Kaunas University of Technology

Faculty of Mechanical Engineering and Design

Research on Functionality of Underpressure Helical Turbine

Master's Final Degree Project

Pavan Kumar Ramachandra

Project author

Prof. Vytautas Grigas

Supervisor

Kaunas, 2020

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Mechanical Engineering (code 6211EX009)

Pavan Kumar Ramachandra
Project author

Prof. Vytautas Grigas
Supervisor

Prof. Valdas Eidukynas
Reviewer

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Kaunas University of Technology

Faculty of Mechanical Engineering and Design

Pavan Kumar Ramachandra

Research on Functionality of Underpressure Helical Turbine

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I confirm that the final project of mine, Pavan Kumar Ramachandra, on the topic „Research on Functionality of Underpressure Helical Turbine, " is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarised from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this project.

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Kaunas University of Technology

Faculty of Mechanical Engineering and Design

Study programme: MECHANICAL ENGINEERING 6211EX009

Task Assignment for Final Degree Project of Master Studies

Student – Pavan Kumar Ramachandra

1. Title of the Project –

Research on Functionality of Underpressure Helical Turbine

(In English)

Žemo slėgio sraigtinės turbinos funkciškumo tyrimas

(In Lithuanian)

2. Aim and Tasks of the Project –

The aim of this research is the evaluation of the functional parameters of underpressure helical turbine.

Tasks-

1. Development of the geometrical model and description of main geometrical parameters
2. Analytical analysis of main functional parameters
3. Creation of the computational model and numerical simulation of underpressure helical turbine
4. Comparison of results of analytical study and numerical simulation.

3. Initial Data –

Underpressure helical turbine,Patent-9600310, ŠTALEC MILAN, 1433 Radeče, SI

4. Main Requirements and Conditions –

Water flow velocity between 1m/s to 4m/s into turbine inlet, Hydraulic turbine speed of 200rpm, The dimension less parameter Rorres (2000) value between 0 and 1 is true.

Project author	Pavan Kumar Ramachandra		
	(Name, Surname)	*(Signature)*	*(Date)*
Supervisor	Prof. Vytautas Grigas		
	(Name, Surname)	*(Signature)*	*(Date)*
Head of study field programs	Prof. Pilkauskas kestutis		
	(Name, Surname)	*(Signature)*	*(Date)*

Ramachandra Pavan Kumar. Research on Functionality of Underpressure Helical Turbine. Master's Final Degree Project/supervisor Prof. dr.Vytautas Grigas; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.

Study field and area (study field group): Technological Sciences, Mechanical Engineering,

Keywords: hydraulic torque, hydraulic efficiency, flow rate, solid works, flow simulation,

Kaunas, 2020. 53 p.

Summary

The electric power plays a significant role in the daily life of human beings. The power generating from fluid majorly water is also called as hydropower is one of the easiest and very renewable types of energy conversion. The hydraulic turbines convert the hydraulic energy obtained from the flow of water into mechanical energy; this received energy is converted into electrical energy with the help of electric power generators. The hydraulic turbines have the row of blades fitted to the rotor element flowing fluid passes through the hydraulic turbine strikes the blades of the turbine and allow the shaft to rotate.

In this research, the underpressure helical turbine is considered. The underpressure helical turbine solves the problem of transformation of potential energy into kinetic energy in rotor sphere. The underpressure helical turbine rotor is performed like a vertical cylinder which has a spiral line executed by its external circumference and is centrally and spherically movable placed inside of the casing. This research evaluates the functional parameters such as hydraulic torque and hydraulic efficiency by varying the geometrical parameters such as diameter of the turbine rotor and pitch of the turbine blade. The geometrical model of the turbine is developed, and the analytical analysis results are obtained for the main functional parameters. The computational model is created for the numerical simulation of the turbine design and results are obtained by using SolidWorks-2018 software. The results are compared between the analytical analysis and numerical simulation to evaluate the functional parameters of the underpressure helical turbine. Hydraulic torque is the ability of turbine to produce the required torque by utilising the flow of water energy to rotate the electric power generator shaft generator. Hydraulic efficiency is the ratio of water power at the outlet to the water power at inlet of the turbine.

Ramachandra Pavan Kumar. Sraigtinės žemo slėgio turbinos funkciškumo tyrimas. Magistro baigiamasis projektas/vadovas Prof. dr. Vytautas Grigas; Mechanikos Inžinerijos ir Dizaino Fakultetas, Kauno technologijos universitetas.

Studijų kryptis ir sritis (studijų krypčių grupė): Technologijos Mokslai, Mechanikos Inžinerija

Raktiniai žodžiai: sraigtinė turbina, hidraulinis sukimo momentas, hidraulinis efektyvumas, debitas, skaičiuojamoji srautų analizė.

Kaunas, 2020. 53 p.

Santrauka

Elektros energija yra ypač svarbi kasdieniame žmonių gyvenime. Elektros energija, gaunama panaudojant vandens srauto energiją, vadinama hidroenergija – ji išgaunama bene lengviausiai ir yra viena iš labiausiai atsinaujinančių energijos rūšių. Hidraulinės turbinos hidraulinę energiją, gautą iš vandens srauto, paverčia mechanine (turbinos rotoriaus sukimosi) energija, kuri elektros generatorių pagalba paverčiama į elektros energiją. Hidraulinių turbinų rotoriai turi vieną ar kelias eiles menčių, kurias slegia per turbiną tekantis skystis (vanduo) ir slėgio atstojamosios jėgos tangentinė dedamoji verčia mentes ir rotorių suktis apie jo ašį.

Šiame darbe nagrinėjama žemo slėgio sraigtinė turbina, kaip ir kitos turbinos, potencinę fluido skysčio ar dujų) srauto energiją transformuojanti į besisukančio rotoriaus kinetinę energiją, kuri generatoriaus pagalba nesunkiai transformuojama į elektros energiją. Vertikalaus cilindro formos žemo slėgio turbinos rotorius su sraigtine (spiraline) mente (ar keliomis mentėmis) ant jo išorinio cilindrinio paviršiaus, įstatomas į korpusą su cilindriniu kanalu taip, kad galėtų laisvai suktis apie savo ašį fluidui aptekant rotorių išilgai kanalo. Analitinio tyrimo metu įvertinti turbinos hidraulinis sukimo momentas ir hidraulinis efektyvumas esant skirtingiems turbinos geometriniams parametrams: turbinos rotoriaus skersmeniui ir mentės žingsniui. Skaičiuojamajai turbinos analizei atlikti SolidWorks programine įranga sukurtas jos 3D geometrinis kompiuterinis modelis, jo pagrindu sudarytas skaičiuojamasis modelis ir skaitiniais metodais gauti jos pagrindiniai funkciniai parametrai esant skirtingoms turbinos konfigūracijoms (geometrinių ir konstrukcinių parametrų deriniams. Lyginant analitinio skaičiavimo ir skaitinio modeliavimo rezultatus įvertinti žemo slėgio sraigtinės turbinos funkciškumo parametrai (hidraulinis sukimo momentas – turbinos sugebėjimas sukurti reikiamą sukimo momentą, panaudojant vandens energijos srautą elektros energijos generatoriaus veleno generatoriaus sukimui; ir hidraulinis efektyvumas – vandens galios išėjimo angoje santykis su vandens galia turbinos įleidimo angoje).

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Introduction

The electric power plays a significant role in the daily life of human beings. The power generating from fluid majorly water which is also called as hydropower is one of the easiest, economical and very renewable type of energy conversion from fluid energy to mechanical energy and then which generates electric energy for the other typical use of the human life. The power generation by waters mostly helps in the areas which still underdeveloped, isolated, where disaster occur eventually the power generation by this type helps in both water flow, and the water storage as the many hydropower units or hydroelectric power plants are constructed where the water flow is very abundant, and enough natural resources are available. The most effective manner to fulfil these needs involves the use of a power generating system which utilise the abundantly available renewable energy resources. The general concept of a hydroelectric power system is to convert the kinetic energy and potential energy of the water (mass) moving with some speed (momentum) into a usable form of energy. Hydropower projects involve various considerations at different levels of project implementation. Underpressure helical turbine solves the problem of transformation of potential energy into kinetic energy in the rotor sphere; thus, its reactivity is 100%. The rotor is performed like a vertical cylinder, which has a spiral line executed by its external circumference and is centrally and spherical-movable placed inside of the casing through bearings and which are fixed with bearer or bearer on the inner wall of the casing. The smallest profile between 2 curves of the spiral line is the passage from pressure into underpressure ratio. According to this, the turbine can be used within systems with small amounts of fluid with high falls – and inversely.

The aim of this research project is the evaluation of the functional properties of underpressure helical turbines.

Tasks:

1. Development of the geometrical model and selection of main geometrical parameters.
2. Analytical analysis of main functional parameters of underpressure helical turbine
3. Creation of computational model and numerical simulation of under pressure helical turbine.
4. Comparison of results of analytical analysis and numerical simulation

The underpressure hydraulic turbine is designed with varying the geometrical parameters, the efficiency is calculated theoretically by assuming the speed of the turbine to optimise the design for the working conditions of the turbine. The hydraulic torque of the turbine is calculated by integrating the turbine torque obtained by each water-filled bucket then the hydraulic torque is calculated throughout the length of the rotor theoretically by calculating the flow rate of inlet water and the pressure difference. The computational model of the designed underpressure turbine is simulated in the Solidworks software by applying calculated input, and boundary conditions, and the results of the average value of torque are obtained compared with the theoretically achieved torque.

The project shows the evaluation of models by varying single geometrical parameters in every turbine rotor and displays the result of functional parameter torque and mass of fluid in the simulation results.

1. Literature review

Hydraulic energy or Hydropower is clean; renewable obtained power to generate electricity from the received hydraulic energy from the mechanical systems which are then converted into mechanical energy. It has been considered the most efficient, accompanied by low maintenance costs [1]. There are several different approaches to generate hydropower, all of which convert potential energy and kinetic energy from water into electrical power [2]. A conventional hydropower -system includes dams that are constructed for storage of waters, where water is diverted to produce an input hydraulic or waterpower to turn the turbine rotor which powers a generator at a powerhouse. The power from a hydraulic turbine depends on an input volume of the flow rate of water and the difference between the above and below the height of the installed hydraulic turbine, which is known as head [3]. The major drawback of conventional hydropower machines is the cost and resources required to plan and construct the hydropower plant [4].

The under-pressure helical turbine is known as micro-hydro systems have an output of less than 100kW and generally used to supply water for the small communities [5]

Compared to the large hydropower project the micro-hydro power projects have less impact on the environment because of its ability to use already running water or streams with low head or high head and less flow rate of water in streams instead of constructing the giant dams which increase the project cost [4]. This micro-hydro power plant helps much in producing the much high power with low heads for the irrigation canals, small districts, and industrial areas. However, these under pressure helical turbine designs are simple in construction, which does not require any installation of dams and reservoirs. The micro-hydropower plants help in producing electricity in already flowing water with the low head instead of installing the large hydropower plants. The head and capacity required to power these micro-hydropower units are smaller than the larger hydropower units ranging between 5MW to 50MW [6].

Unfortunately, when compared to the low head micro-hydro turbines with large hydropower turbine, the micro-hydro turbines are expensive on per megawatt basis electrical power generation [1]. However, these small head sites are found in abundant than conventional large hydropower sites that require the construction of larger structures and more significant sites. The potential sites are already in use the micro-hydropower plants seem like an excellent renewable energy solution.

Turbine also is known as turbomachine is a device in which energy transfer takes place between a flowing fluid and a rotating element due to the action and results in a change of pressure and momentum of the fluid [7]. Turbo machine is divided into two types of machines, which are power-producing machines and the other machines which produce pressure or head which use electric power as the primary input to get the required output [7].

Modern turbines can generally be classified into two categories: impulse and reaction turbines. Impulse turbines are momentum-driven devices, typically designed for sites with a high head. Excellent head conditions (potentially several hundred meters) can create extreme pressures that can create high-velocity water jets when channelised through a nozzle. Impulse turbines direct this high momentum flow into paddles or buckets attached to a central cylinder causing it to rotate. Impulse turbines always operate in the air as operating submerged creates drag forces leading to inefficiencies [8]

The Pelton turbine is a commonly used impulse turbine suitable for high head, typically between 50 m and 1000 m [9]and low flow sites. In Pelton turbines, a high-pressure jet of water is directed at bucket-shaped blades. The shape of the buckets allows for nearly all of the flow energy to be converted to rotational mechanical energy [8]. Another well-known impulse turbine is a Turgo turbine, which is a modification of a Pelton turbine.

In Turgo turbines, the incoming water jet is directed at an angle of 20 degrees to the buckets allowing for a larger jet stream of water relative to the turbine diameter than a Pelton turbine. Therefore, for the same flow and head, a Turgo can generally produce more power or be constructed smaller, though at the expense of reduced overall efficiency [10]. Turgo turbines are suitable for heads typically ranging from 50 m to 250 m [10]. Reaction turbines are generally ideal for sites with heads less than 450 m. Unlike impulse turbines, reaction turbines are designed to operate at peak efficiency when submerged. While impulse turbines are momentum-based devices that harvest the kinetic energy of flowing water, reaction turbines are pressure-driven devices. The turbine blades in reaction turbines are designed to allow the pressure difference across the blades created by the weight and momentum of the water to cause turbine rotation [8].

Reaction turbines account for approximately 80% of all hydropower turbines in use today [8]. The two most common reaction turbines are Francis and Kaplan turbines. In Francis turbines, a pressure difference across the blades is accomplished by changing the flow direction. Flow enters the turbine radially but is redirected in a direction along the axial length of the turbine. The blades are shaped to maximise energy extraction and are typically designed for specific flow conditions 7 [8]. An adequately designed Francis turbine operating under the right conditions can be 90 to 95% efficient [8]. Francis turbines are the most commonly used turbines in large hydropower stations and deliver the best performance for heads between 40 m to 600 m [10]. Kaplan Turbines are another form of reaction turbines, well suited for low heads, typically less than 50 m [8]. Kaplan turbines are a form of propeller turbine that operates similar to boat propellers but in reverse. Instead of the blades pushing against the surrounding water to move a boat, flowing water pushing past the propeller blades creates a pressure difference, causing rotation. Propeller turbines are best suited for heads and flow less than impulse and Francis turbines and are often utilised in slow-moving rivers and streams with modest elevation drops [8]. Kaplan turbines are a specific type of propeller turbine in which the propeller angle can vary to optimise energy extraction for a given flow rate, allowing better performance in unsteady flow conditions [8]. However, most propeller turbine efficiencies are reduced dramatically when the flow rates drop below 75% of the intended design flow, so it is common to see several propeller turbines in parallel, each with different design flows [8].

However, there have been recent studies examining the potential for GHG generation and emission of modern hydroelectric power plants based on the complete life-cycle analysis. Nearly all hydropower station GHG emissions occur during the construction of large dams and supporting facilities and from flooding due to reservoir creation [11]. Hydroelectric dams can often be massive constructions, with some even being among the largest creations produced by humans. Materially, large dams are comprised mainly of concrete and/or earthen material. The construction and transportation of these materials can have large CO2 emissions.

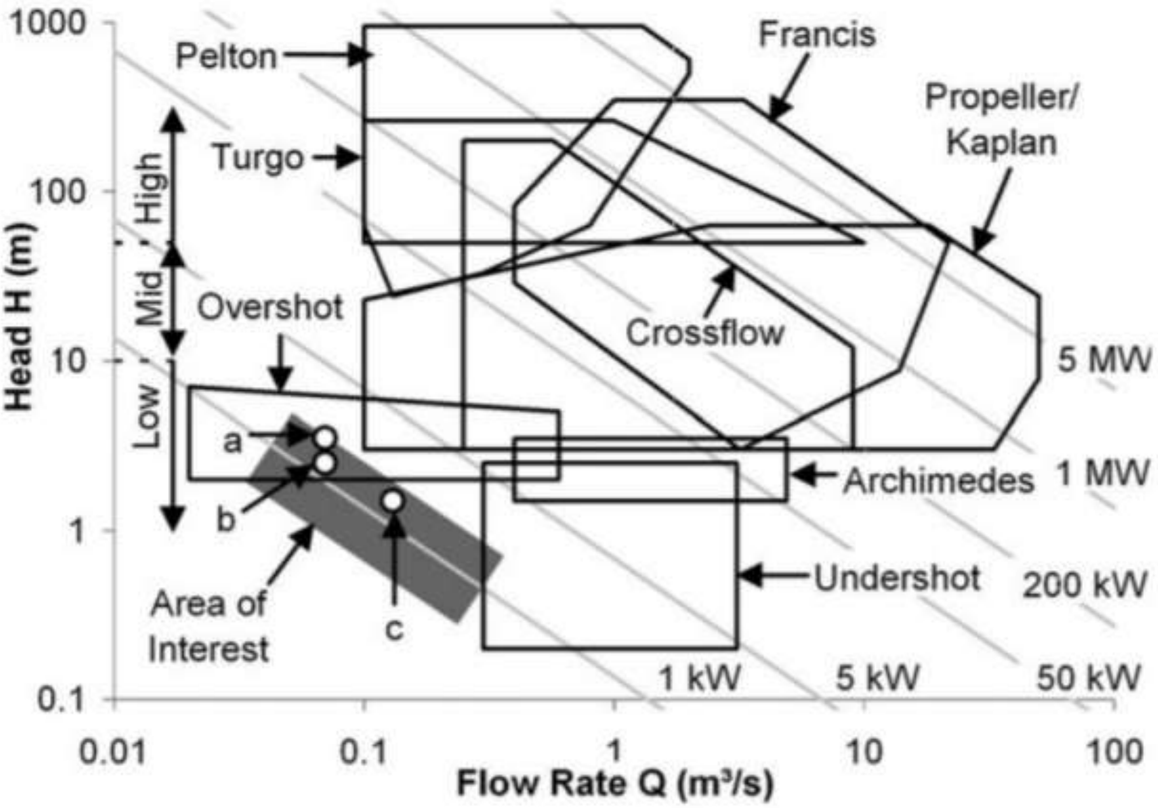


Fig. 1. Head and flow selection criteria for hydro turbines [12]

Fig. 1. Shows the recommended hydro turbine selection criteria, demonstrating the regions of discharge and head suitability for the most common turbine types.

The helical turbine is a reaction turbine capable of providing high-speed unidirectional rotation under a reversible low head pressure and high-velocity fluid flow or vice-versa. The turbine consist of a stator and a rotor were the stator is the supporting structure and rotor is rotating, which of aerofoil shape or the spiral-shaped blades mounted transversely to the direction of fluid flow for rotation in a plane parallel to the fluid flow. The blades of the helical turbine are arranged in a helical shape, and this ensures that the portion of the blade is positioned perpendicular to fluid pressure, which can achieve maximum thrust to spin the turbine rotor with required torque and maintaining the continuous speed of rotation with almost no acceleration and deceleration of the speed. The leading edges further reduce the resistance or friction to the rotation of the turbine. A channel or the inlet section should be provided to direct the flow of fluids to the rotor blades. These helical turbines require minimal gearing multiplication for the generation of electricity and achieve the necessary torque to rotate the generator shaft. The low head fluid pressure for this turbine can achieve high speeds, which for gas turbines are the speeds at which electric generators conveniently operate [13].

Underpressure helical turbine is a hydraulic turbine that solves the problem of transformation od potential energy into kinetic energy in the rotor spline; hence, the reactivity is 100%. The rotor is placed concentrically into the cylinder casing which the rotor placed through bearings and which is fixed to the bearers this supports the rotor for the correct position the underpressure helical turbine input has the complete immersed water flow into the turbine to obtain maximum hydraulic torque and hydraulic efficiency where the fluid mass in the turbine is constant throughout the flow and rotation of rotor.theis under pressure turbine more conveniently used within the system which high amount of fluid and with small falls or the small amount of fluid with high falls [14].

The main geometrical parameters that are allowed to vary for further research are to increase the coefficient of water mass-energy utilisation based on additional ejection of water. To obtain the results ascertain the influence of following parameters upon coefficient of water flow utilization are number of turbine blades, radial variation of rotor diameter and other geometrical parameters of the rotor blades as the main components that develop power is the rotor hence rotor parameter research is the important study of input for finding the functional parameters torque, mass of fluid and efficiency [15].

The flow rate from the input of the under-pressure helical turbine and after the flow of the water from the drainpipe shows the hydraulic efficiency that power developed by the runner with the use of the water flow and hydraulic torque and the flow through the spline where in this research the speed of the turbine as to be assumed due to the lack of manufacturing and experimenting the research as the motor speed has to be assumed and only torque and mass of fluid predict the efficiency of the turbine statically the Hydraulic torque is will be obtained depending upon the turbine blade reactivity. The water flows into the spline, and the hydraulic power efficiency gives the result of the turbine activity against the water [7].

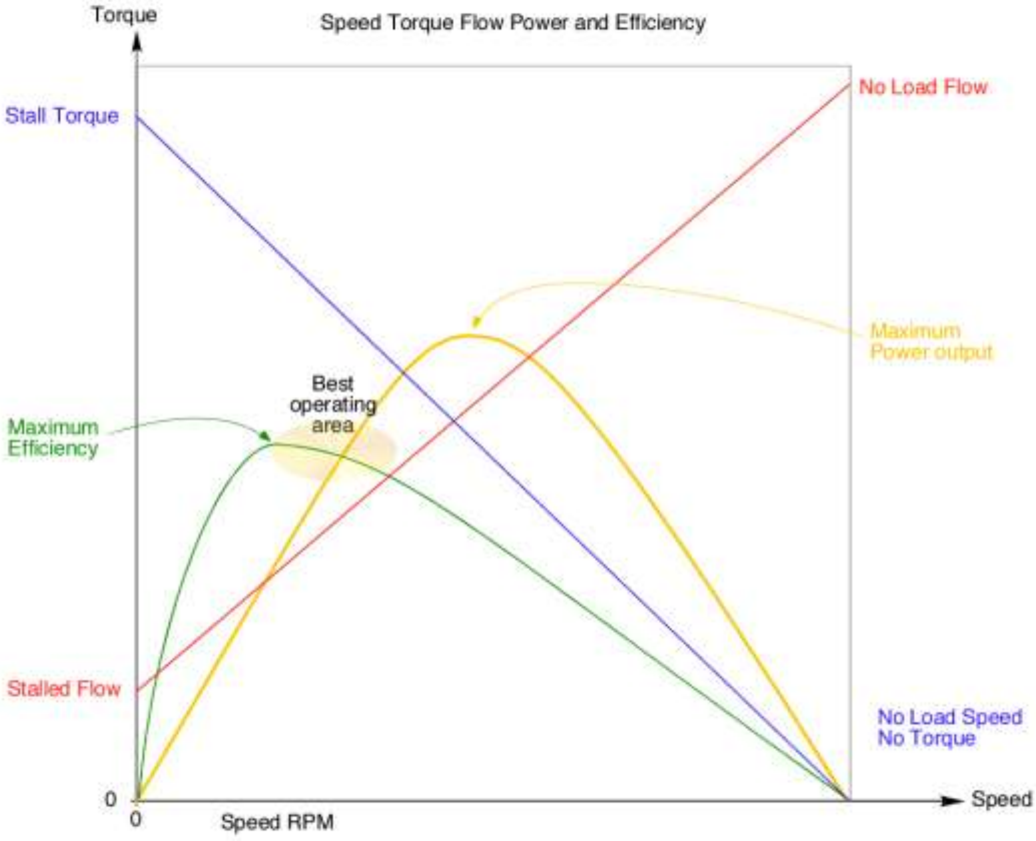


Fig. 2. Graph of speed v/s torque of the hydraulic turbine [16]

Fig. 2. Shows the graph of speed v/s torque for hydraulic turbines were the torque of the hydraulic turbine produced at the outlet is decreases when the speed of the turbine increases as it is due to the

opposite braking torque is not enough to handle the turbine r=torque or hydraulic torque obtained from water flow into the turbine [16].

The angle of installation has the main role in increase and decrease of the efficiency as the water speed tends to increase with higher angle of installation as of the β angle increases the head and flid velocity the turbine achieves the higher torque and the higher speed which helps to increase the efficiency and generate the electrical power in the generator [17]. The Archimedes Screw turbine resembles the same design of the underpressure helical turbine spline, but with only a single blade hence the flow rate of the water can be calculated easily with water flow through a variable spline. Potential energy from the flow of small rivers could be extracted by using a helical/screw turbine. The helical turbine is also a fish-friendly turbine which allows fishes to cross the blades of rotor easily the screw turbine with an outside diameter of 0.143m and water flow rate of 1.2l/s with head of 0.25m can produce the power of 1.4W with 50% efficiency at 22 degree angle of inclination with one blade of helical or screw [3].

The parameter to optimise the design of the underpressure helical turbine is limited to the parameter call Rorres 2000, which is a nondimensional number which lies between 0 and 1 for the working turbine design parameter without failure of structure [3].

2. Hydraulic turbine

Turbo or turbine is of Latin origin, and it implies that which spins or whirls around. A Turbomachine is a device in which energy transfer takes place between a flowing fluid and a rotating element due to the dynamic action and results in the change of pressure and momentum of the fluid [7]. In turbomachines, mechanical energy is transferred into or out of the system in a steady flow process. The turbomachine includes two types of machines which are producing pressure head such as centrifugal pumps compressor blowers etc. and those types which are producing power such as of all kinds of turbines. Here we study the hydraulic turbines precisely which the machines which convert the water-energy into mechanical energy. The water-energy may either in the form of potential energy as we find in dams, reservoirs, or the type of kinetic energy in the flowing water. The shaft of the turbine directly coupled to the electric generator, which converts mechanical energy into electrical.

The Principal components of Hydraulic Turbomachines **Fig. 3.**

1. A rotor carries vanes rotating vanes or spline revolving in the stream of fluid flow.
2. A stationary element which usually acts as a guide vane or casing for the proper control flow direction during the energy conversion process in turbomachines.
3. Input and an output shaft for coupling generator for further conversion of mechanical energy into electrical energy.
4. A conduit pipe and drainpipe for inlet and outlet of the fluid(water) for the generation of dynamic rotation of the turbine.

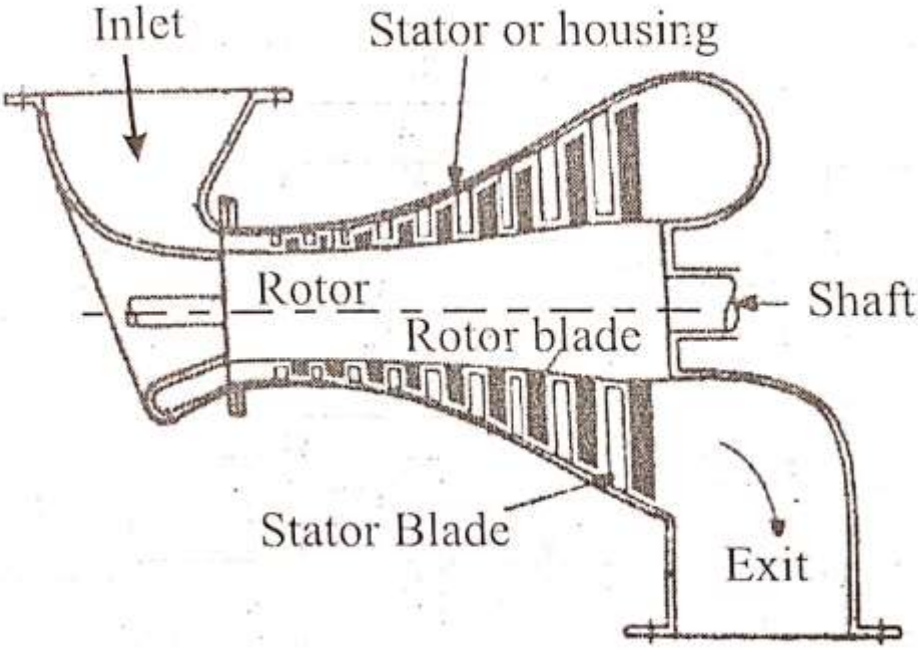


Fig. 3. Principal components of hydraulic turbine [7]

The hydraulic turbine works mainly on this principle that flowing water is directed on to the blades of a hydraulic turbine runner or rotor, creating a force on the blades. Since the runner or rotor starts spinning, the force acts to a distance; this force is called work. In this way, energy is transferred from the water flow to the turbine. Hence the flowing energy water is converted into mechanical energy to generate power or electric energy or rotational energy as required.

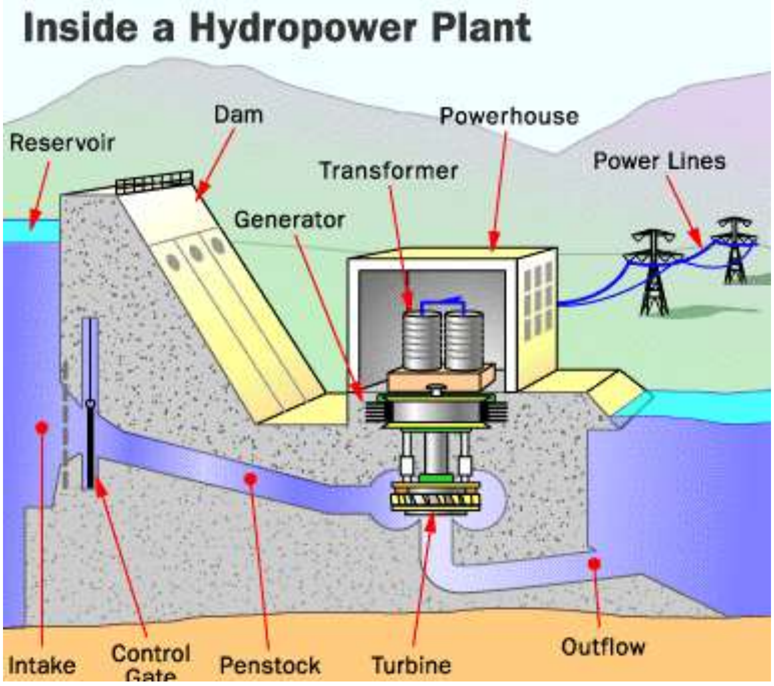


Fig. 4. General working of hydropower plant [8]

The above-shown hydropower plant explains that the water from the reservoir, which is stored by the uses of a dam consist of high pressure, is directed towards the turbine through the penstock by which the control gate is released as per the required flow pressure. The water is passed to the turbine, which converts acquired water flow energy into the rotational energy or mechanical, which in turn converts mechanical energy into electrical with the help of generators and transformers in the powerhouse; this is how the water flow energy is converted into electrical energy in hydropower plant. **Fig. 4.** shows the working of the hydraulic powerplant working.

3. Under pressure helical turbine

The turbomachine, which is selected, is of the hydraulic turbine, which works on the action of water energy on its hydrofoil turbine wings under pressure. It is used in solving the transformation of potential energy into kinetic in the rotor sphere; thus, its reactivity is 100%.

3.1. Gorolov Helical turbine

The helical turbine is also known as Gorolov Helical Turbine is a water turbine evolved from the Darrius turbine design by altering it to have helical blade

The principle of Gorolov helical turbine works as in the form of the Darrieus design; the aerofoils are arranged so that foils are symmetrical and have zero angles, that is, the angle that the aero-foils are set relative to the structure on which they are fixed. This arrangement is most compelling doesn't matter which direction the wind is blowing in contrast to the conventional type, which must be rotated to face into the wind [18].

When the Darrieus rotor is rotating, the aerofoils are rotating in airflow direction through the air in a circular path. Relative to the blade, this oncoming air is allowed to flow vectorially to the wind so that the resultant air-flow possess a varying small positive angle of attack to the blade. This generates a net force pointing obliquely forward along a certain 'line-of-action.' This force can be projected inwards into the turbine axis at a certain distance, giving a positive torque to the rotor shaft, thus helping it to rotate in the direction it is already travelling in. The aerodynamic principles which rotate the rotor are equivalent to that in autogiros, and normal helicopters in autorotation.

The main difference between the Gorolov helical turbine and conventional turbines is the orientation of the axis in relation to current flow. The Gorolov helical turbine is a vertical-axis turbine, which means the shaft is positioned perpendicular to current flow, whereas traditional turbines are horizontal-axis turbines, which means the axis is positioned parallel to the flow of the current. Fluid flows, such as wind, will naturally change direction; however, they will remain parallel to the ground. So, in all vertical-axis turbines, the flow remains perpendicular to the axis, regardless of the flow direction, and the turbines always rotate in the same direction. This is one of the main advantages of vertical-axis turbines [18].

If the direction of the water flow is fixed, then the Gorolov turbine axis could be vertical or horizontal, the only requirement is orthogonality to the flow.

Fig. 5. Grolov hydrofoil helical turbine [19]

Fig. 5. shows the hydrofoil turbine or Gorolov turbine. The turbine is placed horizontally against the flow of the water in the river this type; if turbine does not require to construct the huge structural dams and reservoirs, these turbine work for the flow of water at the higher flow speed of rivers these turbines are also considered as small hydro turbines. The hydrofoil turbine allows the flow of water directly on to the blade without the need for housing. The hydrofoil turbine can produce or generate power up to 10MW. The hydrofoil turbines are also considered as the micro-hydro turbines which are used to provide power for small towns and villages which are constructed near the low-speed river flow.

3.2. Under Pressure Helical Turbine

Under pressure helical turbine solves the problem of transformation of potential energy into kinetic energy in the rotor sphere (2); thus, its reactivity is 100%. The rotor (2) is performed like an erect cylinder which has spiral line (3) executed by its external circumference and is centrally and spherical-movable placed inside of the casing (1) through bearings (4) and (5) which are fixed with bearer (6) or bearer (7) on the inner wall of the casing. The smallest profile (P) between 2 curves of the spiral line (3) is the passage from pressure into under pressure ratio. According to this invention, the turbine can be used within systems with small amounts of fluid with high falls – and inversely [14].

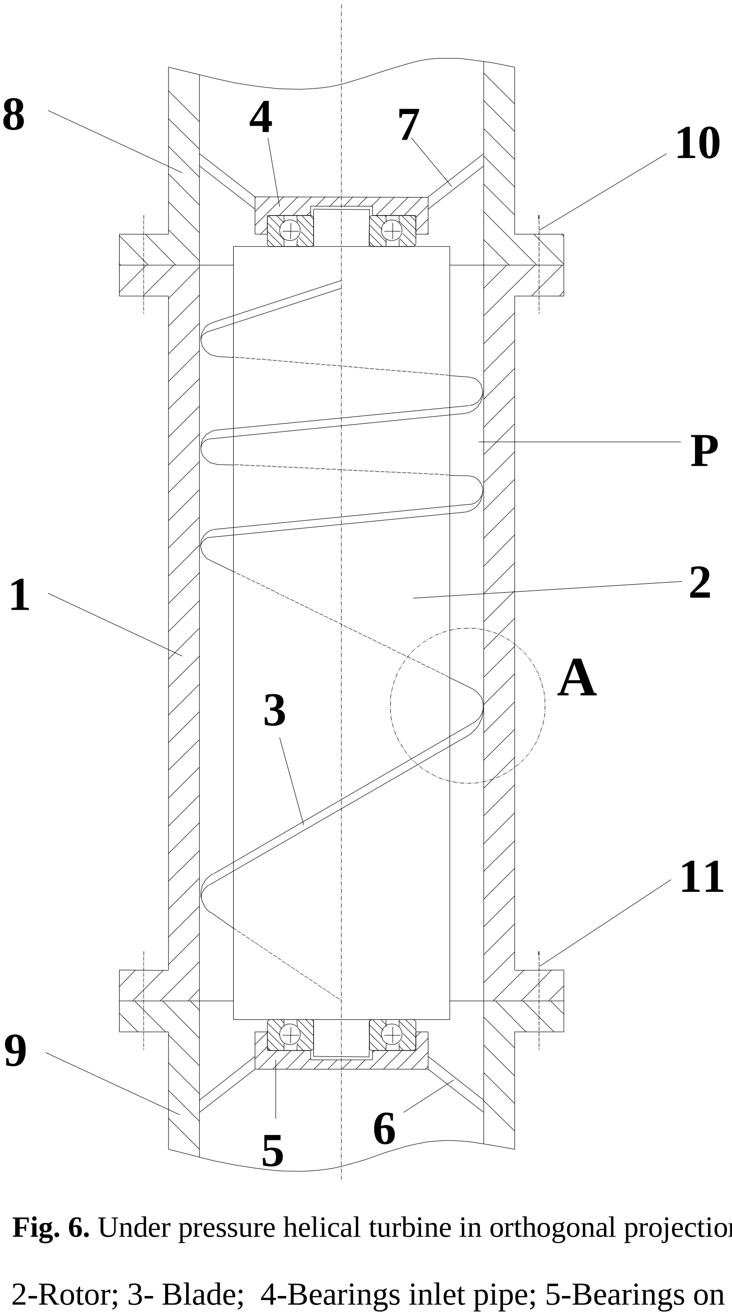


Fig. 6. Under pressure helical turbine in orthogonal projection [14]

1-Turbine Casing; 2-Rotor; 3- Blade; 4-Bearings inlet pipe; 5-Bearings on outlet pipe; 6-Bearers on outlet pipe; 7-Bearers on intlet pipe; 8-conduit pipe; 9-drain pipe; 10-Conduit pipe and casing attached; 11-drain pipe and casing pipe attached; P- smallest profile between 2 curves [14].
‘A‘ shows the detailed profile of the casing, and the blade design of the underpressure helical turbine highest pitch rotor is in contact with the casing.

Fig. 6. shows the underpressure helical turbine model used as initial data for the research of functional parameters and working of the turbine against the angle of attack.

Underpressure helical turbine, which works like driving jet engine with unmovable agents for directing working fluid and with axial decantation of fluid through rotor with small spades in the shape of a disproportionate coil or spiral line by which the speed is transformed into pressure exclusively in the rotor.

It will allow the placing of generator above and below underpressure helical turbine, as well as its with large amounts of water and low or small falls. At the same time, it`s construction is compact and straightforward.

The most famous jet turbine is Kaplan`s turbine, while the most renowned action turbine is Pelton`s turbine. The common point of all these solutions is small spades, fixed or flexible, as well as the fact that with all these solutions, one part of fluid or potential energy of the waterfall is transformed into kinetic energy in the turbine rotor, at which the reactivity is only 50%-60%.

The problem unsolved is above all very complicated construction of these turbines with stator and rotor realisation, which don`t allow the whole transformation of the potential energy into kinetic energy in the extent of the rotor and thus don`t allow them to achieve their 90 % reactivity. Moreover there`s another unsolved issue: how to perform turbine construction, which could be used in systems with small amounts of water and high fall as well as in the systems with large quantities of water and low falls and at the same time having a possibility of placing generator over and under the turbine.

It has simple construction and realisation, and it`s constructed by vertical casing with rotor placed inside, also in a revolvable manner. This turbine has helix or thread in the sense of singled fixed spade realised on its external circumference and rotor is embedded on both ends

The speed of the water would be, within the turbine system between the spades, the highest on the thinnest part.

Water would, by the passing between spades, go over to the under-pressure condition, right after passing from the thinnest part. The passing of the water throws the thinnest part of the rotor would be jerky. But, if the turbine would be designed that way, till the rotation of revolvable driving gear wouldn't come, just because of the symmetrically placed spades on the circumference of the cylindrical driving gear. It would, under and within the system of rotor sphere, create under pressure power, which would cause the rotation of the rotor in the direction of bigger decantation and smaller resistance of the water by the spiral line.

The advantages of that type of water turbine would be (in my opinion) a smaller loss of water energy on the stator and rotor part. The perfect spiral line would be in the shape of the logarithmic curve, which runs by the external circumference of the driving gear.

Water, which moves in the cylinder, would be exposed to the pressure condition (till the thinnest part), and then, with the passage throw this, it would be exposed to siphon or under pressure condition. This would be with distance from the thinnest part smaller and smaller. In conclusion, the passage from the pressure to under pressure condition would be momentary for the water, which would pass throw the thinnest part. That proportion of strength within the cylinder effects to the speed of the water, which would be with approaching and passing throw the thinnest part jerky accelerated, with the digression from the thinnest part would be decelerated.

Revolvable underpressure helical turbine by the passage of the water by spiral line reduces resistance, and with this, the length of the water passage in the way that it rotates the turbine in the direction of smaller resistance. [14]

4. The main geometrical parameters of the underpressure helical turbine

The main geometical parameters are selected as shown in the **Fig. 11.** The parameters are varied according to the required underpressure helical turbine model. Single parameter is varied for each design and models are created and results are calculated based on varying following geometrical parameters.

1. **Number of turbine blades(N)**: The turbine blades are varied according to the required head of water and the force or pressure which the turbine withstands when the water flows into the inlet pipe of the turbine when the water flow is very high, and the amount of water flow into the turbine reaches the value more then the single blade turbine can work then the number of blades or the opposite spline is increased as per the required conditions [15].
2. **Radial variation of the geometric parameters of the rotor blades:** Radial variation of the rotor blades refers to the variation of the radius ratio which is defined as the ratio of the outer radius(R_o) to the inner radius(R_i) of the turbine when this radius is varied accordingly to the required flow rate the power of the turbine obtained will be the maximum utilized towards the rotor [15].
3. **Axial variation of the geometric parameters of the rotor blades(L_b):** The axial variation of the rotor blade is varying the length of the blade so that the volume of the water flow into the turbine blades are maximum and the leakage and overflow losses of the turbine are reduced as the blade length is in optimal condition and the blade length will be always lesser to the rotor length to easy flow water and utilize the maximum pressure obtained from the water flow from the inlet pipe.
4. **Pitch variation of the geometric parameters of the rotor blades(λ):** The pitch (S_1 and S_2) variation of the rotor blades refers to the variation of pitch ratio is defined as the ratio of geometric pitch of the turbine to the diameter of the turbine rotor equation .9. shows the pitch ratio. The pitch S_1 and S_2 is varied to obtain the maximum efficiency.
5. **The angle of the turbine location concerning water current(β):** The angle of the location of the turbine concerning water current is a major parameter to obtain the required flow for the turbine which the turbine gets the maximum flow rate and the pressure required to rotate the turbine and generate power and increase the efficiency [15].

5. The functional parameter of the under-pressure helical turbine.

1. **Hydraulic Torque (T):** The main functional parameter which helps the turbine in the transformation of potential energy into kinetic energy. The torque generated by the water flow into the turbine at a velocity of 2m/s the water tends to rotate the helical turbine on a vertical axis to provide required mechanical torque. In most well-designed turbines, the runway or the no-load speed is 1.8 to 2 x by the impeller speed-rated load speed. This means that no-load conditions the water slide by the impeller surface without transferring any energy because they are moving at the nearly same speed. Another feature of the runway speed is that the turbine output shaft torque will be zero no, matter how much water flows through the turbine. The mechanical power there for null. The torque will rise by applying an external braking torque(the electric generator units electrical load does that), while the speed will decrease, and that means the turbine will start harvesting the power. The water slips partially by the impeller, partially pushing it is equal to energy transfer. Hence the water consumption or flow also decreases so more power for less water and better efficiency. The obtained output torque is used in converting hydraulic energy into mechanical energy [16].

   As the parameters mentioned above in the geometrical parameters, the rotor dimensions are varied and created the models of the rotor to check whether the rotor has achieved enough required hydraulic torque. As the water flows into the turbine the thrust of the pressure from the water strikes the turbine helical blades the blade tends to rotate the rotor and produces the required torque from the pressure as the water tends to drain out of the turbine the rotational movement of the rotor is created this tends to rotate the shaft and this covert the potential energy into kinetic energy. The water at certain velocity flows into the turbine spiral blade or helical blade of the underpressure helical turbine the turbine tends to create the pressure in Y-direction of the turbine and as the turbine rotor is concentrically fitted into the turbine with the help of stator(turbine casing), bearings and bearers the water is only directed complete flow towards the spiral shape of the blade.

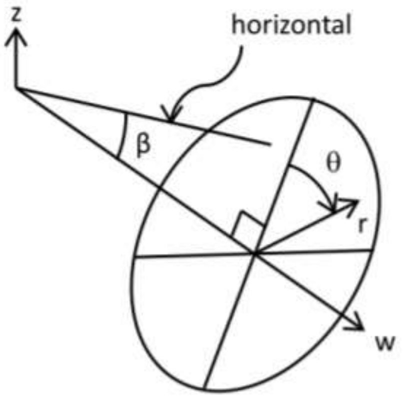


Fig. 7. Coordinate system underpressure helical turbine [12]

Fig. 7. Explains the coordinate system for under pressure helical turbine, which the water flows along w when the rotor rotates to angle ϴ. The rotor inclined to the angle of β against the river water flow horizontally in the river bed with rotor radius r. This coordinate system shows the mechanism of the turbine. According to this turbine, the hydraulic torque of the rotor can be calculated when the rotor rotates to the angle from 0 to 2π by integrating the equation of torque from outer radius to inner radius and concerning angle 0 to 2π.

In this research, the rotor is static, and water flows through the computational model and tends to produce higher values of the torque as braking torque applied to the rotor is highest; the speed is assumed to be 0 according to the computational analysis of the turbine.

2. **Hydraulic efficiency(η_h):** The hydraulic efficiency is defined as the ratio of power developed by the runner or rotor to the power input at the inlet of the turbine. The functional parameter hydraulic turbine is considered in obtaining the overall efficiency of the turbine; the overall efficiency is defined as the power available at the shaft to the power input at the inlet of the turbine, and it also obtained by multiplying the hydraulic efficiency and mechanical efficiency of the turbine. As the hydraulic efficiency is the amount of water utilised by the turbine to generate the power by the runner hence the increase in hydraulic efficiency increases the efficiency of the turbine and more the work done by the rotor. This research shows the investigation of hydraulic efficiency by the mathematical model for the created geometrical model by varying the mentioned parameters.

6. Design of the Underpressure helical turbine.

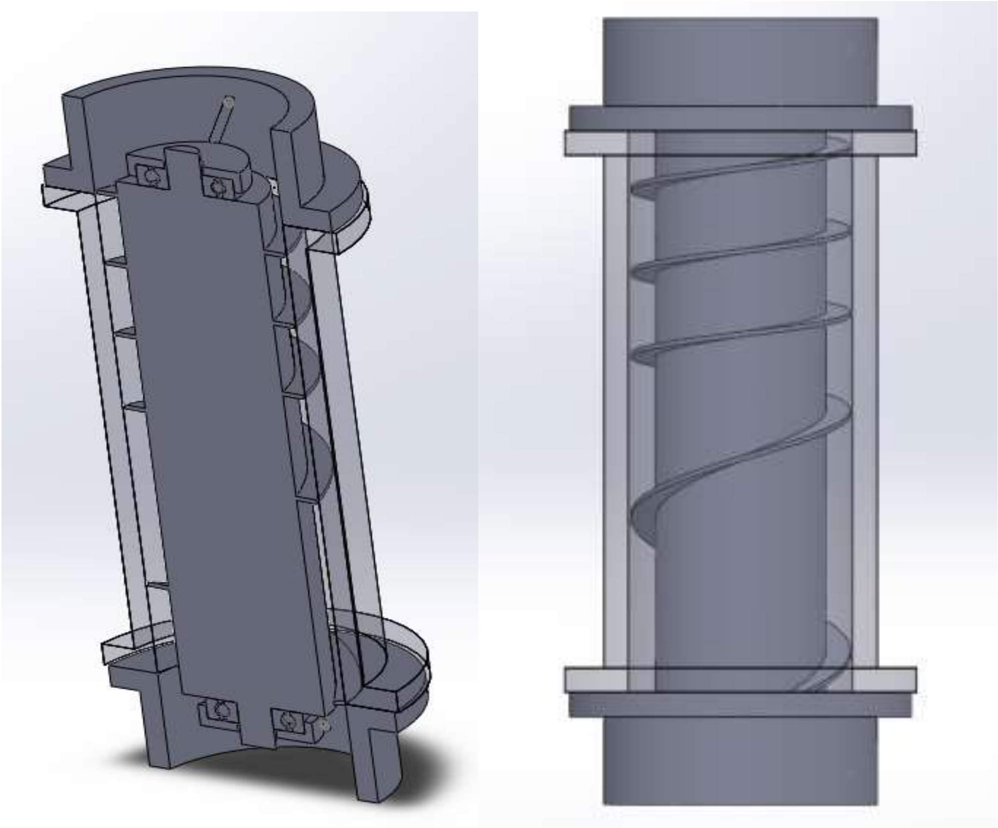


Fig. 8. Underpressure helical turbine assembly and cut plot

Fig. 8. shows the design of the underpressure turbine with a variable pitch rotor. The Underpressure helical turbine consists of an inlet pipe or conduit pipe where the river water flows into the turbine casing and rotor at the average speed of 2m/s [20]. This water flow from the conduit pipe flows through the rotor and strikes the helical blade of the turbine, which creates the thrust pressure on the turbine, which in turn rotates the rotor, and potential energy from the water is converted into kinetic energy.The water inflow into the turbine is calculated according to the dimensions here the water inflow rate is 0.319m^3/s this flow rate is enough to calculate the required torque. The Hydraulic torque is the essential functional parameter considered in this research project, which is obtained by simulating the underpressure helical turbine design assembly in SolidWorks software 2018-19. Hydraulic efficiency is calculated using the functional Parameter flow rate, Torque, and speed.The speed of the turbine is assumed in this research. The rotor is free to rotate on the vertical axis which is supported by bearers and bearings the bearings allow the rotor to turn freely when water strikes the rotor blade.**Fig. 9.** shows the rotor of the underpressure helical turbine, which has a helical blade with pitch as the other models will be created by varying the geometrical parameters of the rotor of the under-pressure helical turbine to calculate the torque and the efficiency of the turbine by assuming the speed of the turbine.These models show the different efficiency and different torque concerning the parameters varied; these calculated results are compared to the analytical or simulated outcomes. The drain pipe is in the environment pressure condition as the water flows out the turbine completely through the drain pipe.

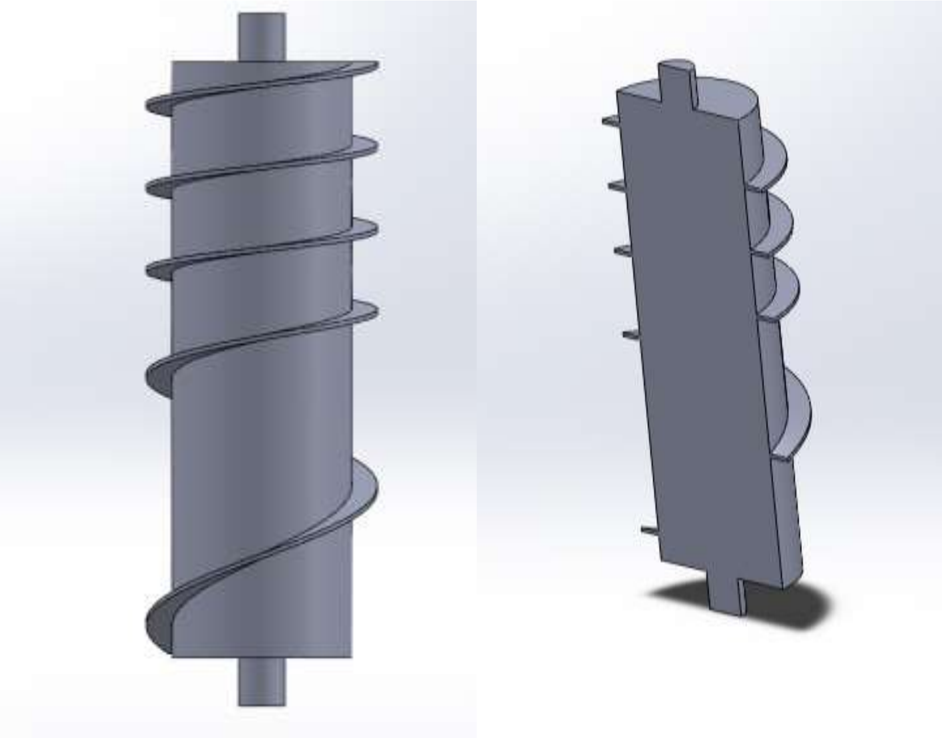


Fig. 9. The rotor of the Underpressure helical turbine

The rotor is constructed according to the initial data of the research as the dimensions of the turbine rotor and assembley is from the initial data scale model [14]. The rotor design has given more importance on the surface of water flow, and the blade position and the rest all material and the density and weight condition are not much required to calculate the turbine efficiency as it is neglected in the theoretical calculation for input needed in the calculation.

7. Theoretical Calculation for Underpressure Helical Turbine.

In this theoretical calculation, the hydraulic torque and efficiency of the rotor of varied parameters are calculated by the design equations in which the water flows through the spline, and the hydraulic efficiency is obtained to compare the rotor of required higher efficiency. Hydraulic efficiency of the turbine is defined as the ratio between power delivered by the water to the runner of the turbine and the power supplied by water at the inlet of the turbine [7].

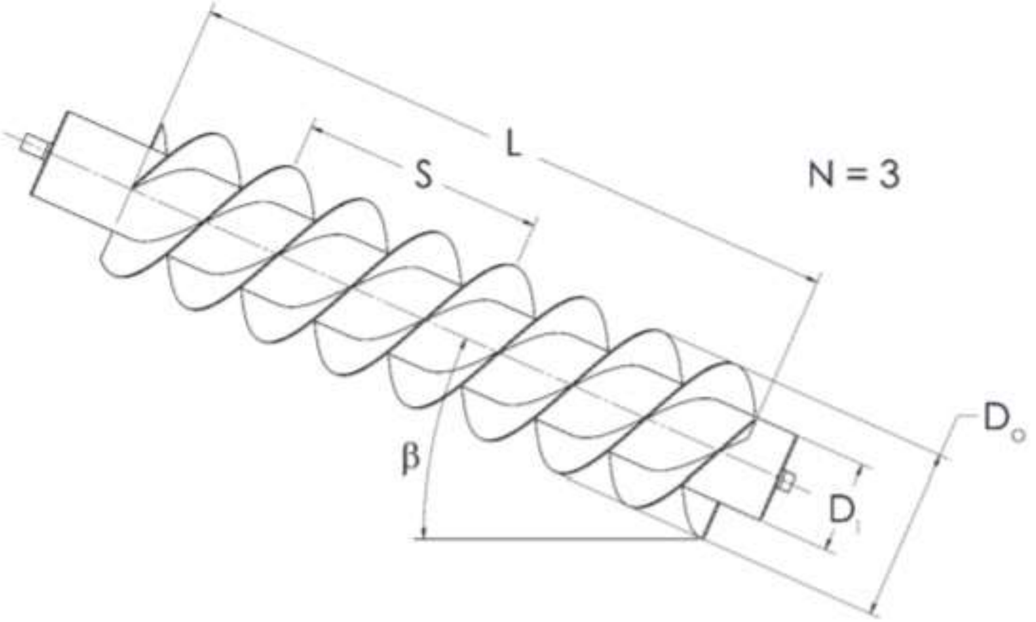


Fig. 10. 3-Blades turbine geometry of underpressure helical turbine [17]

Fig. 10. shows the geometry of the underpressure helical turbine with 3-blades, where the turbine shows the parameter that can be varied and used in the calculation of the turbine torque and hydraulic efficiency. From this geometry, the angle β is considered as the angle of the turbine location concerning water currents. The other geometrical parameters are shown in **Fig.11.** with respect to the single blade and the variable pitch of the helical blade of the underpressure helical turbine. (Lb) Length of the blade, (S_1) first pitch of the rotor blade, (S_2) second pitch of the rotor blade, (R_i) Inner diameter of the rotor, (R_0) Outer diameter of the rotor. The models are created by taking these main parameters into the account, and theoretical results are calculated. The functional parameter hydraulic torque, efficiency, and mass of fluid are dependent on these geometrical parameters to achieve the required results for generating electricity from the generator. The design of the turbine is optimised the turbine design.**Fig.11.** Show the single blade turbine which is considered in this reach on the functionality of the underpressure helical turbine.

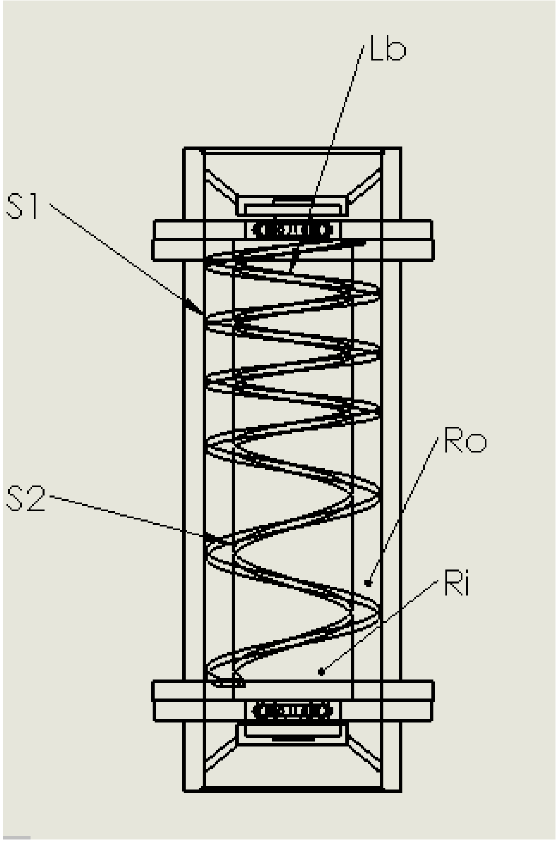


Fig. 11.Single blade turbine with geometrical parameters that are varied

7.1. The calculation for varied rotor diameters.

The hydraulic Torque is calculated by reducing the speed of the turbine to least value to obtain the hydraulic torque, or the torque that is produced by the water flow into the rotor as the braking torque applied to the turbine will be the highest as the speed is reduced to the least value as this calculation shows the torque obtained is high enough to generate the electricity and optimise the design by varying the geometrical parameters this hydraulic torque obtained shows the efficient design of turbine to obtain higher hydraulic efficiency

Table 1. Geometrical parameter of underpressure helical turbine varying rotor shaft diameter

Sl.no	**Rotor diameter, m**	**S_1 pitch of the blade, m**	**S_2 Pitch of the blade, m**	**Length of the rotor, m**	**Casing diameter,m**	**β, angle of the turbine, Degree**	**N, number of blades on the rotor**
1	0.4	0.17	0.56	1.230	0.46	20	1
2	0.35	0.17	0.56	1.230	0.46	20	1
3	0.3	0.17	0.56	1.230	0.46	20	1
4	0.25	0.17	0.56	1.230	0.46	20	1

7.1.1. Hydraulic Torque calculation of the underpressure helical turbine

Table 1. shows the geometrical parameters of the underpressure helical turbine for the calculation of required hydraulic torque. The model calculates the torque created by the helical bucket water volume using the same point and coordinate definitions defined in **Fig.7.** It is the water pressure on the helical planes that generate the torque experienced by the helical blade. Assuming static conditions within the buckets, the model determines the hydrostatic pressure at any given point on the plane surfaces. The pressure difference in the inlet of the turbine and outlet of the turbine is used to calculate the hydraulic torque of the turbine.

Hydraulic torque calculation for rotor diameter 0.4m:
The pressure difference (P_1-P_2) is given by

$$(P_1 - P_2) = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

1- [21]

To calculate the velocity v_2 at the outlet of the turbine

$$A_1 v_1 = A_2 v_2$$

2- [21]

Substituting the values of velocity and water density (ρ = 1000kg/m^3) in the equation.1 pressure difference between the inlet and outlet of the turbine is obtained.

$$(P_1 - P_2) = 14580.5Pa$$

Considering that the net pressure at any point on the helical plane surfaces is the difference between the inlet and outlet water pressures, the net torque on an element area of the helical plane surface is then given by:

$$\delta T = (P_1 - P_2)\frac{S}{2\pi} r dr\, d\theta$$

3- [12]

Where P_1 and P_2 are the pressures on either side of the plane surface, r is the outer diameter of the turbine S is the pitch of the spline. The total hydraulic torque (T) generated by a single spline/bucket can be determined by integrating the elemental hydraulic torques for the entire spline/bucket [12].

$$T = \int_{r_i}^{r_0} \int_{0}^{2\pi} \delta T$$

4- [12]

By substituting for δT from equation.3 in the equation.4, the torque of the single spline or bucket can be obtained. The r_o is the outer radius of the rotor and r_i is the inner diameter of the radius for the pitch $S_1$and S_2. The torque obtained from the above equation.4 is the result of hydraulic torque produced from each bucket of the helical turbine.

The torque obtained for the pitch S_1:
T_1 = 129.85 Nm.

The torque obtained for the pitch S_2:
T_2 = 73.16 Nm
The torque T_1 and T_2 are the torques produced from each bucket of the spline pitch length of S_1 and S_2, respectively.

In the model mentioned above, the variable pitch of the spline is used on the rotor; hence, the torque value for spline S_1 and S_2 can be obtained by calculating the torque of the length L_1 which consists of spline $S_1$and the length L_2 consisting spline S_2. The total torque experienced by the full length of the helical turbine is then scaled proportionally to the total number of buckets along the entire turbine rotor length:

$$T_{total} = T2\left(\frac{NL_1}{S_1}\right) + T1\left(\frac{NL_2}{S_2}\right)$$

5- [12]

Where:
Number of blades (N) = 1
First Pitch (S_1) = 0.17 m
Second Pitch (S_2) = 0.56 m
Length (L_1) = 0.51 m
Length (L_2) = 0.72 m
Outer radius of rotor = 0.225 m
Inner radius of rotor = 0.2 m

By substituting all these required values in the equation.5, the total torque of the turbine is obtained:

$$T_{total} = 483.56Nm$$

The total torque obtained is the torque generated by the flow of water into the turbine through the surface of the blades by fixing the rotor. This hydraulic torque value shows the ability to apply the required braking torque, as explained in section.5. Functional parameters of underpressure helical turbine. this result shows the reactivity of the turbine blades for the water flow into the underpressure helical turbine

7.1.2. The calculation for hydraulic efficiency of underpressure helical turbine.

The hydraulic efficiency is calculated by assuming the turbine rotor speed 200rpm [22] according to the experimental study of the micro-hydro turbine system; the rotor value is selected. The hydraulic efficiency refers to water utilisation by the turbine for work done to generate the kinetic energy or covert the hydraulic energy into mechanical energy.
Calculating the inlet hydraulic power of the underpressure helical turbine:
Radius of the pipe (r_1) = 0.230 m

The radius of the spindle(r_2) = 0.045 m

The velocity of the river water(V) = 2 m/s

The flow rate of the river at the inlet of the turbine conduit pipe:

$$Q = A \times V$$

6- [21]

A = area of the inlet pipe

The area at the inlet pipe is obtained by subtracting the area of the rotor spindle by the area of the conduit pipe at the inlet.

$$A_1 = \pi r_1^2$$

$A_1 = 0.1661 m^2$

A_1 is the area of the pipe at the inlet.

Similarly, A_2 is the area of the rotor spindle at the inlet of the turbine.

$A_2 = 6.361 \times 10^{-3}$

Now the area at the inlet of the turbine is as follows;

$A = A_1 - A_2$

$A = 0.15983 m^3$

Now the flow rate at the inlet of the turbine according to the equation.6

$Q = 0.319\ m^3/s$.

Hydraulic power at the inlet of the turbine is given by the below equation:

$$P_i = \rho g h Q$$

7- [7]

The density of the water flowing into the turbine(ρ) = $1000 kg/m^3$

Gravitational force (g) = $9.81 m/s^2$

Head of the turbine at the inlet = 0.5m

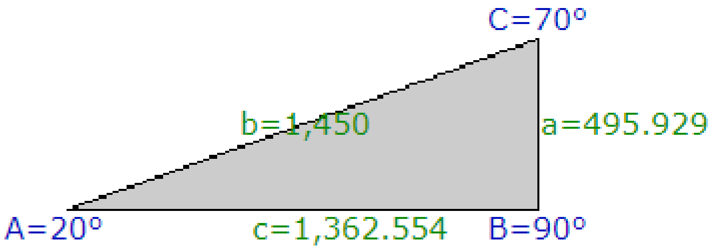


Fig. 12.water head calculation for the turbine inclined at 20^0

Fig. 12. shows the approximate arrangement of the turbine against the concerning river currents. b=1450 is the length of the turbine, including conduit pipe, casing, and drain pipe. When the turbine is inclined to an angle of A = 20^0 the head obtained is approximately equal to a = 0.5m as shown above.

Now substituting the obtained values in the equation.7 the power hydraulic power at the inlet of the turbine is calculated:

P_i =1.564kW

The power at the outlet of the turbine is calculated by the flow rate through the spline to be calculated. The flow-through variable pitch rotor is calculated by assuming the speed of the rotor at 200rpm [22].

This speed concluded based on experiments and studies conducted on the micro-hydro helical turbines. This calculated flow shows the efficiency of the underpressure helical turbine.

Geometrical parameters of the rotor with diameter 0.4m to calculate the flow rate of the turbine:

The outer radius of the rotor(R_o) = 0.225m

The inner radius of the rotor (R_i) = 0.2m

First pitch of the rotor blade (S_1) = 0.17m

Second pitch of the rotor blade(S_2) = 0.56m

To calculate the volume of the bucket V_u the dimensionless parameter is introduced by Rorres(2000) the value of the parameter must be between 0 and 1 to obtain the correct values of the optimised design and to satisfy the required volume of bucket values [23].

The radius ratio of the turbine is given by the equation.8:

$$\rho = \frac{R_i}{R_0}$$

8- [23]

$\rho = 0.8$

Calculating the flow rate across the first pitch S_1 on the rotor

The pitch ratio of the turbine is given by the equation.9:

$$\lambda 1 = \frac{S_1 Tan\beta}{2\pi r_0}$$

9- [23]

$\lambda 1 \ = \ 0.04376$

To calculate the volume of the bucket V_u the dimensionless parameter is introduced by Rorres(2000) the value of the parameter must be between 0 and 1 so it is true to obtain the correct values of the optimized design and to satisfy the required volume of bucket values this value is known as volume ratio [23].

The volume ratio(ν_U) is the ratio of radius ratio and pitch ratio obtained by the equation.8 and equation.9 as follows:

$$\nu_{U1} = \frac{\lambda 1}{\rho}$$

10- [23]

ν_{U1} =0.0547

To determine the volume V_U, the volume ratio (ν_U) is substituted in the equation.11 by the above values for the first pitch of turbine rotor:

$$\nu_{U_1} = \frac{V_{U1}}{\pi r_0^2 S_1}$$

11- [23]

$V_{U1} = 1.47x10\hat{} - 3$ m^3

The volume per turn ratio is calculated to obtain the flow rate around the rotor of diameter 0.4m.

$$\lambda_1 v_{U_1} = \frac{V_{U_1} Tan\beta}{2\pi^2 r_0^3}$$

12- [23]

$\lambda_1 v_{U_1}$ =1.85x10^-3

The water flow in the rotor turbine is calculated by the equation.13 by substituting the values obtained above:

$$Q_{w_1} = \frac{2\pi^2 r_0^3}{\tan\beta} \lambda_1 v_{U_1} \frac{n}{60} x_1$$

13- [23]

$Q_{w_1} = 0.01523 \text{m}^3\text{/s}$

Similarly for calculating for the second pitch S_2 by substituting the values obtained by equation into the flow rate equation the flow rate Q_{w_2} is obtained by a similar method of calculation across the rotor.

The vales of the parameters required to calculate the flow of water around the pitch S_2 as follows.

Radius ratio of the(ρ) = 0.8

Pitch ratio of the turbine of pitch $S_2(\lambda_2)$ = 0.1441

The volume ratio of the turbine of pitch $S_2(\nu_{U2})$ = 0.1801

The volume of the bucket of pitch $S_2(V_{U2})$ = 0.01604m^3

Volume per turn ratio for the pitch $S_2(\lambda_2 v_{U_2})$ = 0.02654

The flow rate of water around the pitch $S_2(Q_{w_2})$ =0.0819

The total water flow rate around the rotor of the underpressure helical turbine is the total flow around the spline $S_1$and the spline S_2 this flow rate is used to calculate the power output by the hydraulic turbine.

$$Q_{total} = Q_{w_1} + Q_{w_2}$$

Hence the total flow rate around the underpressure helical turbine of the rotor is:

Q_{total} = 0.09713m^3/s

Now calculating the hydraulic power output of the underpressure helical turbine after the flow of water into the turbine rotor and casing:

The hydraulic power output of the turbine is given by the equation.14:

$$P_0 = \rho g h Q_{total}$$

14- [7]

$P_0 = 0.349kW$

The hydraulic efficiency is the ratio of hydraulic power output to the hydraulic power input of underpressure helical turbine.

$$\eta_h = \frac{P_0}{P_i} x100$$

$\eta_h = 22.3\%$

The obtained hydraulic efficiency of the turbine is the amount of potential energy from water used by the turbine to obtain the required kinetic energy transformation by this underpressure helical turbine.

8. Theoretical results of underpressure helical turbine by varying the geometrical parameters of the rotor.

Fig. 13. and **Fig . 14.** Shows the results of hydraulic torque and hydraulic efficiency of the turbine by varying the diameter of the rotor the hydraulic efficiency increases by the decrease in the diameter whereas the torque is increased in the diameter of 0.35 and 0.3 as the water force utilised in this diameter is maximum. The results are calculated for the rotor design based on varying the inner diameter of the rotor of the underpressure helical turbine. **Table 2.** shows the summary of Torque and hydraulic efficiency results obtained from the theoretical calculation.

Table 2. Hydraulic Torque and efficiency results for a varied rotor diameter of underpressure helical turbine

Sl.No	**Diameter,m**	**Hydraulic Torque T_1, Nm**	**Hydraulic Torque T_2, Nm**	**Hydraulic Torque total, T_{total}, Nm**	**Hydraulic efficiency η_h**
1.	0.4	129.2	73.16	483.56	22.3%
2.	0.35	232.4	81.2	669.28	30.818%
3.	0.3	161.83	76.54	583.3	35%
4.	0.25	105.6	68.5	416.53	41.2%

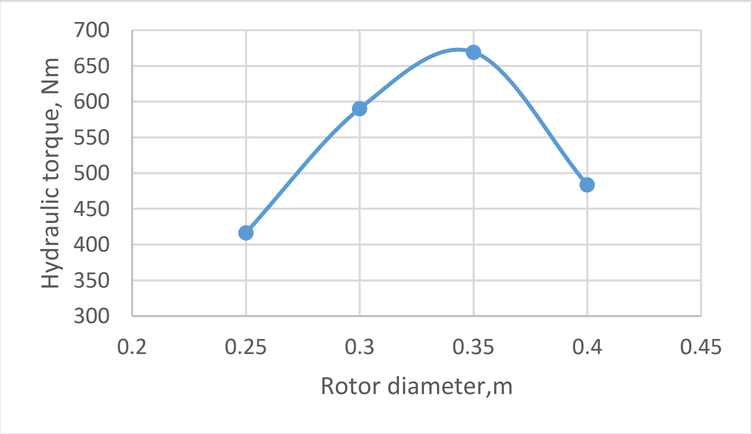


Fig. 13. Graph of Hydraulic torque v/s Diameter

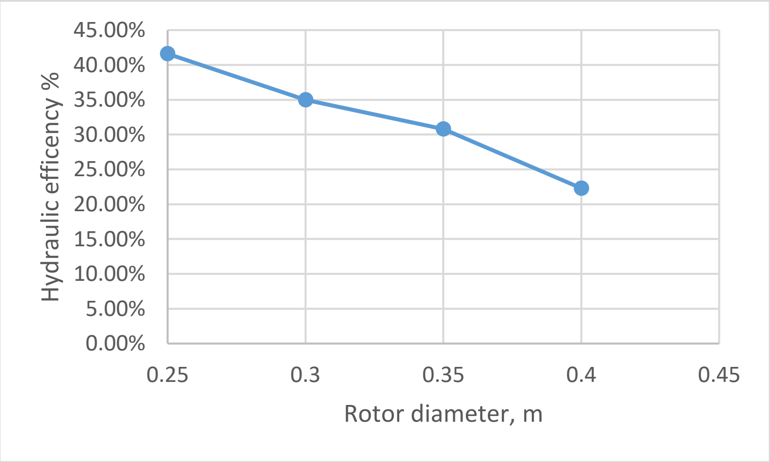


Fig. 14. Graph of Hydraulic efficiency v/s Diameter

Fig. 15. and **Fig. 16.** Shows the results of hydraulic torque and hydraulic efficiency are calculated for the rotor design based on varying the constant pitch S_1 throughout the rotor length of the underpressure helical turbine rotor.**Table.3** shows the results of the functional parameters of the total torque and hydraulic efficiency of the turbine based on the varied constant pitch obtained by the theoretical calculations.

Table 3. Hydraulic efficiency and Torque results for varied rotor constant pitch of underpressure helical turbine

Sl.No	**Pitch length S,m**	**Hydraulic Torque T, Nm**	**Hydraulic torque total T_{total}, Nm**	**Hydraulic efficiency η_h**
1.	0.17	263.4	1881.17	18.5%
2.	0.27	215.6	1002.2	26.2%
3.	0.37	203	762.5	30.5%
4.	0.47	196	728	36%
5	0.56	187	532	42.2%

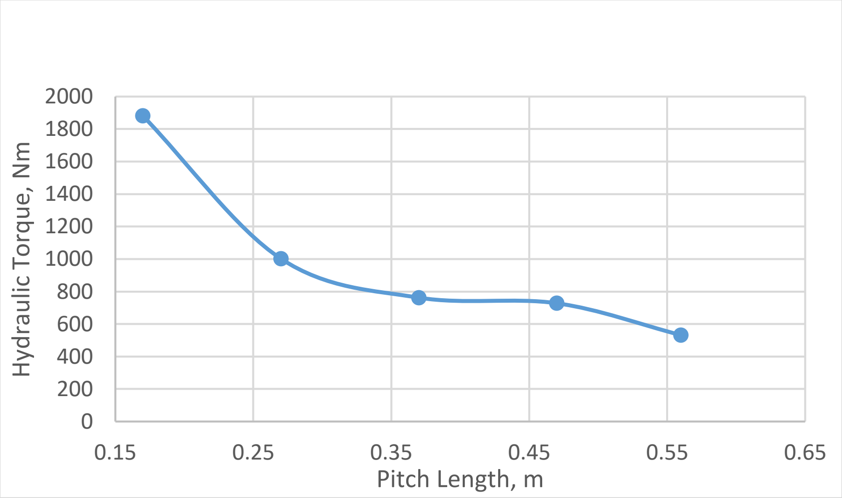


Fig. 15.Graph for hydraulic torque v/s pitch for the varied constant pitch

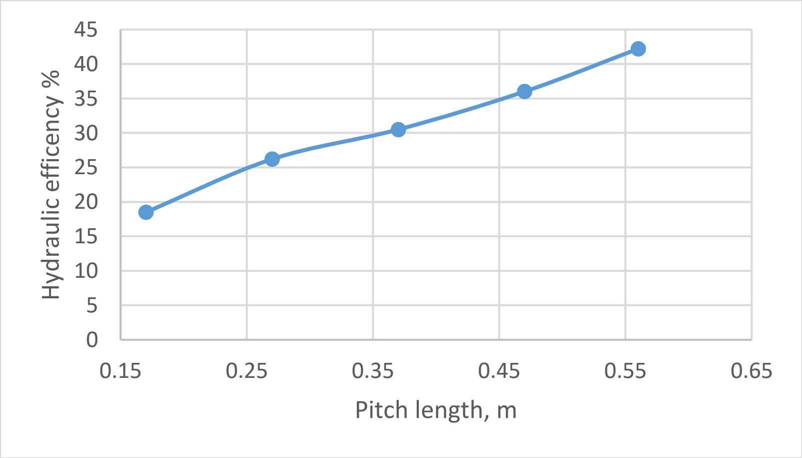


Fig. 16. Graph for hydraulic efficiency v/s pitch for the varied constant pitch

The results **Fig. 17.** And **Fig. 18.** shows the hydraulic torque and hydraulic efficiency calculated for the design of varying pitch S_2. The pitch S_2 is constant and equal to 0.17m the obtained results show the increase in efficiency by increasing the pitch variable S_2 and decrease in the hydraulic Torque generated by the water flow as the rotation or the speed of the rotor is null. **Table 4.** Shows the parameters varied for the rotor design of the underpressure helical turbine.

Table 4.Hydraulic torque and efficiency results for the varied pitch combination of underpressure helical turbine

Sl.no	**Pitch S_1,m**	**Pitch S_2,m**	**Hydraulic Torque T_1, Nm**	**Hydraulic torque T_2, Nm**	**Hydraulic torque total T_{total}, Nm**	**Hydraulic efficiency η_h**
1.	0.17	0.27	232.4	219.3	1086.4	24.2%
2.	0.17	0.37	232.4	184	783.4	32.3%
3.	0.17	0.47	232.4	136.4	683.6	37.9%
4.	0.17	0.56	232.4	81.2	669.28	41.2%

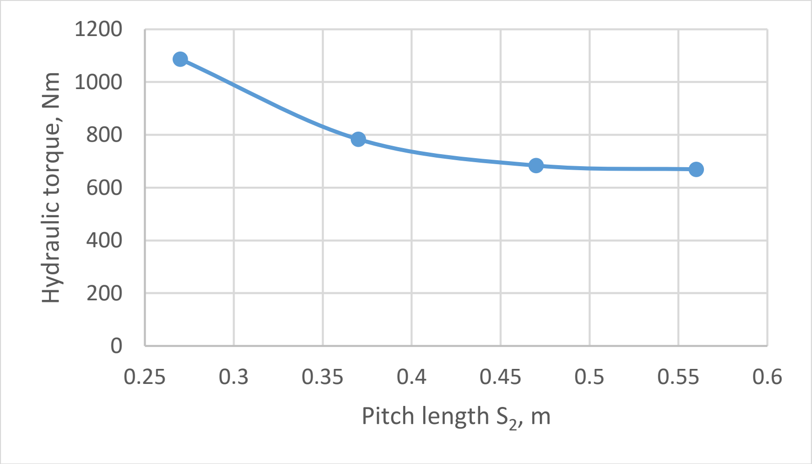


Fig. 17.Graph for results of hydraulic torque for varied pitch S_2 and S_1 constant

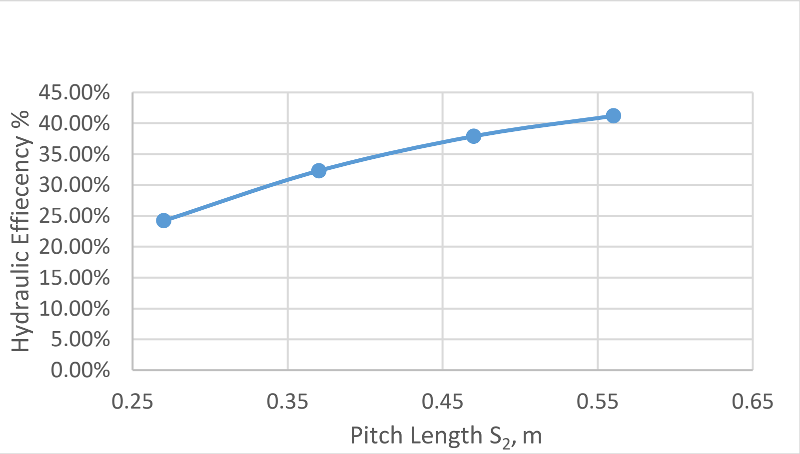


Fig. 18. Graph for results of hydraulic efficiency for varied pitch S2 and S1 constant

9. Numerical simulation of the underpressure helical turbine.

The design and simulation of underpressure helical turbines are created by using the Solidworks 2018 version software, **Fig. 19.** Shows the design of underpressure helical turbine assembly consists of conduit pipe, rotor, casing, drain pipe, bearings, and beares. The design of the rotor blade is a variable pitch helical structure on the rotor shaft. **Fig. 20.** shows the structure of the rotor.

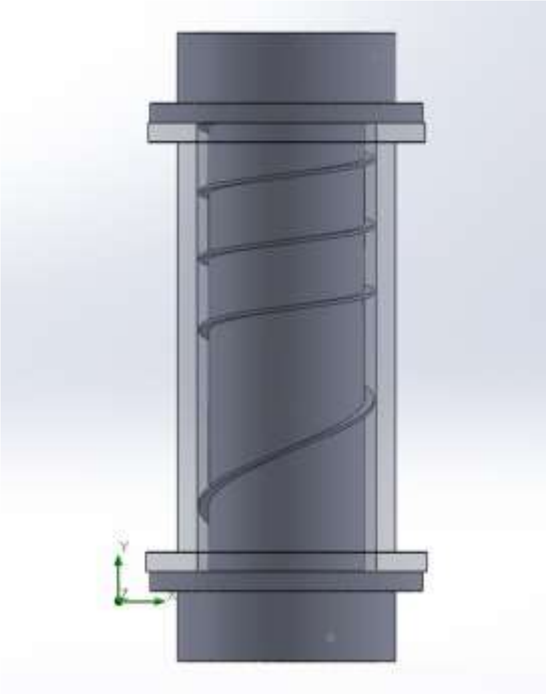


Fig. 19. Design of underpressure helical turbine assembly of rotor diameter 0.4m

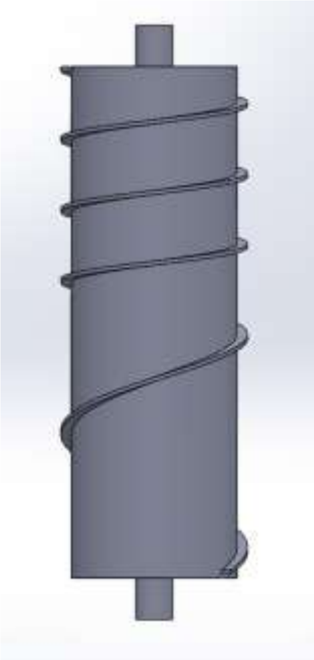


Fig. 20. Rotor design underpressure helical turbine

The assembly created is subjected to flow simulation to obtain the results of hydraulic torque. The lids are created at the inlet and outlet flow of water. The new project is created by using the Wizard, and the general settings are selected based on the model. Analysis type is internal flow with excluded cavitations, and gravitational force is included. The water fluid is selected to flow into the turbine inlet. Initial conditions are environment pressure conditions. This procedure creates the computational domain between the solid surface and fluid flow.

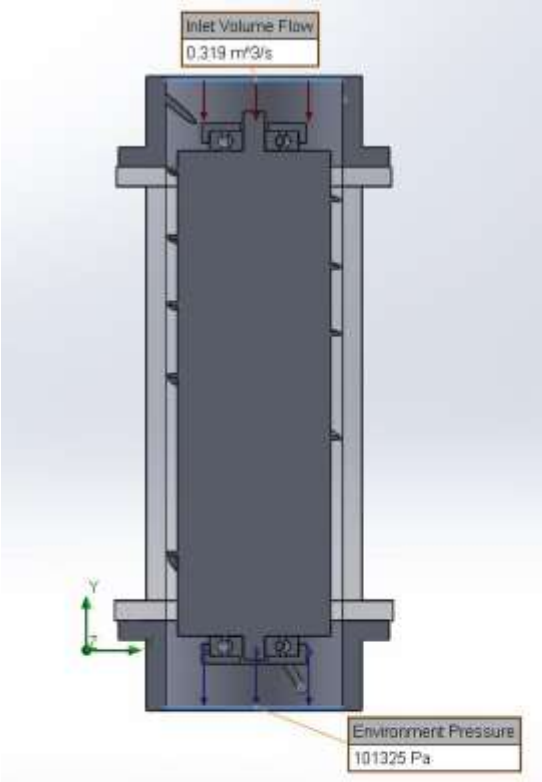
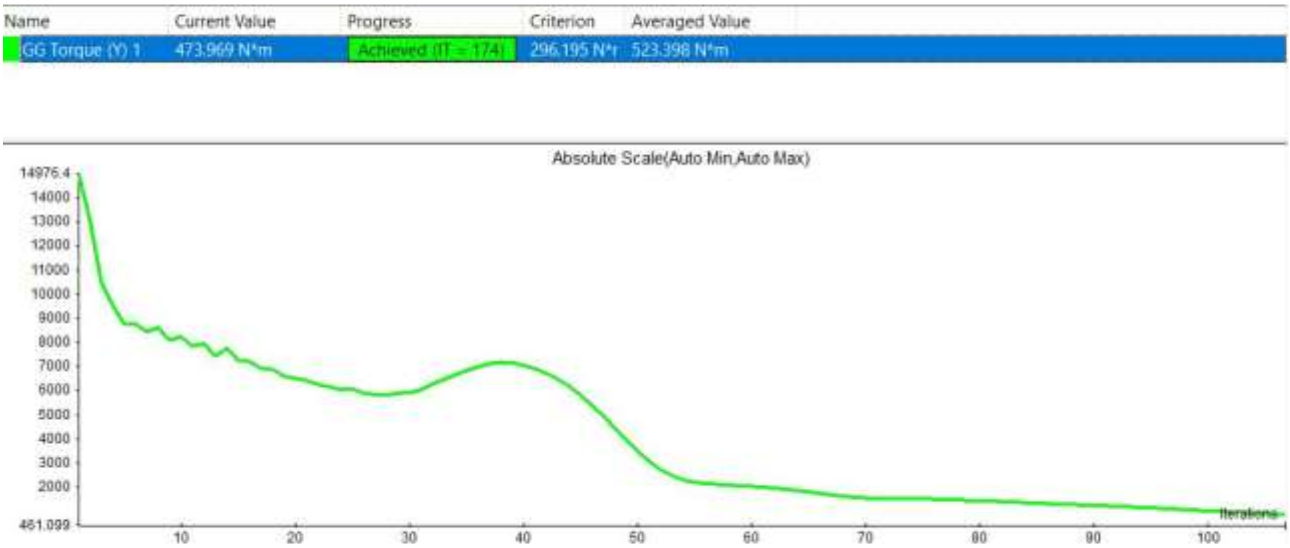


Fig. 21.The boundary condition for the flow of fluid into under pressure helical turbine

Fig. 21. Shows the boundary conditions of the underpressure helical turbine. The inlet volume flow of 0.319m^3/s is obtained by the calculation of water flow into the turbine according to the diameter and velocity of water at the inlet of the turbine, as shown in section 7.1.2. The fluid is allowed to flow towards the outlet of the turbine and the environment pressure boundary condition is applied at the outlet of the turbine. The global goals torque on the y-axis is selected as per the design and the fluid flow into the underpressure helical turbine. The fine mesh is created to obtain the accurate results of the turbine hydraulic torque. The rotor remains static, and the fluid flows int the turbine gives the results of the static analysis. This results in torque created by water against the turbine blades.



Name	Current Value	Progress	Criterion	Averaged Value
GG Torque (Y) 1	473.969 N*m	Achieved (IT = 174)	296.195 N*r	523.398 N*m

Fig. 22.Torque results of underpressure helical turbine of diameter 0.4m

Fig. 22. Shows the torque results of underpressure helical turbine rotor 0.4m of diameter assembly after 174 iterations the average value is found to be 523.3 Nm these results show the decreasing graph of torque values after iterations.

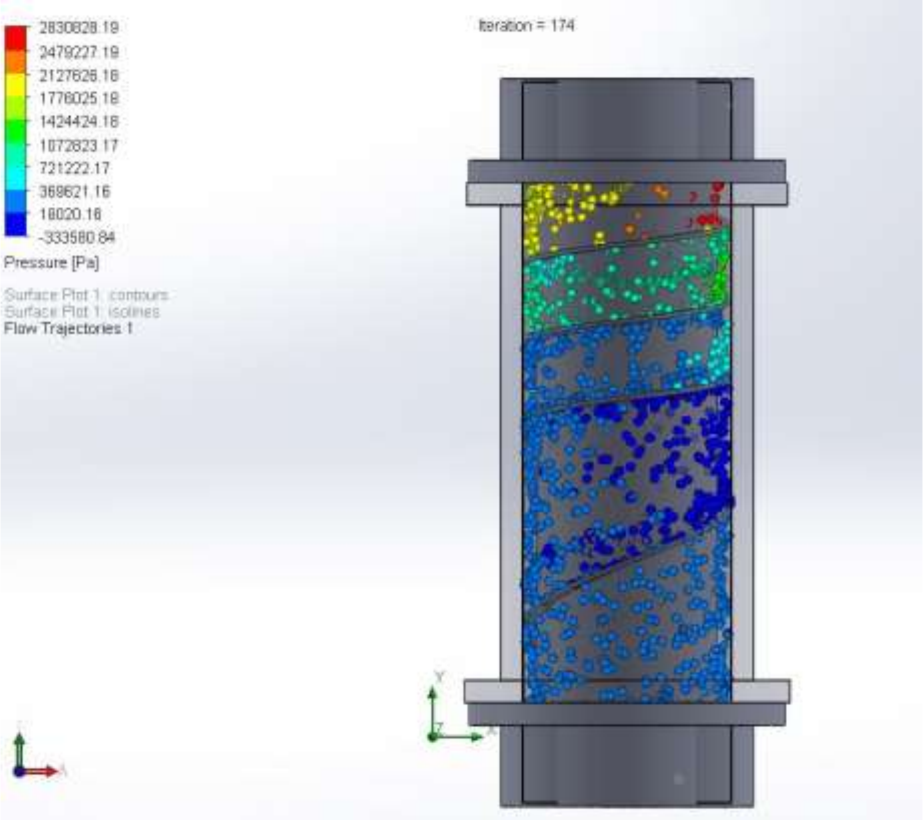


Fig. 23. Flow trajectories of water and pressure distribution

Fig. 23. Shows the flow trajectories of water and the pressure distribution in the turbine during the flow of water into the turbine. The flow of water at the inlet of the turbine shows the high pressure in the pitch S_1 which is small pitch creates the high pressure as water flows down to the second variable the pressure tends to decrease and the torque produced by second pitch is less compared to the first

pitch. The lowest pressure is created in the middle of the rotor as the geometry of the turbine shows the change of pitch from 0.17m to 0.56m. This allows the fluid to flow smoothly through the surface of the rotor blades and an increase in hydraulic efficiency.

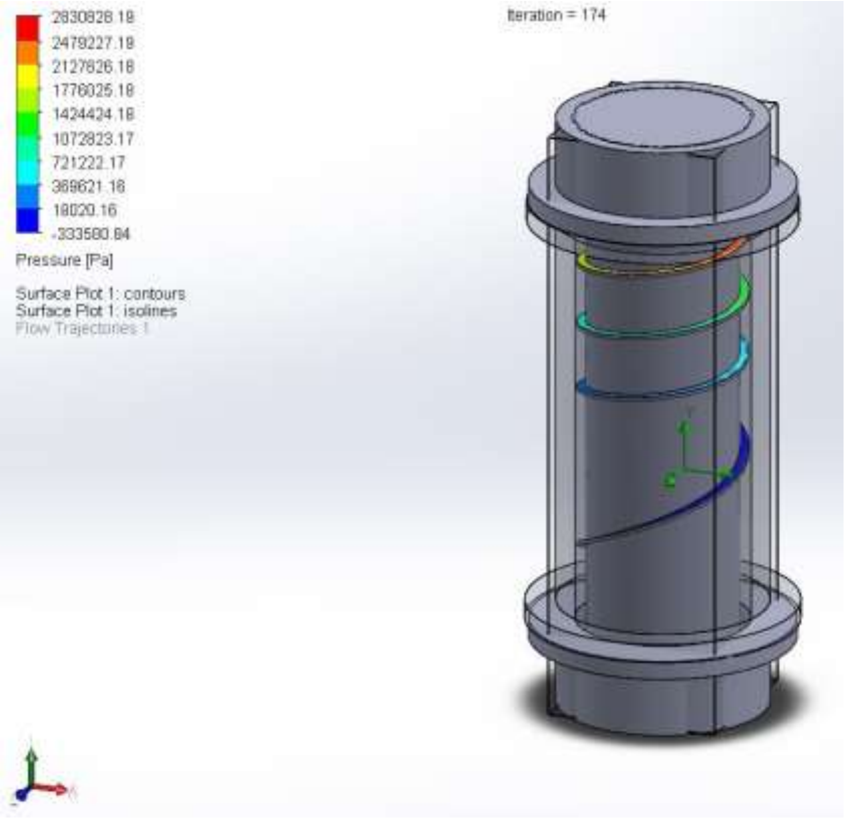


Fig. 24. Surface plot of pressure on the blades of the underpressure helical turbine

Fig. 24. Shows the surface plot of the pressure distribution on the helical blade of the underpressure helical turbine rotor the results show the decrease in the pressure of the water reactivity on the turbine of the blade pitch 0.56m as it allows the water to flow with less pressure and increase the hydraulic efficiency of the underpressure helical turbine.

9.1. Numerical simulation results for hydraulic torque for underpressure helical turbine increasing the rotor diameter.

Table 5. And **Fig. 25.** Shows the results obtained by analytical simulation of the rotor by varying the rotor diameter of the underpressure helical turbine with the same flow simulation method with an inlet volume flow of 0.319m^3/s water flows into the turbine. The results show the reactivity of water on the blade to create the torque on the turbine rotor. The hydraulic torque produced is highest from the rotor with diameter 0.3m and 0.35m as they produce a higher value of pressure when the water let to flow into the turbine. The rotor with diameter 0.25m produce less torque is due to the water flow and the losses of water energy while the transformation of potential energy into kinetic energy in the turbine as the water tends to flow freely than the other turbines as it results in the pressure created in the casing of the turbine hence the lower torque produced. The rotor diameter with 0.4m produces less torque compared to rotor diameter 0.3m and 0.35m, respectively, as the water flow in such a case is reduced, and the pressure is also much reduced due to the flow of water s less into the turbine the pressure distribution in this turbine is less.

Table 5.Numerical simulation results for hydraulic torque by varying rotor diameter

Sl.No	**Rotor diameter, m**	**Hydraulic Torque, Nm**
1.	0.4	523.398
2.	0.35	749.871
3.	0.3	630.825
4.	0.25	404.258

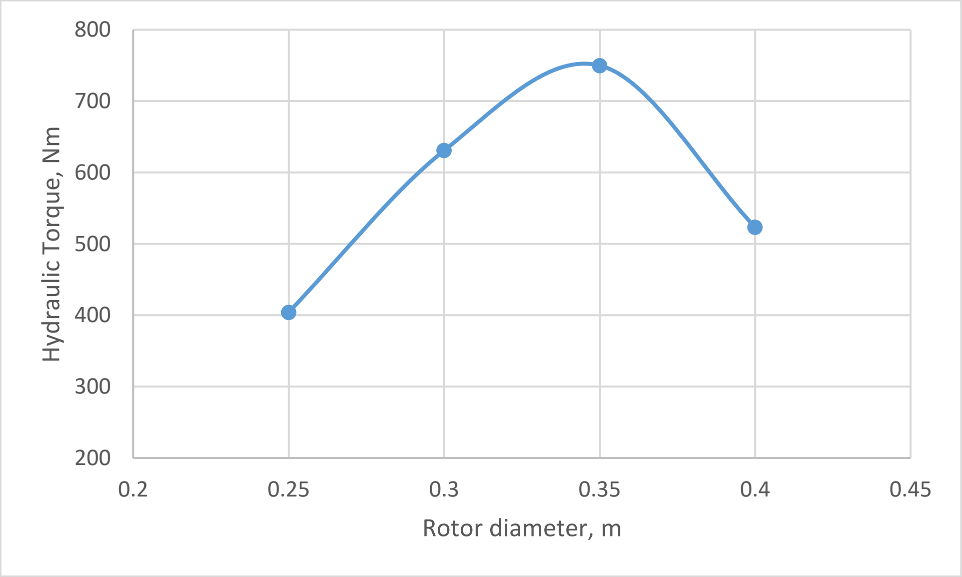


Fig. 25. Graph of numerical simulation results. Hydraulic torque v/s diameter by varying rotor diameter

9.2. The numerical simulation results for hydraulic torque of underpressure helical turbine changing the pitch of the rotor blade.

Fig. 26.The rotor of the underpressure helical turbine with pitch 0.17m

Fig. 26. Shows the design of the rotor of 0.35 diameter and blade with the constant pitch of 0.17m. the design is created using SolidWorks-2018 version software. **Fig. 27.** Shows the assembly of underpressure helical turbine rotor assembled with a casing, conduit pipe and drain pipe. The rotor is supported by bearings and bearers.

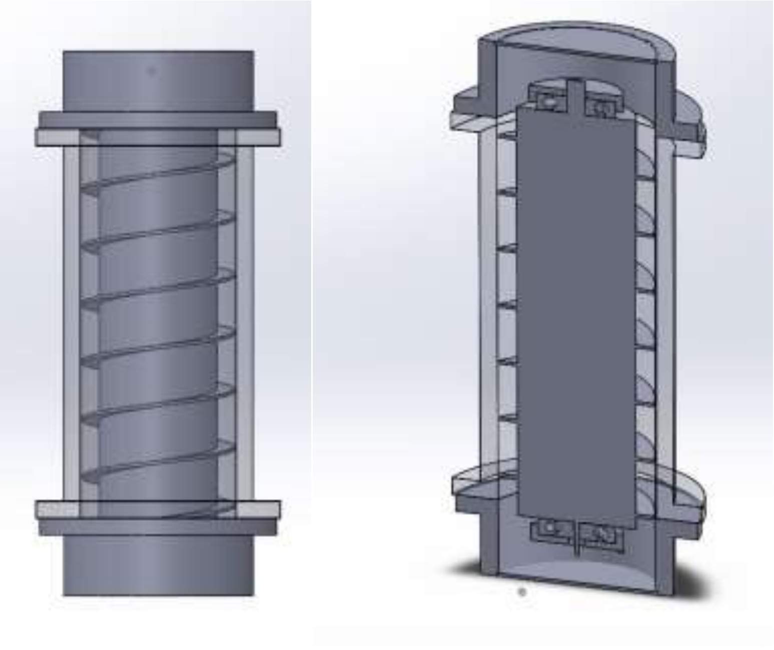


Fig. 27. Assembly of underpressure helical turbine roto of pitch 0.17m

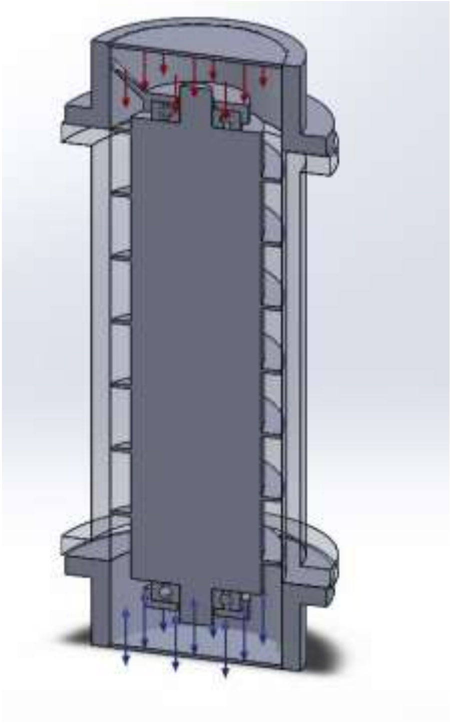
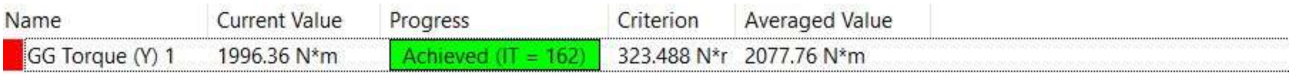


Fig. 28. Boundary conditions for underpressure helical turbine rotor of pitch 0.17m



Name	Current Value	Progress	Criterion	Averaged Value
🟥 GG Torque (Y) 1	1996.36 N*m	Achieved (IT = 162)	323.488 N*r	2077.76 N*m

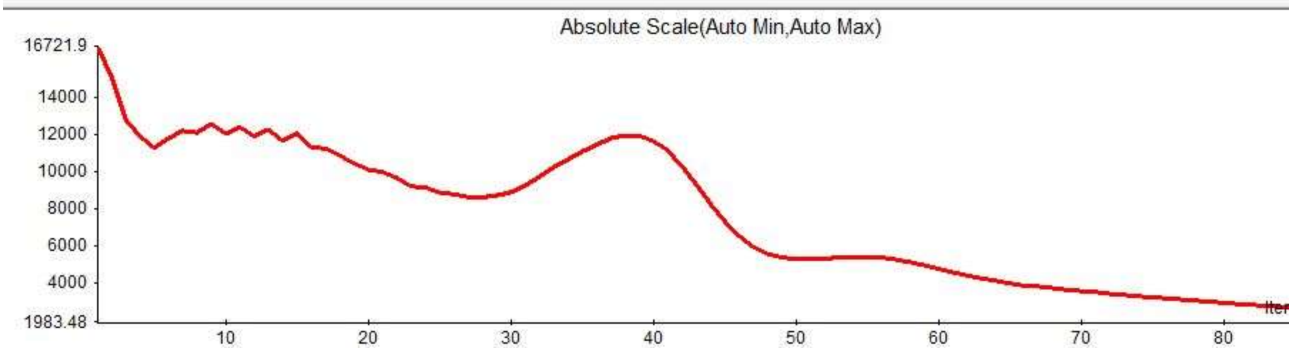


Fig. 29. Hydraulic torque results of turbine rotor of pitch 0.17m

Fig. 28. shows the Boundary conditions applied for the created design of underpressure helical turbine of blade pitch 0.17m of the rotor. The water flow rate at the inlet of the turbine is 0.319m^3/s and the outlet of the turbine is at environmental pressure conditions. **Fig. 29.** Shows the results of flow simulation after the fine meshing of the assembly. The average value of the hydraulic torque is 2077.76Nm

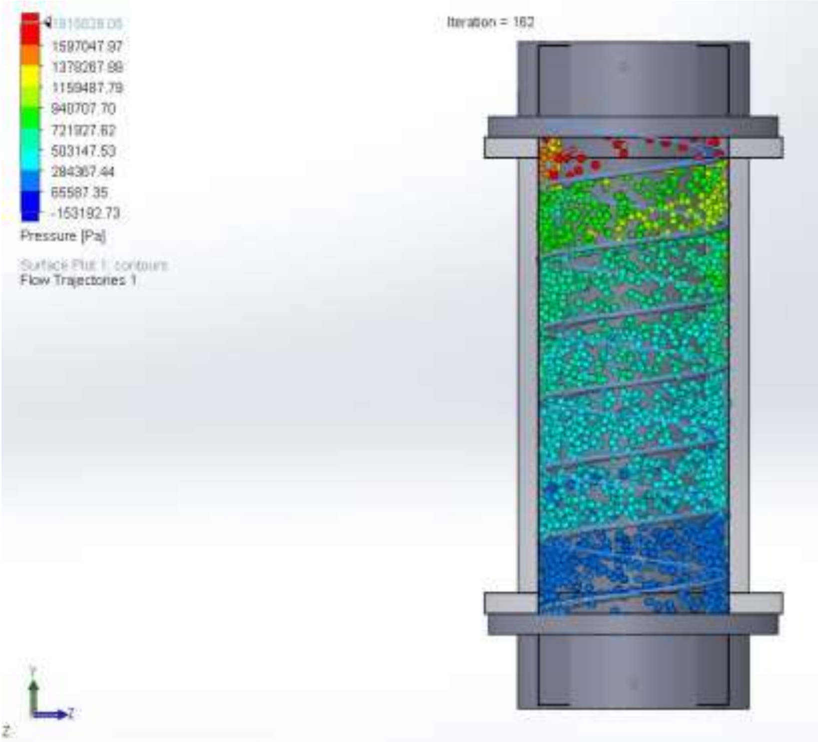


Fig. 30.flow trajectories of underpressure helical turbine rotor of pitch 0.17m

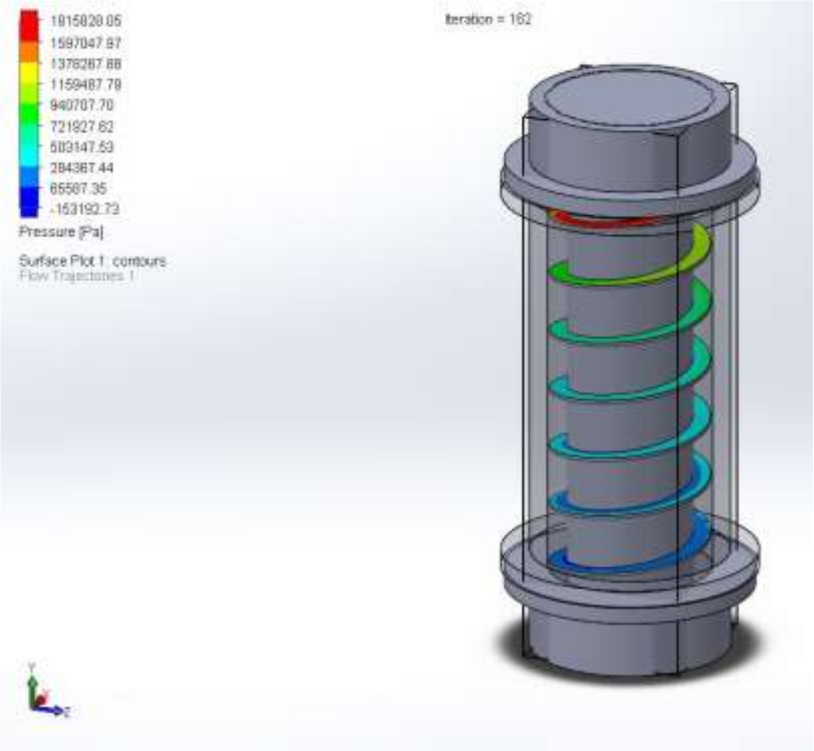


Fig. 31. surface plot pressure distribution result on turbine blade of pitch 0.17m

Fig. 30. Shows the flow trajectories of the water in the underpressure helical turbine. The pressure distributed at the inlet of the turbine is highest and the constant pressure distribution of pressure by the water is shown through the constant pitch 0.17m of the rotor and the pressure decreases at the

outlet of the turbine through drain pipe **Fig. 31.** Shows the surface plot pressure distribution on the underpressure helical turbine blade of pitch 0.17m. The pressure distribution of the blade is shown as the water flow into the turbine this shows the reactivity of the blade design for the flow of water to create the required hydraulic torque.

Table. 6. Show the results obtained by numerical simulation of the rotor by changing the pitch of the turbine. The pitch is constant throughout the length of the underpressure helical turbine rotor.

Fig. 32. shows that the pitch of the turbine blade increases the hydraulic torque of the turbine decreases.

The rotor blades with lower pitch length tend to create higher pressure; hence, the torque generated by the water increases. The pressure variation in the constant pitch length remains approximately remains equal in all the buckets of the underpressure helical turbine rotor.

Table 6. Numerical simulation results for hydraulic torque by varying the constant pitch on the rotor blade

Sl.No	**Rotor pitch, m**	**Hydraulic Torque, Nm**
1.	0.17	2077.76
2.	0.27	1191.27
3.	0.37	906.216
4.	0.47	841.9
5.	0.56	625.573

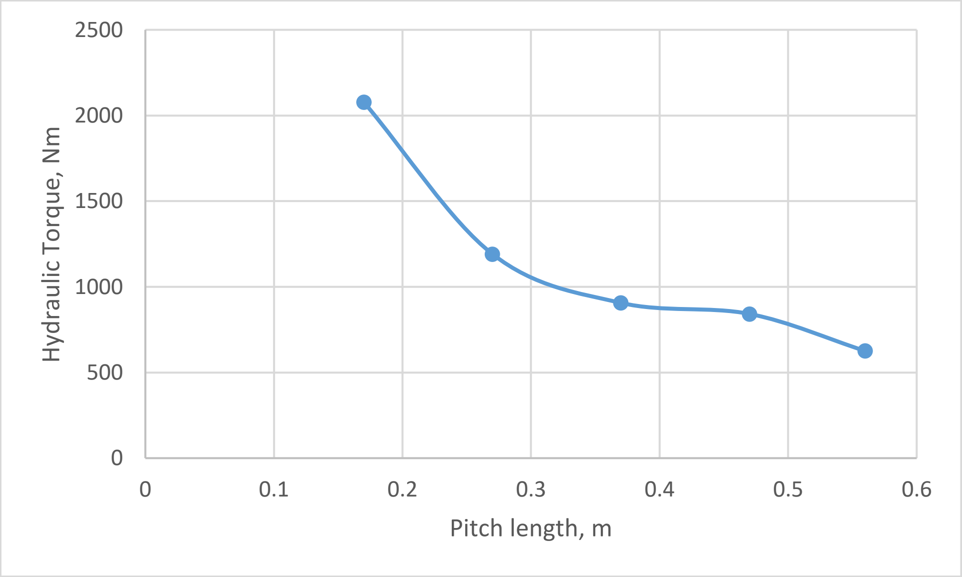


Fig. 32.Graph of numerical simulation results. Hydraulic torque v/s rotor pitch by varying pitch length

9.3. . Numerical simulation results for hydraulic torque for the varied pitch combination of underpressure helical turbine.

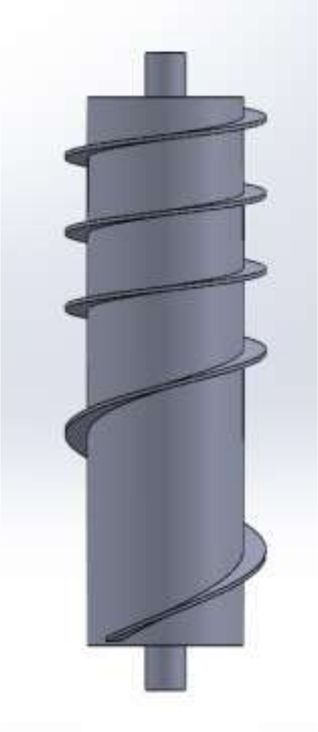


Fig. 33. The rotor of the underpressure helical turbine with pitch 0.17-0.56m

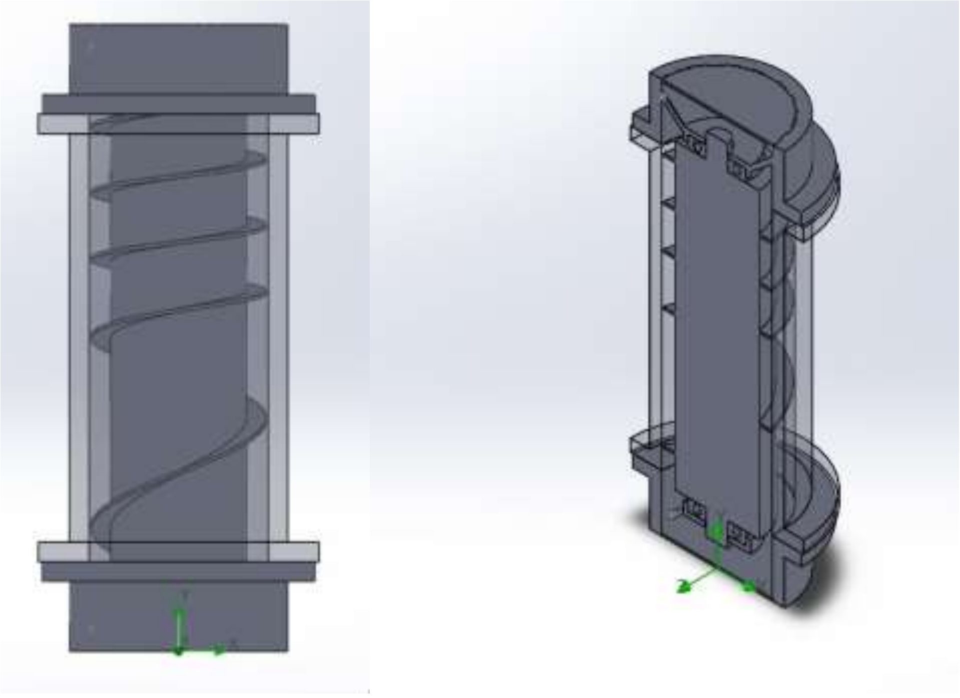


Fig. 34. Assembly of underpressure helical turbine with pitch 0.17-0.56m

Fig. 33. shows the rotor design of the underpressure helical turbine with the pitch of 0.17m – 0.56m variable pitch S_2 of the rotor blade. **Fig. 34**. Shows the assembly and cut section view of the underpressure helical turbine consisting of a casing, rotor, conduit pipe and drain pipe. The rotor is supported by the bearings and bearers.

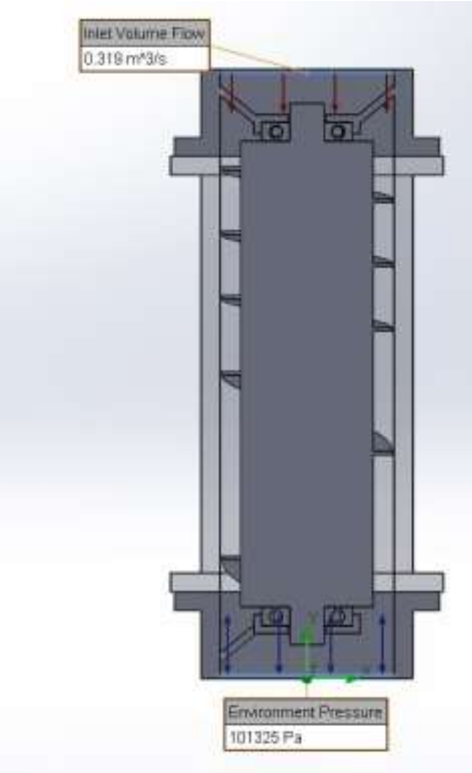
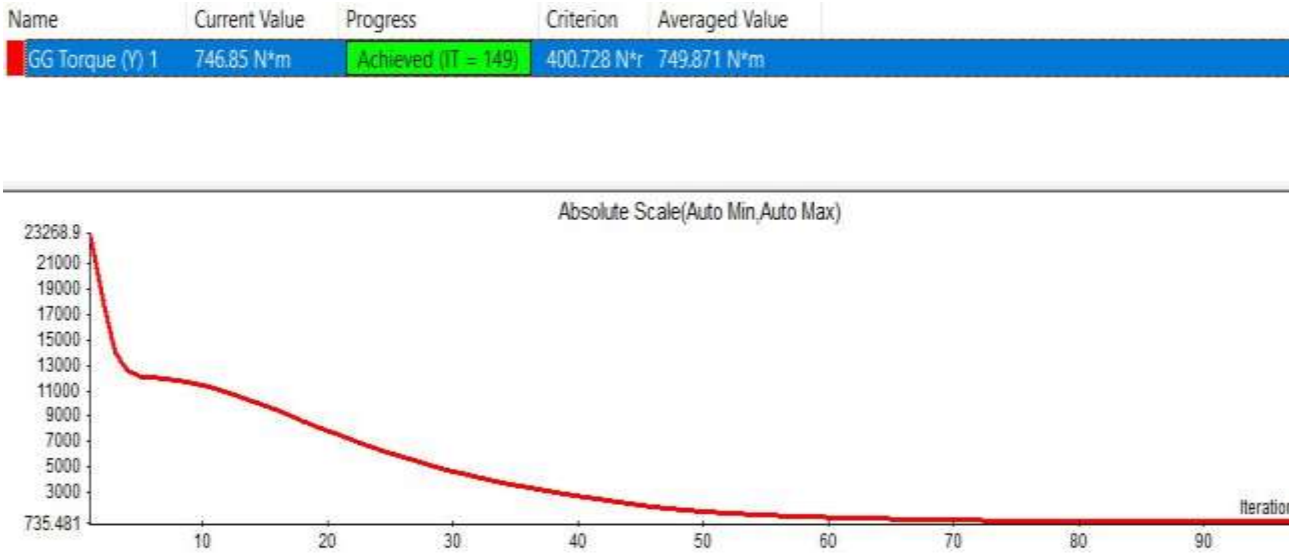


Fig. 35. Boundary conditions for underpressure helical turbine rotor of pitch 0.17-0.56m



Name	Current Value	Progress	Criterion	Averaged Value
GG Torque (Y) 1	746.85 N*m	Achieved (IT = 149)	400.728 N*r	749.871 N*m

Fig. 36. Hydraulic torque results of turbine rotor of pitch 0.17-0.56m

Fig. 35. Shows the boundary condition applied for the underpressure helical turbine for flow simulation. The inlet volume flow is 0.319m^3/s and the outlet of the turbine is subjected to environment pressure condition. **Fig. 36.** shows the results of the calculated by numerical simulation. The obtained hydraulic torque to the underpressure helical turbine of rotor pitch 0.17m-0.56m is 749.871Nm.

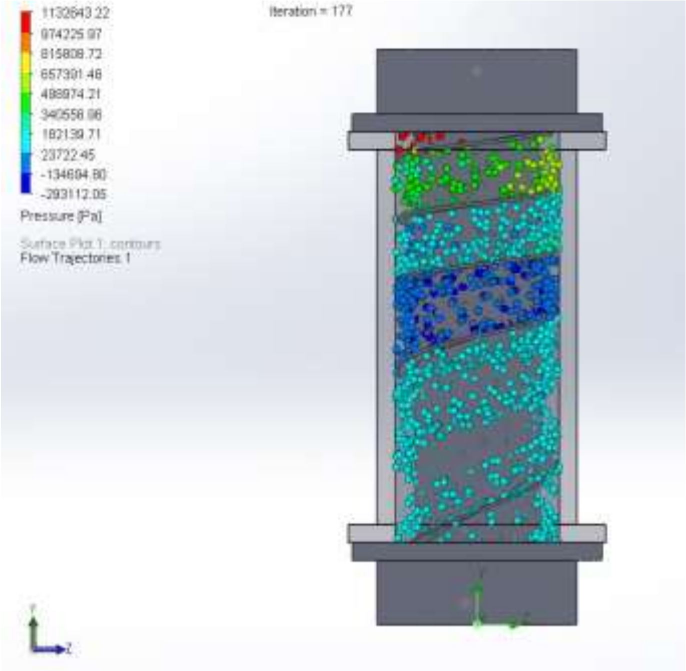


Fig. 37. Flow trajectories of underpressure helical turbine rotor of pitch 0.17m-0.56m

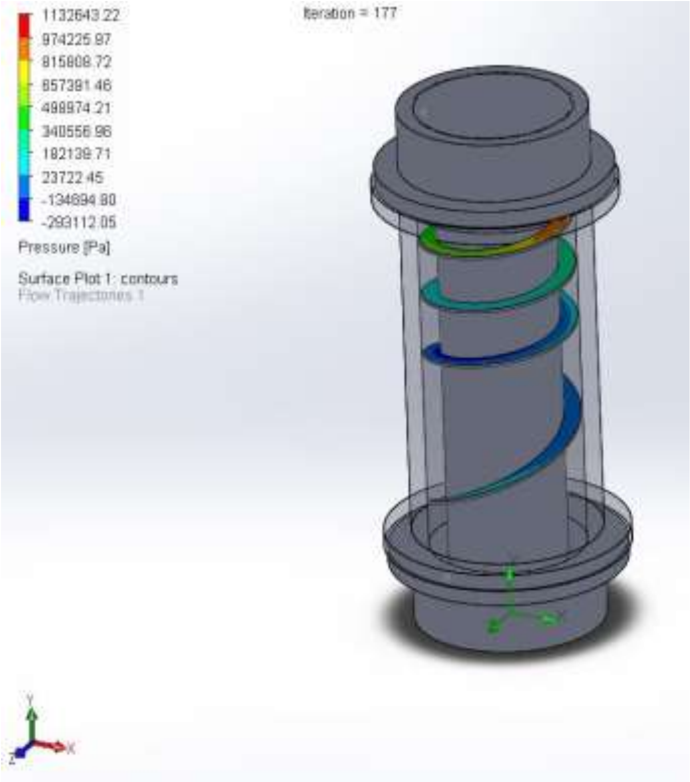


Fig. 38. Surface plot pressure distribution result on turbine blade of pitch 0.17-0.56m

Fig. 37. Shows the flow trajectories of water flow into the turbine and shows the pressure distributed by the water around the rotor of the turbine.the pressure distribution id higher around the pitch 0.17m and it decreases at the change of pitch to 0.56m due to increase in the pitch and gradually increases. The pressure at the outlet of the turbine decreases as the water flow out of the turbine. **Fig. 38.** Shows

the surface plot pressure distribution results on the blade. This shows the reactivity of the blade to the flow of water to create the hydraulic torque.

Table 7. Shows the analytical results of the hydraulic torque for the underpressure helical turbine rotor by varying the pitch S_2, and the pitch S_1 is constant and equal to 0.17m. **Fig. 39.** Shows the graph for the results of hydraulic torque obtained by the numerical simulation method. The graph results show that the torque is increased as the pitch length S_2 of the blade is decreased. The pressure distribution is highest on the blade with a lower pitch length.

Table 7. Numerical simulation results for hydraulic torque for the varied pitch of rotor blade

Sl.No	**Pitch length S_1, m**	**Pitch length S_2, m**	**Hydraulic Torque, Nm**
1.	0.17	0.27	1293.76
2.	0.17	0.37	991.001
3.	0.17	0.47	729.514
4.	0.17	0.56	749.87

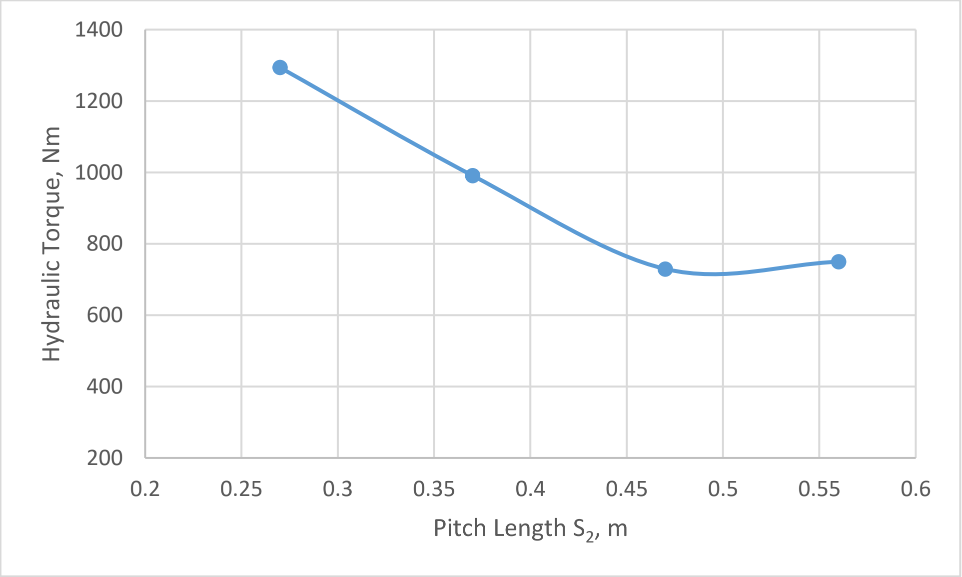


Fig. 39. Graph of numerical simulation results. Hydraulic torque v/s rotor pitch by varying pitch length S_2 and S_1 is constant

10. Comparison of theoretical results and numerical simulation results.

The obtained theoretical values by analytical analysis of varied geometrical parameters are compared with the numerical simulation results of the underpressure helical turbine for the created designs in the Solidworks-2018 software. The error percentage is calculated between the theoretical results and the numerical simulation results. **Table. 8.** shows the error calculation results between the theoretical results and numerical simulation for the varied diameter of the underpressure helical turbine rotor. The error was found to be between 3.806% to 10.47% for the created models.

Table 8. Error percentage results for the varied diameter of the turbine rotor

Sl.no	Rotor Diameter,m	Theoretical hydraulic torque, Nm	Numerical simulated Hydraulic torque, Nm	Error
1.	0.4	483.56	523.98	7.61 %
2.	0.35	669.28	749.871	10.47 %
3.	0.3	583.3	630.825	7.53 %
4.	0.25	416.53	404.258	3.806 %

Table 9. Shows the error percentage results between the theoretical hydraulic torque results and the numerical simulation hydraulic torque results for the varied constant pitch for the underpressure helical turbine of the rotor. The error was found to be 10.41% to 14.87% for the created models.

Table 9. Error percentage results for the varied pitch of the turbine rotor blade

Sl. no	Rotor Pitch length S,m	Theoretical hydraulic torque, Nm	Numerical simulated Hydraulic torque, Nm	Error
1.	0.17	1881.7	2077.76	10.41%
2.	0.27	1002.2	1191.27	14.87%
3.	0.37	762.5	906.216	14.85%
4.	0.47	728	841.9	12.52%
5.	0.56	532	625.573	13.95%

Table 10. shows the error percentage results between the theoretical hydraulic torque results and numerical simulation hydraulic torque results for the varied pitch S_2 for the variable pitch underpressure helical as the other geometrical parameters remain or the underpressure helical turbine rotor. The error was found to be 6.29% - 19.5%.

Table 10. Error percentage results for the varied pitch S_2 of the turbine rotor blade

Sl.no	Rotor pitch length S_2, m	Theoretical hydraulic torque, Nm	Numerical simulated Hydraulic torque, Nm	Error
1.	0.27	1086.4	1293.76	15.3%
2.	0.37	783.4	991.001	19.5%
3.	0.47	683.6	729.514	6.29%
4.	0.56	669.28	749.87	10.74%

Conclusions

The research on the underpressure helical turbine in which the geometrical parameters such as rotor diameter and blade pitch are varied, and designs are created as per varied parameters. The hydraulic torque was calculated theoreticaly of and the hydraulic efficiency of different configurations of the turbine were obtained by means of numerical simulation, by assuming the speed of the rotor as per the literature review. The main functional parameter, such as hydraulic torque, is obtained by numerical simulation.

1. The comparison between theoretical results and numerical simulation results for the varied diameter (0.4 - 0.25 m) of the underpressure helical turbine error was found to be 3.86 – 10.47% for the created models.
2. The comparison between theoretical results and numerical simulation results for the varied constant pitch length (0.17- 0.56 m) of the underpressure helical turbine error percentage was found to be 10.41 - 14.87% for the created models.
3. The rotor pitch S_2 is varied, and the pitch S_1 is constant. The theoretical calculations and numerical simulations were done to know the results of the combination of the pitch for hydraulic torque and hydraulic efficiency.
4. The comparison between theoretical results and numerical simulation for the varied pitch length S_2 (0.27 – 0.56 m) and S_1 remain constant equal to 0.17 m of the underpressure helical turbine error was found to be 6.29 – 19.5% for the created models.
5. The hydraulic efficency of the underpressure helical turbine for the varied diameter (0.4 – 0.25 m) of the rotor was found 22.3 - 41.2 % at 200 rpm.
6. The hydraulic efficency of the underpressure helical turbine for the varied constant pitch (0.17 – 0.56) of the rotor was found 18.5 - 42.2 % at 200 rpm.
7. The hydraulic efficency of the underpressure helical turbine for the varied of pitch length S_2 (0.27 – 0.56 m) and S_1 remain constantequal to 0.17 m of the underpressure helical turbine rotor was found 24.2 - 41.2 % at 200 rpm.

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