Design and Fabrication of Spherical-S Turbine

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Abstract- For the overall development of any nation be it the social, economical or technological, electrical power has found itself to be of essence. The majority of the electrical power is found to be generated from the conventional sources of energy. Due to the rapid exhaustion of the conventional fossil fuels there has been widespread power shortage throughout the globe hindering the upward progressive trajectory of developing nations. In order to solve this problem, the tangible option is to focalize on development of renewal sources of energy. From the different available renewable sources of energy, we chose to study the scope of hydal (water) energy for solving problems of power generation. Hydal energy is the fastest growing energy resource and most importantly is, easily available. Keeping in view all the vital factors low cost hydal energy has been a primary solution. Earlier practices used turbines, but to meet the requirements of task, we choose a different approach in hydal power generation, in small scale power generation and being environmental friendly. This review is a complied study of different in pipe turbines power generation alternatives and selecting the most efficient option. A general Spherical-S turbine configured to rotate transversely with in a cylindrical pipe under the power of fluid flowing either direction there through is operatively coupled with rotating machine or generator to produce electricity. Two vanes are placed to the shaft in the centre of spherical blades to control the flow. The blades of the spherical turbine are airfoil in cross-section to optimise hydrodynamic flow to minimise cavitation and to maximise conversion from axial to rotating energy.

Keywords – Spherical-S turbine, Savonius and Darrieus turbine, Plastic Acrylonitrile Butadiene Styrene

I. INTRODUCTION

Water is a source of renewable energy similar to wind and solar energy. This untapped energy is extractable using underwater turbines capable of converting water kinetic energy into mechanical energy. A turbine with a low cut-in speed is needed to get maximum energy from the water. In this paper, a Spherical - S turbine based on the Darrieus and Savonius vertical axis turbine has been introduced which exploits good features of both turbines. The design procedure elaborates the Hybrid structure of a four curved bladed Darrieus (lift type) turbine along with a Savonius (drag type) turbine. The Savonius turbine is placed on the middle of Darrieus turbine on the same shaft. The Spherical - S turbine is designed in AutoCAD, built and tested at various flow speeds.

Material selection- The choice of the material is obviously crucial. Different criteria include low cost, easy construction, light weight, good corrosion resistance as well as rigidity, recyclable material, etc. In case of S blade, aluminium has been chosen to meet the above criteria. Moreover, it requires a rugged construction as it is designed to provide high starting torque.

The blade manufacturing and material selection is also a decisive aspect of water turbine design, which directly affects the turbine performance. Some manufacturers are selling airfoils which are specially designed for test purposes. But the criteria mentioned are violated due to high cost. In our case, available airfoils in the market which are made with aluminium are not suitable because the total weight of the Spherical - S turbine increases, which directly increases the moment of inertia. so, we have prepared Spherical-S turbine using composite material(FRP).

II. FABRICATION

*Trial spherical – s turbine design using 3d printer***-** The first trial to develop the Spherical - S rotor using 3D was not suitable for the proposed system because the material to build the rotor design cannot withstand the pressure of water when the water flow at maximum velocity inside the pipeline. The material used to build the designed rotor is plastic Acrylonitrile butadiene styrene (ABS). The first sample of Savonius rotor has been built using 3D printer the Savonius rotor design using 3D printer with material plastic ABS from the front, top and side views, respectively.

Figure: Patterns

These 3D patterns are used for making the moulds of aerofoil, cover plate and S blade. Then the fabrication of Spherical – S Turbine is done using the moulds.

FIBRES USED

*Glass fibre***-** Fibreglass refers to a group of products made from individual glass fibres combined into a variety of forms. Glass fibres can be divided into two major groups according to their geometry: continuous fibres used in yarns and textiles, and the discontinuous (short) fibres used as boats, blankets, or boards for insulation and filtration. Fibreglass can be formed into yarn much like wool or cotton, and woven into fabric which is sometimes used for draperies. Fibreglass textiles are commonly used as a reinforcement material for moulded and laminated plastics. Fibreglass wool, a thick, fluffy material made from discontinuous fibres, is used for thermal insulation and sound absorption. It is commonly found in ship and submarine bulkheads and hulls; automobile engine compartments and body panel liners; in furnaces and air conditioning units; acoustical wall and ceiling panels; and architectural partitions.

Fibreglass can be tailored for specific applications such as Type E (electrical), used as electrical insulation tape, textiles and reinforcement; Type C (chemical), which has superior acid resistance, and Type T, for thermal insulation.

The basic raw materials for fibreglass products are a variety of natural minerals and manufactured chemicals. The major ingredients are silica sand, limestone, and soda ash. Other ingredients may include calcined alumina, borax, feldspar, nepheline syenite, magnesite, and kaolin clay, among others. Silica sand is used as the glass former, and soda ash and limestone help primarily to lower the melting temperature. Other ingredients are used to improve certain properties, such as borax for chemical resistance. Waste glass, also called cullet, is also used as a raw material. The raw materials must be carefully weighed in exact quantities and thoroughly mixed together (called batching) before being melted into glass.

Chopped Strand Mat- CSM is a form of reinforcement used in fibreglass. It consists of glass fibres laid randomly across each other and held together by a binder. It is typically processed using the wet lay-up technique, where sheets of material are placed in a mould and brushed with resin. Because the blinder dissolves in resin, the material easily conforms to different shapes when wetted out. After the resin cures, the hardened product can be taken from the mould and finished. Using chopped strand mat gives fibreglass with isotropic in-plane material properties.

Woven Roving- Woven Roving is made from continuous glass fibre roving which are interlaced into heavy weight fabrics. Compatible with most resin systems. Used in most cases to increase the flexural and impact strength of laminates. Ideal for multi-layer wet lay-up applications where great material strength is required. Good drivability wet out and cost effective. With Woven Roving as a general rule estimate the resin/reinforcement ratio at 1:1 by weight. Woven Roving is available in a variety of weavers, weights, widths and finishes to suit a wide range of applications.


Glass Fibre


Chopped Strand Mat


Woven Roving

MATRIX USED

*Epoxy resin***-** The large family of epoxy resins represents some of the highest performance resins of those available at this time. Epoxies generally out-perform most other resin types in terms of mechanical properties and resistance to environmental degradation, which leads to their almost exclusive use in air craft components. As a laminating resin their increased adhesive properties and resistance to water degradation make these resins ideal for use in applications such as boat building. Here epoxies are widely used as a primary construction material for high-performance boats or as a secondary application to sheath hull or replace water-degraded polyester resins and gel coats. It gives more strength when compared with the polyester resin.

Hand lay-up technique- This fabrication is done by the hand lay-up process. Hand lay-up is the method of cutting lengths of fibre reinforcement off of rolls. The reinforcement most often comes in the form of chopped fibre, woven fibre, and stitched fibre. Once a layer is placed in the mould, resin is applied either by pouring on by hand, or it can be sprayed on with a mixing gun the layers are consolidated and air bubbles are removed by using squeegees and hand rollers.

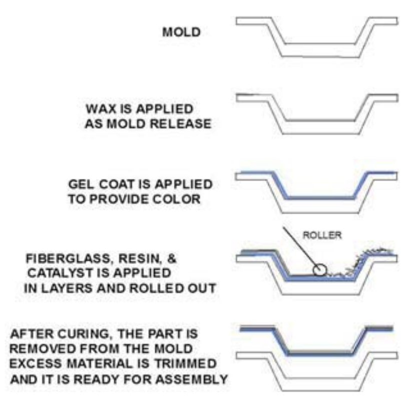

Figure. Hand Lay-up Technique

STEPS INVOLVED IN MAKING OF TURBINE:

- Cleaning of the mould.
- Apply wax pol such that during the release of piece there does not be any problem of blow holes or air gaps.
- And later it is cleaned using cotton, and after cleaning Polyvinyl Alcohol (PVA) is applied so that the laminate is removed without any difficulty.
- Cut the layers of glass fibres, woven roving, CSM, and filament to the required sizes.

- Firstly, on the prepared mould chopped span mat is placed and Epoxy resin (90%) which is mixed with diluter (10%) and Hardener (10%) is applied on the CSM.
- Later after glass fibre, woven roving, and filament are placed as layers on CSM.
- The mould is closed and clamped firmly.
- The mould is allowed for curing for 5-6 hours.
- After curing, the product is removed from mould and later it is grinded for good surface finish.

III. RELATED WORK

K. Sornes [1] in his paper have discussed about various types of blade design used in Hydro-Micro turbines. The two most common small scale hydro-kinetic turbine concepts are axial flow turbine and cross flow turbines. The axial concept has a rotational axis of rotor which is parallel to the incoming water stream. The cross flow concept on the other hand, has a rotational axis of rotor which is parallel to water surface. The advantage of cross flow turbines over axial flow turbine is that they can rotate uni-directional even with bi-directional flow. Cross flow turbine can be divided into two groups, namely Vertical axis (Axis vertical to water plane) and In-plane axis (Axis on the horizontal plane of water surface). In cross flow turbine the water passes through the turbine transversely, or across the turbine blade. It provides additional efficiency. Cross flow turbines are often constructed as two turbines of different capacity that share the same shaft .The different types of Cross-flow turbines are explained below. **J. Khan [2]**, in his research paper have discussed about In-plane axis. In-plane axis are better known as floating water wheels. These are mainly drag based devices and inherently less efficient than their lift based counter parts. The large amount of material usage is another problem for such turbines. Darrieus turbines with In-plane axis may also fall under this category. But such systems are left common and suffer from bearing and power take off problems. **G. J. M. Darrieus [3]**, has presented two major types of Darrieus mechanisms. They differ on how they handle the centrifugal force impose on the blade of the turbine, one is called Squirrel cage variant which consists of two disks at top and bottom with the aerofoil running straight up and down between their rims. This allows the centrifugal force to be handled by the relatively sturdy construction of the disks. The advantage of turbine is to be able to progressively get into rotation. The disadvantage of it is the low Reynolds number. **S. Roy et al [4]**, in his work have described about H-darrieus



turbine.

H-Darrieus are breed of vertical axis wind turbine designed by George Darrieus in 1920‟s. They are capable of producing much power than most typical wind turbine. H-Darrieus rotor is a lift type device having two or three blades designed as airfoils. The blades are attached vertically to centre shaft through support arms. The support to vertical axis helps rotor to maintain its shape. One major disadvantage of H-type Darrieus turbine is that since lift forces drives them that must be brought to a minimum speed before the forces generated as sufficient to propel the turbine. The starting torque coefficient is zero and at low tip speed ratio it is even negative. Therefore, a special motor is required to start the rotor. With increase of height to diameter ratio, velocity magnitude difference from inlet up to rotor increases up to height to diameter ratio 1.0 and then decreases loss of performance for turbine with increases of height to diameter ratio. It can be concluded that velocity difference from inlet up to rotor is responsible for power stroke of blades during its clockwise direction. The Tip Speed Ratio of H-Darrieus turbine is high, hence, it rotate faster. **L. J. Hagen et al [5]**, in his research paper has summarized about Darrieus turbine. This design of turbine was patented by Georges Jean Marie Darrieus, a French aeronautical engineer in 1931. Darrieus turbine is a vertical axis turbine. It has streamlined blades turning around an axis perpendicular to the flow. The turbine consists of number of curved airfoil blades mounted on a vertical rotating shaft or framework. The curvature of the blade allows the blade to be stressed only in tension at high rotating speeds. It is powered by the phenomenon of lift. There are major difficulties in protecting the Darrieus turbine from extreme speed of fluid and in making it selfstarting. In Darrieus blades the airfoils are arranged so that they are symmetrical and have zero rigging angle, that is, the angle that the airfoil are set relative to the structure on which they are mounted. This arrangement is equally effective no matter which direction the flow of fluid is flowing in contrast to the conventional type, which must be rotated to face into the fluid. One problem with the design is that the angle of attack changes as the turbine spins, so each blade generates its maximum torque at two points on its cycle, that is, at front and back of the turbine. The Tip Speed Ratio of Darrieus turbine is high approximately same as H-Darrieus, hence, it rotate faster. Its self-starting capabilities are low. **A. M. Gorlov [6]**, have patented information about Gorlov turbine. The Gorlov turbine was invented by Alexander Gorlov in 1995. This turbine is also known as "Cross flow helical turbine‟. It is similar to Darrieus straight blade style turbine, except aerofoil blade profile is swept in a helical profile along its span. One of the advantage of helical blade is that it improves self-starting of Gorlov turbine compared to Darrieus turbine. As helical blade sweeps along circumference of rotation of turbine some portion of blade profile is located at optimum angle of attack even in static or slowly rotating conditions, which allows for more uniform starting torque that depend upon turbine azimuthal position. Also owing to helical blade shape is reduction of torque oscillation during rotation. A Darrieus turbine tends to experience torque oscillation resulting from circumferential void space between discrete blade positions. On the other hand, helical turbine with full blade wrap around its circumference does not experience this problem. Uniform blade coverage, neglecting end effects and wake dynamics, ideally give the turbine torque, although in reality some variations are likely to occur. Gorlov reported from experimental testing that maximum efficiency for Gorlov turbine is around 35%. **I. Dobreva et al [7]**, in his paper have briefed about Savonius turbine. Savonius rotor was invented by Finnish Engineer S. J. Savonius. It was a primarily drag style rotor. It generates high torque at low speed, making it desirable for application such as water pumping and low wind speed application. The rotation of the rotor is due to drag difference between the advancing blade and returning blades. Design of conventional Savonius rotor is simple and cheap to build. Two half cylinders are set with their concave sides facing each other and then offset with a smaller overlap. The power coefficient of Savonius rotor used for micro-hydraulic turbine is affected by varying the clearance ratio. The maximum power coefficient, is larger when rotation direction is counter clockwise for clearance ratio less than 0.73 while power coefficient is larger when rotation of direction is clockwise for clearance ratio greater than 0.73. The drawbacks of Savonius rotor are that it has low efficiency and that it operates at low tip speed ratio which made it difficult to integrate with generator. Several individuals have tested models to optimize performance and altered its conventional design to improve performance. The highest efficiency of all configurations tested was 24% of two stage, two bucket rotor. **Lucid Energy Inc. [8],** Is a provider of renewable energy and smart water management solutions that improve the economics of delivering water. Lucid energy was formed in 2007 with the mission of creating a new way for industries particularly those that use large amount of water and electricity by Rod Schlabach and Gregg semier being president and CEO with group of team. Lucid Energy technology team invented an in-pipe turbine generator that efficiently recaptured energy embedded in fast flowing water inside large diameter pipe line without disrupting operations and with no environmental impact**.** In 2012 Lucid Energy completed the first commercial installation of a 42" lucid pipe system at Riverside public utilities, and in march 2012 Lucid energy officially announced the commercial availability of the Lucid pipe power system. The lucid pipe system in riverside has operated continuously for 3 years with 87% availability to produce electricity. **Mr.Md.A.H.B.Amran [9],** presented a paper on electrical generation using Savonius-Darrieus turbine for RWH system during- 2014-15 as part of his B.E (Electrical) in Universiti Teknologi Malaysia. In his project he conducted performance test on 2 types of turbine blades, Savonius and Savonius-Darrieus used to generate electricity in the proposed RWH system. The proposed RWH systems were able to generate the small electricity. All the concept of the theory and mathematical equations that related with this study have been applied in his project. The designs and specifications of the rotor also have been discussed in his undergraduate report briefly. **AshitoshDhadwad, AmolBalekar and Parag Nagrale [10],** there are various modification done in Hydro-micro turbines to improve certain parameters such as efficiency, tip speed ratio, self-starting ability, torque etc. For example, hybrid of Darrieus and Savonius turbines are available. Double Savonius which is recently been developed have greater efficiency than Savonius turbines. Darrieus turbine, which is the typical lift-type vertical axis wind turbine, has many advantages over horizontal axis types. In particular, this turbine is suitable for stand-alone power systems on isolated islands and in mountainous regions where the power supply using utility grids is very difficult. Thus, this paper discusses the suitable hybrid configuration of Darrieus lift-type rotor and Savonius drag type rotor for stand-alone wind turbine-generator systems using our dynamic simulation model. **Kevat et al [11],** there are two categories of modern wind turbines, namely horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs), which are used mainly for electricity generation and pumping water. The main advantage of VAWT is its single moving part (the rotor) where no yaw mechanisms are required, thus simplifying the design configurations significantly. Scientists have developed numerous designs based on several aerodynamic computational models. These models are crucial for deducing optimum design parameters and also for predicting the performance of VAWT. In this review, the single stream tube aerodynamic model that has been used for performance prediction and design of straight bladed Darrieus-type VAWT is discussed. Single stream tube model can predict the coefficient of performance easily before experiment of the turbine. In this paper co-efficient of torque by single stream tube model is discussed.

IV. RESEARCH METHODOLOGY

The process of the project from beginning until the end of the process is explained. The first step is to understand the concept of turbines in a pipe system from previous works. Several of information related to water turbine type were sought to get more information about this project. From that research information, is to find the enhance method to improve the performance of the water turbine for in pipe system. One of the solution is by using deflector plate to give more striking on advancing plate and to use the Darrieus-Savonius as a type of water turbine.

The flow of the process started by doing the literature review, reading other research papers, to get more information and also to find what is the available methods to improve the output power of the previous In-pipe water system. In this project, the Spherical-S rotor with deflector was designed in order to improve the performance of Spherical rotor. The research and study about the Savonius-Darrieus rotor has been done before designing and developing phases. Some parameter must be considered, particularly the best shape of rotor and internal overlap because these factors may affecting the performance of Spherical-S rotor.

The summary of the method is constructed and interpreted in the project flow plan shown in Figure 3.1.

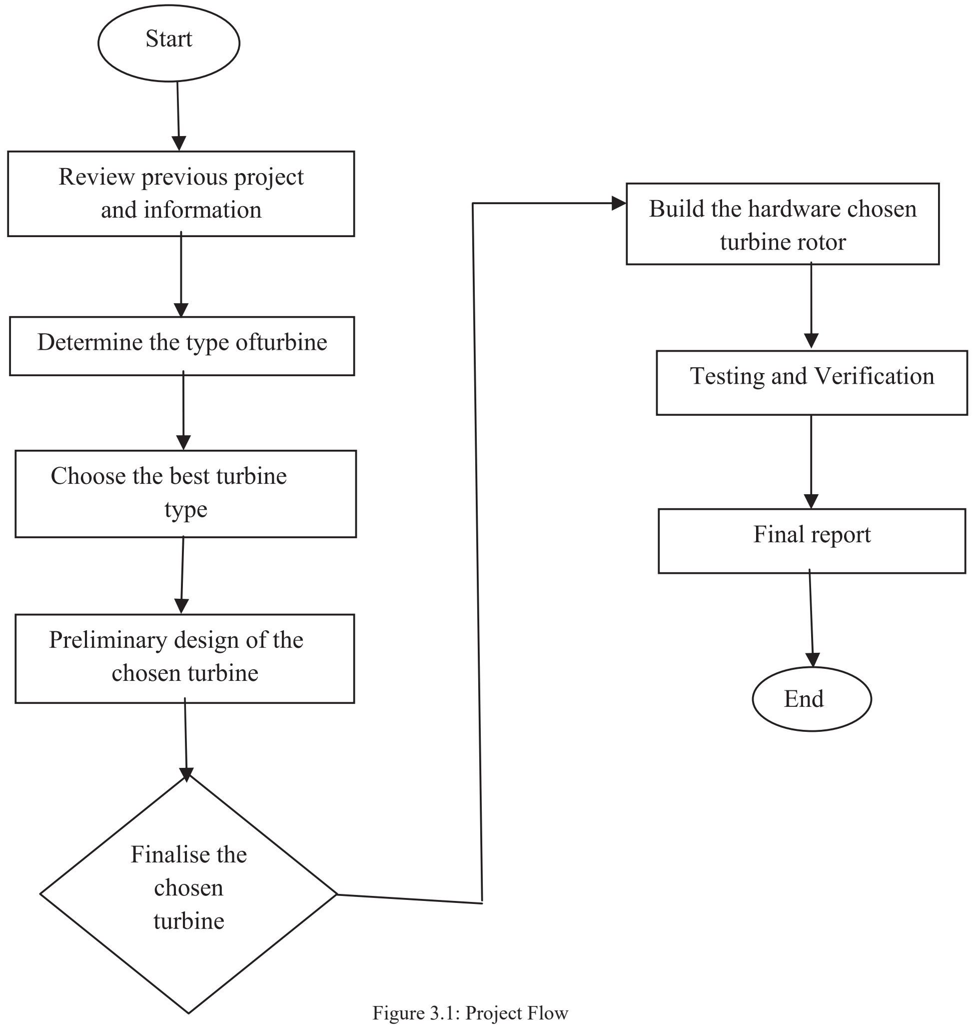

Figure 3.1: Project Flow

V. EXPERIMENTAL SET-UP

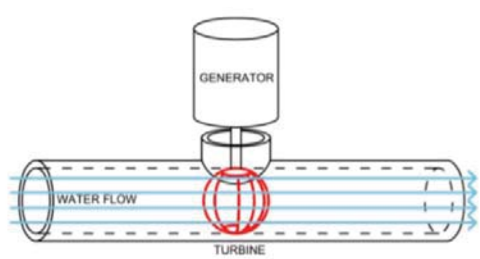

Figure: Structure of the proposed system

Experimental set-up- The experiment was conducted on the Spherical – S turbine Figure shows the process of the system.

- The water flows into the small pipe line to maximise the velocity of water stream to give enough pressure to the rotating turbine,
- When the water flow strike on the rotor, it make the rotor to rotate. The shaft of the rotor is connected to a DC generator by gears. Then the generator producing the electricity due to the rotating rotor.

- The power generated from the generator was stored in the battery before it being used for electrical equipment or other loads.

Figure: Experimental Set up

VI. RESULT

When water from the pipe strikes the blades of turbine, it rotates with certain speed and power is transmitted by means of shaft from turbine. The turbine shaft is connected to DC motor. This in turn connected with a battery or LED such that it is stored in battery.

S.NO	TRIAL	DIAMETER OF PIPE(INCHES)	SPEED (RPM)
1	1	2	180
2	2	2	200
3	3	3	230
4	4	3	250

S.NO	TRIAL	DIAMETER OF PIPE(INCHES)	VOLTAGE (VOLTS)
1	1	2	1.56
2	2	2	3.76
3	3	2	2.54
4	4	2	4.56

Experimental Results

The fabricated turbine has been tested for different pressures by varying the positions valve at the input pipe from the pump and noted the speed of the shaft also by connecting DC motor noted the voltage generated with the help of a multimeter.

VII. CONCLUSION

The proposed system has been successfully built and tested to study the performance of the Spherical-S rotor. The proposed systems were able to generate the small electricity. All the concept of the theory and mathematical equations that related with this study have been applied in this project. The designs and specifications of the rotor also have been discussed in this undergraduate report briefly.

Based on the results shown in above chapter, it can be conclude that the higher power output can be generated when the high volume of water is used. This is due to the pressure of water which increased the velocity of the water to flow inside the pipeline. Besides that, from the theoretical equation of power generated, the pressure of the water also affected the output power of the system. Moreover, due to the high velocity of the water, it made the rotor of the water turbine rotates faster at the shorter length and it can generate more output power.

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