 3.1: Methodology flow chart for FYP 1

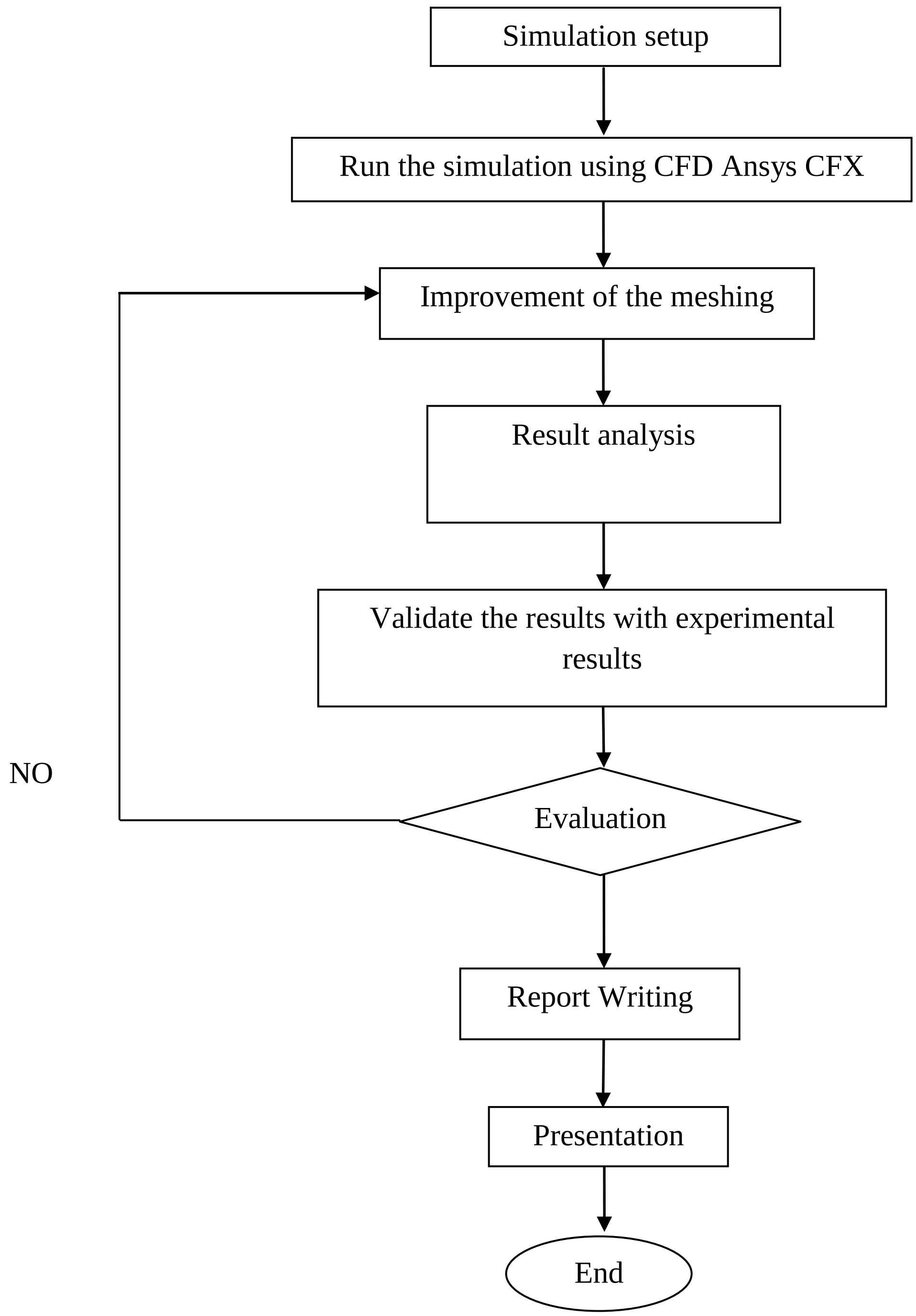


Figure 3.2: Methodology flow chart for FYP 2

3.3 GEOMETRY GENERATION

Geometry generation is usually carried out by using Solid Work or Computer Aided Design (CAD). In Solid Work, only the fluid flow region is constructed rather draw the whole picture. The domain should be solid and the flow region will be hollow. An Archimedean screw is drawn in Solid Work where the screw blade is extruded cut from a solid cylinder.

The enclosure for the screw runner is drawn in solid work and assembled with screw blade in CAD. The Boolean effect is used in geometry to identified the domain and the screw blade. Figure 3.1 and figure 3.2 shows how the domain and tool bodies is defined in CFD by using Boolean effect.

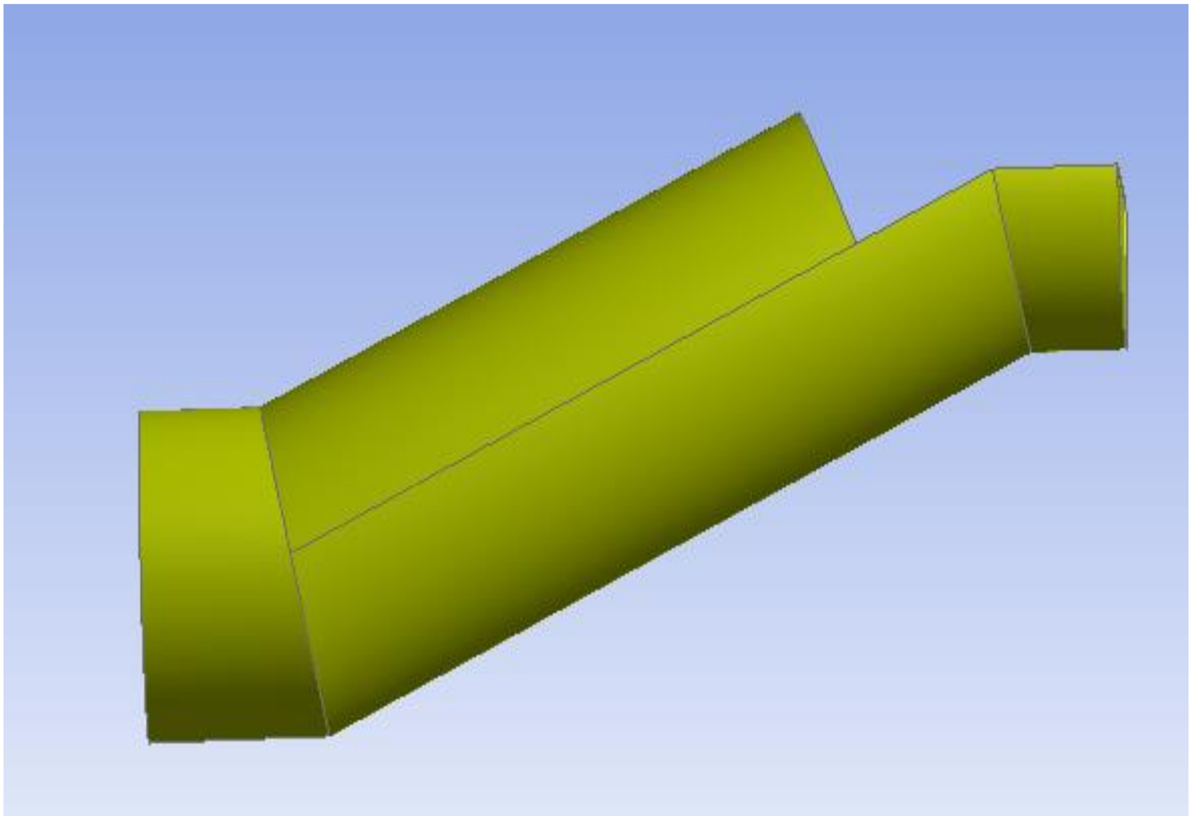


Figure 3.3 : Target Bodies

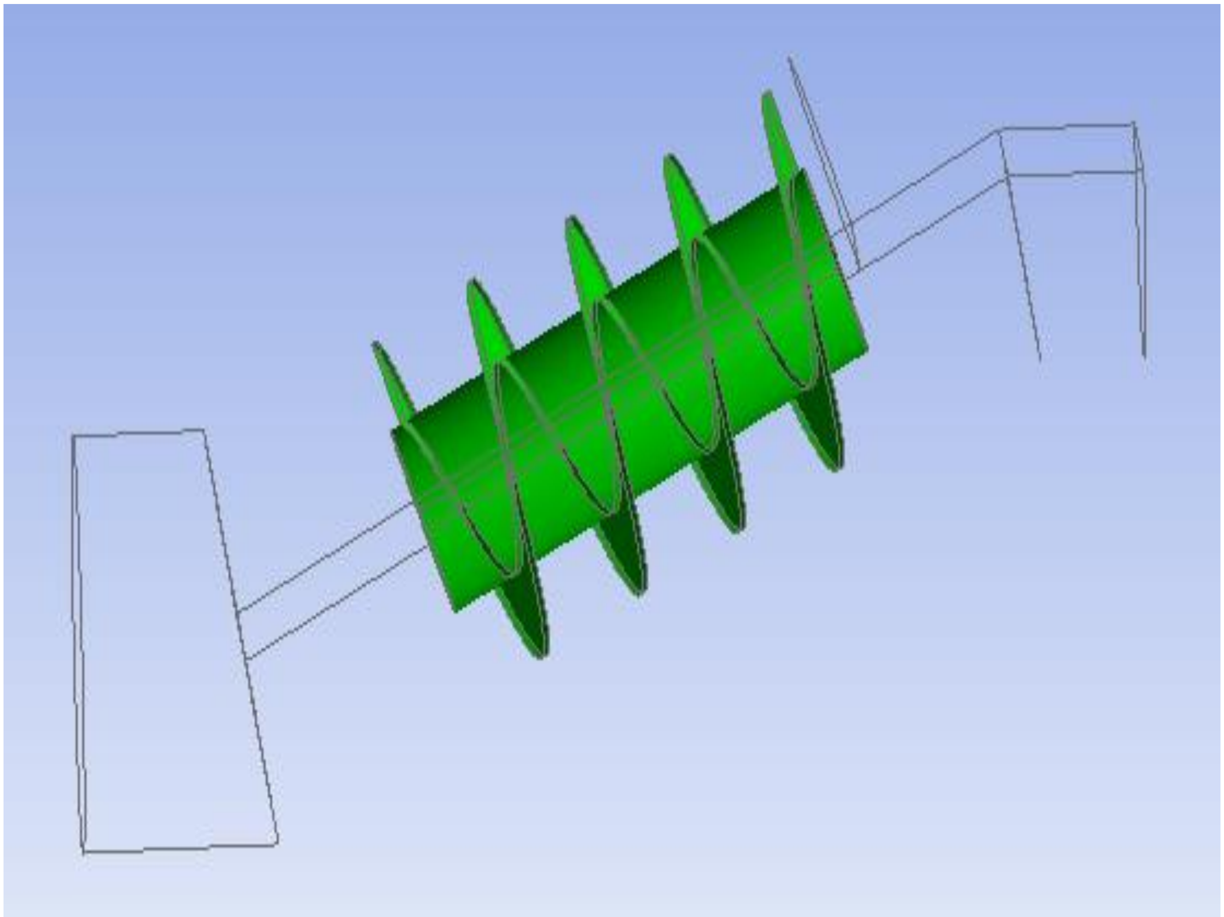


Figure 3.4 : Tool Bodies

3.4 SOLID WORK DESIGN

Solid work designs for different orientation angles and angles between blade. In this research, the performance of the screw blade is analyzed by using different angles between the blade and different angles with the horizontal.

3.4.1 Angle between blade (Angle of attack)

Figure 3.5, 3.6 and 3.7 are pictures of screw blade with different angle of attacks. Solidwork is used to draw the screw blade with different angles. The performance of the screw with different angles is then analyzed using CFD.

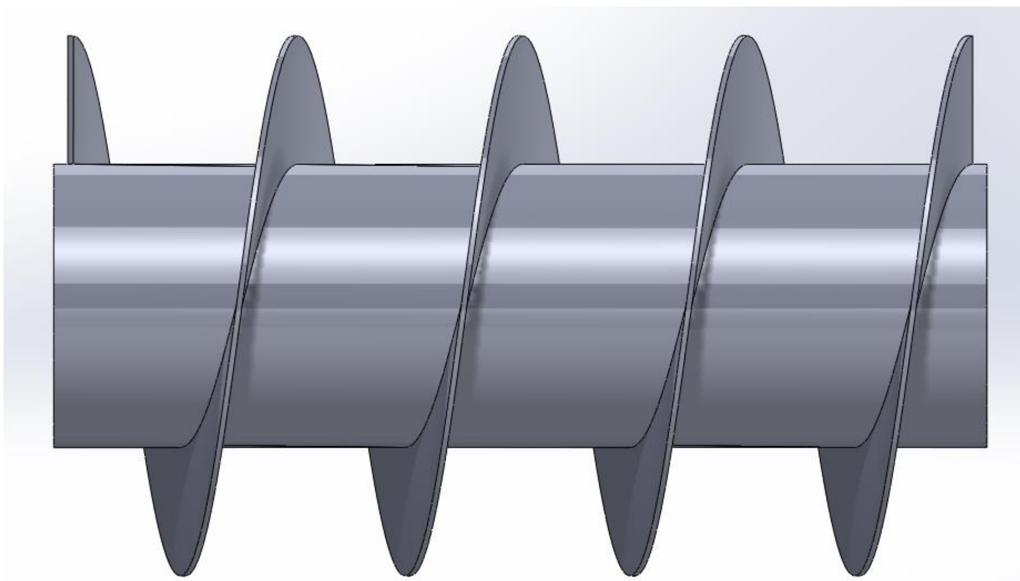


Figure 3.5 : Screw blade with an angle of 90^o

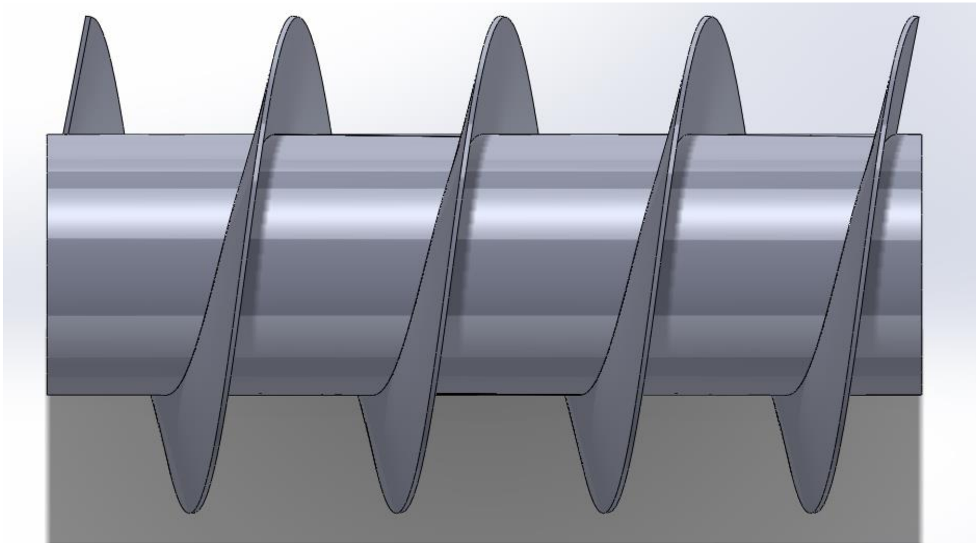


Figure 3.6 : Screw blade with an angle of 80^o

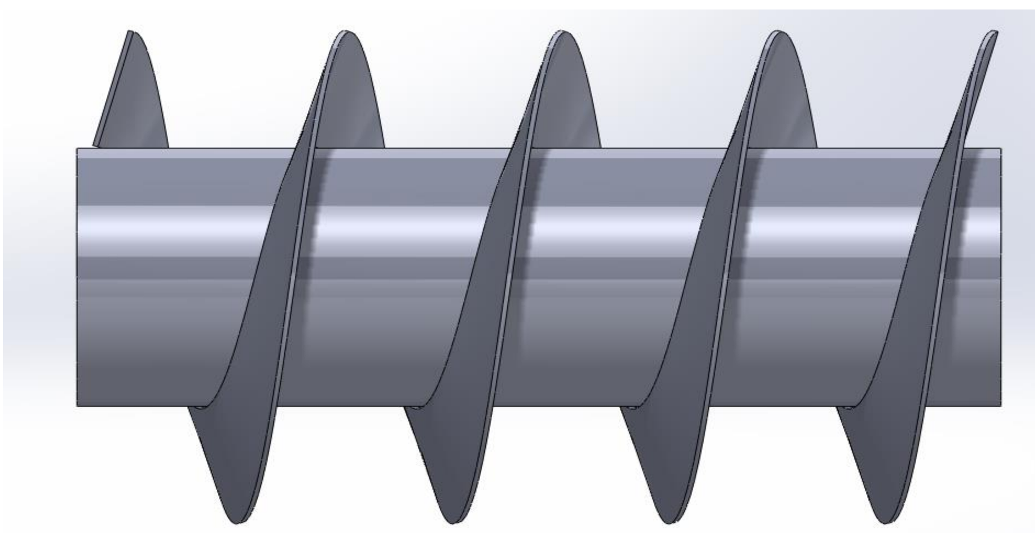


Figure 3.7 : Screw blade with an angle of 75^o

3.4.2 Orientation angle (Angles between screw blade and horizontal)

Figures 3.8, 3.9 and 3.10 shows the screw runner with different orientation angle, α. The orientation angle is very important as it determines the efficiency of the screw runner. The efficiency of the screw runner decrease as the orientation angle, α of the screw runner increase.

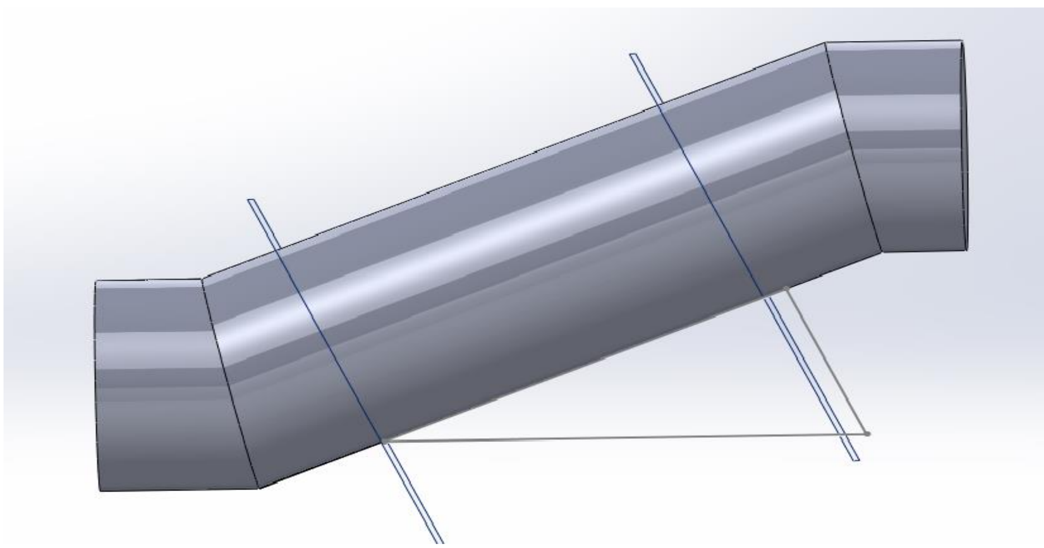


Figure 3.8 : Screw blade with an orientation angle of 23.58^o

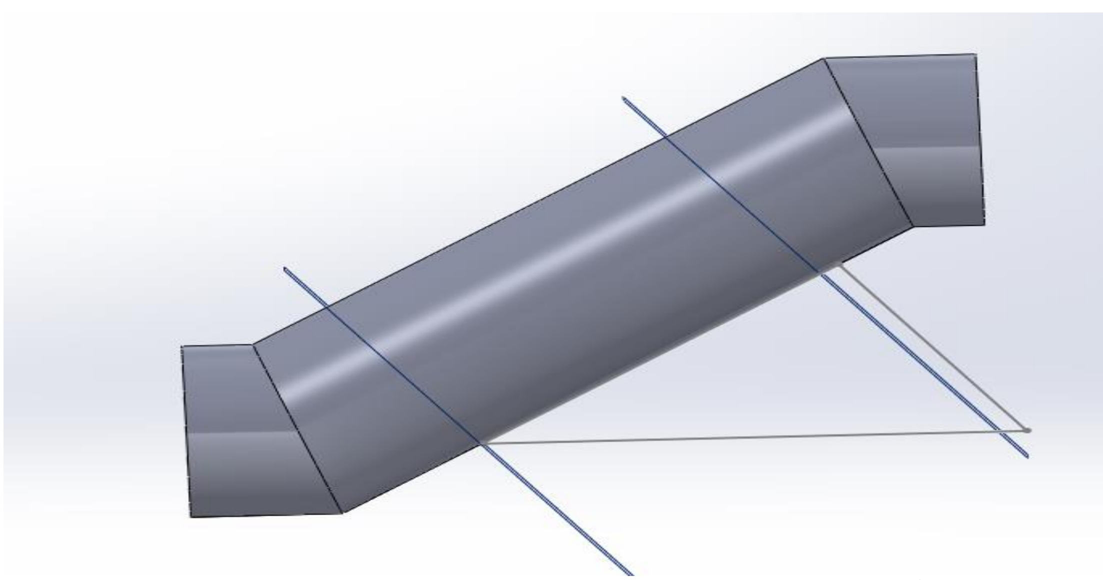


Figure 3.9 : Screw blade with an orientation angle of 35^o

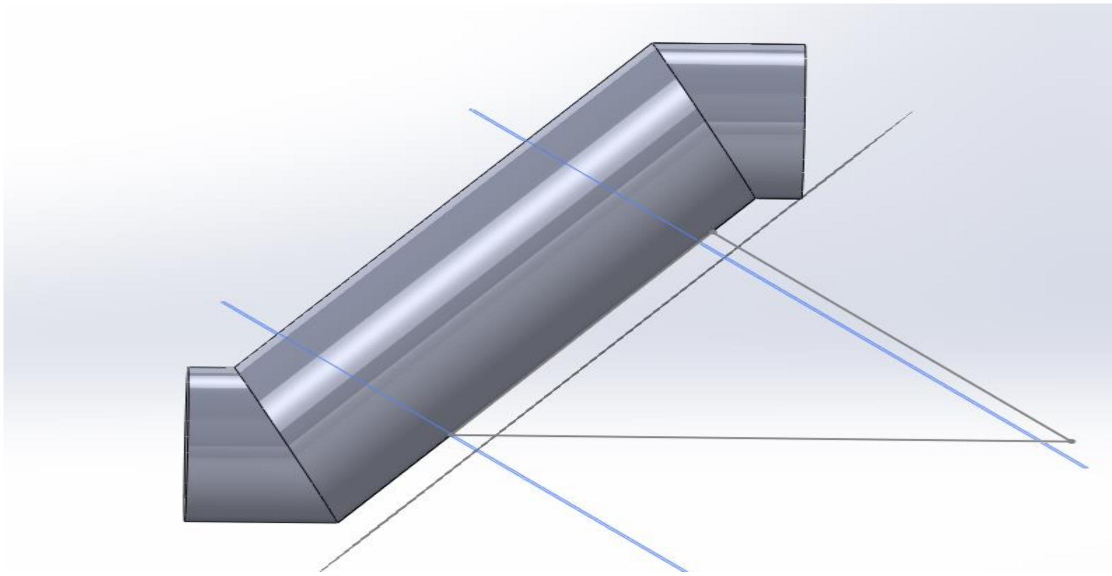


Figure 3.10 : Screw blade with an orientation angle of 50 ^{o}

3.5 MESH GENERATION

For the next step, Mesh is generated from the input geometry. CFD requires the number of smaller, non-overlapping sub domains to solve the flow physics within the domain geometry-results in the generation of a mesh (or grid) of cells (elements or control volumes) overlaying the whole domain geometry. Accuracy of CFD solution is governed by the number of cells in the mesh within the computational domain.

Figure 3.11 below shows the mesh generation of screw blade for orientation angle of 23.58^{o}. The mesh size used is "fine" where small cells will appear on the domain as shown.

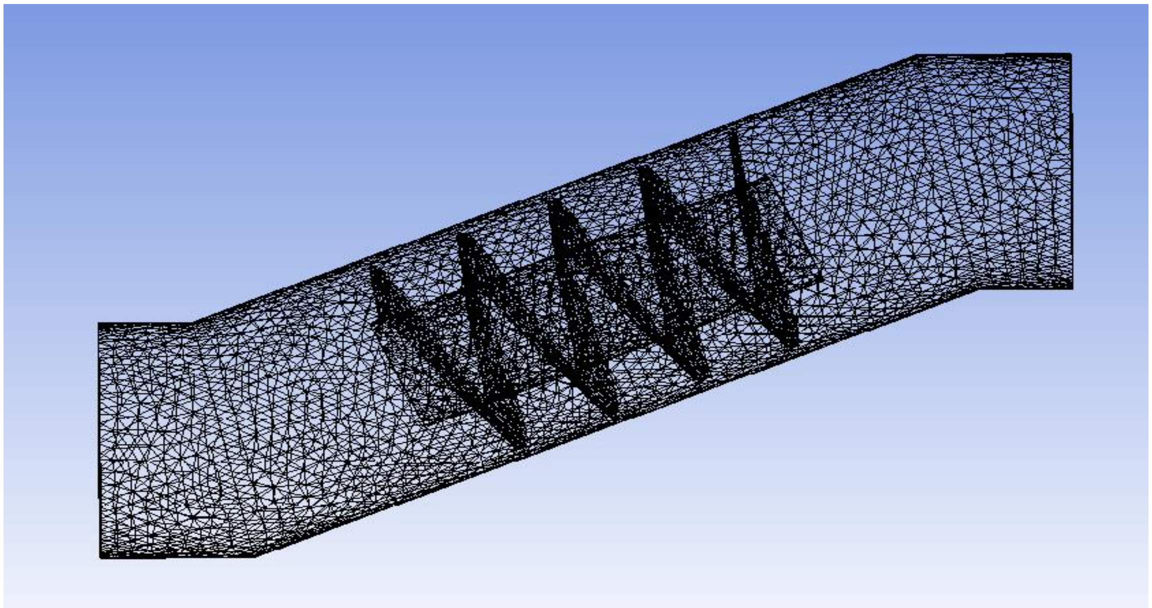


Figure 3.11 : Mesh view for the screw runner with orientation angle of 23.58^o

3.6 BOUNDARY CONDITION

The boundary condition is specified such as the inlet and outlet. Inlet is the entry or starting point for the fluid. Outlet is the exit for the fluid flow. The figure below shows the boundary setup for the screw runner.

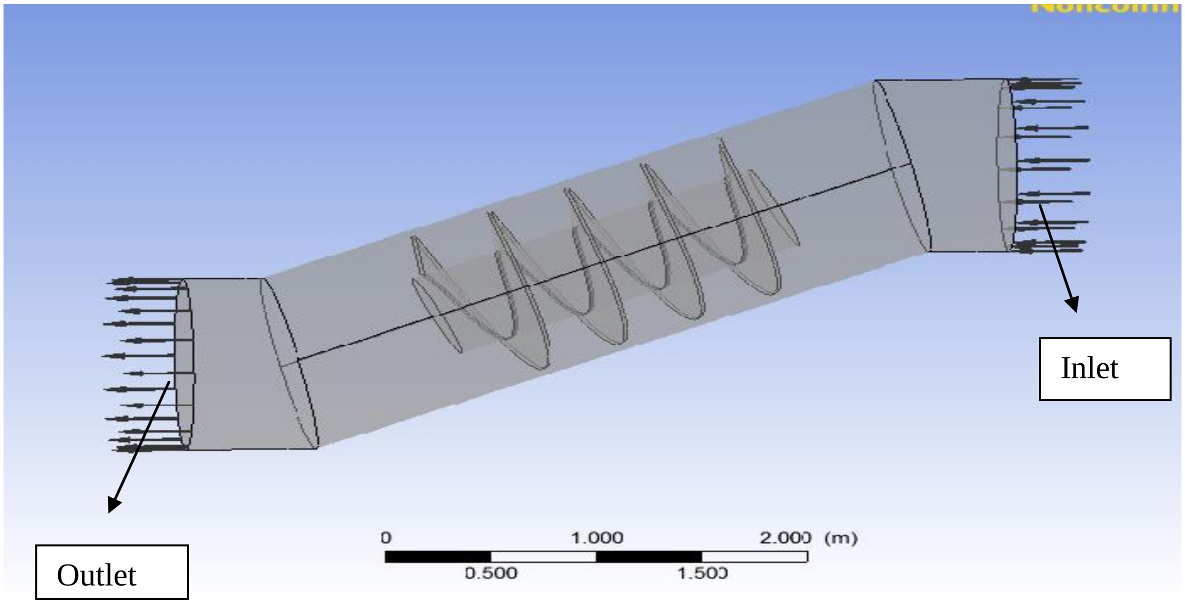


Figure 3.12 : Boundary setup of a screw runner

TABLE 3.1: Boundary Setup

PARAMERS	**UNITS**
DENSITY	1000 kg/m^3
DYNAMIC VISCOSITY	0.001 kg/m^{-1}
SPEED	2.4667 m/s^{-1}
OUTER DIAMETER	1100 mm
DIAMETER OF SHAFT	550 mm
LENGTH OF VERTICAL HELICAL	250 mm
PITCH OF BLADE	400 mm
NUMBER OF TURNS	4

A wall boundary is created for both shaft and blade of the screw runner. This boundary is created in order to calculate the force exerting on the shaft and blade. By calculating the force, the efficiency of the screw runner can be determine. The figures below shows how the region shaft and blade is chosen as the wall boundary.

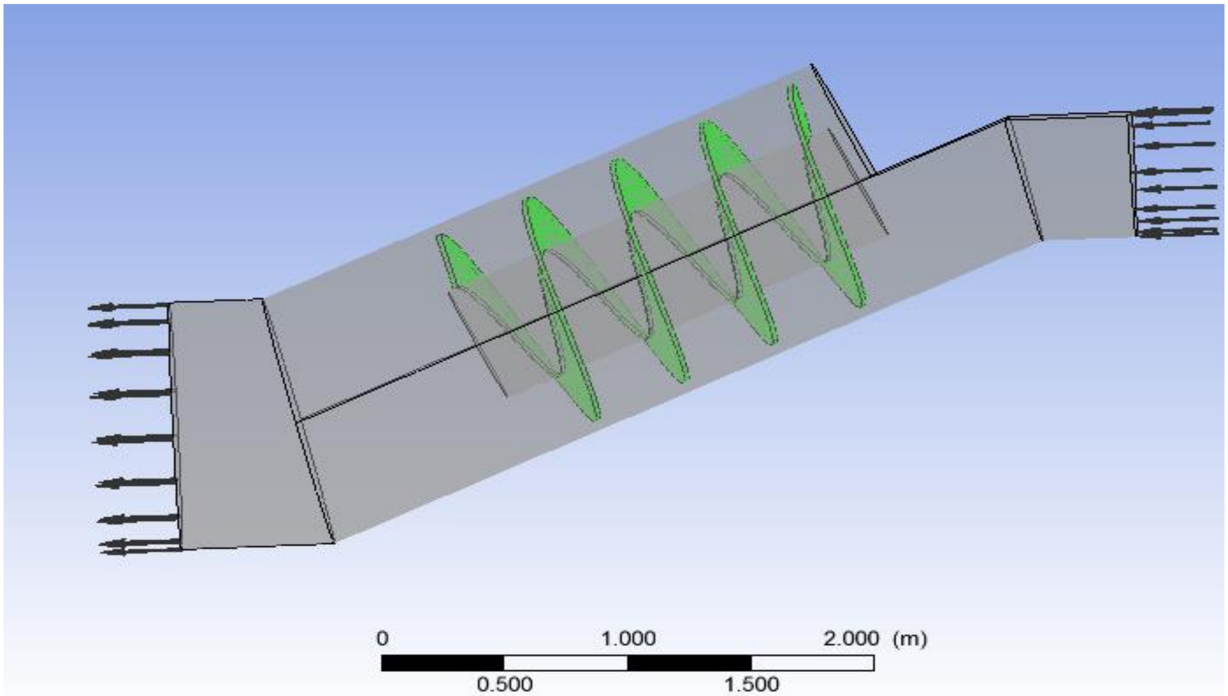


Figure 3.13 : Blade of the screw runner as wall boundary

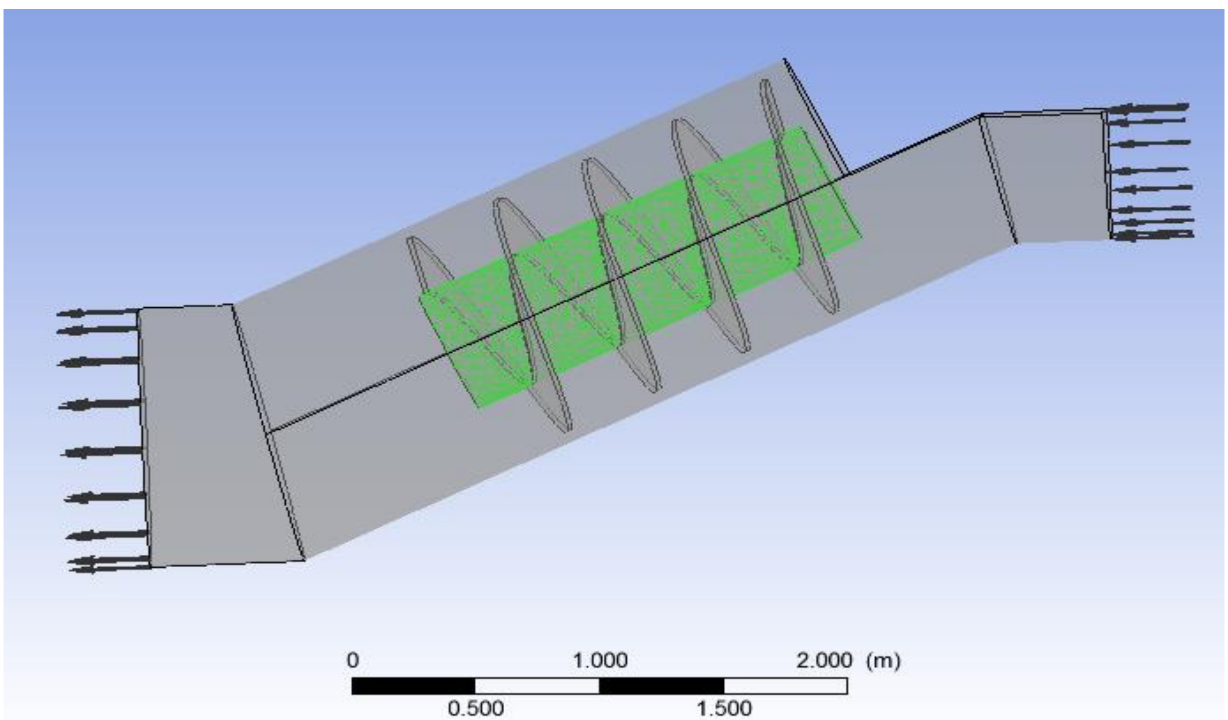


Figure 3.14 : Blade of the screw runner as wall boundary

3.7 SIMULATION

Once done with the setup part, next step is to run the simulation. The simulation is done using Ansys, CFX. Since the fine sizing is used in the mesh, it takes longer time to complete the simulation. A lot of simulation is done before the exact simulation is obtained. Each mistake was corrected before the results for the real simulation is obtained. For each trial simulation the number of iteration was increased each time running the new simulation. By increasing the number of iteration, more perfect results can be obtained. Each simulation was saved for further observation. Simulation with best results is then analyzed for further data.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

A study was conducted in this chapter to optimize the mesh and computational domain for a turbulence CFD analysis. This studies is very important and quite common in numerical field to prove the results for this simulation. In this chapter, the outcome of the simulation is presented. The effect of the orientation angle and angle between blades will be performed in this chapter. All the calculation has been done and shown in below. Best design is selected for each parameter out of three designs. A validation has been done to compare the obtained results with other experimental researcher.

4.2 VELOCITY OF THE FLUID FLOW

The velocity of the fluid flow will decrease as the water flow through the screw blade. The approach velocity to the screw is smaller than the inlet velocity. Velocity of the screw blade is calculated theoretically to find the efficiency of the screw runner. The figure 4.1 below shows the flow of the water and the changes in the velocity. The approach velocity V_1 is calculated.

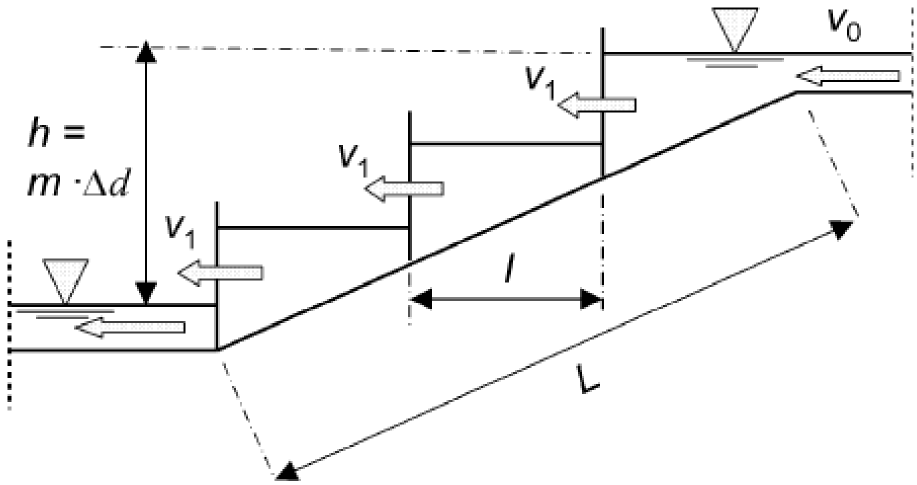


Figure 4.1: The velocity acting on the screw blade

Source: Muller, 2009

$$\Delta d = \frac{h}{m} \tag{4.1}$$

where Δd is the inner diameter of the shaft, h is the height and m is the number of rotation of the screw blade.

The approach velocity, V_1 :

$$V_1 = \frac{d_0}{d_0 + \Delta d} V_o \tag{4.2}$$

where d_0 is the inlet diameter and V_0 is the inlet velocity.

The initial velocity at the inlet of the screw blade is set to be 2.4667 m s^{-1}, which is the velocity of the Pahang river. For all the simulation, both the V_1 and V_o will be the same.

d_0= 575 mm

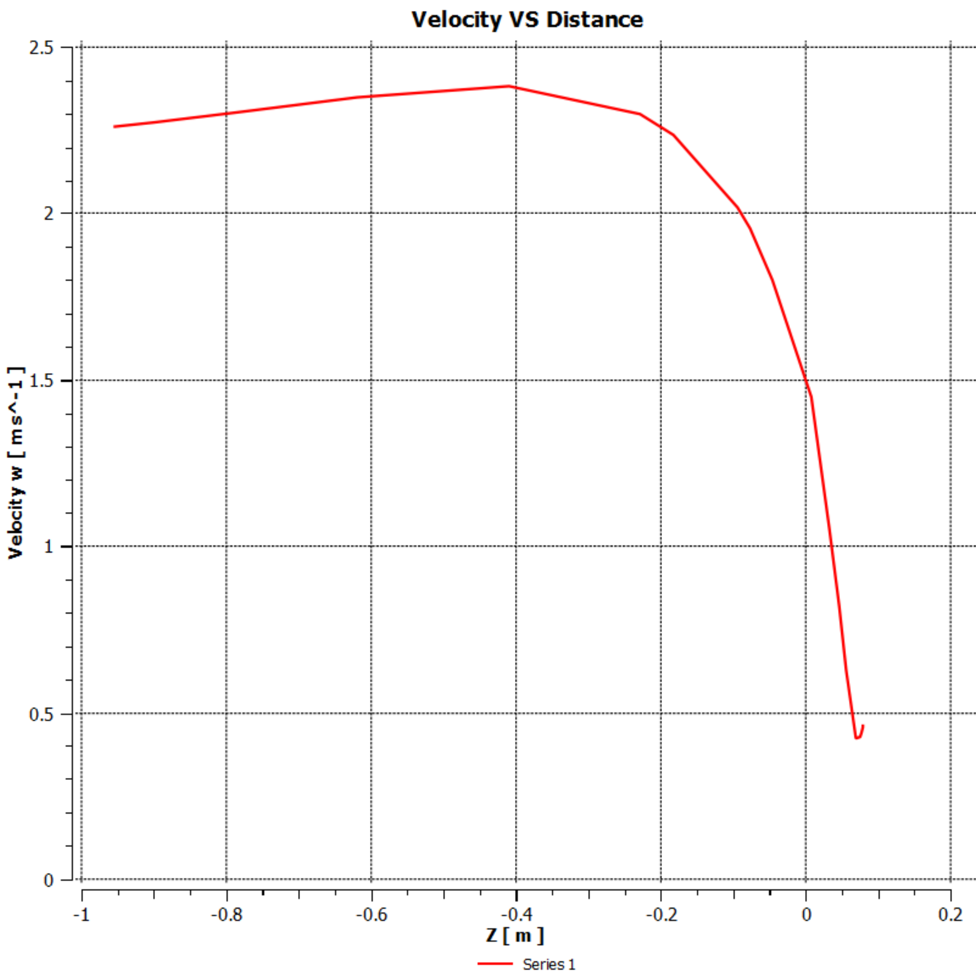
Δd = 525 mm

V_o = 2.4667 m s^{-1}

$V_1 = \frac{575}{575+525} 2.4667$

$= 1.2894\ m\ s^{-1}$

Graph below shows the velocity of the fluid flow through the screw runner. The velocity of the water decreases as going down the screw blade.



Graph 4.1: Velocity versus distance

4.3 FORCEOF THE SCREW BLADE

The force exerted on the screw blade is determined in order to calculate the efficiency of the screw runner. In CFD analysis, a wall boundary is created on the blade to find the exerting force. The force for a rectangular section of unit width is then determined by using CFD. Table 4.1 and 4.2shows the force exerted on the screw blade for each simulation according to the angles.

Table 4.1 : Orientation angle

Angle (Degree)	Force (N)
23.58	329.804
35	291.157
50	283.343

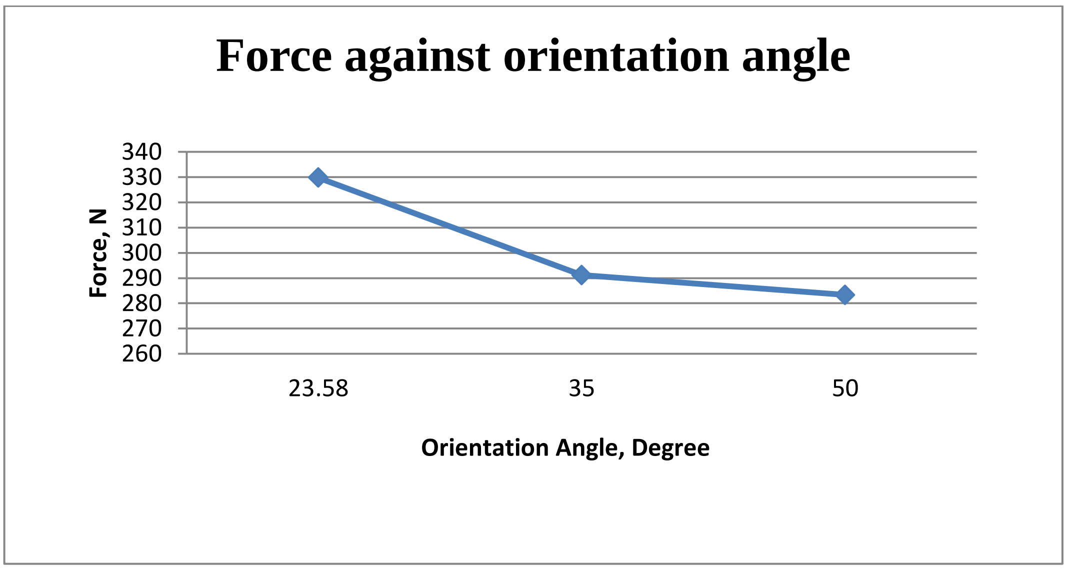


Figure 4.2: Graph shows force distribution for the various orientation angle

Table 4.2 : Angle between blade

Angle (Degree)	Force (N)
90	329.804
80	423.136
75	552.023

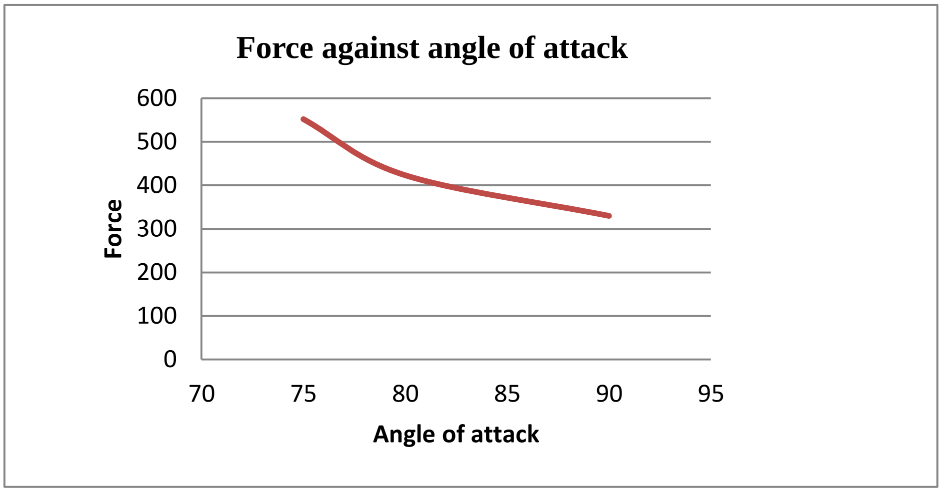


Figure 4.3: Graph shows force distribution for the various angle of attack

The force exerted on the screw blade is different for all the six simulation as the angles is different for all the designs except for the first blade for each category, the orientation angle and angle between of the blade is same to compare with other design.

4.4 HYDRAULIC POWER OF THE SCREW BLADE

Hydraulic power is also equivalent to the power input. The power input is same in all the simulation. The power input is generated by the water or the river flow as the water flow down through the screw blade. The power input generated is high than the power output. The power input is determine by using the following formulae ;

Power Input, $P_{hyd} = \rho.g.Q.h = \rho.g.d_0.V_0.m.\Delta d$ 4.3

Power Input, P_{hyd} = 1000 x 9.81X0.575x2.4667Xx0.525

= 7304.87

4.5 POWER OUTPUT OF THE SCREW BLADE

The power output is calculated using the force of the blade which determined from the simulation. The value of the power output is smaller than the power input. For micro hydro, the power output range is between 100-1000 kW. Table 4.3 and 4.4 below is the power output calculated for each design using the formula below.

$$P = F_{blade} . V_1 \qquad 4.4$$

Table 4.3 : Power output for orientation angle

Angle (Degree)	Power Output (W)
23.58^0	425.24
35^0	375.42
50^0	365.342

Table 4.3 shows as the orientation angles increases the power output decreases. The power output is depend on the force exerted on the screw blade. Power output is directly proportional to the force exerted on the screw blade. As the angle increases the tangential weight of the water exerting on the screw runner decreases.This cause a decrease in the force exerting on the screw blade and gives a lower power output.

Table 4.4 : Power Output for angles of attack

Angle (Degree)	Power Output (W)
90^0	425.24
80^0	545.59
75^0	711.79

Table 4.4 shows the power increases as the angle between blades decreases. This is because, as the angle decreases the screw runner will act as fast forward runner which will cause the velocity of the fluid increase. Not only that, the weight of the water exerting on

the screw runner is higher as the angle between the blades decreases. This cause a higher force acting on the screw runner and gives greater power output.

4.6 EFFICIENCY OF THE SCREW BLADE

Efficiency of a screw blade depends on the power output which obtain by rotating the blade. In this simulation the blade is assumed to be static and by calculating the force for different simulation the efficiency of the screw runner can be obtained for different parameters. Table below shows the efficiency which is calculated by using the equation 4.4.

$$\eta, Efficiency = \frac{P_{output}}{P_{hyd}} \qquad 4.4$$

Table 4.5: Efficiency for Orientation angle

Angle (Degree)	Efficiency
23.58	0.0582
35	0.0513
50	0.0500

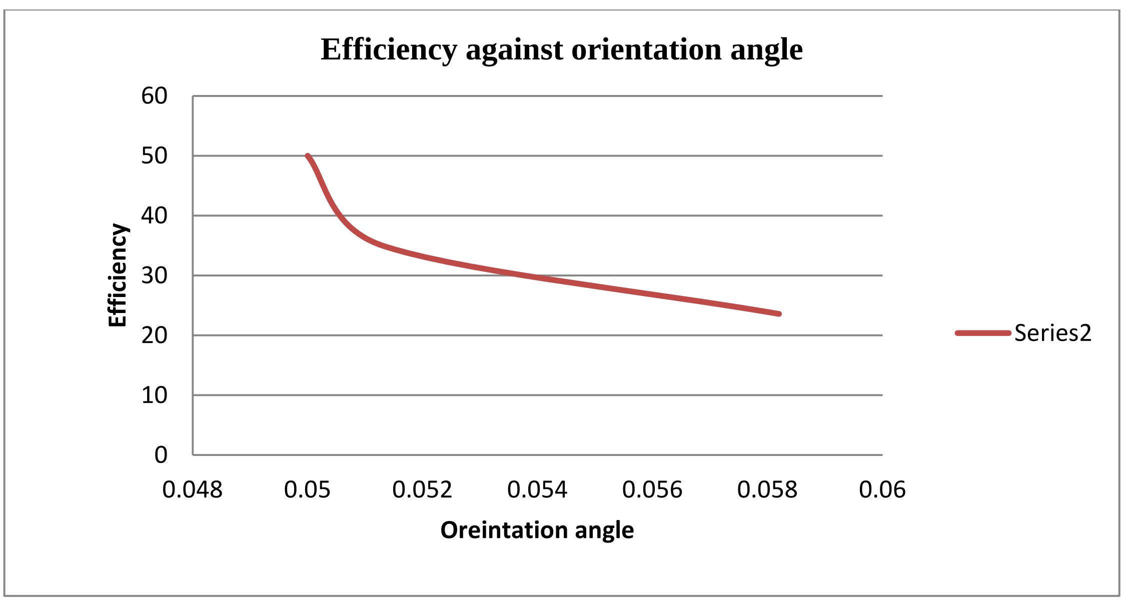


Figure 4.4: Graph shows efficiency for various orientation angles

Figure 4.5 shows the efficiency of the screw blade decreases as the orientation angle increases. The efficiency of a screw runner is depend on the power output of the screw runner and power output on the other hand is depend on the force exerted by the screw blade and directly proportional to the force. Since the force exerted is decrease as the orientation angle increases therefore the efficiency of the screw runner decrease as well.

Table 4.6: Efficiency for angle of atack

Angle (Degree)	Efficiency
90	0.0582
80	0.0746
75	0.0974

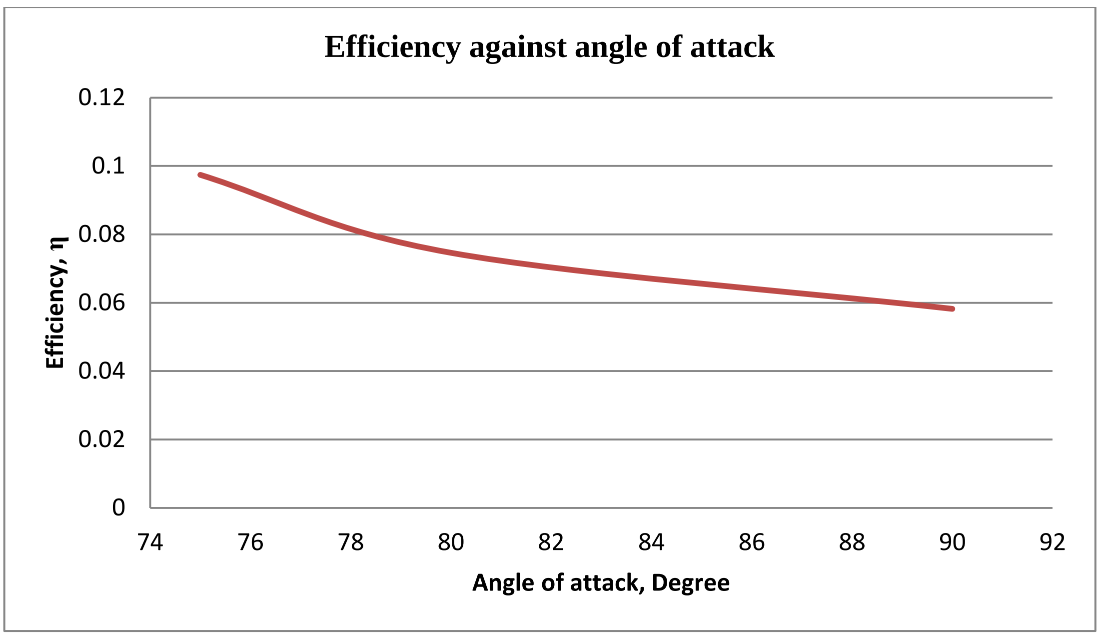


Figure 4.5: Graph shows efficiency for various angles of attack

The figure 4.6 shows graph efficiency against angles between the blade. As mentioned above the efficiency of the screw runner is mainly depend on the force exerted on the screw blade. For this case the efficiency of the screw runner increase as the angle decrease. This shows that as the angles decrease the screw runner change its behaviour as a fast forward runner from backward runner.

4.7 STREAMLINE PICTURE

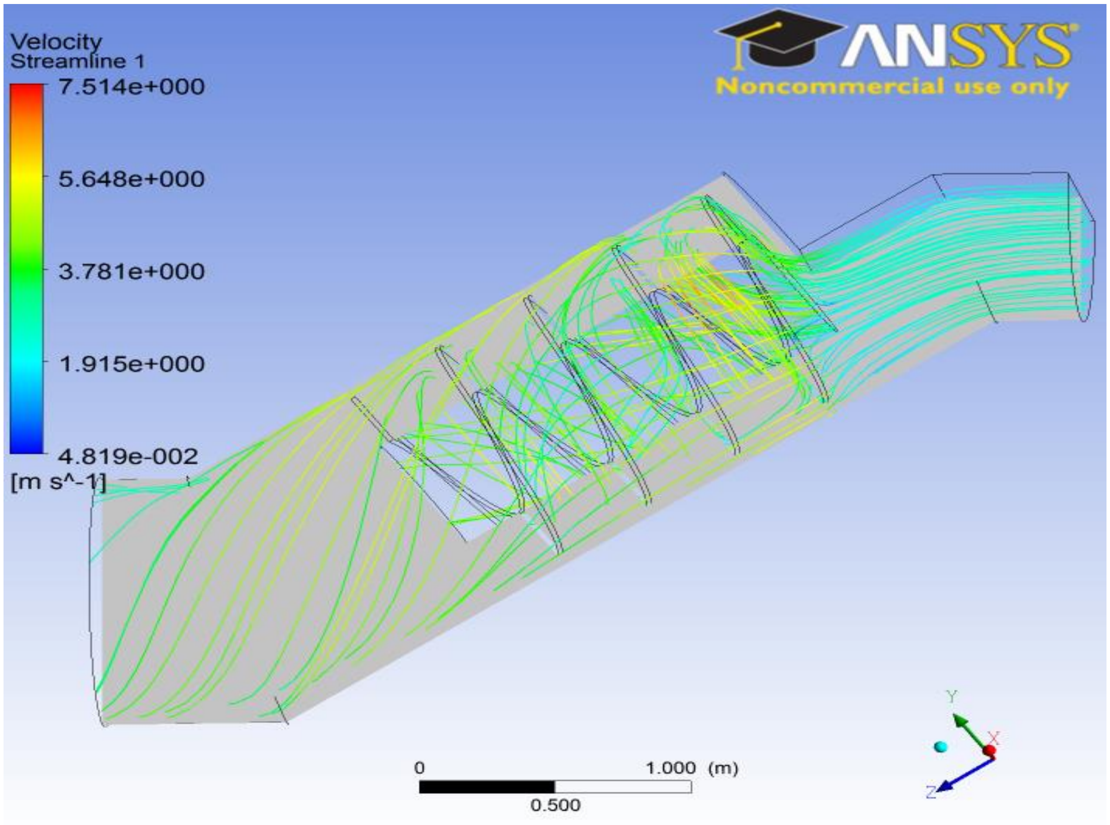


Figure 4.6 : Streamline Picture

Figure 4.7 shows a streamline picture from the simulation done using Ansys CFX. The flow of the water can be seen from the picture. The water enters from the inlet and pass through the screw blade by flow around the blades cause a force is exerted on the screw blades.

4.7 COMPARISON

Figure 4.4 shows that as the orientation angles increase the efficiency of the screw runner is decrease. From the simulation which had be done shows that the force of the screw blade which indicates the efficiency of a screw runner decrease as the angles increase. Hence the efficiency decreases. The theory also implies that in order to maintain higher efficiencies, the upstream water level should be kept constant and high compared with the radius. Shallower angles for the screw give higher efficiencies, although they result in a larger construction effort and causing higher costs.

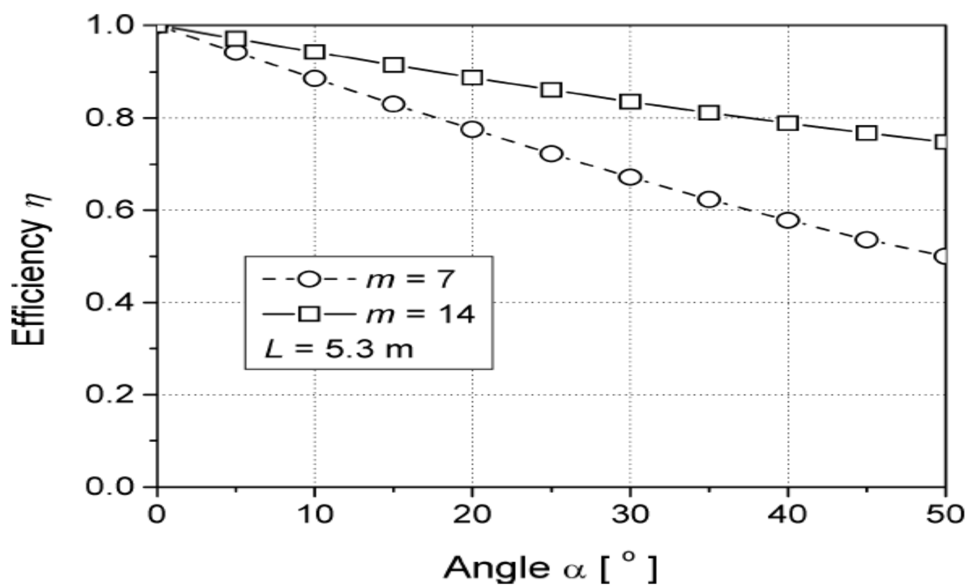


Figure 4.7 : Efficiency against orientation angles

Source: Muller (2009)

Figure 4.7 shows the efficiency of the screw runner which decrease as the orientation angles increase. This theoretical result shows that the efficiency of the screw runner decreases as the orientation angle increases. The same results is obtained by using

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

For the overall project, objective stated earlier was achieved. The two points focused in the research are to find the efficiency of the screw blade for different orientation angles and for different angle of attack. The performance of the screw blade for different parameters has been determined.

Validation between simulation results and experimental result has been done to prove the obtained result. For overall research, screw blade with lowest orientation angle and higher angle of attack has higher efficiency.

5.2 RECOMMENDATION

Methods that I choose to discuss and explain my results are simple for easy understanding for beginners. Only limited terms were used in this report based on literature review done so far. For the upcoming research in Archimedean screw, more studies on journals and related papers to be done to broaden the knowledge in this field.

Model that have been used for the simulation in this paper is Ansys, CFX. In future research, I would like to recommend to do the research using finite element method and Ansys Fluent for more better results. To be more precise and efficient, the screw blade should be rotating in the future research rather than fixed as stationary.

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APPENDIX A1

Gantt Chart FYP1

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
OBJECTIVE, SCOPE AND PROBLEM STATEMENT	■	■												
LITERATURE REVIEW			■											
Design Of Screw Blade				■	■									
Learning CFD Software					■	■	■							
Dimension of Screw Blade							■	■						
Discussion									■	■	■			
Report Writing												■	■	
PSM Presentation 1														■

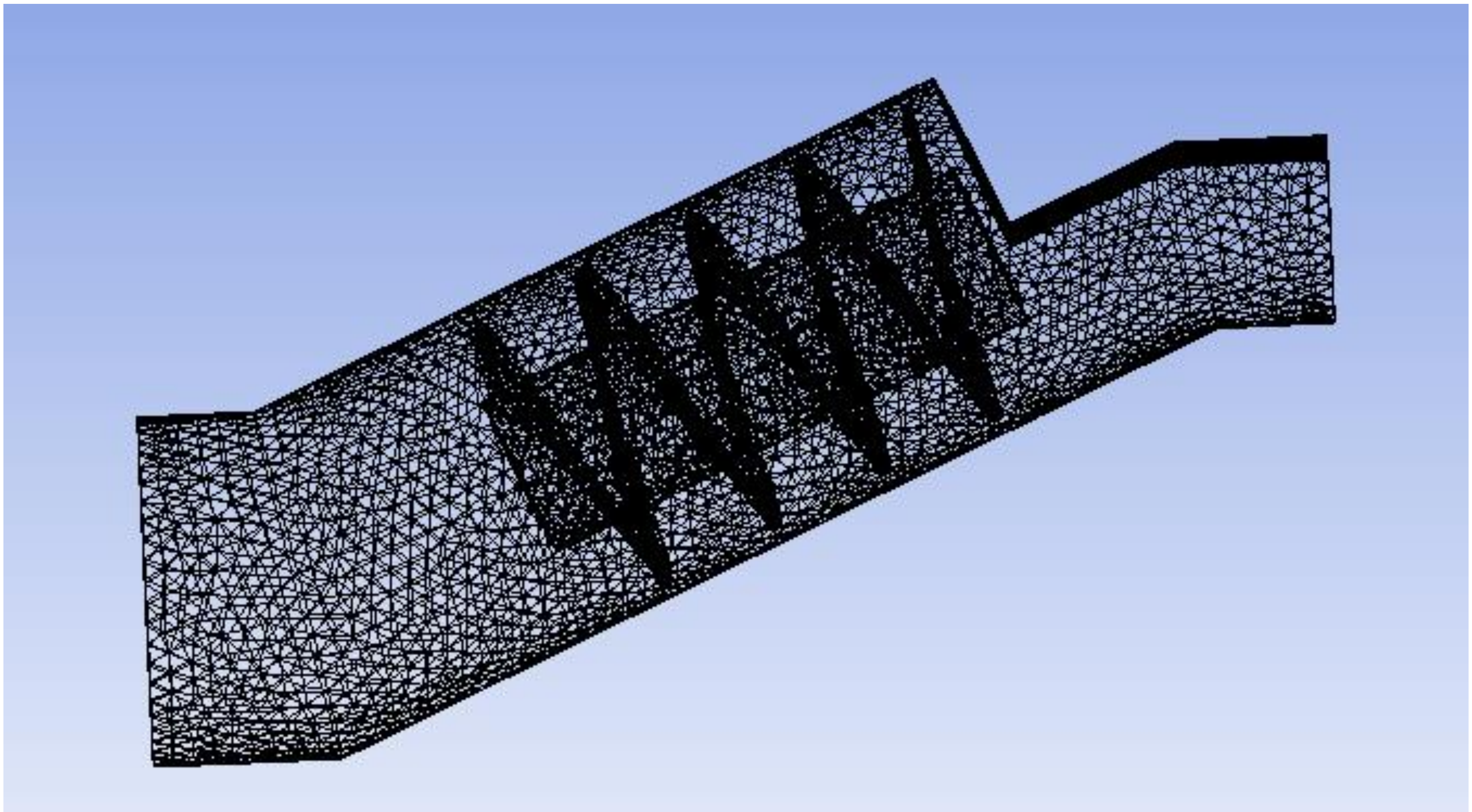
APPENDIX A2

Gantt Chart FYP2

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
SIMULATION SETUP	■	■												
COMPUTE THE SOLUTION			■	■										
MODELLING					■	■								
BOUNDARY CONDITION						■	■							
RUN SIMULATION							■	■	■					
DISCUSSION									■	■				
RESULT ANALYSIS									■	■	■			
REPORT WRITTING												■	■	
PRESENTATION														■

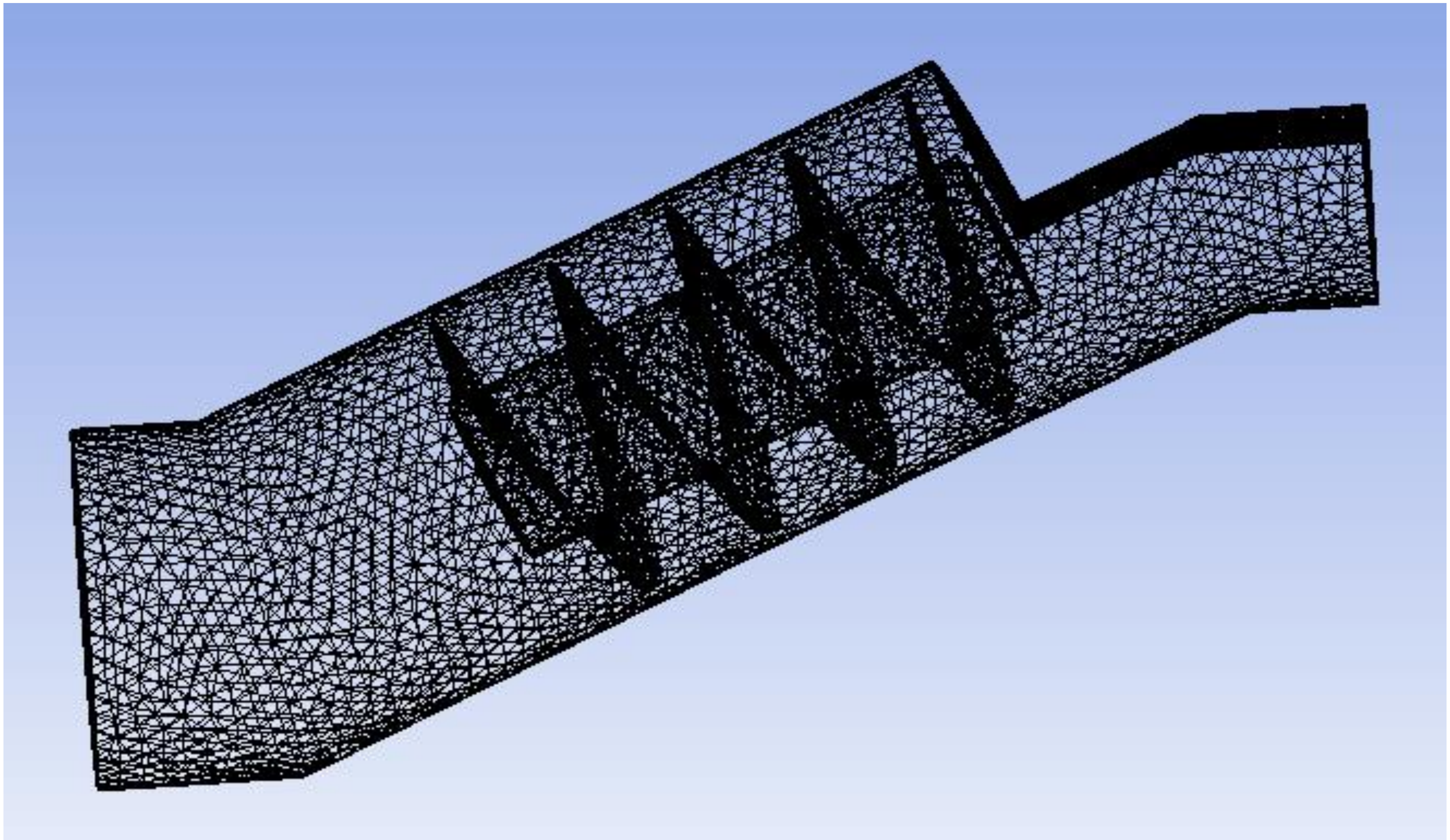
APPENDIX B1

Mesh view for angle of attack 75°



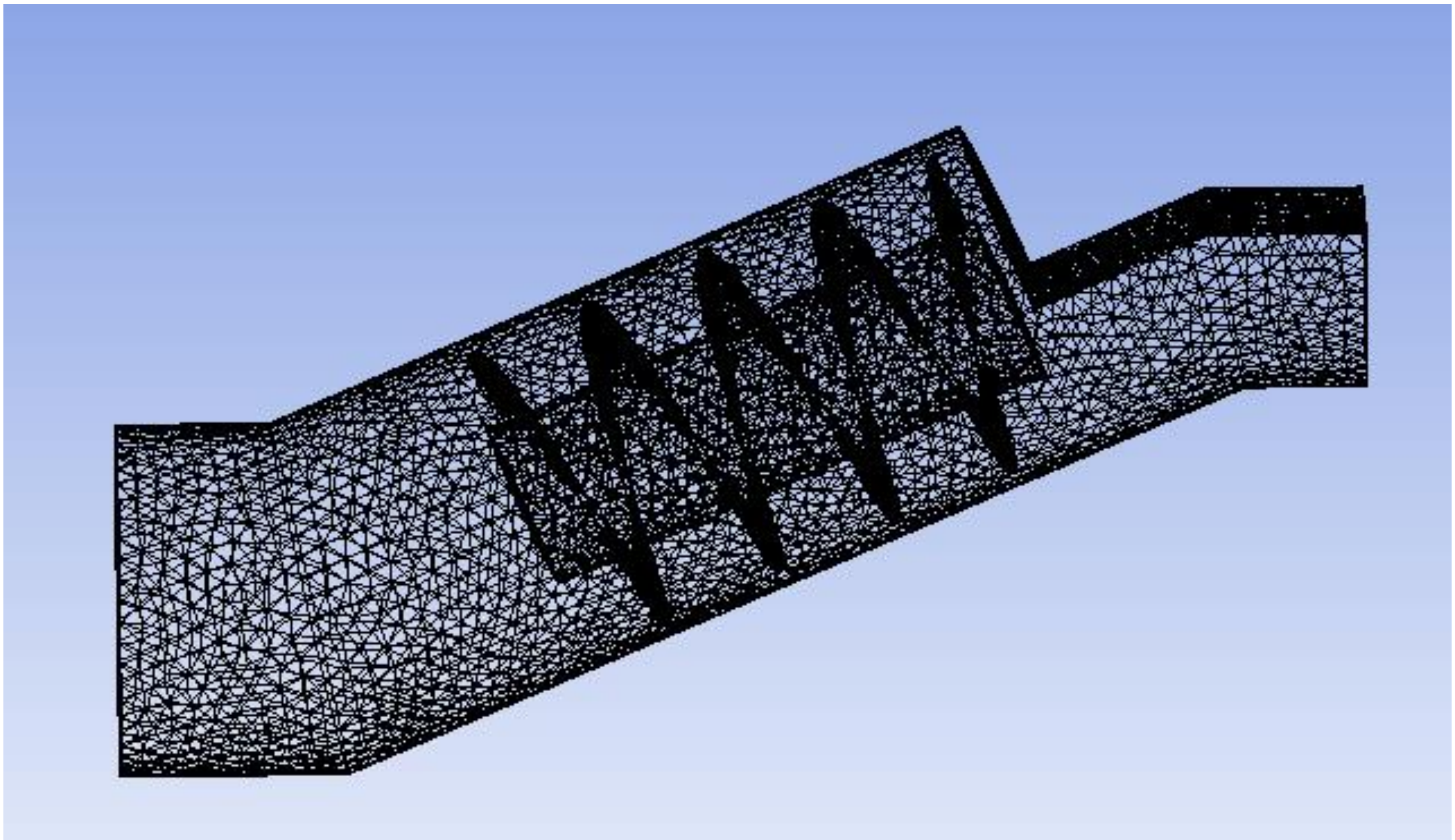
APPENDIX B2

Mesh view for angle of attack 80°



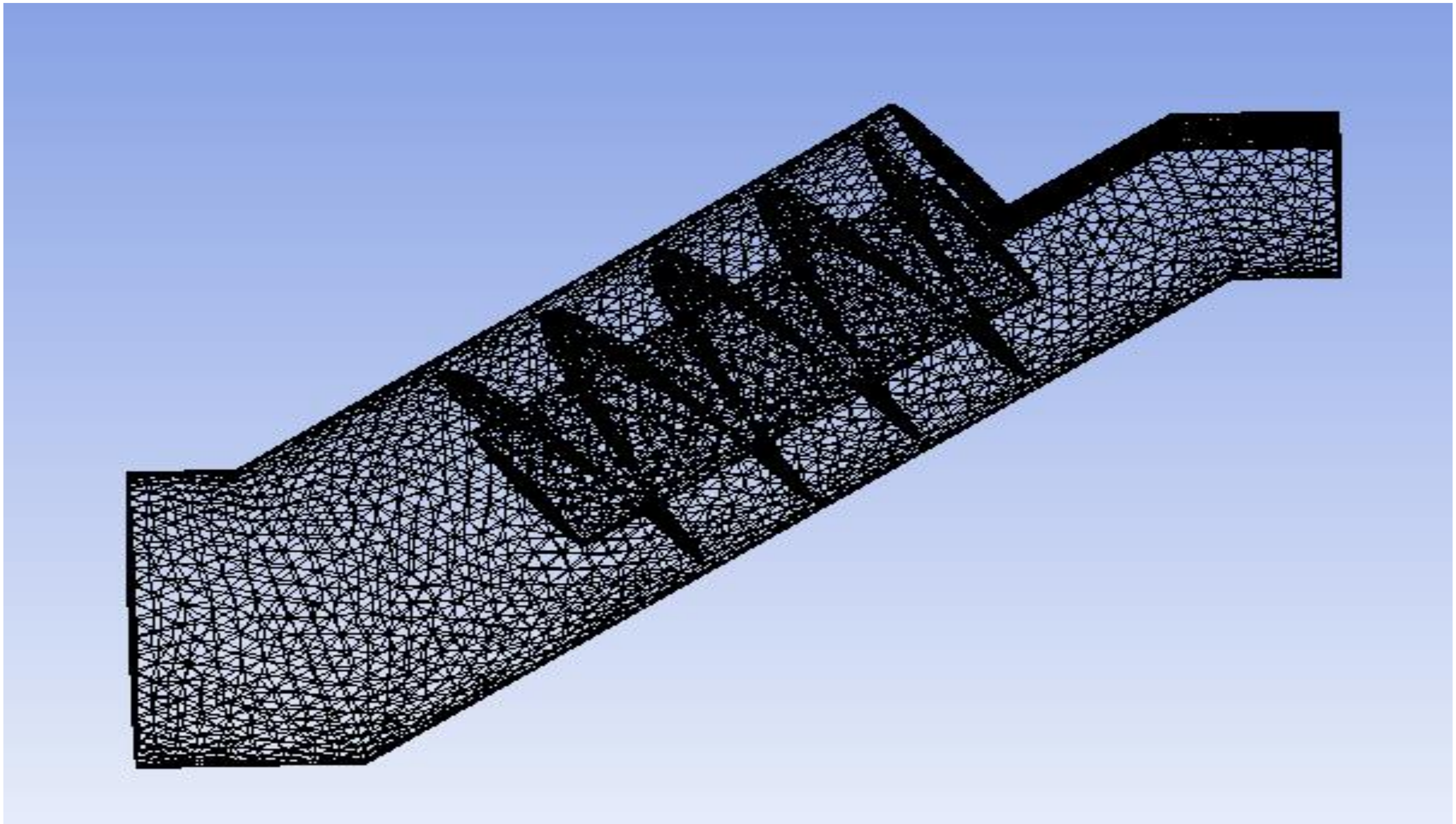
APPENDIX B3

Mesh view for angle of attack 90°



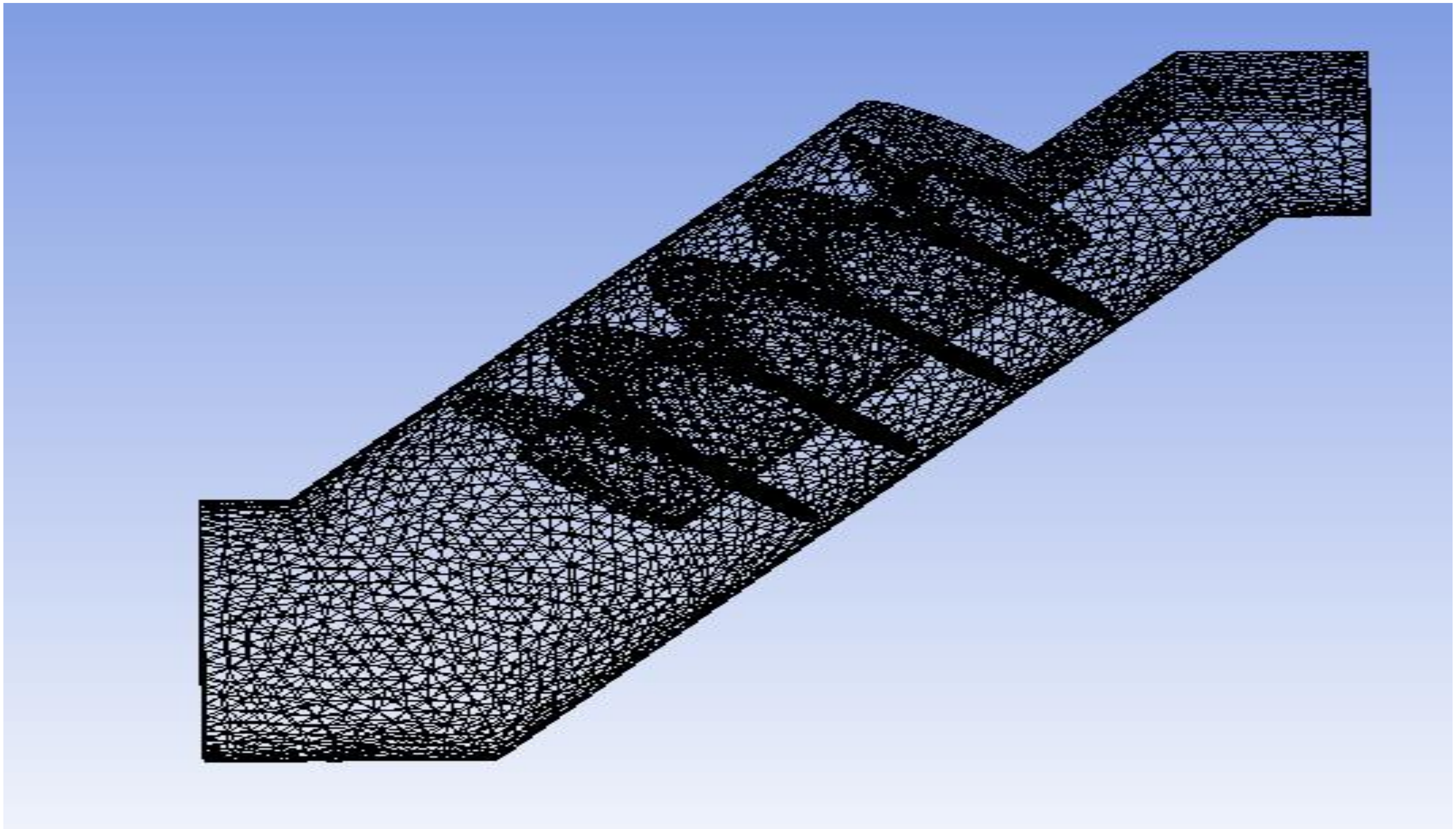
APPENDIX C1

Mesh view for inclination angle 35°



APPENDIX C2

Mesh view for inclination angle 50°



APPENDIX D

Velocity plane picture