

MODELLING AND ANALYSIS ON GRAVITATIONAL WATER VORTEX TURBINE

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CERTIFICATE

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ABSTRACT

Energy generation through water is one of the most economic sources of power. Among the hydro-power plants, micro-hydro power plants are more preferred since they require lower heads and smaller flow rates to generate electricity.

The main advantage of micro-hydropower plants is the combination of feasibility, ease of installation, efficiency and economy into a single source of power.

In the category of micro-hydro power plants, gravitational water vortex turbines are emerging currently due to their ease of installation, reduced setup time and minimal expertise required for installation. Generally, a gravitational water vortex turbine, which mainly comprises a runner and a tank, generates electricity by introducing a flow of water into the tank and using the gravitation vortex generated when the water drains from the bottom of the tank. This water turbine is capable of generating electricity using a low head and a low flow rate with relatively simple structure.

Gravitational water vortex turbine is an ultra-low head turbine, which can operate in as low head range of 0.7-2 m with similar yield as conventional hydroelectric turbines used for production of renewable energy characterized with positive environmental yield.

The gravitational vortex is a milestone in hydrodynamic development because in the past we needed energy to aerate water, but now this technique uses a water aeration process to produce electrical energy.

However, the turbine has a low efficiency. Although changes in geometry could increase it. In this study is focused on the optimization of the runner to improve the efficiency of the gravitational water vortex turbine.

In this project, we mainly focused on to increase the efficiency of the pre-existing turbine by optimising the turbine basin and flat blades with baffle plates.

The analysis is carried out runner blade profiles. ANSYS CFX was used to analyse the fluid flow through the channel, basin, turbine hub and blade, and results were used to evaluate the efficiency of the runner design.

The results showed that turbine with optimised basin and flat blades with baffle plates gave efficiency of 43.06%. it is also found that the tank geometry and the water flow rate effect the efficiency of the turbine. With increase in water flow rate, the efficiency became higher, also it is recommendable to select a suitable design.

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CHAPTER 1
INTRODUCTION

There are 1.2 billion people around the world that lack access to electricity, some 85% of them in rural areas. Based on current trends, 1.2 billion people or 15% of the world's population will still lack access in 2030. This growing demand for electrical energy, whilst reducing carbon emissions, is one of the main reasons pushing the advancement and implementation of renewable resources such as solar photovoltaics, wind and hydropower. Implementing these in rural areas allow communities to generate and manage their own resources locally. Water energy being a clean, cheap and environment friendly source of power generation is of great importance for sustainable future; being aware of this fact, still major of the hydro energy is under-utilized. There are mainly two approaches to harness energy from water, namely, hydrostatic and hydrokinetic methods. Hydrostatic approach is the conventional way of producing electricity by storing water in reservoirs to create a pressure head and extracting the potential energy of water through suitable turbo machinery hydrokinetic approach, the kinetic energy inside the flowing water is directly converted into electricity by relatively small-scale turbines without impoundment and with almost no head.

1.1 HYDRO-ELECTRIC POWER PLANTS

Hydro-electric power plants can serve as a solution to the current energy crisis of the world since they use the energy stored in a free stream of water to generate electricity rather than using oil and other fuels. In hydro-electric power plants, water is stored at a higher potential. This water is then passed onto the blades of a hydraulic turbine. Using the turbine, mechanical energy can be harnessed from the potential and kinetic energy of the flowing water. Once mechanical energy has been generated, then this energy may be converted to electrical power which can be transmitted through electric lines for use.

A hydraulic turbine may be classified as impulse and a reaction turbine. In impulse turbines, the rotation of the rotor is caused by the impact of a high velocity jet of fluid on the blades of turbine. The impulse resulting due to the flow of fluid on the blades causes the rotor to rotate. Reaction turbine is the type of turbine, in which the rotor blades rotate as a result of the reaction to the force/weight of the fluid. The comparison of reaction and impulse turbines is shown in Figure 1.1.

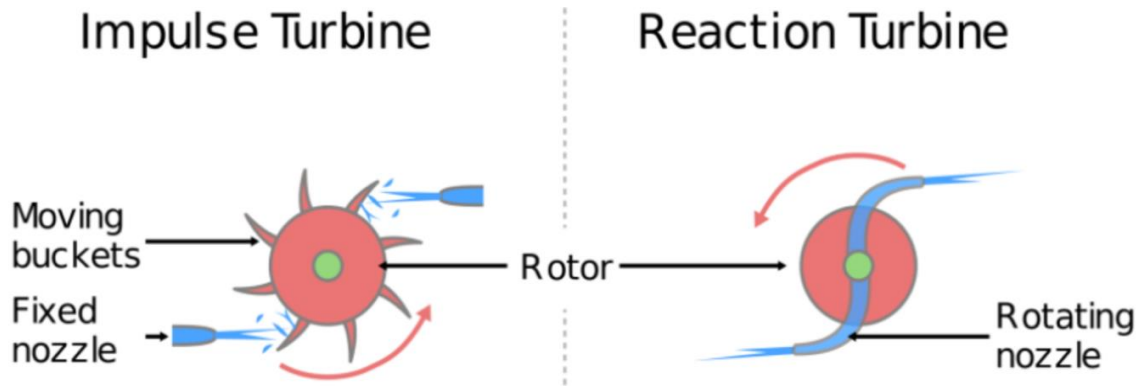


Fig. 1. 1 Comparison of Impulse and Reaction Turbines

Another classification of the hydraulic turbines may be based upon the pattern of flow. The flow of the fluid in the turbine may either be radial, axial or mixed as shown in Figure 1.3. The turbines may be termed as radial flow, axial flow and mixed flow turbines respectively. In mixed flow turbines, the flow of the fluid is in radial as well as axial directions.

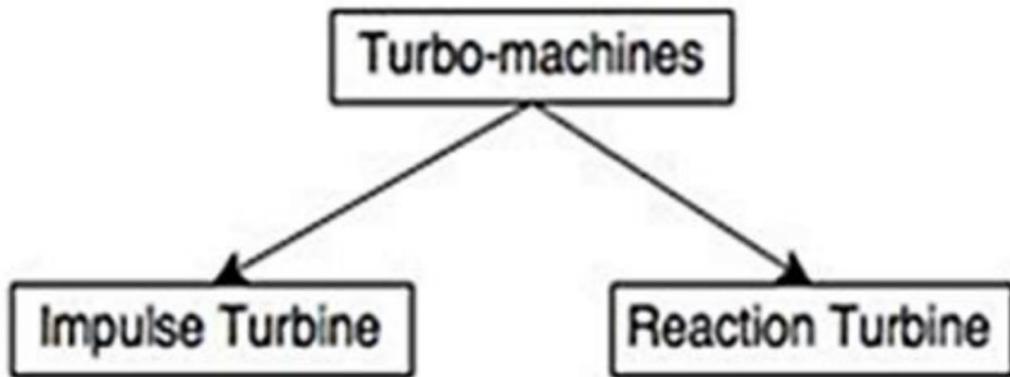


Fig. 1.2 Turbine classification on the basis of working mechanism

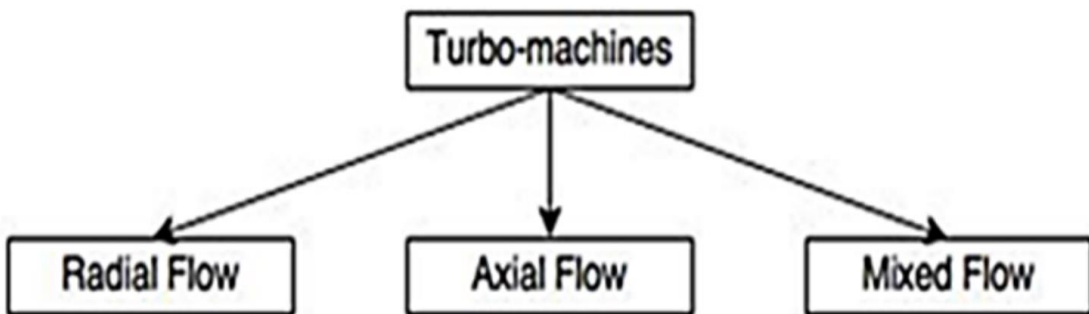


Fig. 1.3 Turbine classification on the basis of flow pattern

Hydro-power plants may also be classified as large, medium, small, mini, micro and pico hydropower plants. This classification is based on the production capacity. Besides the main advantage of being environment friendly, hydroelectric power plants have certain advantages over other sources of power generation, which are:

- i. The running cost of hydro-electric power plants is considerably lesser than thermal power stations since it uses freely available water instead of fuel.
- ii. Since there is no fuel usage, therefore the expenditure for fuel purchase, quality check, transportation, storage and ash handling equipment is not incurred in hydro-electric power plants.
- iii. It does not produce any hazardous gases and thus does not cause any environmental pollution.
- iv. The hydro-electric turbines run at a lower rpm as compared to steam turbines and thus are easy to handle.
- v. They are safer as there are no boilers associated with hydro-electric power plants.
- vi. The water flowing out of the turbine after the power has been extracted, can be easily used for consumption and irrigation purposes, since it does not contain any harmful pollutants.
- vii. Once the initial investment has been recovered, the hydro-electric plants operate almost free of cost.
- viii. They do not emit any hazardous radiations as in case of nuclear power plants.

1.2 MICRO-HYDRO POWER PLANTS

Micro-hydro power plants are the types of hydro-electric power plants which are capable of producing a maximum power output of 100kW. They are of smaller size as compared to the conventional hydro-electric power plants and are thus suitable for developing countries, where initial investment is a major issue. Turbines of this type can be installed much more easily since their requirements are not as high as hydro-electric power plants.

These plants operate on the natural flow of the water (run of the river method) and are capable of providing electrical power to a small nearby community. These plants do not require a dam or huge reservoir for water storage, which reduces the initial investment required for the plant construction. A portion of the water from a river is diverted through a channel, which can be used for the operation of the plant. The basic layout out of micro hydro power plant is shown in Figure 1.4.

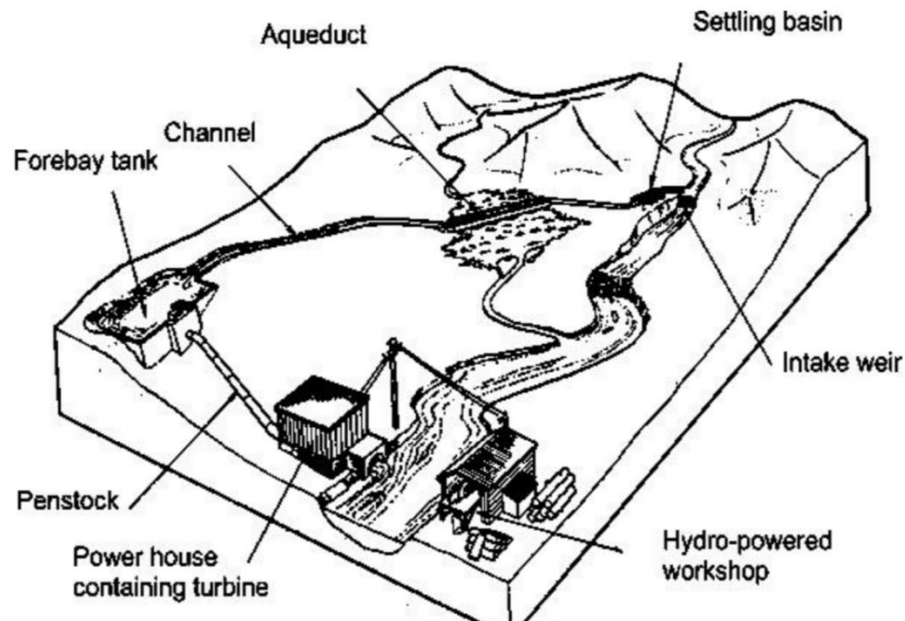


Fig. 1.4 Basic layout out of micro hydro power plant

There are various types of micro-hydro turbines. Some of these are:

- i. Screw Turbine
- ii. Turgo Turbine
- iii. Split Pipe Turbine
- iv. Counter Rotating Turbine
- v. Barker's Mill
- vi. Cross-flow Turbine
- vii. Gravitational Water Vortex Turbine

Just as hydro power plants have advantages over steam and fuel operated power plants, in the same way, micro-hydro power plants also have certain advantages over other types of power production mechanisms. These advantages are discussed in the following section:

- i. Micro-hydro power plants require a small flow rate and a small head to generate electric power.
- ii. No water storage dams or reservoirs are needed, which reduces the risks associated with dam collapse , thus they can be installed near to the point of utilization.
- iii. Since dams and reservoirs are not needed, so this reduces the capital investment required initially.
- iv. They operate along the run of river, so they can be installed along the river without disturbing the aquatic life.
- v. In regions, which are potentially feasible for hydro-power generation, these can serve as the most cost-effective system due to their free of cost operation and cheaper maintenance.
- vi. They have almost no negative impact on the environment.
- vii. These power-plants can serve as an off-grid solution to energy crisis and supply electric power to nearby locations.
- viii. The cost and losses associated with long transmission lines are minimized in case of micro-hydro power plants, since they are located near to the point of utilization.

1.3 GRAVITATIONAL WATER VORTEX TURBINE (GWVT):

Free surface vortices are a common and an important phenomenon in the field of hydraulic engineering. Vortices are formed at the intake of hydraulic structures due to a design flaw, where a large amount of water is drained into the intake. This flow into the intake causes a vortex to initiate at the free surface due to the Coriolis Force. This vortex gradually intensifies, causes the water rotation to speed up and in turn causes the pressure in the centre of the vortex to decrease. This pressure gradually decreases to an extent that ultimately it reduces below the atmospheric pressure and sucks the air into the intake and

forms an air core. The radius of the air core gradually reduces while moving from the free surface to the intake.

The vortex formed may either be in clockwise or anti-clock wise direction, depending upon the location with respect to the equator. In northern hemisphere, the vortex formed is in anticlock-wise direction, while in southern hemisphere, the vortex formed is in clockwise direction. The concept of water's natural energy stored in the form of vortex was initially given by Viktor Schauberger (1885-1958) an Austrian forest caretaker and a naturalist, who was commonly known as the water wizard. He observed the circulation of water along a river, when an egg-shaped stone started circling due to the force of the water. The idea of Viktor Schauberger was turned into a GWVPP by an Australian engineer, Franz Zotlöterer while trying to aerate water without any external input of power. This was done by generating a vortex in a cylindrical basin with an exit hole at the bottom. The increased surface area of the water would ultimately aerate the water. From the rotational path followed by the water in the air-core vortex, he expected it to generate rotational energy if a vertical axis rotor was placed at the vortex centre. The concept of a GWVPP as shown in Figure 1.5 below.

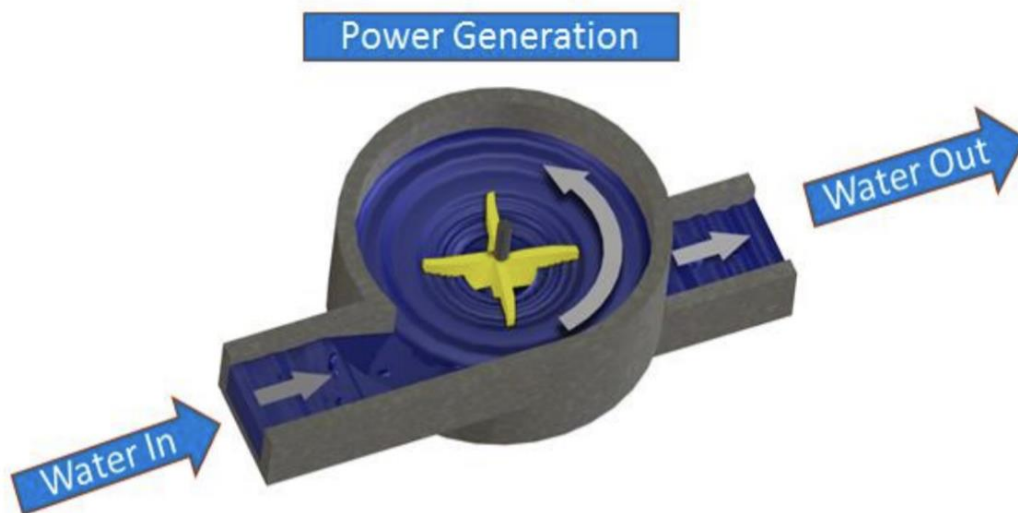


Fig. 1.5 Schematic of GWVPP

GWVPP was first installed in Obergrafendorf, Austria. The turbine was patented by its inventor in 2004. The plant had a discharge of $1\text{m}^3/\text{s}$ and a total head of 1.3m. The recorded efficiency of the plant was upto 80%. This plant was capable of generating power up to 10 kW.

In this system, the energy contained within an artificially induced large water vortex over a small head is harnessed. Water flows tangentially into a cylindrical basin with an orifice at the bottom as shown in Figure 1.5. The combined effect of the localized low pressure at the orifice and the circulation which is induced as a result of the tangential entry through inlet, causes the water to restructure into a vortex like flow pattern. The potential energy of the entering water is entirely converted to kinetic energy which can be extracted from it by the use of coaxial turbine which has a vertical axis.

All the micro-hydro power plants have certain advantages over each other. But the GWVPP has certain advantages over all other types of micro-hydro power-plants such as:

- i. It operates at a low rpm and does not cut the natural stream of water therefore it does not harm the aquatic and marine life.
- ii. It increases the water surface area and thus enhances the process of aeration therefore it is useful for the aquatic life as compared to its contemporaries, which depletes the water quality and also cut the natural stream of water.
- iii. It is easy to install and the return on investment starts after a very short time.
- iv. It does not produce any harmful pollutants.
- v. It considerably increases the flow velocity of the water without any external effort.
- vi. It is better in terms of power generation since the water acts on all the blades at the same time.
- vii. It can be installed along the run of the river, so there is no need for dam construction.
- viii. The installation costs and transmission losses associated with long transmission lines are minimized.

- ix. It has very simple and few moving parts so serviceability and operating costs are low.
- x. Parts can be manufactured locally.
- xi. It is a low head (0.7m - 3m) micro-hydro turbine and can be easily installed on irrigation canals and rivers.
- xii. This type of turbines does not require a large water storage reservoir
- xiii. For the same flow conditions, GWVTs produce more output power as compared to other micro-hydro power plants.
- xiv. A number of such turbines can be installed on the same river in cascaded form, in such a way that they do not affect the flow of the following turbines in the system as shown in Figure 1.6.

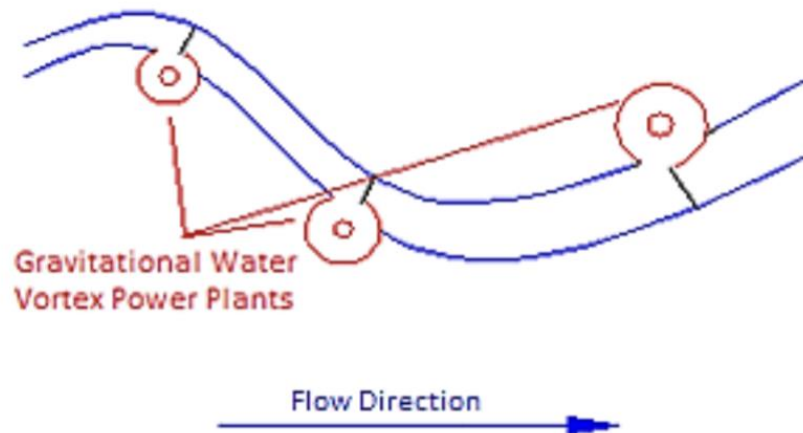


Fig. 1.6 Schematic for the cascaded system of GWVPP

Gravitational water vortex turbine is an ultra-low head turbine, which can operate in as low head range of 0.7-2 m with similar yield as conventional hydroelectric turbines used for production of renewable energy characterized with positive environmental yield.

The gravitational vortex is a milestone in hydrodynamic development because in the past we needed energy to aerate water, but now this technique uses a water aeration process to produce electrical energy.

The water passes through a large, straight inlet through the channel and then passes tangentially into a round basin, which forms a powerful vortex; an exit hole is made at the bottom of the basin through which the vortex finds its outlet. The turbine does not work on pressure differential but on the dynamic force of the vortex; not only does this power plant produce a useful output of electricity, it also aerates the water in a gentle way. Said aim is achieved by as hydroelectric power plant which supports the formation of a stable gravitational vortex which tends to be formed also in the upper reaches directly in front of the turbine inlet of conventional river stations as a lost vortex and is therefore prevented as much as possible there. The inventive hydroelectric plant, however, ensures that the necessary current-related conditions are fulfilled for reinforcing the rotational movement of the water, which is created when the water flows off, in an unimpeded manner into a stable gravitational vortex without using pressure lines and directing devices. A turbine that rotates in a coaxial manner within the gravitational vortex and is impinged upon along the entire circumference thereof withdraws rotational energy from the gravitational vortex, which is converted into electric power in a generator.

In addition, gravitational water free vortex turbine is found to be advantageous due to the following properties of water vortex:

- a. Increases the water surface area.
- b. Maximizes the velocity of flow on the water surface area.
- c. Disseminates homogenously contaminants in the water.
- d. Increases the contact surface of the disseminate contaminants for microorganisms and water plants.
- e. Aerates the water naturally, because of the high velocity of the flow on the water surface area.
- f. Increase the heat of evaporation so water can reduce the temperature itself at rising temperatures in summer.

CHAPTER – 2
LITERATURE REVIEW

Pongsakorn Wichian et.al [1]:

This article is based on a study that focuses on increasing the efficiency of the water free vortex turbine by installing baffle plates on the propellers order to find the most suitable size and proportion for the baffle plates, the study used the CFD program to design baffle plates which have a diameter of 45 cm. and a height of 32 cm. The results showed that 5 baffle plates, with a propeller baffle area of 50% gave the highest degree of torque. Propellers, with no baffle plates, were also created and were tested along with a turbine with 50% baffle plates at the flow rate of 0.04 - 0.06 m/s. The results showed that the propellers with a 50% baffle plate proportion helped to increase the torque at an average of 10.25% and with an average of overall efficiency of 4.12%.

P Sritram et.al. [2]:

This article presents the results of the study on the effect of blade number and turbine baffle plates on the efficiency of a free-vortex water turbine. The laboratory experimentation performed to determine the power generation efficiency. The 2 to 7 blade water turbines were built and tested to find the most appropriate number of blades, and the result showed the 5-blade turbine being appropriate because it yields the highest torque from receiving impact from water flow. Next, the baffle plates were designed and attached to the top and bottom of the turbine blades. Four different sizes of space from 25% to 100% of the curve area around the blades were used. Experiments were carried out at the water flow rates of 0.04 to 0.06 m³/s. The finding showed the 50% proportion of the curve area being most appropriate, and the blades installed with top and bottom baffle plates had the highest efficiency of 43.83%, which was 6.59% higher than without baffle plates. It was also found that when the water flow rate increased, the system efficiency became higher.

Haryadi et.al [3]:

Vortex turbine is one of the solutions to utilize the low head hydro energy resources. In recent studies, researchers employ four main runner types, namely: flat radial, paddle, centrifugal, and modified form. The turbine performance can be increased by improving the turbine runner from these types into three dimensions (3D) type. In this present work, the performance of a 3D type runner was designed and examined experimentally. The

experiment showed that the maximum efficiency was around 24%, at rotational speeds about 90 to 120 rpm. The maximum efficiency was reached at the design condition. The turbine has demonstrated its capability to run from low rotational speed around 40 rpm to relatively high rotational speed 194 rpm. Compared with the previous runner profile, the 3D runner profile can produce a higher rotational speed and showed its stability to run in a wider range of rotational speed. At low rotational speed, power and efficiency decrease because water leaves the runner blade too fast before transferring its energy to the blade. Whereas at high rotational speed the water tends to be pushed out. The turbine performance and efficiency still can be increased by improving the runner profile.

Alejandro et.al [4]:

The small hydroelectric power plants have become a great solution to the energy problem in the non-interconnected zones that have a low flow river. The gravitational vortex turbine is a small power plant easy to install, low maintenance and economically viable for these areas. However, the turbine has a low efficiency. Although changes in geometry could increase it. In this study, concave and convex designs are proposed for the gravitational vortex turbine tank, which are studied numerically and experimentally. The numerical study was developed in ANSYS CFX V19.1 software and the experimental phase was carried out in the fluid's laboratory of the Instituto Tecnológico Metropolitan. The numerical and experimental results of the concave and convex design show a difference of 62% and 60%, respectively. The vortex formation and output velocity are the numerical parameters analysed with the software, and the electric power and torque are the parameters on the experimental phase. The tank geometry is the most important parameter to increase the turbine's efficiency, so it is recommendable to select a suitable design.

Sagar Dhakal, et.al [5]:

This study is for the development of efficient basin design . We have optimized the conical basin of this plant by changing the four design parameters of basin such as : notch angle ,canal height , notch inlet width and cone angle. Different geometric models are developed by using SolidWorks software and simulation is done with the help of Commercial CFD code ANSYS Fluent. Mathematical relationship among these design parameters with the

water velocity are established . Thus formed mathematical model is optimized using different optimization tools which is followed by experimental verification by measuring the power output.

Gheorghe-Marius MARIAN et.al [6]:

For a new concept of micro hydropower plant with gravitational vortex and turbine with rapidity steps has been modelled the waterflow through the conical channel in the absence and the presence of steps. In the first case , the power lines appear as conical propellers. Axial and radial velocity of the water are not zero only in the boundary layer. In the second case the structure of the water flow is changes with the formation of swirls every area of the blades. The water velocity increases rapidly as proximity to the drain hole and strongly depends on water flow.

R. Dhakal, et.al [7]:

The gravitational water vortex power plant (GWVPP) is a new type of low head turbine system in which a channel and basin structure is used to form a vortex, where the rotational energy from the water can be extracted through a runner. This study is focused on the optimization of the runner to improve the efficiency of the GWVPP. Computational fluid dynamics (CFD) analysis is carried out on three different runner designs with straight, twisted and curved blade profiles. ANSYS CFX was used to analyze the fluid flow through the channel, basin, turbine hub and blade, and results were used to evaluate the efficiency of each of the runner designs. The CFD analysis showed curved blade profile to be the most efficient profile, with a peak efficiency of 82%, compared to 46% for the straight blade runner and 63% for the twisted blade version. An experimental test of the turbine system was carried out to validate the runner analysis, in a scale version of the GWVPP. The testing showed that the runner behaved as predicted from the CFD analysis, and had a peak efficiency point of 71% at 0.5m head.

V. Naderi, S. Gaskin [8]:

A free surface vortex is a mass of water rotating around an axis which at a low intensity of rotation results in a dimple at the water surface and at a high intensity of rotation can result in

an air-core at its centre. Air-core vortices can occur at intakes withdrawing water from reservoirs. Existing vortex models provide general information about the symmetric vortex structure. The aim of the present study was to examine the vortex structure at the critical submergence condition occurring in an approach flow which results in a non-symmetric velocity distribution and structure of the vortex throughout the flow depth. A steady strong air-core vortex over a bottom intake was created in a recirculating flume in which the water depth, mean velocity of the approach flow, and intake discharge could be adjusted. A combination of flow visualization and detailed PIV data allowed the asymmetric structure of the strong air-core vortex in an approach flow to be studied. Flow visualization was used to observe the formation and evolution of the three-dimensional structure of the air-core. Planar particle image velocimetry (PIV) was used in a series of horizontal and vertical planes to reconstruct the three-dimensional structure of the (strong air-core) vortex. Analysis of this data revealed an asymmetric vortex structure in the horizontal plane throughout the flow depth due to the approach flow creating a mixing zone upstream of the vortex.

M. M. Rahman, et.al [9]:

Gravitational water vortex power plant is a green technology that generates electricity from alternative or renewable energy source. In the vortex power plant, water is introduced into a circular basin tangentially that creates a free vortex and energy is extracted from the free vortex by using a turbine. The main advantages of this type of power plant is the generation of electricity from ultra-low hydraulic pressure and it is also environmental friendly. Since the hydraulic head requirement is as low as 1m, this type of power plant can be installed at a river or a stream to generate electricity for few houses. It is a new and not well-developed technology to harvest electricity from low pressure water energy sources. There are limited literatures available on the design, fabrication and physical geometry of the vortex turbine and generator. Past researches focus on the optimization of turbine design, inlets, outlets and basin geometry. However, there are still insufficient literatures available for the technology to proceed beyond prototyping stage. The maximum efficiency obtained by the researchers are approximately 30% while the commercial companies claimed about 50% of efficiency with 500W to 20kW of power generated. Hence, the aim of this paper is to determine the gap in the vortex power plant technology development through past works and a set of research recommendations will be developed as efforts to accelerate the development of GWVPP.

Sujate Wanchat, et.al [10]:

This study is the analysis and design of a basin structure which has the ability to form a gravitational vortex stream. Such a high velocity water vortex stream can possibly be used as an alternative energy resource. In this study we are interested in the formation of a water vortex stream by gravitation, which is a new technique used in the field of hydro power engineering. The advantage of this method for electrical generation is the capability of producing energy using low heads of 0.7 to 3 meters. It can be applied in a low head micro hydro power plant. The governing equations are the Navier-Stokes equations. The SIMPLE method was adopted to solve the discretized equation. The flow fields in the flume, under different incoming flow conditions and basin configurations, were numerically simulated using the software ANSYS Fluent. The studies investigated parameters which affect the velocity vector flow field, which include 1) Outlet diameter at the bottom centre of basin 2) Gravitational vortex head and 3) Flow rate. Computational fluid dynamics is used to simulate the vector flow field. The tangential and radial velocity distribution is used to determine the suitable turbine blade for testing. A gravitational vortex power plant model is created to investigate electrical power output.

G. P. SCHIVLEY, J.L. DUSSOURD [11]:

A pump which operates by setting up a vortex in a chamber in front of the impeller is often called a vortex pump. Vortex pumps by virtue of this design have a large free and open flow passage which permits the pumping of solid materials without danger of obstruction. They are thus in common use as materials handling pumps. A one-dimensional analytical model of such a pump is created, handling a Newtonian single-phase fluid. Calculated performance parameters are compared with those measured on a laboratory model. Overall pump characteristics are also computed and compared to those of a number of test pumps of various geometries. Finally, an examination is made of the similitude parameters governing this style of pump.

Ajay Kumar Jha, et.al [12]:

The study presents about the technical feasibility of innovative low head turbine technology, Gravitational Water Vortex Hydropower Plant fitted with conical basin. The development of conical basin technology started in Nepal since 2013. This study presents the technical feasibility assessment of 1 kW vortex turbine system. After series of site visit, detail design of the system components was done on the basis of which, the cost estimate has been done. The estimated cost of development of the 1 kW pilot system is about 19.5 Lakh Nepali Rupees. Areas for cost reduction are also indicated. It is finally suggested that the system be developed as a research-oriented pilot project which will reveal information regarding installation of scaled up system that can produce significant amount of power for successfully covering operation and system maintenance costs.

Suman Acharya , et.al [13]:

Among the different hydropower system, GWVPP is an emerging concept and showing its future possibility in power production by utilizing low head. It is an ultra-low head turbine which can operate in a low head range of 0.7 to 2 m, which is often seen as too low for conventional hydro turbines, and has a similar yield to conventional hydroelectric turbines. There of number of parameters associated with basin and turbine geometry which affect the efficiency of GWVPP. Altering some parameters among them changes the efficiency of the system. However these research conducted are based on hit and trial method followed by experimentation. No particular analytical calculation has been done. So, this work is intended to optimize the runner of Gravitational Water Vortex Power Plant. Among different parameters affecting torque, power and efficiency two parameters inlet jet angle and radius of curvature of turbine blade are considered for this study. These two parameters are computed from analytical analysis and verified using 3-d simulation. The maximum torque at impact jet angle 18° , radius of curvature 285mm was found to be 0.413 Nm with the deviation of 2.37% between analytical and numerical analysis.

CHAPTER – 3

MODELLING AND ANALYSIS ON GRAVITATIONAL WATER VORTEX TURBINE

In this project, we are using CATIA v5 as a modelling tool.

3.1 About CATIA:

CATIA currently stands at version level 6, better known as CATIA V6.

The first release of CATIA was back in 1977 by Dassault Systèmes, who still maintain and develop the software. It was initially developed for use in designing the Dassault Mirage fighter jet.

Nowadays, the most widely used version is CATIA V5, with CATIA V4 still being used in some industries, mostly in conjunction with V5. Between versions, CATIA has varied significantly in terms of usage and appearance. Each Version brings significant additional functionality. Between V4 and V5, the fundamentals to the design process were developed and between V5 and V6 the handling of data changed. Within each version, Dassault Systèmes also offer updates in the form of releases. New releases are typically released annually and also bring additional functionality within the Version as well as bug fixes.

CATIA V4:



Fig. 3.1 CATIA version 4 module

CATIA V5:

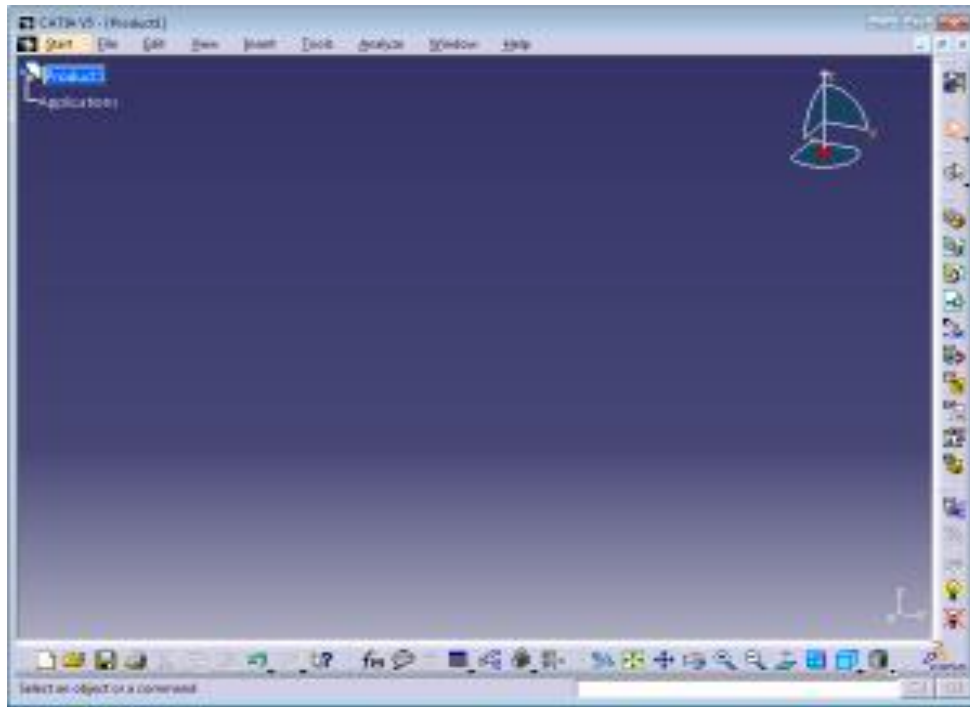


Fig. 3.2 CATIA version 5 module

CATIA V6:

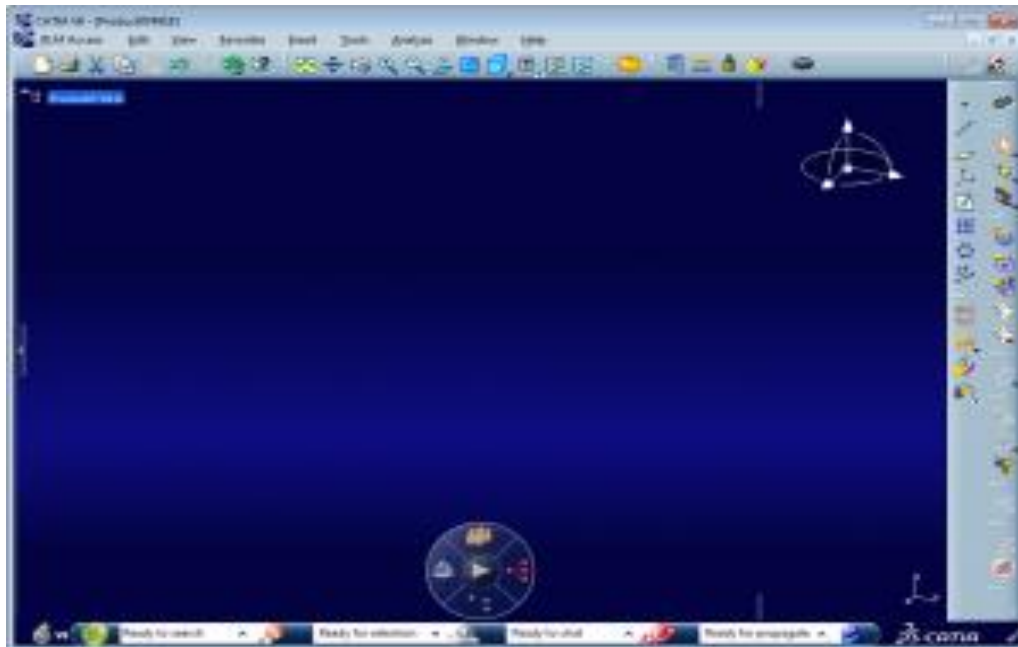


Fig. 3.3 CATIA version 6 module

For large organisations, it can be difficult to handle large amounts of data and allow users to share this data. This can be controlled using PLM (Product Lifecycle Management) products. CATIA V5 can be used file based or alongside another software package which incorporates PLM, such as ENOVIA or SMARTEAM. CATIA V6 however already has ENOVIA V6 integrated. The main benefits for using a PLM product are the prevention of data loss and security context control.

3.2 FUNCTIONALITIES OF CATIA

CATIA has capabilities in multiple domains.

The majority of users do not require all functionalities available in CATIA, which has significant cost impacts on the user or organisation. Licenses are therefore broken down to include required functionality and are pre-defined. Depending on the licence, additional workbenches become available and/or additional tools within workbenches become available. Workbenches in CATIA work a bit like different software held within CATIA. They allow the user to perform different tasks, from:

3.2.1 Part Modelling

Part Design workbench

The Part Design workbench enables users to design precise 3D mechanical parts. From assembly sketching to detailed design, the Part Design application accommodates the vast majority of design requirements.

3.2.2 Assembly Modelling

Assembly Design workbench

The Assembly Design workbench enables users to design cooperate with Part Design and Generative Drafting apps on scalable design projects. Various visual tools allow for 3D navigation through large assemblies.

3.2.3 Surface Modelling

Generative Surface Design workbench

The Generative Surface Design workbench enables users to create wireframe construction elements and enrich existing mechanical part design with wireframe and surface features.

3.2.4 Finite Element Analysis

Generative Structural Analysis

The Generative Structural Analysis enables users to perform first order mechanical analysis for 3D systems.

This workbench includes:

- Generative Part Structural Analysis (GPS) for obtaining mechanical behaviour information.
- ELFINI Structural Analysis (EST) for mechanical analysis developments.
- Generative Assembly Structural Analysis (GAS) for analysis of the mechanical behaviour of a whole assembly.
- Generative Dynamic Analysis (GDY) for working in a dynamic response context.

Sheetmetal Part Design

Generative Sheetmetal Design

Generative Sheetmetal Design enables users to perform associative feature-based modelling, making it possible to design sheet metal parts in concurrent engineering between the unfolded or folded part representation.

Rendering

Real Time Rendering workbench

The Real Time Rendering workbench enables users to define material specifications that will be shared across the whole product development process, while mapping materials onto parts and products to produce realistic renderings.

Engineering Drawing creation

Generative Drafting workbench

The Generative Drafting workbench enables users to generate drawings from 3D parts and assembly definitions.

3.3 CATIA TOOLS

3.3.1 Select Toolbar



See **Select Sub-toolbar** below



See **Scan Sub-toolbar** below

3.3.2 Select Sub-toolbar



Select

See **Selecting Using The Selection Traps**



Select

See **Selecting Using The Selection Traps**



Selection Trap

See **Selecting Using The Selection Traps**



Intersecting Trap

See **Selecting Using The Selection Traps**



Polygon Trap

See **Selecting Using The Selection Traps**



Paint Stroke Selection

See **Selecting Using The Selection Traps**



Outside Trap Selection

See **Selecting Using The Selection Traps**



Intersecting Outside Trap Selection

See **Selecting Using The Selection Traps**

3.3.3 Scan Sub-toolbar



Quick Select

See **Quick Selection of Geometry**



Scan or Define In Work Object

See **Scanning the part and Defining In Work Objects**

3.3.4 Insert Toolbar



See **Insert Sub-toolbars** below



3.3.5 Insert Sub-Toolbars



Body

Inserting a New Body in the Part Design User's Guide



Body in a Set

See **Inserting a Body into an Ordered Geometrical Set**



Geometrical Set

See **Managing Geometrical Sets**











Ordered Geometrical Set

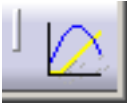
See **Managing Ordered Geometrical Sets**

3.3.6 Wireframe Toolbar



-  See **Points Sub-toolbar** below
-  See **Line-Axis Sub-toolbar** below
-  **Plane**
See **Creating Planes**
-  See **Projection-Combine Sub-toolbar** below
-  See **Offset2D3D Sub-toolbar** below
-  **Intersection**
See **Creating Intersections**
-  See **Circles-Conic Sub-toolbar** below
-  See **Curves Sub-toolbar** below





3.3.7 Law Toolbar



-  **Law**
See **Creating Laws**

3.3.8 Points Sub-toolbar



-  **Point**
See **Creating Points**
-  **Points and Planes Repetition**
See **Creating Multiple Point and Planes**
-  **Extremum**
See **Creating Extremum Elements**
-  **ExtremumPolar**
See **Creating Polar Extremum Elements**

3.3.9 Line-Axis Sub-toolbar



Line

See **Creating Lines**



Axis

See **Creating an Axis**



Polyline

See **Creating Polylines**

3.3.10 Project-Combine Sub-toolbar



Projection

See **Creating Projections**



Combine

See **Creating Combined Curves**



Reflect Line

See **Creating Reflect Lines**

3.3.11 Offset2D3D Sub-toolbar



Parallel Curve

See **Creating Parallel Curves**



3D Curve Offset




See **Create a 3D Curve Offset**

3.3.12 Circle-Conic Sub-toolbar








Circle

See **Creating Circles**

-  **Corner**
See **Creating Corners**
-  **Connect Curve**
See **Creating Connect curves**
-  **Conic**
See **Creating Conic Curves**







3.3.13 Curves Sub-toolbar



-  **Spline**
See **Creating Splines**
-  **Helix**
See **Creating a Helix**
-  **Spiral**
See **Creating Spirals**
-  **Spine**
See **Creating a Spine**
-  **Isoparametric Curve**
See **Creating Isoparametric Curves**

3.3.14 Surfaces Toolbar



-  See **Extrude-Revolution Sub-toolbar** below
-  See **OffsetVar Sub-toolbar** below
-  below **Sweeps Sub-toolbar** See
-  **Fill**
See **Creating Filling Surfaces**
-  **Multi-sections Surface**
See **Creating Multi-Sections Surfaces**
-  **Blend**
See **Creating Blended Surfaces**

3.3.15 Extrude-Revolution Sub-toolbar



Extrude

See **Creating Extruded Surfaces**



Revolve

See **Creating Revolution Surfaces**



Sphere

See **Creating Spherical Surfaces**



Cylinder

See **Creating Cylindrical Surfaces**

3.3.16 OffsetVar Sub-toolbar



Offset

See **Creating Offset Surfaces**



Variable Offset

See **Creating Variable Offset Surfaces**



Rough Offset

See **Creating Rough Offset Surfaces**

3.3.17 Sweeps Sub-toolbar



Sweep

See **Creating Swept Surfaces**



Adaptive Sweep

See **Creating Adaptive Swept Surfaces**

3.3.18 Operations Toolbar



See **Join-Healing Sub-toolbar** below



See **Trim-Split Sub-toolbar** below



See **Extracts Sub-toolbar** below



See **Fillets sub-toolbar** below



See **Transformations Sub-toolbar** below



Extrapolate

See **Extrapolating Curves** and **Extrapolating Surfaces**

3.3.19 Join-Healing Sub-toolbar



Join

See **Joining Surfaces or Curves**



Healing

See **Healing Geometry**



Curve Smooth

See **Smoothing Curves**



Untrim

See **Restoring a Surface**



Disassemble

See **Disassembling Elements**

3.3.20 Trim-Split Sub-toolbar



Split

See **Splitting Geometry**






Trim

See **Trimming Geometry**








3.3.21 Extracts Sub-toolbar



-  **Boundary**
See **Boundary Curves**
-  **Extract**
See **Extracting Geometry**
-  **Multiple Extract**
See **Extracting Multiple Elements**


3.3.22 Fillets Sub-toolbar



-  **Shape Fillet**
See **Creating Bitangent Shape Fillets** or **Creating Tritangent Shape Fillets**
-  **Edge Fillet**
See **Creating Edge Fillets**
-  **Variable Radius Fillet**
See **Creating Variable Radius Fillets** or **Creating Variable Bi-Tangent Circle Radius Fillets Using a Spine**
-  **Chordal Fillet**
See **Creating Chordal Fillets**
-  **Styling Fillet**
See **Styling a Fillet**
-  **Face-Face Fillet**
See **Creating Face-Face Fillets**
-  **Tritangent Fillet**
See **Creating Tritangent Fillets**

3.3.23 Transformations Sub-toolbar



-  **Translate**
See **Translating Geometry**
-  **Rotate**
See **Rotating Geometry**



Symmetry
See **Performing a Symmetry on Geometry**



Scaling
See **Transforming Geometry by Scaling**



Affinity
See **Transforming Geometry by Affinity**



Axis to Axis
See **Transforming Elements From An Axis To Another**

3.3.24 Replication Toolbar



See **Repetitions Sub-toolbar** below



See **Patterns Sub-toolbar** below



Duplicate Geometrical Set
See **Duplicating Geometrical Sets and Ordered Geometrical Sets**



See **Power Copy Sub-toolbar** below



See **UserFeature Sub-toolbar** below

3.3.25 Repetitions Sub-toolbar



Object Repetition
See **Repeating Objects**

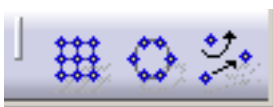





Points Creation Repetition
See **Creating Multiple Points and Planes**



Planes Between
See **Creating Planes Between Other Planes**



3.3.26 Patterns Sub-toolbar



-  **Rectangular Pattern**
See **Creating Rectangular Patterns**
-  **Circular Pattern**
See **Creating Circular Patterns**
-  **User Pattern**
See **Creating User Patterns**

3.3.27 Power Copy Sub-toolbar



-  **PowerCopy Creation**
See **Creating Power Copies**
-  **Save In Catalog**
See **Saving Power Copies into a Catalog**





3.3.28 UserFeature Sub-toolbar



-  **UserFeature Creation**
See **Creating User Features**
-  **Save In Catalog**
See **Saving User Features into a Catalog**

3.3.29 Advanced Surfaces Toolbar



-  **Bump**
See **Creating Bumped Surfaces**
-  **Wrap Curve**
See **Deforming Surfaces Based on Curve Wrapping**
-  **Wrap Surface**
See **Deforming Surfaces According to Surface Wrapping**
-  **Shape Morphing**
See **Deforming Surfaces According to Shape Morphing**

3.3.30 Developed Shapes Toolbar



Unfold

See **Unfolding a Surface**



Transfer

See **Transferring Elements**



Develop

See **Developing Wires and Points**

3.3.31 Volumes Toolbar



Volume Extrude

See **Creating Extruded Volumes**



Volume Revolve

See **Creating Revolution Volumes**



Multi-sections Volume

See **Creating Multi-Sections Volumes**



Volume Sweep

See **Creating Swept Volumes**



Thick Surface

See **Creating a Thick Surface**



Close Surface

See **Creating a Close Surface**



See **Volume drafts Sub-toolbar** below



Shell

See **Creating a Shell**



Sew Surface

See **Creating a Sew Surface**



Thickness




See **Creating Thicknesses**



See **Volumes operations Sub-toolbar** below





3.3.32 Volume Drafts Sub-toolbar



-  **Draft Angle**
See **Creating a Draft**
-  **Variable Draft Angle**
See **Creating a Variable Angle Draft**
-  **Draft Reflect Line**
See **Creating a Draft From Reflect Lines**






3.3.33 Volumes Operations Sub-toolbar



-  **Add**
See **Adding Volumes**
-  **Remove**
See **Removing Volumes**
-  **Intersect**
See **Intersecting Volumes**
-  **Union Trim**
See **Trimming Volumes**

3.3.34 BiW Templates Toolbar



-  **Junction**
See **Creating Junctions**
-  **Diabolo**
See **Creating a Diabolo**
-  See **Holes Sub-toolbar** below
-  **Mating Flange**
See **Creating a Mating Flange**
-  **Bead**
See **Creating a Bead**

3.3.35 Holes Sub-toolbar



Hole
See **Creating a Hole**



Hole Curve
See **Creating a Hole Curve**

3.3.36 Apply Material Toolbar



Apply Material
See **Applying Materials Onto Surfaces**

3.3.37 Measure Toolbar



Measure Between
See **Measuring Minimum Distances and Angles**



Measure Item
See **Measuring Properties**



Measure Inertia
See **Measuring Inertia**

3.3.38 Tools Toolbar













Update All
See **Updating Parts**



Manual Update mode
See **Manually Updating a Part**









Create 3D Axis System
See **Defining an Axis System**

-  **Show Historical Graph**
See [Using the Historical Graph](#)
-  See **Grid Sub-toolbar** below
-  See **2D Visualization Mode Sub-toolbar** below
-  **Mask**
See [Creating Masks](#)
-  **Create Datum**
See [Creating Datums](#)
-  **Temporary Analysis Mode**
See [Creating Offset Surfaces](#)
-  **Insert Mode**
See [Inserting Elements](#)
-  See **KeepNoKeep Sub-toolbar** below
-  **Only Current Body**
See Display in the *Part Design User's Guide*
-  See **Instantiation Sub-toolbar** below

Geometrical Set.  **Select current tool**
See [Selecting Bodies](#)







3.3.39 Grid Sub-toolbar



-  **Work On Support**
See [Working with a Support](#)
-  **Work On Support 3d**
See [Working with a 3D Support](#)
-  **Snap To Point**
See [Working with a Support](#)
-  **Work Supports Activity**
See [Working with a Support](#)
-  **Grid Featurization Switch**
See [Working with a 3D Support](#)
-  **Plane System**
See [Creating Plane Systems](#)



3.3.40 2D Visualization Mode Sub-toolbar



-  **Pickable visible background**
See **Managing the Background Visualization**
-  **No 3D background**
See **Managing the Background Visualization**
-  **Unpickable background**
See **Managing the Background Visualization**
-  **Low intensity background**
See **Managing the Background Visualization**
-  **Unpickable low intensity background**
See **Managing the Background Visualization**
-  **Lock**
See **Managing the Background Visualization**



3.3.41 KeepNoKeep Sub-toolbar



-  **No Keep Mode**
See **Keeping the Initial Element**
-  **Keep Mode**
See **Keeping the Initial Element**

3.3.42 Instantiation Sub-toolbar



-  **Catalog Browser**
See **Instantiating Power Copies Using the Catalog**
-  **Instantiate From Document**
See **Instantiating Power Copies**

3.3.43 Constraints Toolbar



See **Creating Constraints**



See **Creating Constraints**

3.3.44 Annotations Toolbar



See **Annotations Sub-toolbar** below

3.3.45 Annotations Sub-toolbar



Text With Leader

See **Creating a Text With Leader**



Flag Note With Leader

See **Creating a Flag Note With Leader**

3.3.46 Views/Annotation Planes Toolbar



See **Views/Annotation Planes Sub-toolbar** below

3.3.47 Views/Annotation Planes Sub-toolbar



Front View/Annotation Plane
See **Creating a Front View**



Section View/Annotation Plane
See **Creating a Section View**



Section Cut/Annotation Plane
See **Creating a Section Cut View**

3.3.48 Analysis Toolbar



See **Analysis Sub-toolbar** below

3.3.49 Analysis Sub-toolbar



Connect Checker
See **Checking Connections between Surfaces**



Curve Connect Checker
See **Checking Connections between Curves**



Feature Draft Analysis
See **Performing a Draft Analysis**



Surfacic Curvature Analysis
See **Performing a Surface Curvature Analysis**



Porcupine Analysis
See **Performing a Curvature Analysis**



Apply Dress-Up
See **Setting Dress-Up Options**



Remove Dress-Up
See **Setting Dress-Up Options**



Geometric Information
See **Displaying Geometric Information on Elements**



WYSIWYG Mode

See **Working With the WYSIWYG Mode**

3.3.50 User Selection Filter Toolbar



Point Filter

See **Selecting Using A Filter**



Curve Filter

See **Selecting Using A Filter**



Surface Filter

See **Selecting Using A Filter**



Volume Filter

See **Selecting Using A Filter**



Feature Element Filter

See **Selecting Using A Filter**



Geometrical Element Filter

See **Selecting Using A Filter**



Intersection Edges Selection

See **Selecting Using A Filter**



Work On Support selection state

See **Selecting Using A Filter**



Quick Select

See **Selecting Using A Filter**

3.4 MODLE OF GRAVITATIONAL WATER VORTEX TURBINE

In this project we are modelling the existing turbine with some little changes in dimensions and shape and then perform analysis.

DIMENSIONS:

For runner basin:	
Channel width	4m
Channel basin height	2m
Inlet diameter	3m
Outlet diameter	1m
Channel length	10m
Channel height	1.5m
For turbine blades:	
Height	1.5m
Length of blades	1.5m (along the length upto baffle plates)
	1.3m (upto starting of baffle plates)

Table 3.1 Dimensions of the GWVT

3.5 STEPS FOLLOWED TO MODEL THE GRAVITATIONAL VORTEX TURBINE

3.5.1 Basin:

1. Consider a plane X-Y draw a circle of diameter 1m.
2. Consider a plane parallel to X-Y at a distance of 4 m and draw a another circle of diameter 2m. combine them using multi section solid option
3. Pad the bigger circle upward to a length of 2m. draw the outline of runner shape and pad to produce as shown in the fig 3.4 below.

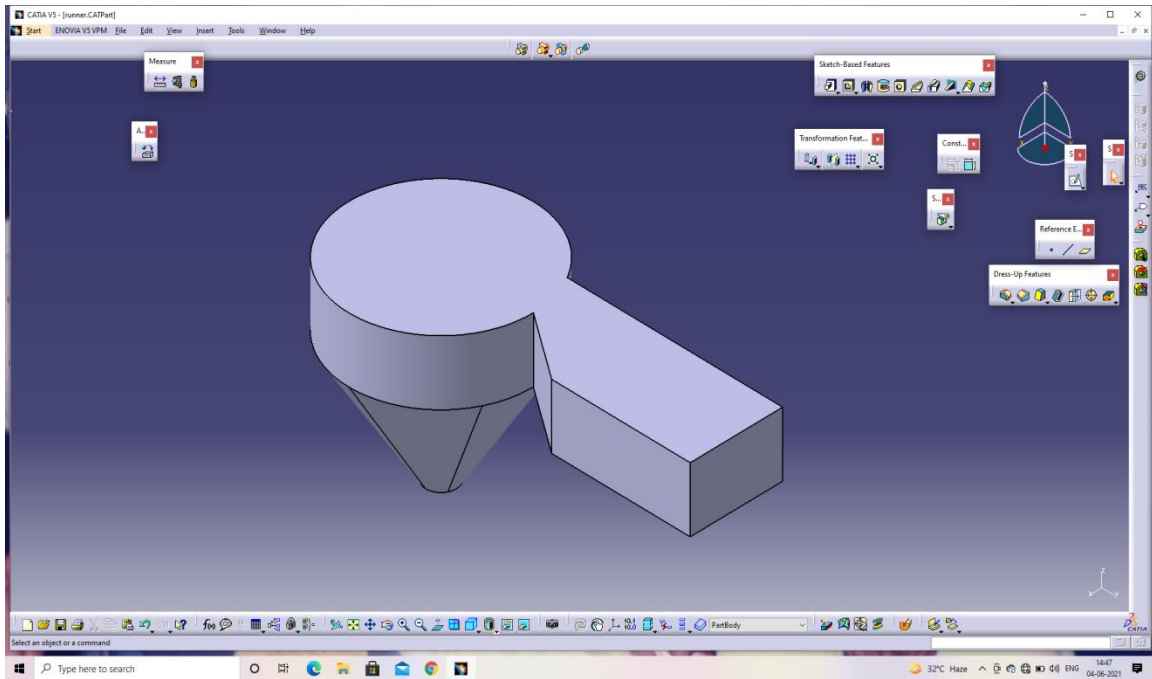


Fig 3.4 Model of gravitational water vortex turbine

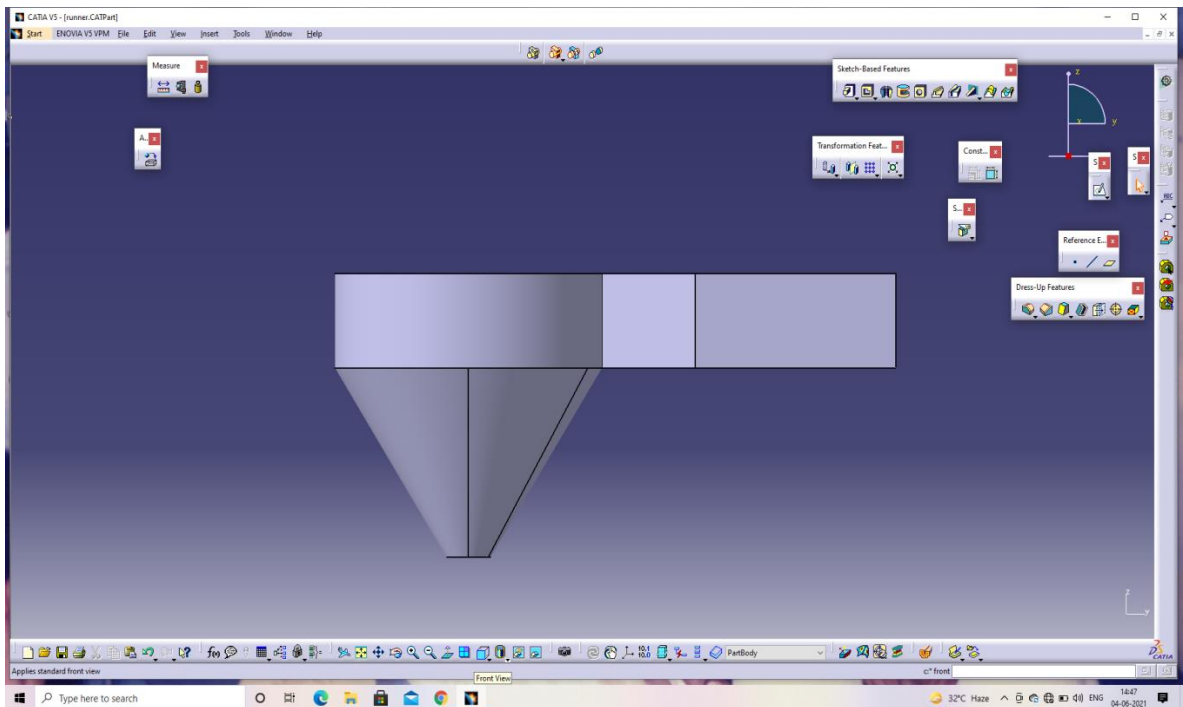


Fig 3.5 Front view of gravitational water vortex turbine

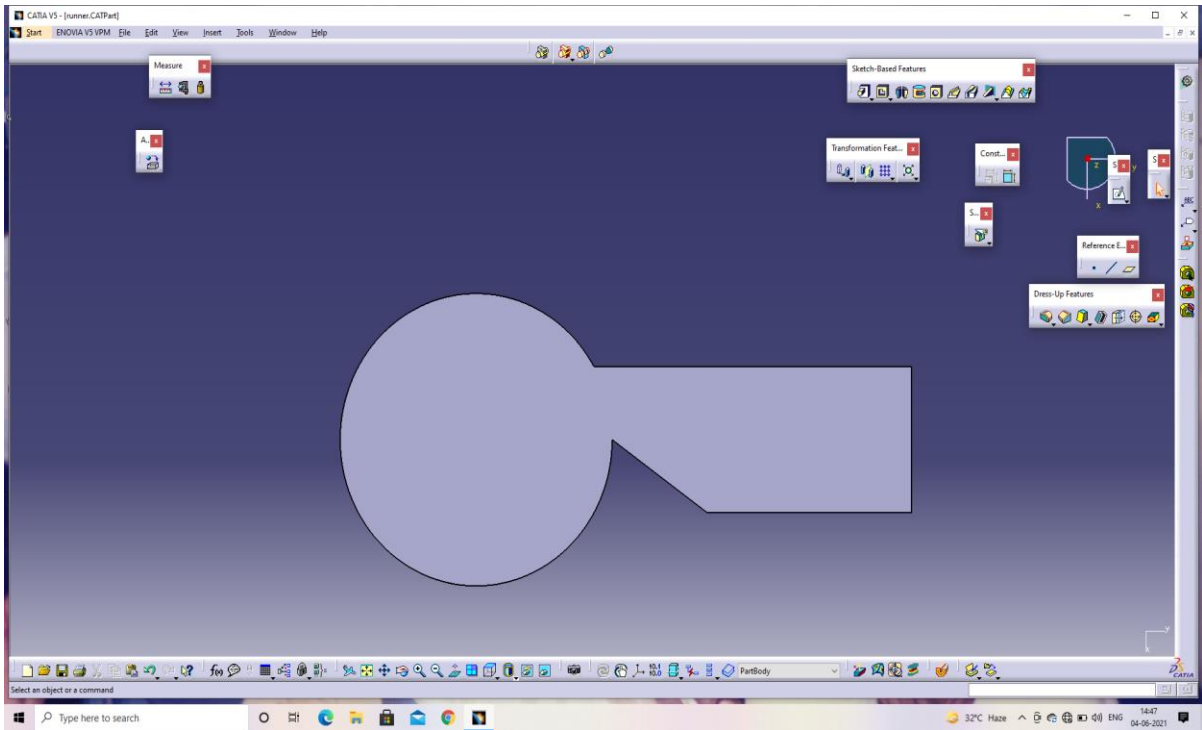


Fig 3.6 Top view of gravitational water vortex turbine

3.5.2 Turbine Blades:

1. Draw a circle and pad it to get the cylinder.
2. Draw a rectangle shape on the same plane of the circle and pad it to the surface of cylinder.
3. Taking an angle place the baffle plates at the end of rectangular plate as shown in the fig 3.7 below.

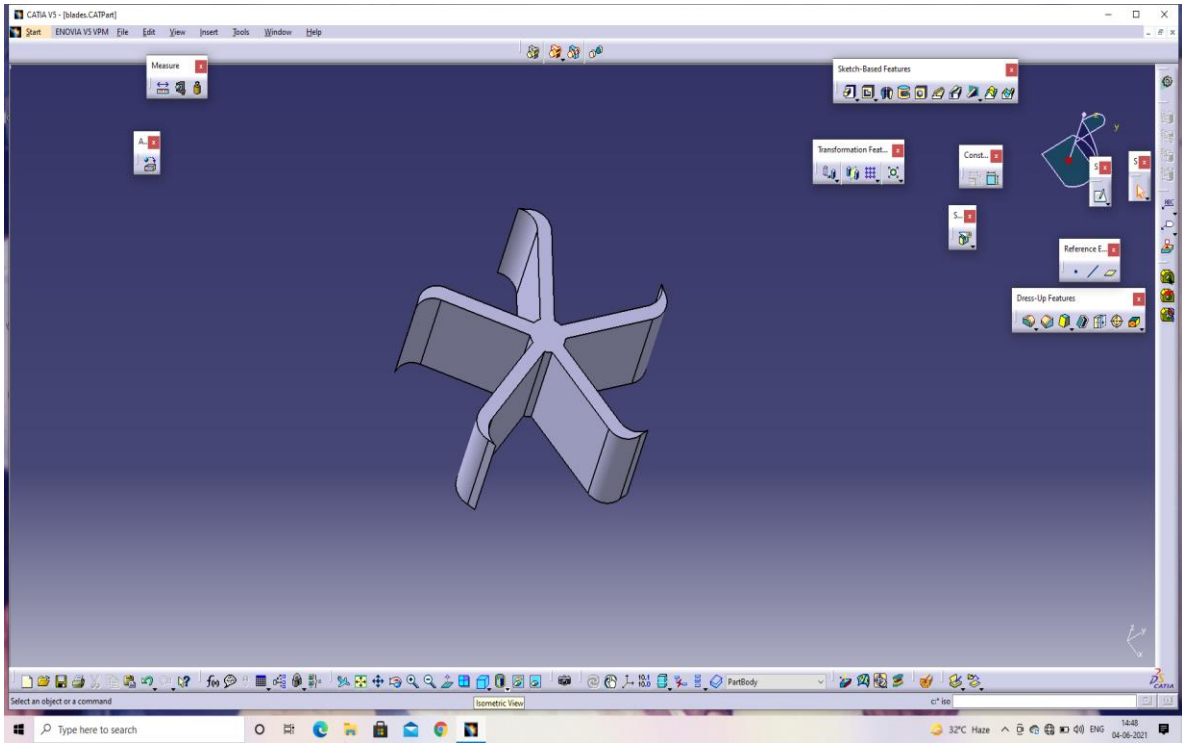


Fig. 3.7 Turbine blades

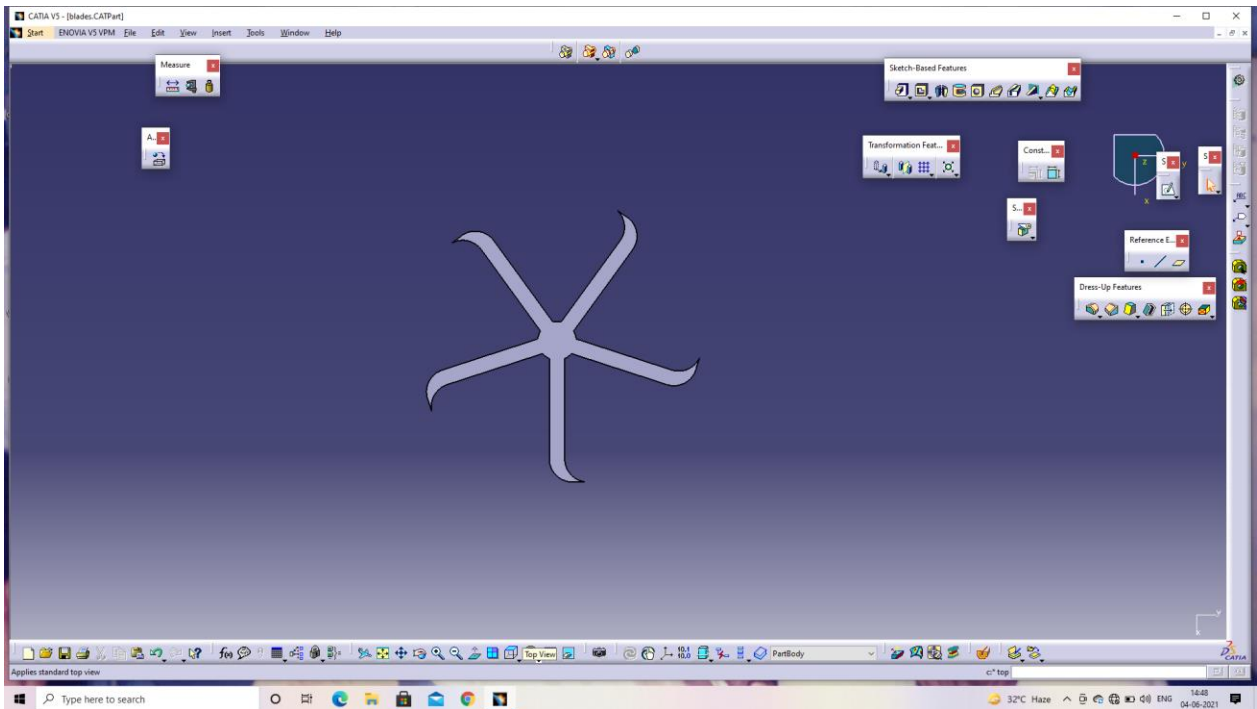


Fig. 3.8 Top view of turbine blades

3.5.3 Assembly:

Import the Runner and fix it using fix option, again import the turbine blades. With the help of surface constraints and offset constraints assemble them.

3.5.4 Drafting:

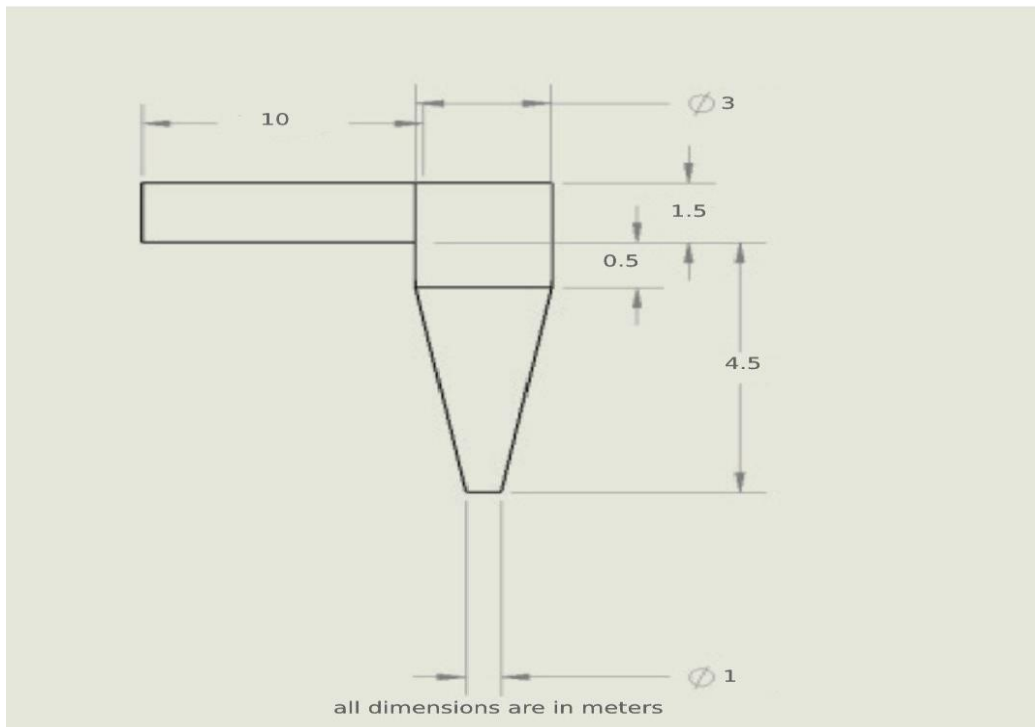


Fig. 3.9 Drafting of GWWT

3.6 Analysis software:

In this project we are using ANSYS R21 as our analysis software.

3.6.1 ANSYS 21:

Introduction

The Ansys finite element solvers enable a breadth and depth of capabilities unmatched by anyone in the world of computer-aided simulation. Thermal, Structural, Acoustic, Piezoelectric, Electrostatic and Circuit Coupled Electromagnetics are just an example of what can be simulated. Regardless of the type of simulation, each model is represented by a

powerful scripting language . The Ansys Parametric Design Language (APDL). APDL is the foundation for all sophisticated features, many of which are not exposed in the Workbench Mechanical user interface. It also offers many conveniences such as parameterization, macros, branching and looping, and complex math operations. All these benefits are accessible within the Ansys Mechanical APDL user interface.

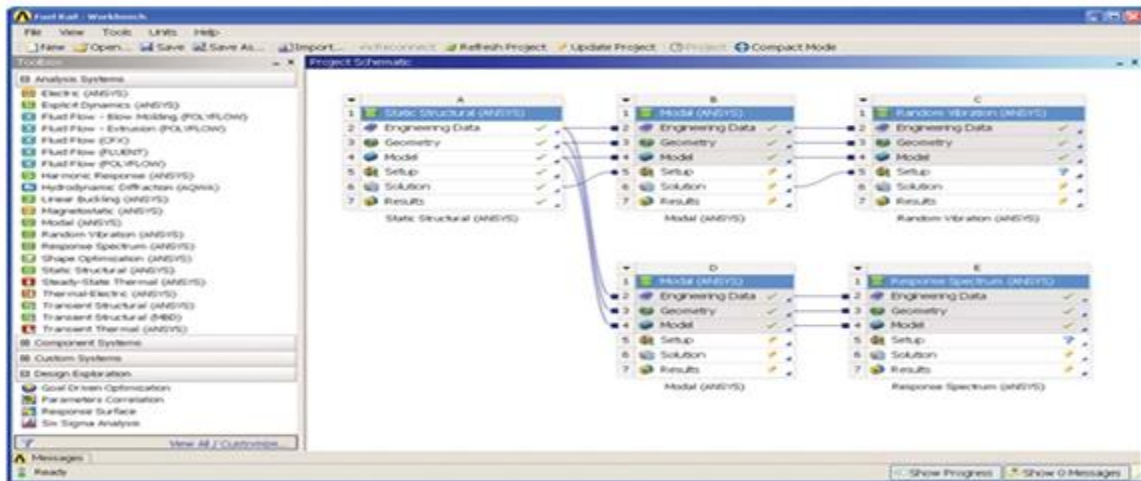


Fig. 3.10 Steps and levels of analysis

The ANSYS Workbench platform automatically forms a connection to share the geometry for both the fluid and structural analysis, minimizing data storage and making it easy to study the effects of geometry changes on both analyses. In addition, a connection is formed to automatically transfer pressure loads from the fluid analysis to the structural analysis.

3.6.2 ANSYS Workbench Features:

- Bidirectional, parametric links with all major CAD systems.
- Integrated, analysis-focused geometry modelling, repair, and simplification via ANSYS Design Modeler.
- Highly automated, physics-aware meshing.
- Automatic contact detection.
- Unequalled depth of capabilities within individual physics disciplines.
- Unparalleled breadth of simulation technologies.
- Complete analysis systems that guide the user start-to-finish through an analysis.

- Comprehensive multi physics simulation with drag-and-drop ease of use.
- Flexible components enable tools to be deployed to best suit engineering intent.
- Innovative project schematic view allows engineering intent, data relationships, and the state of the project to be comprehended at a glance.
- Complex project schematics can be saved for re-use.
- Pervasive, project-level parameter management across all physics.
- Automated what-if analyses with integrated design point capability.
- Adaptive architecture with scripting and journaling capabilities and API's enabling rapid integration of new and third-party solutions.

ANSYS provides an interface to the LS-DYNA explicit finite element program and is used to calculate fast solutions for large deformation dynamics and complex contact problems.

- In addition to the above analysis types, several special-purpose features are available
- Fracture mechanics
- Composites
- Fatigue
- p-Method

In ANSYS we have done the analysis by importing the model. After importing the model we then do the meshing.

To start meshing first we need to apply boundary conditions to the model.

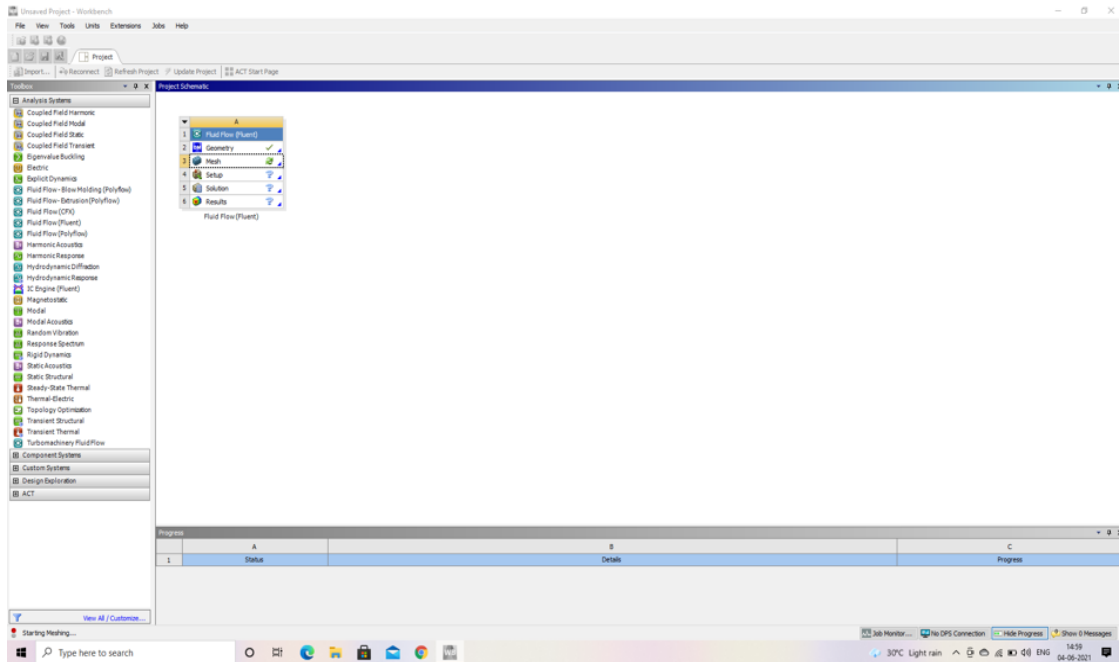


Fig 3.11 Applying boundary conditions.

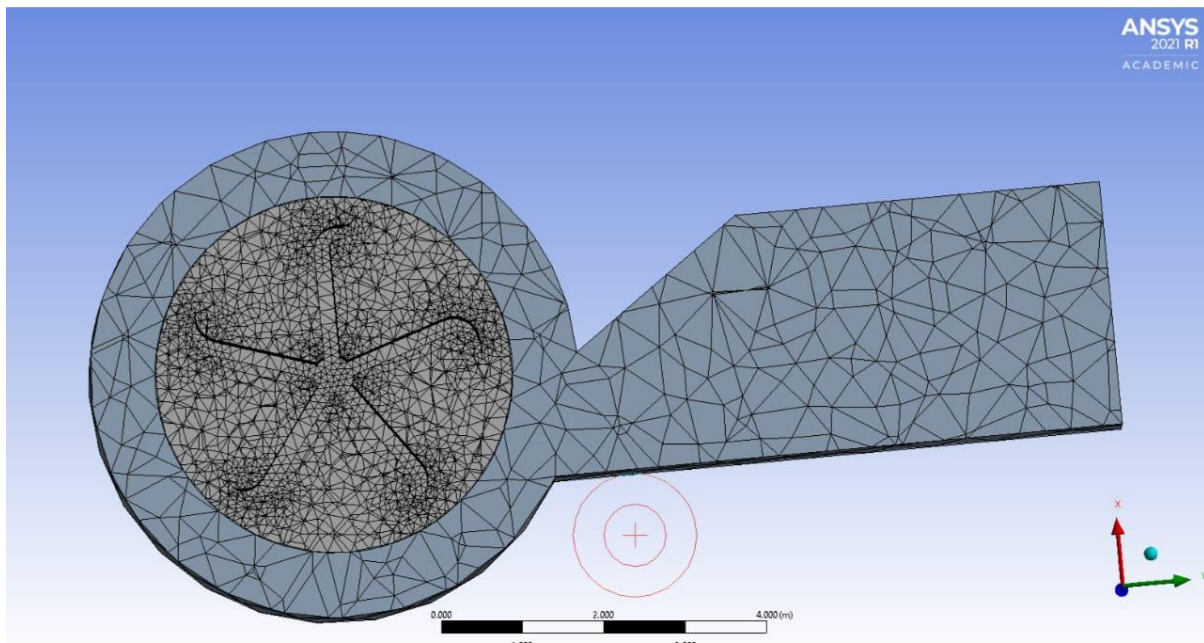


Fig. 3.12 Meshing before inflation (top view)

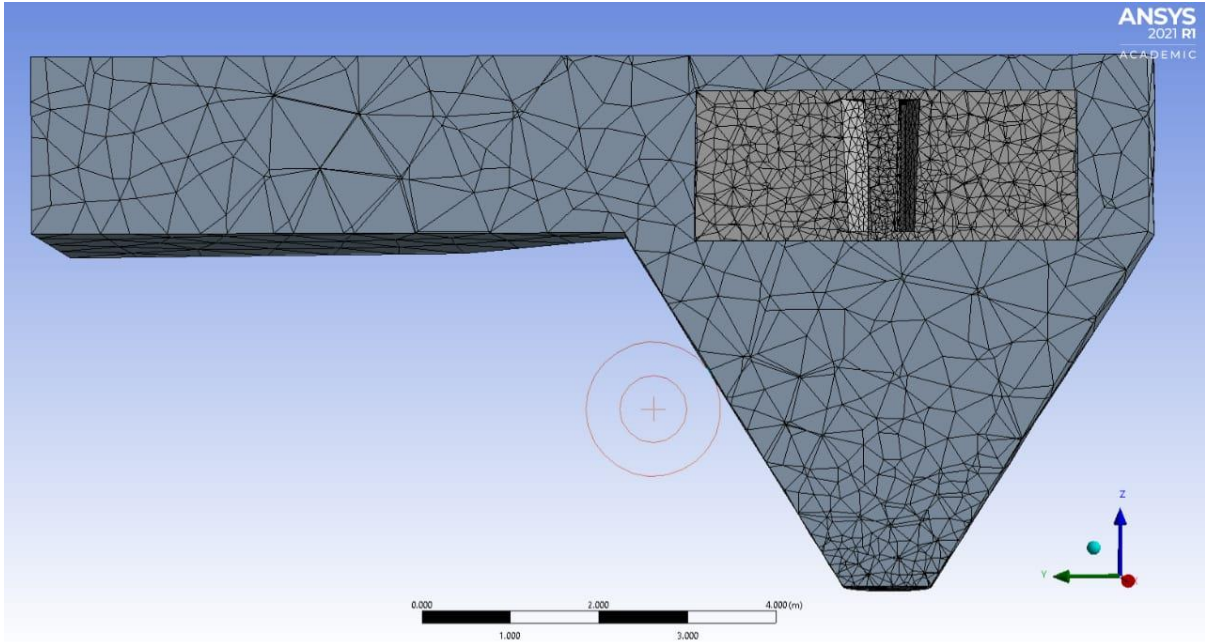


Fig. 3.13 Meshing before inflation (front view)

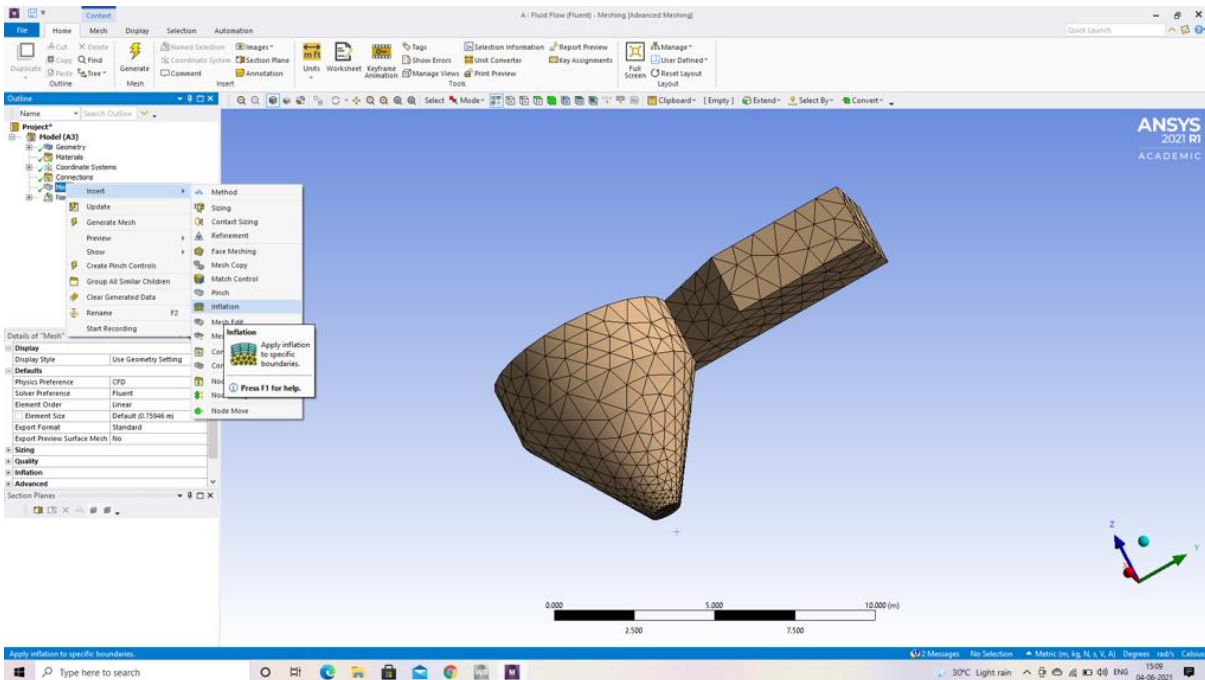


Fig 3.14 Complete meshing

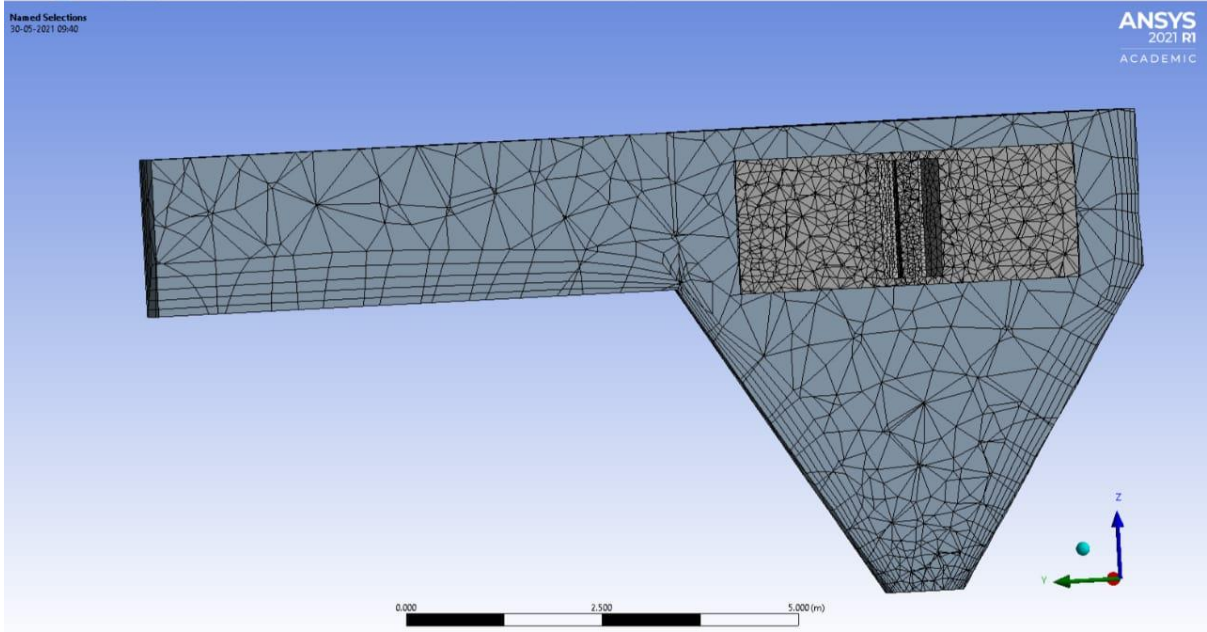


Fig. 3.15 Meshing after inflation (front view)

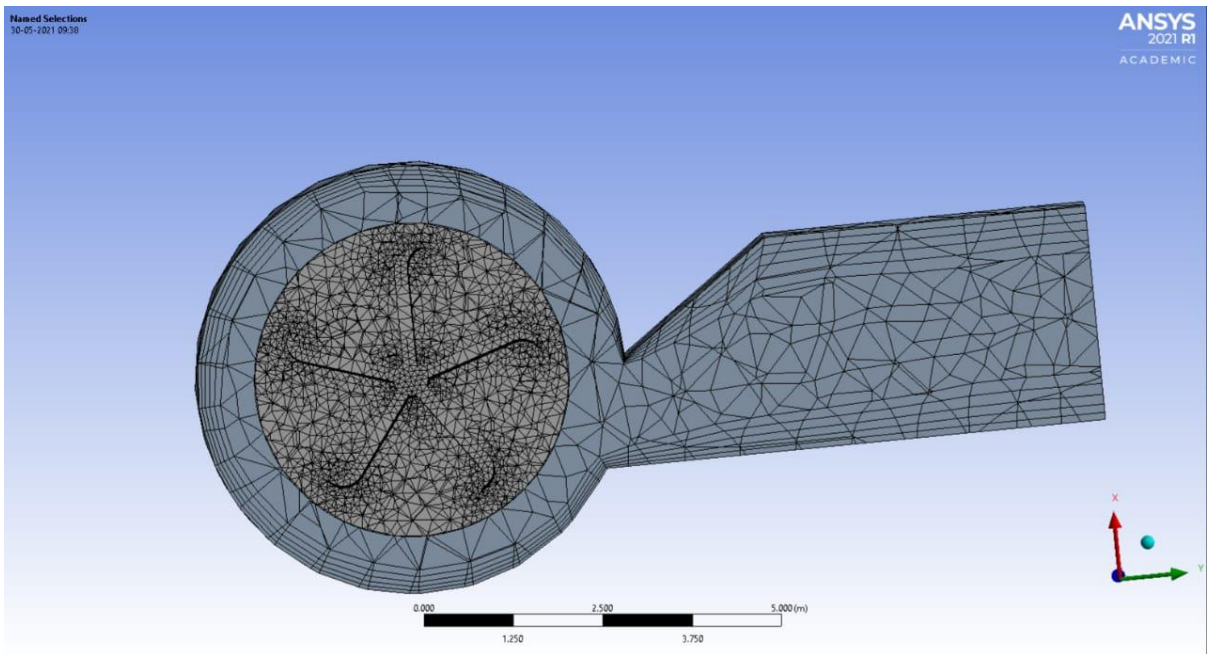


Fig. 3.16 Meshing after inflation (top view)

Now, Start the setup on required conditions.

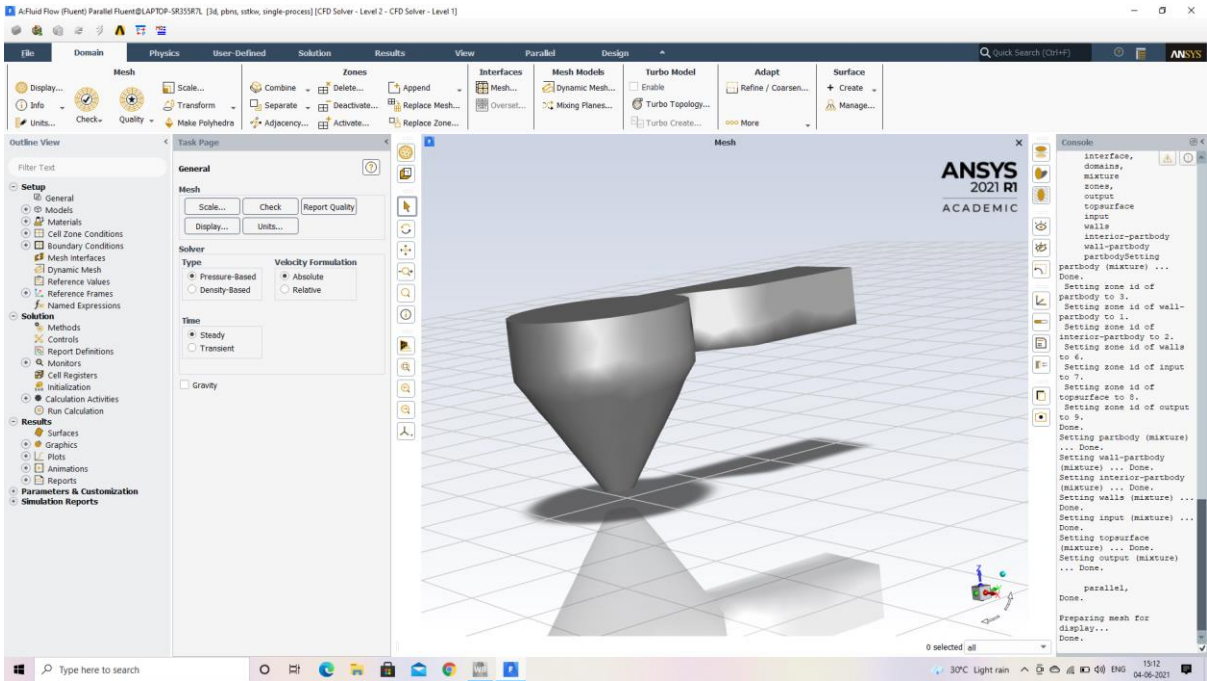


Fig. 3.17 Setup for analysis on GWVT

CHAPTER – 4
RESULTS AND DISCUSSIONS

RESULT:

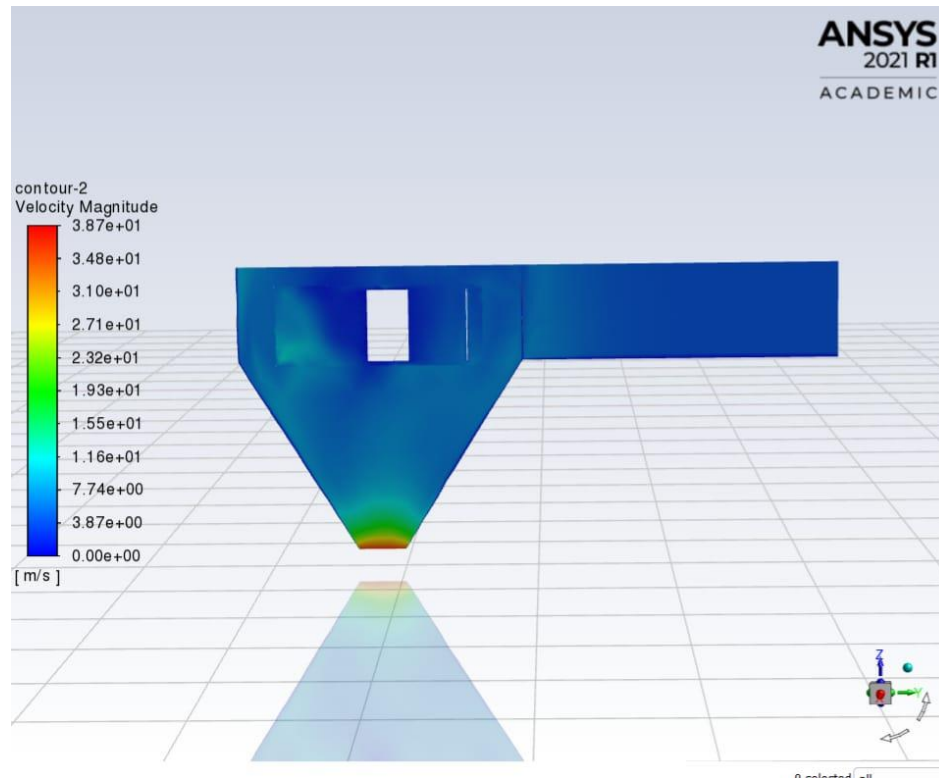


Fig. 4.1 Velocity contour

From the above velocity contour we can say that the water flowing from the inlet to outlet is different and at inlet, the water is almost still and when it enters into the turbine basin, due to the shape of the basin and tangential flow of water through out the basin will generate vortex, then the formed vortex hits the turbine blades and rotation of the blades takes place, therefore in the above figure 4.1 we can observe how the velocity varies at different points.

Residual velocities:

The velocities which were lost in the due process of working of a turbine , which may be due to turbulence of the water, inertia of the turbine rotating part (blades). Viscosity is also known as the residual velocity. If the residual velocities are more, then the efficiency of the turbine will be less. The following graph give the relation between residual velocities and iteration.

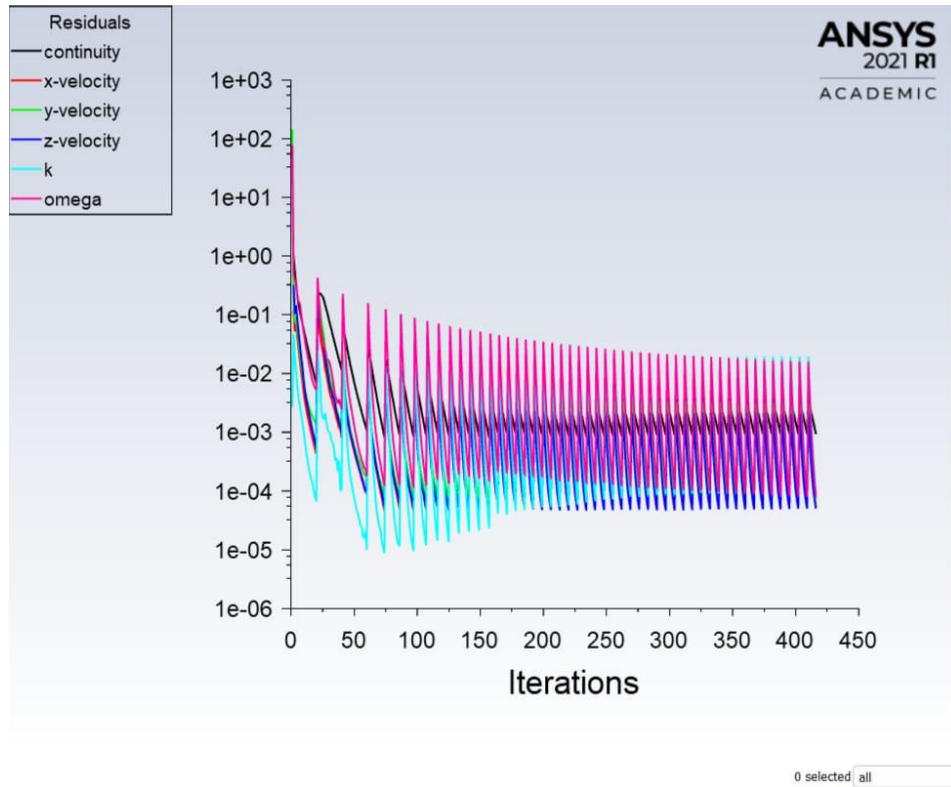


Fig 4.2 Residual velocities

Turbine moment vs time:

The following graph is plotted for the turbine moment and flow time. This gives the ideas of how the turbine moment (torque) changes with the flow time of water after reaching the optimum velocities or rpm the momentum oscillate about avg. torque.

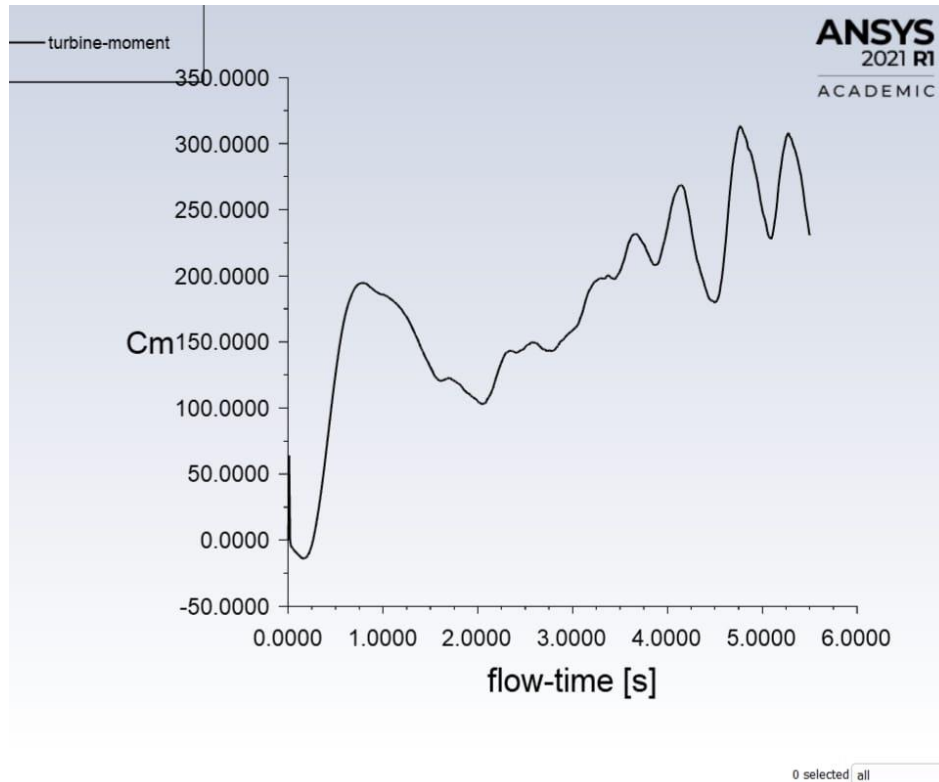


Fig 4.3 Torque vs time

CALCULATIONS:

Since we lack in experimental setup, we chose the previously published for reference for our project. So we are considering their paper as a base for our project and took their calculations.

Paper : CFD evaluation of performance of Gravitational Water Vortex Turbine at different runner positions, KECConference2019, Kantipur Engineering College, Dhapakhel Lalitpur.

Jet impingement on the curved blades:

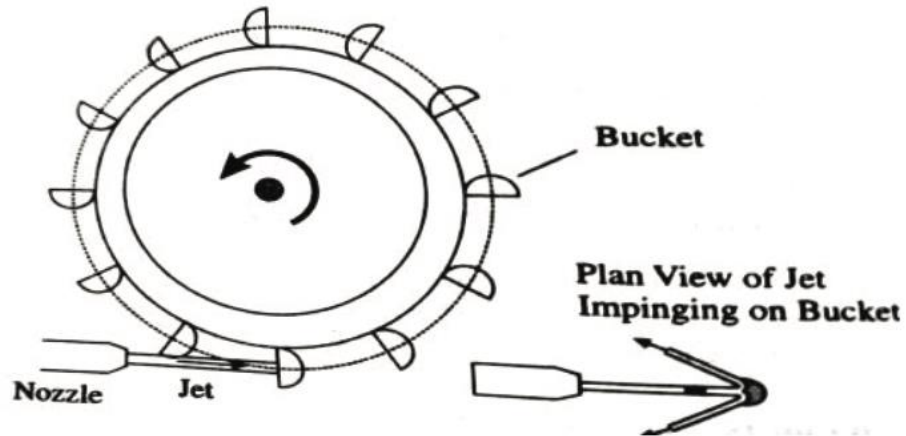


Fig. 4.4 Jet impingement on curved vanes

Consider the linear momentum equation in the x- direction:

$$\sum(\text{Forces in } x - \text{direction}) = (\text{Momentum flux in } x \text{ direction})_{\text{out}} - (\text{momentum flux in } y \text{ direction})_{\text{in}}$$

$$0 - R_x = [-\rho A v (v-u) \cos\theta] - [\rho A v (v-u)]$$

$$R_x = \rho A v (v-u) (1 + \cos\theta) \quad (1)$$

If F_x be the force on the vane in the x-direction, F_x is equal and opposite to R_x .

Thus, the idealized force on the vane in the direction is

$$F_x = \rho A v (v-u) (1 + \cos\theta) \text{ acting in the positive } x\text{- direction.}$$

By linear momentum equation in the y-direction:

$$\sum(\text{Forces in } y - \text{direction}) = (\text{momentum flux in } y\text{- direction})_{\text{out}} - (\text{momentum flux in } y\text{- direction})_{\text{in}}$$

$$0 - R_y = [\rho A v (v-u) \sin\theta] - [\rho A v (v-u) \sin\theta] - 0 = 0$$

Hence R_y , the force in the vane in y-direction is zero.

Work done by the jet per second = Power transmitted to the wheel

$$=F_x \cdot u = \rho A v (v-u)(1+\cos\theta) \cdot u$$

$$\text{Kinetic energy on the jet per unit time} = \frac{1}{2} \rho A v \cdot v^2 \quad (2)$$

$$\begin{aligned} \text{Efficiency of system, } \eta &= \frac{\text{power transmitted to the wheel}}{\text{kinetic energy supplied by the jet per unit time}} \\ &= \frac{\rho A v (v-u)(1+\cos\theta) \cdot u}{\frac{1}{2} \rho A v \cdot v^2} \end{aligned}$$

$$\eta = \frac{2u(v-u)(1+\cos\theta)}{v^2} \quad (3)$$

Where, v – initial velocity of the water

u – peripheral velocity

η – efficiency of the turbine

θ – vane angle

Analytical Calculations:

from the analysis, we get. $v = 9.91 \text{ m/s}$

$$u = 6.8 \text{ m/s}$$

$$\theta = 90^\circ$$

$$\begin{aligned} \text{Now, efficiency is } \eta &= \frac{2u(v-u)(1+\cos\theta)}{v^2} \\ &= \frac{2(6.8)(9.91-6.8)(1+\cos 90^\circ)}{9.91^2} \\ &= 0.430677 \\ \eta &= 43.067\% \end{aligned}$$

CHAPTER – 5
CONCLUSION

CONCLUSION:

The GWVPP is an efficient power plant that can be used to generate power easily using a low head. Based on the findings of the research, it can be concluded that:

- i. An increase of flow velocity or mass flow rate into the basin causes a rise in the height of water level with an increase in the tangential velocity.
- ii. The velocity increase in the vortex is maximum when a full air core is formed.
- iii. The air core and vortex height cannot be directly related to each other since the air-core formation depends upon many other factors as well.
- iv. Increasing the flow rate by increasing the inlet depth is a better option as compared to the inlet width.
- v. Air core can be formed by increasing the outlet diameter keeping all other parameters constant.
- vi. When the basin diameter is reduced, the water level in the basin slightly increases. But the reduction of basin diameter causes the air core to decrease till the air-core eventually dies.
- vii. As the basin diameter is increased from the optimum value, the vortex height decreases, and thus the strength of the vortex.
- viii. When a basin of larger diameter is used, the vortex height drops and almost all the water glides along the floor of the basin. This causes a great frictional loss in the velocity of the water.
- ix. Optimum torque lies in the mid of the whole rpm range i.e. between no load condition and maximum load condition. Best efficiency point also lies in the mid of the rpm range.
- x. Heavier blades result in lower rpms.
- xi. When the load on the turbine is increased, it decreases the height of the vortex.

We used CATIA V5 to model the Gravitational Water Vortex Turbine and ANSYS R21 student version to simulate the model.

The efficiency of the turbine actually varies from 42% to 82% depending upon the blades used. The efficiency is generally high for the curved plates. The blades we used is flat blades with baffle plates The efficiency for the model which we created is $\eta = 43.067\%$

FUTURE RECOMMENDATIONS:

1. Installation of guide vanes
2. Further optimization of Cross flow and twisted blades
3. Testing of the proposed blade profiles in different basin geometries
4. Using a better quality mesh for the improvement of results.

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