EXPERIMENTAL STUDY OF A LOW COST HYDRAULIC WHEEL

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Submitted by

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ABSTRACT

A Hydraulic-wheel is a ancient or basic Pelton turbine of modern world as it works on the principle of conversion of energy i.e. hydro mechanical conversion device as it converts the gravitational energy or the flow energy of elevated water into mechanical and then into electric energy.This conversion of energy is done via electric generator or step up motor (DC motor). The kinetic energy of the water is directed tangentially to the buckets (Blades) of the wheel. The water strikes on the convex profile or the inner side of the blade which results in propelling the rim on which the blades are attached and do to rotation of the rim the rotational energy is harnessed by step up motor connected by the shaft of the rim and is further converted into electric energy.

In this present study the basic design of the hydraulic wheel is modified to that of Pelton wheel without using water jet as the source of water flow, as we all know that Pelton turbines uses flow from the jet for the rotation of rim in closed environment. The initial shape and of hydraulic wheel is modified with that of Pelton wheel which is an impulse turbine in which buckets of elliptical shape are attached to the periphery of a rotating wheel. The study has brief discussion and comparison of design and efficiency respectively for the basic design of Hydraulic wheel by conducting various experiments in a flume. It has consists of runner diameter, bucket. Only the facts are considered to design the Modified Hydraulic wheel turbine are preferred in the study so as to bring down the cost of turbine thus making it useful in open channel flows and wide spreading its use in open channels and making electricity easily available at low cost.

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CHAPTER 1

INTRODUCTION

1.1 RISING DEMAND OF ELECTRICITY

In today's era we all are dependent on electricity for making our life's simpler and easier. It is the important discovery in the human race history. Electricity can be said as the major source of power or type. Electricity or power is generated via multi stage conversion of energy from one form to other with help of natural resources like coal, natural gas, nuclear power etc. With the rise in demand of power our dependency on the resources have increased but on the other hand these resources are limited in nature which are depleting on a alarming rates, these methods involves conversions of energy from heat to mechanical and mechanical to electricity which results in polluting the environment as well air and land pollution is caused which is undesirable in sustainable development of world.

Electricity's extraordinary versatility as a source of energy means it can be put to an almost limitless set of applications which include transport, heating, lighting, communications, and consumption etc. Electrical power is the backbone of modern industrial society, and is expected to remain so for the foreseeable future.

Now a day's demand of electricity is going way up high day by day and resources used of generation of electricity and environment is depleting day by day. Which is a cause of worry, so to maintain a balance we need to shift are focus from traditional ways generation of electricity to new and greener ways like Hydro power, solar power etc. This will result in lesser load on fossil fuels and will also lower down the carbon emissions as well.

1.2 DIFFERENT TYPES OF ELECTRICITY GENERATING POWER PLANTS

1.2.1 Thermal power plants:

A thermal power station is a type of power plant in which water is converted into steam by heating it and the steam is collected and used to drive the steam turbines which further drives a electric generator to produce electricity .after this the steam is condensed and again entire process is repeated this is also known as Rankine cycle. The variation in design of the thermal power plant may be because of type of fossil fuel used as fossil is burnt to heat the water. Some researcher and scholars call thermal power station as energy center because such facilities converts forms of energy (Heat to electric). Certain thermal power plants also are designed to produce heat energy for industrial purposes of district heating, or desalination of water, in addition to generating electrical power. Globally, fossil fuelled thermal power plants produce a large part of man-made CO_2 emissions to the atmosphere, and efforts to reduce these are many, varied and widespread.

1.2.2 Geothermal power plant:

These types of plants feed on natural hot water reservoirs which are found on the earth's surface or below it. The steam is collected and directly fed to the turbine and electricity is generated. There are three types of geothermal plants: dry steam, flash steam, and binary cycle.

1.2.3 Nuclear power plant:

A nuclear power plant is a thermal power station in which the heat source is a nuclear reactor. As in all conventional thermal power stations the heat is used to generate steam which drives a steam turbine connected to a generator which produces electricity.

1.2.4 Wind power plants:

Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to make electrical power, windmills for mechanical power, wind pumps for water pumping or drainage, or sails to propel ships.

1.2.5 Hydro power plants:

Hydroelectric power plants convert the hydraulic potential energy from water into electrical energy. Such plants are suitable were water with suitable head are available.

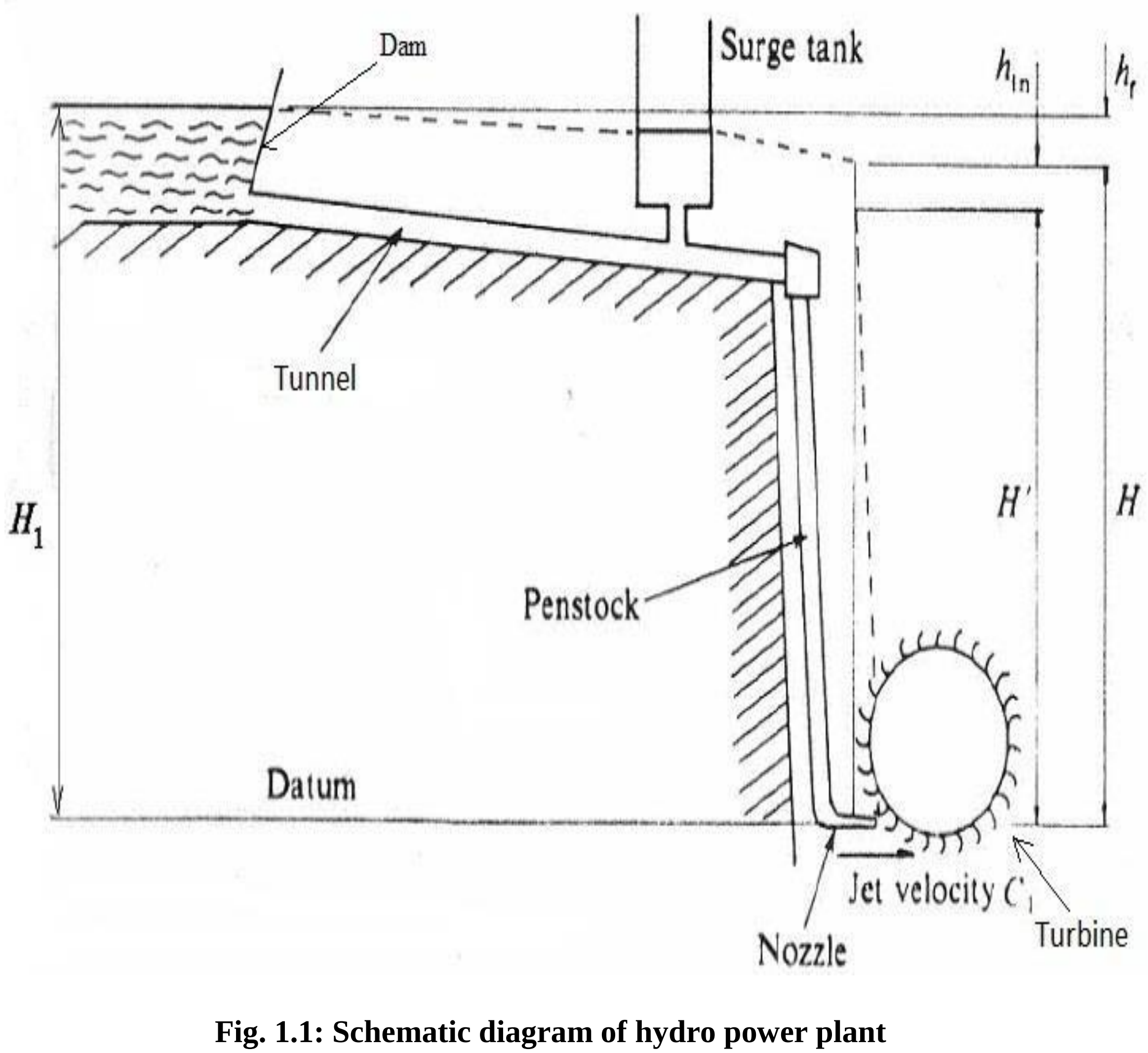

Fig. 1.1: Schematic diagram of hydro power plant

1.3 ABOUT HYDRO POWER PLANTS

1.3.1 Dams:

Dams are manmade structured made to harness electric energy by hydraulic pressure caused by gradient. They are built over rivers or streams to stop the water flow and form a reservoir. The water stored in the reservoir is then diverted to water turbine via a separate tunnel with a very steep gradient so that water can achieve maximum flow velocity before striking the blades of the turbine. The dams collect water during the rainy season and store it, thus allowing a steady flow through the turbines throughout the year. Dams are also used for controlling floods and irrigation. The dams should be water-tight and should be able to withstand the pressure exerted by the water on it. There are different types of dams such as arch dams, gravity dams and buttress dams.

1.3.2 Spillway:

It’s a way of spilling water from dams. It is used to release flood water from dams to prevent over topping of dams which could lead to failure or damage to the structure. Spillway can be of two type’s controlled or uncontrolled spillway. The uncontrolled has no gates to regulate the flow whereas in controlled flow can be regulated.

1.3.3 Penstock and Tunnel:

Penstocks are also known as pipes or conduits. They are used to carry water from the reservoir to the turbines inside power station. They are usually made up steel or cast iron in old ages .They may be equipped with gate systems to control the flow of water into turbine or vice versa. Steel pipes are preferred in modern world as they can withstand high pressure as Water flows through the penstock under high pressure. A tunnel also serves the same purpose as a penstock and is also cheap in economic terms. It is used when there may be an obstruction is present between the Dam and power station such as a mountain or other such difficulties.

1.4 STUDY OVERVIEW

Modern world depends on electricity to continue daily activities so to compensate the electricity demands it is best suitable to harness electricity in eco friendly manner so as to contribute towards sustainable development and harnessing electricity in best economic way .Hydraulic wheel is a one of the way to do it since ancient times.

In this study hydraulic wheel is developed as per the flume available in lab and experimental analysis is done to obtain its efficiency with keeping the cost of hydraulic low so that it is affordable to remote area population having abundance of open streams in their vicinity. These stream carries a huge amount of Hydraulic power as they have natural flow velocity which goes wasted by not harnessing the energy, it can be harnessed by building up small scale dams which is only possible for streams having greater amount of flow then only it would be economical but for rivulets, open channels ,canals and small streams dams and turbine turn to impossible and expensive for such flow hydraulic wheel can be used as it is easy to install and run as no technical knowledge is needed.

The Model designed and fabricated is attached to battery which charges the battery by running in stream 24 x 7. The wheel harnesses the energy by rotating and transferring the mechanical energy to the DC generator in which the rotor rotates and develops electromagnetic induction and gives out or generates electricity hence converting the mechanical energy to electricity or power. This electricity is stored in battery for further usage or can be kept as backup in case of main power failure. In both the cases it’s useful.

1.5 IMPORTANCE OF HYDROELECTRICITY

Hydroelectricity energy offers a number of advantages to its consumers, environment and electricity suppliers few of them are as follows.

1.5.1 Hydroelectricity is a renewable source of energy as it uses the running water without reducing its quantity and does not pollute it as well.

1.5.2 Hydroelectricity makes it achievable to use other inexhaustible sources hydroelectric power plants with aggregation stores offer unique operational adaptability, since they can promptly react to variances in power demands. The adaptability and capacity limit of hydroelectric power plants make them progressively proficient and prudent in supporting the utilization of irregular wellsprings of sustainable power source, for example, sun powered energy or Aeolian energy.

1.5.3 Hydroelectricity promotes guaranteed energy and price stability as it does not depend on any other resources rather than water as a primary and secondary resource contrary to oil and gas and is free from market fluctuations.

1.6 HYDRAULIC POWER PLANT.

Hydraulic power plants are of various types depending upon the situation or the type of site and requirement. They can be classified on the basis of head, type of reservoir, nature of load etc.

1.6.1 Classification on the basis of Head

There are three types of heads based on the total head available at the hydroelectric power plant which are Low Head, Medium Head and High Head hydraulic power plants.

1.6.1.1 Low Head Hydro power plants: Low Head Power plants are the one having the available water head less than 30 m for the dead storage. Dam for such head is of a small head as well it can be of few meters also. Weirs are also used as dams to control pr obstruct flow mostly used in plain areas for modulating the flow of river. This type of plant is insufficient for low flow period of the river hence it is seasonal as it requires abundant flow as head is small water cannot be stored for longer and greater capacity. This dependency on season lower downs the amount of power generated by the plant throughout the year; they are of less producing capacity by design.

1.6.1.2 Medium Head Hydro Power plants: Plants having head more than 30 meters and less than 300 meters are considered as medium hydro power plants. As the head is reasonable so these types of plants are best suited or deign for mountainous region across the valleys and Gorges where the head is possible on stream or rivers. With this a reservoir is provide to store water so it is not dependent on season .Water can be used from the reservoir to generate electricity even in the driest period of the year as the design. These type of are small capacity but consistent capacity.

1.6.1.3 High Head Hydro Power plants: In this type of plants the head ranges from 300m to 2000m or more .These are most common types of dams in India and world as they have high head and are capable of producing electricity throughout the year as they have consistency in water feeding mechanism to the turbines. As they high head it is possible and is adopted to design a reservoir having high head hence increasing the storage capacity of the plants which allows to store water in rainy season reaching its peak .This peak value is sufficient to generate electricity throughout the year and can supply or connect to the national grid but on the other hand it has a longer buyback period among all as initially cost are very high. Most efficient plant as well.

1.6.2 Classification on the Basis of Reservoirs

Reservoirs are also important for the plant as they only decide the capacity of turbine in a plant as high depth of reservoir helps the plant to generate throughout the year with a constant capacity.

1.6.2.1 Run-Off Rivers without pond: These plants do not have any mechanism to store water they directly feed on the flowing power of the water.

They are not suitable for High and medium heads as they have low power capacity and head. They Reach Peak Value in rainy or during high flow period. Best suited for streams and rivulets flowing throughout the year.

1.6.2.2 Run-Off rivers with pond: Plants having a Feeding mechanisms for their turbine making them run throughout the year by having tank, pond, reservoir artificial or natural lake this allow them to function throughout or longer period even in dry season as well. It may fluctuate a little depending upon the storage capacity but is capable to give long time output at reasonable investment and cost.

In case of giving lake tail race conditions ought to be with the end goal that floods don't raise tail-race water level, in this way diminishing the head on the plant and hindering its viability. This sort of plant is similarly increasingly solid and its producing limit is less subject to accessible rate of stream of water.

1.6.2.3 Reservoir Plants: Plants having reservoir of size such that it can store water from the wet season to the next driest season of the year. Water is stored at the behind of the dam and flow is controlled by gates and weirs and may or may not supply via tunnel or conduit as explained earlier. Such plants have a better capacity and can use storage efficiently which makes them to supply the national grid throughout. Its capacity can also be changed by base load or peak loads. They can also satisfy the load demands as well therefore majority of hydroelectric plants but require high head and cost of installation.

1.6.3 Classification on the bases of nature of load

1.6.3.1 Base load Plants: Plants designed for a constant or steady flow as a output is known as base load plants as they are designed for supplying a steady or constant supply of water not depending upon the load on the grid or the Demand. These types of plants are engineered to run throughout the year expect in maintenance or repair period.

Base load is based or designed upon low cost generation, efficiency and safety of the outputs and structure.

They cannot match the load curve as they are not designed for variable output as compared to thermal plants or any other plants. To compensate the demand of load curve they may be attached with the thermal power plant to generate power so as to satisfy the demand by national grid to follow the load curve by using the same water for steam turbines and then reusing it for other purposes.

Each base load plant is designated to supply the grid and is designed by the load curve graph itself. For running of the Plant, decided guidelines are expresses so that the base load power is generally 35-40% of the greatest load during the entire year. Burden factor of such plants is high. Vacillations, pinnacles or spikes in client power request are taken care of by littler and increasingly responsive sorts of Power plants.

1.6.3.2 **Peak load Plants:** Plants designed as per to satisfy the load curve and peak demands throughout the years is known as peak load plants. There may be a chance of that to supply adequate the demand gas turbine or thermal plant may be connected with it to meets the target throughout the period even in the driest and wettest time of season.

Basically to satisfy the load curve the usage of secondary may or may not be required.

1.7 NEED FOR HYDRAULIC POWER PLANTS.

1.7.1 As Discussed above Hydro power is beneficial in all terms of way and if we do not harness the energy it’s a waste.

1.7.2 India's steady interest for the following decade is anticipated to be the most astounding on the planet. This expanding vitality request likewise makes an interpretation of in to higher interest for power.

1.7.3 In North-east India have lots of hydro power resources like streams or rivulets in most of the hilly areas which have the potential for using for utilization of hydro power.

1.7.4 The Plants having low head or low capacity of reservoir does not require greater amount of investment and can be maintained easily

1.7.5 The components of micro hydro power plants can be manufactured and built locally and does not require large number of technical staff or worker for working and maintenance.

1.7.6 The possible target sites for micro hydro system are in isolated areas, which are not connected to national grid or does not have 24 hour power supply and have abundance of natural open channels which can be harnessed.

1.8 HYDRAULIC WHEELS

Hydraulic wheels are also known as water wheel. Water wheel are the one of the earliest and oldest machine known to man and is used from a long time, earlier they were made of wood and other materials available by which they were able to get the work done but with minimal efficiency but as industrial revolution hit the globe new metals and materials came into news and were adopted by people and mechanics for designing and building or fabricating water wheel. With new materials introduced like wrought iron, new efficient designs also came into light as to increase efficiencies which changed the shape, size and conversion of energy and usage of wheels. Basically with Industrial revolution water wheels also got revolutionized and became popular in Switzerland and Germany. Water wheels got popular in beginning of twentieth century after that turbines changed its places as they was fast latest and more efficient. Water wheels stayed in wide spread use until the 1950's after which they vanished for all intents and purposes totally. Today, almost no is thought about the phase of advancement achieved at that point.

1.8.1 Developments in Hydraulic wheel and design

Water wheels are considered as an experimental innovation having a place with the pre-steam time. In all actuality be that as it may, researchers and architects paid a lot of regard for this Hydraulic vitality/Energy converter. The British architect John Smeaton was the first to decide the efficiency of water wheels utilizing a progression of model tests in 1759. He found that over shot wheels had efficiencies of over 60%, though undershot wheels just achieved 30%. The improvement of hydraulic building in blend with another material – old fashioned wrought iron, which was a lot more grounded and permitted hydraulically progressively ideal shapes - brought about further developmental advance water wheels into rather proficient vitality/energy converters for low heads. During the modern upheaval and in the nineteenth and mid twentieth Century, water wheels were in this manner significant hydraulic vitality/energy converters. Indeed, even after the approach of the water turbines after roughly 1850, Water wheels were utilized as mechanical power hotspots for flour and mineral factories, material and instrument making machines, wire drawing and sledge works, oil plants or water supplies, to create power and for different purposes. The principle explanations behind the utilization of water wheels were comparatively low costs compared with steam engines, reportedly high efficiencies for a wide range of flow rates.

1.8.2 Types of Hydraulic wheels

To utilize head difference they are differentiated between three types of water wheel are developed.

1.8.2.1 Overshot wheels: In this type of water wheel the water enters wheel from above. These wheels are applicable for head differences 2.5 to 10 meters and flow rates of 0.1 m^3/s to 0.4 m^3/s per meter width.

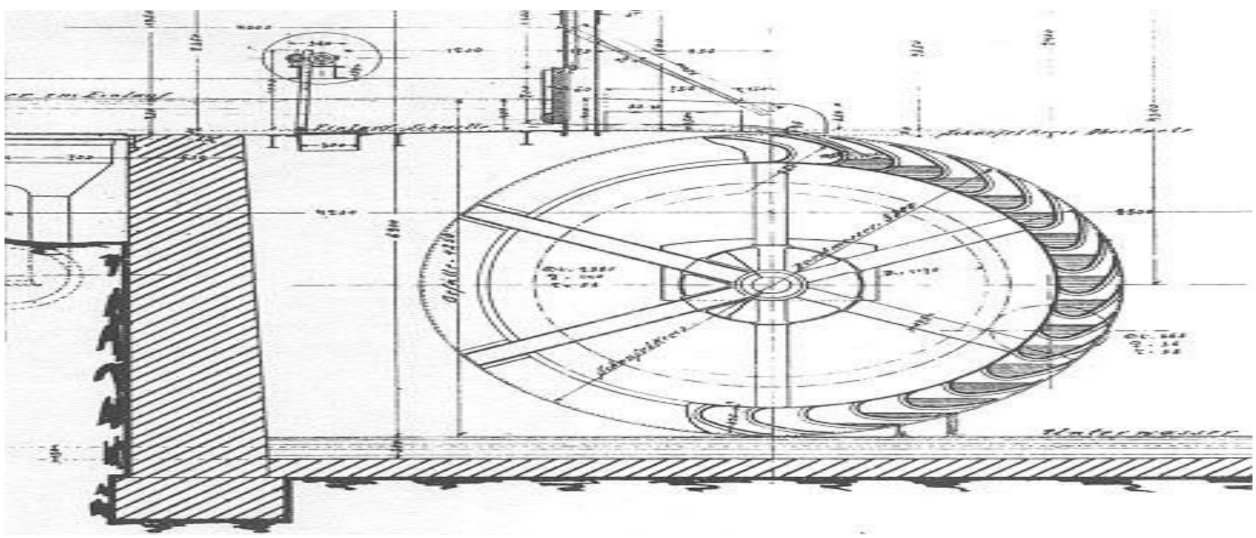

Fig. 1.2: Overshot wheel.

1.8.2.1.1 They are made up of steel and have different geometry of cells and for inflow details.

1.8.2.1.2 The cells are designed in such a manner that the angle of fall of water is kept to be naturally so that water enters the each cell easily.

1.8.2.1.3 Opening of each cell or bucket is kept big so that water can escape easily and enter as well. They are also kept narrower so as to counter balance the weight of water to make it more effective almost immediately.

1.8.2.1.4 It is designed in such a manner that the cells are allowed to fill 30-60 percent of their volume to prevent early loss of water causing a decline the efficiency as hydraulic lift would be less.

1.8.2.1.5 The peculiar shape of the cells holds the water within the cell until the lowermost position, when it at long last discharges quickly. No water is persisted the lowermost point.

1.8.2.2 **Breast shot wheels:** In this type of wheel the water enters from the level of the wheel axis and they can be employed for head differences of 1.5 meter to 4 meter depending upon the size or the diameter of the wheel and flow rates of $0.35m^3/s$ to $0.65m^3/s$ per meter width.

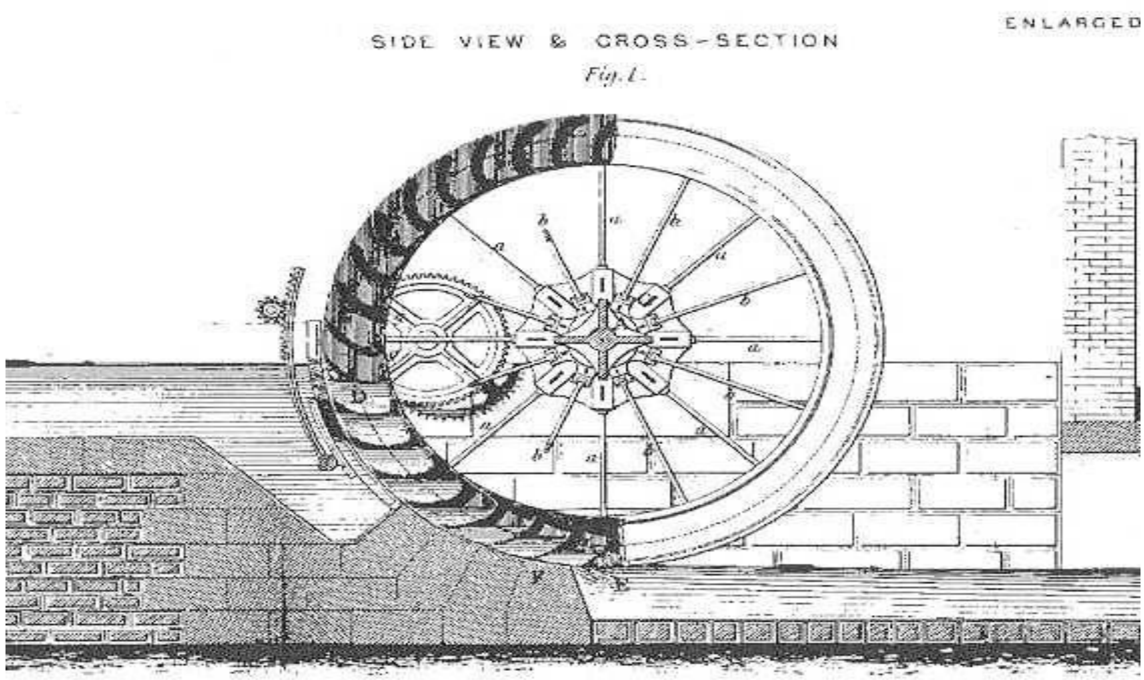

Fig. 1.3: Breast wheel.

1.8.2.2.1 In these types of wheels the water enters the wheel at a steep angle to ensure rapid filling and emptying of cells.

1.8.2.2.2 The cells are inclined at such an angle so that the resultants force acts in the direction of the motion of the wheel and the exits in the downstream at right anlge to avoid losses in the cycle.

1.8.2.2.3 Cells are kept ventilated for air to escape during inflow hence increasing the capacity of the cell. This also helps to lighten up the wheel weight hence causing less need of driving force to run the wheel.

1.8.2.3 **Under shot or Zuppinger wheels:** In this type of wheel the water enters from the base or below the level of axis of the wheel. This is the most suitable one for the case of stream without pond or reservoir. They can be employed for flows of range 0.5 meter or more per meter width.

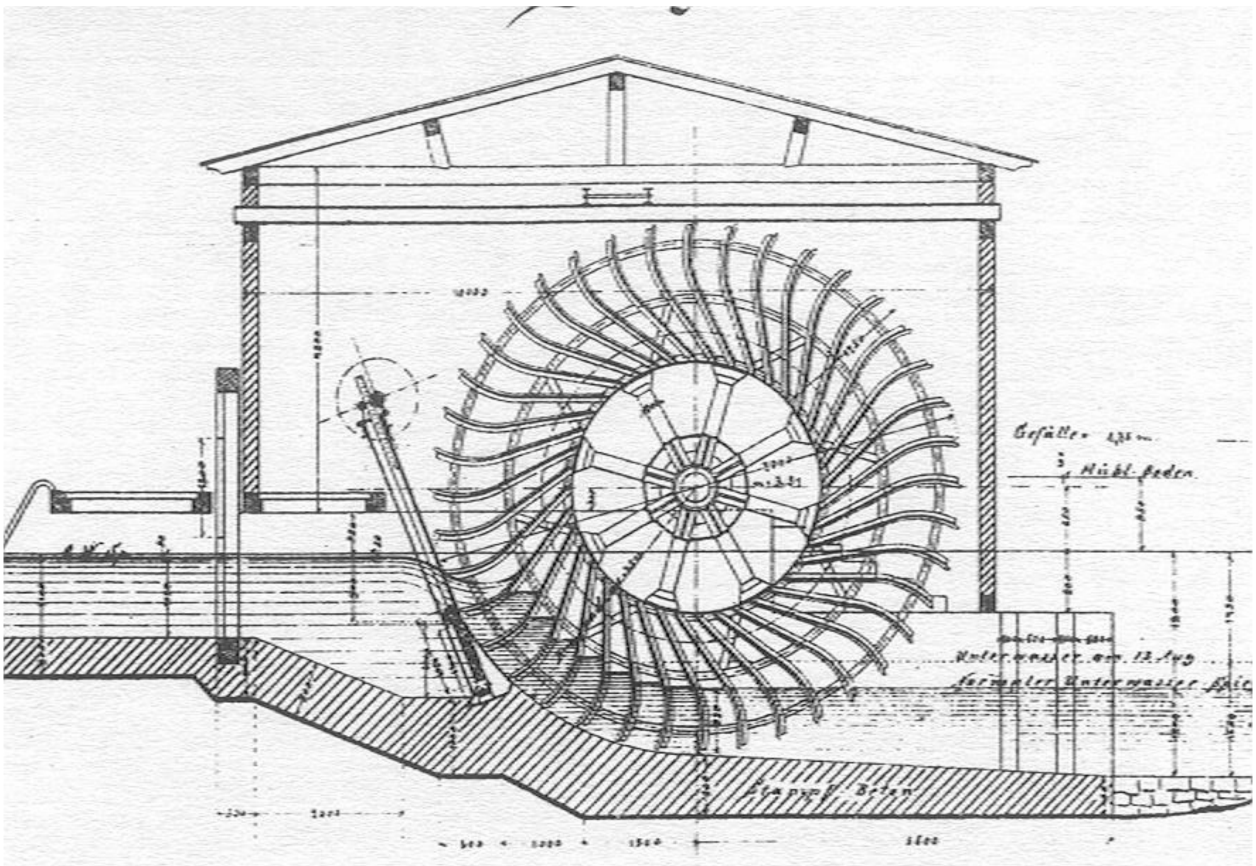

Fig. 1.4: Undershot wheel.

1.8.2.3.1 These are well suitable for underrated flows which are continuous and unharnessed for small heads and they were original used impulse wheels as they employ kinetic energy of the flow current.

1.8.2.3.2 French engineers Poncelet anyway seen that the potential vitality/energy of the moderate moving water masses in little streams was obviously bigger than the dynamic vitality/energy, and designed the main wheel for low head contrasts which utilized the potential vitality/energy as it were.

1.8.2.3.3 French engineer, Sagebien, improved the first design. The most productive shape for these wheels was at last created by the Swiss hydraulic designer Walter Zuppinger.

1.8.2.3.4 Water wheels use potential and kinetic energy of the flow as the principle driving force.

1.8.2.3.5 The cells are orchestrated in a manner in order to evade losses at the water section, at that point to continuously diminish the head of water in every cell lastly to release the water, again with at minimal losses.

1.8.3 Role of Water wheels for electricity generation As we have been discussing Industrialization helped to achieve better efficiencies with time and in today's era Water wheel has high efficiencies surprisingly for wide range of flows. This has a remarkable advantage that electricity could be generated even from minimal flow volumes without any complex controlling elements like in case of turbines etc.

1.8.3.1 **Flat power speed curves** shows that the speed control is not very critical as long as the wheel is designed to operate.

1.8.3.2 **Slow speed of water wheels** gives us a hint that their gear boxes are with a transmission ratio of 1:100 have to employed such gear boxes are helpful in preventing the losses by 2-3 percent

Slow speed gear boxes also helps to control the economics as they lower down the cost of the wheel (25-30% for undershot, 40-45% for overshot wheels) of a water wheel installation.

1.8.4 Transformation of water wheel

Due to low efficiency and bulky design water wheel got outdated in 1950 this led to invention of water turbines like Pelton, Kaplan and other turbines which are used

nowadays in dams and other hydro power plants.
These modern age turbines are efficient and compact in size and shape but are costly and are not easy not handle and operate as they need minimum flow rate to generate electricity.

These modern age turbines are restricted just to produce electricity, No other uses like grinding in mill etc could be done.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION.

Hydropower has been utilized since old occasions to crush flour and perform different assignments. In ancient age Hydraulic Wheel were used to do mechanical work as the shaft attached to wheel rotated and was further connected to grinding mills or lifting purposes. In the mid-1770s, French specialist Bernard Forest de Bélidor contributed Architecture Hydraulique which depicted vertical-and even pivot water driven machines. By the late nineteenth century, the electrical generator was created and could now be combined with water power to obtain electricity but it had minimal power efficiency as at that time, efficient designed and material were not available. With the passage of time efficiency increased. The developing interest for the Industrial Revolution gave advancement in efficiencies. In 1878 the world's first hydroelectric power plan was created at Cragside in Northumberland, England by William Armstrong. It was utilized to control a solitary circular segment light in his specialty exhibition on a small scale project as it was not able to produce a large amount of output being a small scale model. The old Schoelkopf Power Station No. 1 close Niagara Falls in the U.S. side started to deliver power in 1881. The primary Edison hydroelectric power station, the Vulcan Street Plant, started working September 30, 1882, in Appleton, Wisconsin, with a yield of about 12.5 kilowatts. By 1886 there were 45 hydroelectric power stations in the U.S. furthermore, Canada. By 1889 there were 200 in the U.S. alone.

Toward the start of the twentieth century, numerous little hydroelectric power stations were being built by business organizations in mountains close metropolitan regions to supply or feed the energy demands of the neighboring cities at cheaper prices as being near to them keeping cost of transmission low. Grenoble, France held the International Exhibition of Hydropower and Tourism with more than one million guests. By 1920 as 40% of the power delivered in the United States was hydroelectric, the Act was instituted into law. At that time government and world understood the need and importance of the idea which was to produce or harness electricity from unharnessed source of electricity which is water. The

Act made the Federal Power Commission to manage hydroelectric power stations on government land and water. As the power stations increased, their related dams build for extra purposes to incorporate flood control, water system and route. Building dams helped in creating bio diversity in the vicinity and helped the locals living nearby as they got accessed to drinking and irrigation water. Government subsidizing ended up important for huge scale advancement and governmentally claimed organizations; for example, the Tennessee Valley Authority (1933) and the Bonneville Power Administration (1937) were made. Furthermore, the Bureau of Reclamation which had started a progression of western U.S. water system extends in the mid twentieth century was presently building huge hydroelectric ventures, for example, the 1928 Hoover Dam. The U.S. Armed force Corps of Engineers was additionally engaged with hydroelectric advancement, finishing the Bonneville Dam in 1937 and being perceived by the Flood Control Act of 1936 as the chief government flood control organization.

These laws by the federal's was happily accepted by the population as they all understood the idea and got benefitted in return by cheap accessible electricity, water for other uses like drinking, consumption, irrigational and commercial activities such as navigation etc.

Hydroelectric power stations kept on increasing all through the twentieth century as the idea and technology widespread all over the world. Hydropower was alluded to as white coal for its capacity and bounty as it was then compared to coal (thermal power). Hoover Dam's underlying 1,345 MW power stations was the world's biggest hydroelectric power station in 1936; it was obscured by the 6809 MW Grand Coulee Dam in 1942 with the advancement in industrialization and techniques. The Itaipu Dam opened in 1984 in South America as the biggest; creating 14,000 MW yet was outperformed in 2008 by the Three Gorges Dam in China at 22,500 MW. Hydroelectricity would inevitably supply a few nations, including Norway, Democratic Republic of the Congo, Paraguay and Brazil, with over 85% of their power continuously without giving out any hazardous emission as compared to other sources of energy. The United States as of now has more than 2,000 hydroelectric power stations that supply 6.4% of its absolute electrical creation yield, which is 49% of its inexhaustible power. In India hydraulic wheel is operational and used to generate electricity in Udaipur and various other sites but is not that much popular as in India is dependent upon fossil fuels.

2.2 LITERATURE STUDY

2.2.1 ***J. L. Gordon, M. ASCE, P. C. Helwig, L. G. Sturge (1986)*** worked upon and evaluated High Head Hydro Powerplant. At point when the head on a hydroelectric power plant was between around 250- \ 700 m (800-2,300 ft) the turbine can be either drive or response Francis unit. For each sort of unit the operating characteristics and design of the power plant will be significantly extraordinary. This paper outlines a comparison of the two kinds of power plant, which was embraced for the 136 MW Cat Arm Developments in Newfoundland, where a gross head of 386.5 m (1,268 ft) was saddled. The initial money saving advantage analysis indicated that a Francis unit ought to be chosen, however a Pelton unit was picked, in view of an analysis of the operating characteristics and other advantages.

2.2.2 ***Dr. Gerald Muller (2004)*** worked upon water wheel design and fabrication since antiquity which is from industrial revolution. With Industrial revolution, hydraulics sciences took a different turn in development as new materials rather than wood were introduced plus different method and types of hydraulics evolved which help him to design more efficient hydraulics wheels allowing rational analysis and improved strength and geometry. Water wheels did not vanish with the appearance of steam motors and water turbines yet advanced further so that even toward the start of the twentieth Century countless water wheels were in task, dominatingly in Central Europe. For all intents and purposes all water wheels vanished in the 1950's and 60's and little information is accessible from momentum reading material with respect to their structure or execution. A point by point investigation of the accessible writing covering the building structure of water wheels was led. The structure of water wheels was overwhelmed by the prerequisite for a geometry which would limit misfortunes, and hold the water to the extent that this would be possible in the machine. Reports of trial examinations on the efficiencies of overshot and undershot wheels were likewise found. Very much planned water wheels can achieve efficiencies of 71% (undershot) to 85% (overshot). Some little organizations are again assembling water wheels for power generation. He proved by his work and studies that undershot wheels gave the highest efficiency as they did obstructed and experienced drag forces on entire wheel and frictional losses are minimum as the area of contact between water flow and wheel is minimal.

2.2.3 ***Dr. Gerald Muller & C Wolter (2004)*** worked upon Breast shot wheel and conducted model tests. Breast shot wheels where the wheels in which the water enters approximately at the level of the axis, they were in widespread in England and Germany during the nineteenth and early twentieth century. Although this type of wheel has a potential in present century for its economic design and environmentally acceptable with low heads from 1.5 m to 2.5 m but on the other hand very little is known about its performance characteristics. To more about they conducted test on model at Queens University at Belfast. Test computations for a 4m distance across wheel are given to clarify the plan standards. Tests on a 1:4 scale, 1m breadth model gave efficiencies of 78.5% over a wide scope of streams. In view of these estimations and perceptions, improved geometries for in and out pouring were created, bringing about most extreme efficiencies of 87.3%. An underlying environmental appraisal showed that waterwheels may have an essentially diminished biological effect when contrasted and turbines. The breast shot waterwheel was observed to be a productive and biologically adequate pressure driven vitality converter with the potential for further improvement.

2.2.4 ***S.R. Turnock, G. Muller, R. F. Nicholls-Lee & et al (2007)*** a proposal was made for use of traditional stream waterwheel suspended between two floating catamaran NPL series demi-hulls as means of generating electrical power. Two model gadgets, of lengths 1.6m and 4.5m, have been created, built and tried. It was discovered that the idea is sound albeit more note worthy speculation is required concerning the materials and both hydrodynamic and streamlined plan of the waterwheel to guarantee a financially suitable framework. The work exhibited focuses on pragmatic viewpoints related with structure, development and preliminary testing in Southampton water of the 4.5m model. The generally ease, simplicity of organization, and the way that ordinary pontoon securing frameworks are compelling, join to make this an alluring elective vitality answer for remote network.

2.2.5 ***Ayesha Zaman, Taslima Khan (2012)*** performed an analysis, evaluation and systematic representation of techniques of a low head micro hydropower system using a fixed water source and designing of wheel. They also concluded support system to the national grid system as a backup system useful in areas where electricity is not available for longer period or areas which are more prone to power failure due to terrain and other factors. Water is siphoned up to the upper store during the off-crest hour and when required water is discharged from the upper repository through the turbine to create power. This framework utilizes a fixed measure of water that put away in a lower supply in the wake of flowing through the turbine. A water wheel is picked as a turbine for the framework and this paper is centered on to structure and development of a water wheel reasonable for the miniaturized scale hydropower site. Water wheels have been known since relic. With the mechanical upheaval, pressure driven sciences were created and new materials, for example, fashioned iron ended up accessible taking into consideration a sound investigation and improved quality and geometry of water wheels. A nitty gritty investigation of the accessible writing covering the building plan of water wheel was directed. The plan of water wheel was overwhelmed by the prerequisite for a geometry which would limit misfortunes, and hold the water as far as might be feasible in the machine. Hypothetical yield power was determined for a scope of water stream and a chart has been plotted utilizing the applicable qualities. This work was similar to Dams and hydropower plants are water was stored and pumped to high grounds which increase the cost of the project and limiting the use of it to open channel flow system.

2.2.6 ***David Gensler and Kristoph-Dietrich Kinzli, M.ASCE (2013)*** worked upon a case study in United states of America they Examining the Feasibility of Hydropower Generation in Irrigation Canals: Middle Rio Grande Conservancy District, Irrigation districts in the American West and throughout the world have broad waterway organizes that could be used to generate a significant measure of hydropower. As the world endeavors to turn out to be less reliant on carbon-based energy assets, little scale hydropower (SSH) is an appealing potential asset for new energy advancement. The Middle Rio Grande Conservancy District (MRGCD) in focal New Mexico has a broad trench system, and hydropower is being considered as a practical type of sustainable power source. Presently, the MRGCD has recognized and categorized nine potential hydropower destinations within its framework with the goal of maximizing its commitment to the region's energy needs. Their paper delivered key issues identified with hydropower in irrigation districts and examines the practicality of incorporating hydropower generation in the MRGCD trench framework. With entire all year usage of SSH generation at the nine areas investigated by them, the MRGCD could have a generating limit of 2.2 MW and produce more than 10 million kWh during the year. This speaks to an income from power generation for the MRGCD of $1.032 million at the present power costs. All the more significantly, usage of SSH would result in 1,340 homes being controlled by perfect, sustainable power source while simultaneously delivering water to irrigators. It is the desire for the creators that the contextual investigation introduced will help irrigation districts investigating the incorporation of hydropower in their waterway systems.

2.2.7 ***Praful Yelguntwar, Pranay Bhange et al (2014)*** worked upon developing a prototype of overshot water wheel using a Hydram pump and concluded that efficiency or generated power depends on the torque and rotational speed of the wheel which is gained by water flow But on high speed lots of water is wasted as the amount of water accommodated by the blades are less as compared to the water flowing this wastage of water energy develops need of water jet nozzle for more efficient system. Hydram pump is used to generate water pressure to distribute it .this research work combined the Hydram pump system and waterwheel to build the Hydram pump system prototype which can be used to increase torque as a new method for maintain overflow keeper as the nozzle helps to generate additional torque .they used to FEM to obtain the optimal design of prototype and checked it with available software.

2.2.8 ***B J Lewis, J M Cimbala, and A M Wouden (2014)*** they gave a record of developments and timeline of water wheel from the past back to Greece. Throughout the following a few centuries the innovation spread everywhere throughout the world. The way toward touching base at the design of the advanced Francis runner endured from 1848 to around 1920. In spite of the fact that the cutting edge Francis runner has little similarity to the first turbines designed by James B. Francis in 1848, it ended up known as the Francis turbine around 1920, to pay tribute to his numerous commitments to water powered building examination and design. The advanced Francis turbine is the most generally utilized turbine design today, especially for medium head and enormous low rate circumstances, and can accomplish over 95% efficiency.

2.2.9 ***Kevin Jacob, Kishore K Abraham, Mathew James et al (2014)*** they developed a multi micro turbine for micro power generation keeping India in mind as they main focused to bring out a economical and efficient turbine as India is 70 % dependent on fossil fuels and hydro power is limited to areas which have abundant supply of water plus the technology is limited to some departments and bodies. They developed a simple gear mechanism for river flows. this concept worked on the basis of collecting the mechanical power of the two rotors spinning by the effect of higher river velocity and connecting the rotors to pinion joint gears to Dc generator which is run by the small pinions joints connected to rotor’s gear. Their project gave a simpler model having low cost and high usage and adaptability and acceptance in India.

2.2.10 ***Lie Jasa et al (2015)*** they conducted a experimental investigation of micro hydro waterwheel models. It shows variations in the types of blades. The Study shows power generated by the waterwheel is dependent upon its blades, water wheel diameter, location, nozzle position and gradient. This Study states the characteristic which affect the optimal efficiency of the wheel. Method used in this exploration is design, model, testing and gathering information from each of the three model water wheel. Estimated information is taken by the adjustment in position edge pivot and edge spout. The after effect of this examination demonstrates that the triangular model yielded the most noteworthy efficiency among propeller and bended as it was most efficient because of the angle at which it was attached to the flywheel. Be that as it may, the area where is small scale hydro introduced firmly decides the model design of waterwheel to work ideally.

2.2.11 ***Emanuele Quaranta and Roberto Revelli (2016)*** in this work, a breast shot wheel is investigated by numerical recreations, and the outcomes are approved with lab experimental tests. The average differences between the numerical shaft torque and the test torque was lower than 5%. The numerical model is then used to investigate the exhibition and the pressure driven conduct of the wheel for various quantities of sharp edges blades (16, 32, 48, and 64 cutting edges) and at various water powered conditions. The increase in efficiency from 16 sharp edges to the ideal edges number ranges between 12 to 16% in capacity of the water powered conditions. Exact laws are likewise answered to measure the improvement in efficiency with the sharp edges number. These laws can bolster the design procedure of comparative breast shot water wheels. The ideal sharp edges number for this kind of wheel is recognized in 48 or 24.

CHAPTER 3
METHODOLOGY

3.1 EXPERIMENTAL SETUP.

For depicting Open channel flow scenarios a suitable undershot wheel needs to be designed and fabricated as per the flume having dimension 8 meter in length, 0.4 meter in depth and 0.32 meter in width and the flow velocity can be changed as per the requirement via valve mechanisms.

Fig.3.1: Flume used for testing the model for different flow rates.

3.1.1 Instrumentation used:

Table 1: Instrument used for the experiments

Serial number	Instrument	Application
1	Flume	Used for depicting Open channel flows.
2	Hydraulic wheel	Used to Generate Hydraulic energy or Power.
3	Voltmeter	Used to measure Voltage
4	Ammeter	Used to measure Current.
5	Dc Generator	Used to Convert Hydraulic energy or Power to Electrical power.
6	Digital Velocity meter	To measure the Velocity of the flow at the cross section.
7	Stop watch	Recording of time.
8	Counter	Counting the number of Revolution of the Flywheel.

3.2 DESIGN

In this Section we discuss about the design of Hydraulic wheel and its entire component. By comparing and analyzing the literature its is beneficial to use a the natural flow streams like rivulet as they carry a amount of flow throughout the year and have abundance in rural hilly areas. These open channels may fluctuate flow as per season but flow speed is constant as they flow at a certain gradient similarly in chase of irrigation canals etc.

It is possible to harness energy from the flow flowing at a low head by using the undershot wheel as it best for the flows and have a good efficiency.

This kind of flow can be staged by using a Flume system or apparatus.

For depicting these flow scenarios lab trials are conducted in a flume having dimension similar to the rivulet or a small irrigation canal. The dimension of the flume used is 8 meter in length, 0.4 meter in depth and 0.32 meter in width and the flow velocity can be changed as per the requirement via valve mechanism.

3.2.1 Design of undershot hydraulic wheel

After analyzing the literature and recent developments it is possible and beneficial to modify/change the ancient design of runner from rectangular bucket to the recent cup shaped blades used in famous turbine i.e Pelton wheel or Kaplan turbine to increase the efficiency.

This modification would help in more concentration force by flow velocity and will allow the model to run at higher speed as the model will become light in weight.

Other modification like switching to lighter material such as steel rather than wood and cast iron is also a modern possibility. **Dr. Gerald Muller & C Wolter (2004)** also followed Bach's recommendations for design hydraulic wheel and its components at Queens University so following these recommendations modifications and design are adopted in this experimental study.

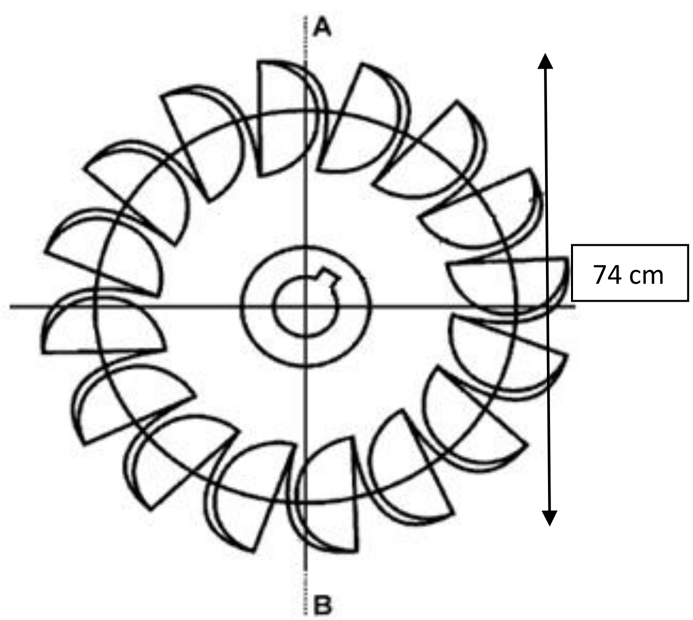

Fig. 3.2: Design of Hydraulic wheel turbine.

Fig. 3.3: Actual image of Hydraulic wheel designed for the flume.

3.2.1.1 Components and layout of Hydraulic wheel

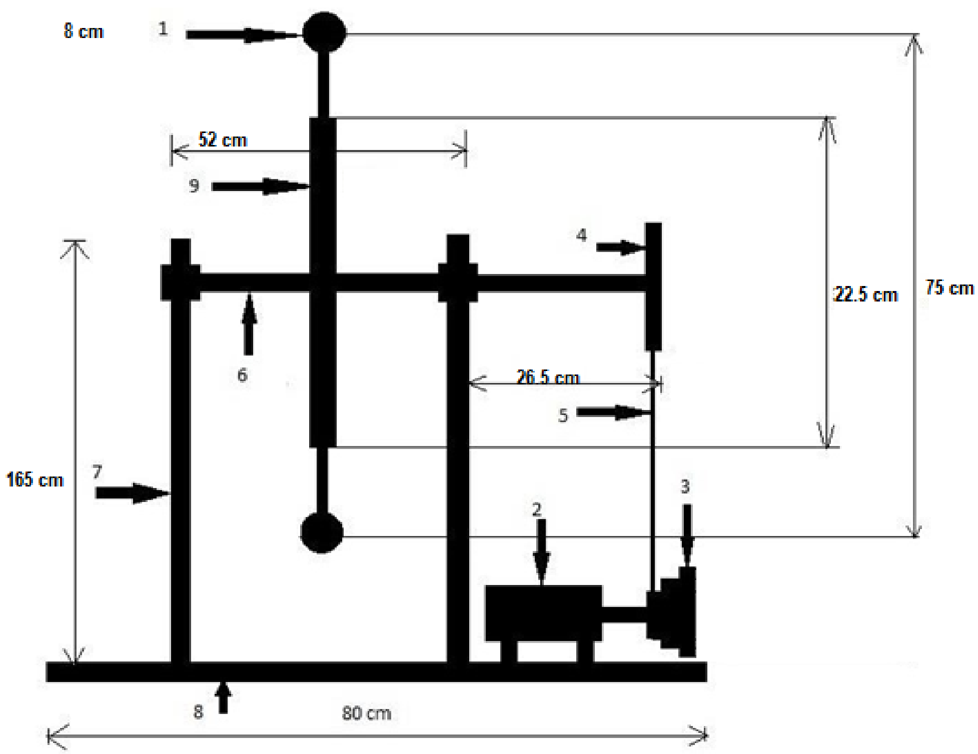

Fig. 3.4: Layout of Model.

1. TURBINE BLADE
2. D.C MOTOR
3. MOTOR PULLEY
4. SHAFT PULLEY
5. POWER TRANSMISSION ROPE
6. MAIN SHAFT
7. TURBINE STAND
8. BASE
9. TURBINE WHEEL

3.2.1.2 Design of Blade

Dr. Gerald Muller & C Wolter (2004) gave recommendations on the basis of Vonvon bach's model which gave minimum blade diameter empirical formula to:

Depth of the blade$=0.4\sqrt[3]{\frac{D}{H}}\ to\ 0.5\sqrt[3]{\frac{D}{H}}$.

A s we know the shape of bucket or runner is quite complex and designing and fabrication of it for a model it will be expensive as special order need to be placed which would increase the cost and has its own complications.

From literature it's feasible to use Cup shaped material available in market like service spoons used in domestic kitchen etc. it is readily available and is also cheap & light weight.

In order to make an efficient bucket of the wheel which will do the same work as the scientifically proved diagram of the bucket used some household whose shape resembles to that of a bucket.

Therefore using service spoon is optimum for the model hence using spoons of radius of 8cm.

Fig. 3.5: Image showing Spoons used as blades of the flywheel.

In previous studies ***Emanuele Quaranta and Roberto Revelli (2016)*** introduced number of blades should be equally distributed as per the flywheel so using 24 blades is optimum for flywheel having diameter of 22.5 cm. Number of cups can be decreased depending upon the flume flow but here its beneficial to use maximum number of them therefore 24 are used.

3.2.1.3 Design of frame

Design of the frame is important as it work accordingly to the model scale of the flume The frame should have the capability to hold the whole model steady so that it could not shake or break down during the running water or running of the wheel during its running operation. As this would lower down the speed and efficiency of the model.

Designing of frame is done measuring the dimensions of flume from the lab. Using Ms Steel for constructing the frame is opt as it is strong, cheap and light in weight. Therefore, using square MS steel pipes for construction.

Fig.3.6: Side View of the Frame.

3.2.1.4 Design of Shaft

Design of shaft is the most aspect thing in the model as shafts diverted the hydraulic force of the water to the gear and then to dynamo or the electric generator. So using a circular steel rod of 25 mm diameter and 100 cm in length is optimum as steel is strong enough to handle the forces and 100 cm leaves us with extra space for attaching gear mechanism easily.

Layout the shaft is as follows,

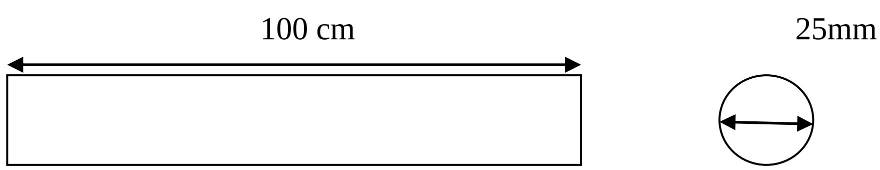

Fig. 3.7: Dimensions and layout of the shaft.

To place and fit the shaft with the base frame it is best suitable to use Bearing housing having internal diameter of 25mm and have less friction, therefore choosing best available in the market as friction in bearing will lower done the efficiency and speed of the flu wheel. These set of bearing are then welded with the top of the frame as shown in the layout above in the design of frame.

At one end of the shaft a gear is also welded for chain gear mechanism to transfer the rotational energy to the electric generator. It is advised to make sure the welded are tight and strong to prevent any accidents during the running of the model.

To associate the DC generator and the shaft chain is utilized. For chain a gear is welded to the shaft and a flywheel so that they both are connected via chain drive mechanism to the DC generator. The Gear is then associated with the DC generator by a chain similarly to that in bicycles. Along these lines the turning movement of the shaft is moved to the DC generator which produces power. As the shaft rotates the gear which further drives the chain and chain being attached with Dynamo.

3.2.1.5 Power Transmission mechanism:

To transfer the rotary motion of shaft to the DC generator to convert the rotary motion to electrical energy we use flexible drives. To transfer the rotary motion we use gear and chain mechanism. It consists of three element driving gear (Connected at the end of the shaft), driven gear (Connected at the end of the dynamo or the electricity generator) and Gear Chain.

The main advantage of this flexible drive compared with other drives is as follows:

3.2.1.5.1 It can transmit power over a comparatively long distance.

3.2.1.5.2 The operation of rope drive is smooth and silent. It also holds the entire mechanism tight and allows transmission with minimal losses of energy in transmission like in a bicycle.

3.2.1.5.3 This drive is cheap and can easily be maintained as no technical knowledge is required hence making it long time cheap investment.

3.2.1.5.4 They can transmit only definite load, which if exceed, will cause the chain to slip over the gear, thus protecting the parts of the drive against overload and unwanted accidents and slipping.

3.2.1.5.5 Since the intermediate link is long and flexible, it absorbs shock loads.

Here we use a large diameter Gear in driving shaft as compared to the driven shaft to get high rpm in the motor shaft.

Using chain and gear avoids slipping and is a durable mechanisms having long running period as compared to belt mechanisms as belt mechanisms require maintenance and periodic replacement of belt.

Fig. 3.8: Image showing the gear chain mechanism used for transmission of mechanical energy to the DC Generator.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 IMPORTANCE OF THE STUDY.

Hydraulic wheel is a renewable source of energy with zero emissions and with a eco friendly process to produce energy in terms of mechanical and can harness huge amount of energy as we all know for ex. In case of hydro power plants huge water turbines used in them are predecessors of hydraulic wheel. With passage of development turbines were invented.

Hydraulic wheel were overtaken by turbines but installing a turbine need lots of work such as Developing a proper head, pressure and gradient difference which can only be done for large projects.

For domestic usage hydraulic wheel is appropriate for it as it has low maintenance, low investment and can be operated by a non technical person with training.

Advancement of a drifting tidal energy framework appropriate for use in shallow water by S.R. Turnock and G. Muller (2007) gives the thought regarding the plan of waterwheels which is helpful in the power in shallow water. It might be conceivable that appropriately planning the waterwheel, the power age is conceivable indeed, even in shallow just as stream line water.

Efficient hydraulic wheel can be used in Canal and Sewage flows ignoring the quality of water as water flow in this type of stream are free from siltation of reservoir, submergence of forest, relocation of population like in case of hydro power plants

Unlike in other renewable sources like wind And solar projects fluctuations in output is a common thing as they depend upon weather much which is dynamic in nature but in case of small hydro plant installed where abundance of water or sewage constant output can be taken throughout the year despite of weather and the cost is variable low and area required to harness energy is very small in comparative to that of solar and wind projects.

As hydraulic water wheel uses nature flow energy and has zero percent of consumption as well as emission it becomes optimum for today's situation as in modern era pollution is a major factor harming lifestyle of the major population all over the world.

4.2 HYDRAULIC WHEEL AND COMPONENT DESIGN DEVELOPMENTS.

Design of hydraulic wheel changed with centuries and with inventions in respective centuries.

Earlier hydraulic wheel were built of hardwood or bamboo making it bulky, bigger in size and non durable for long term as they required regular maintenance as per the literature available. With industrialization the design got more efficient with use of caste iron which further became lighter in weight with advancement and invention of alloys like steel and aluminum.

Using metals instead of wood and all revolutionized the Hydraulic wheel as they became more efficient and durable with longer working time span but using metal caused increase in cost of construction and craftsmanship.

In modern or present age it is feasible to use waste metals as waste has become a separate issue to the present society .So using waste metal promises no harm to environment and also contribute lower carbon emissions.

In Experiment entire wheel structure is built by waste metals which are dumped and never recycled in India for example: The fly wheel can be built by using cycle rim or other such thing.

Selection of Materials In order to make an efficient bucket of the wheel which will do the same work as the scientifically proved diagram of the bucket, we had used some household serving spoon whose shape resembles to that of a bucket.

Other materials are as follows given in the Table 2.

Table 2: Selection of material

Serial Number	Parts	Material
1	Turbine blade	Carchi/Service spoon
2	D.C motor	12-24 volt Dynamo
3	Motor pulley	M.S Pulley
4	Shaft pulley	M.S Pulley
5	Power transmission rope/belt	Chain or Car Engine belt
6	Main shaft	Iron/steel rod
7	Turbine stand	Iron frame
8	Base	Plywood
9	Turbine wheel/fly wheel	M.S /Cycle Rim

The above table gives an idea about easy available waste which is utilized properly for construction of model for this study. Using above metals and waste things also lowered down the cost to minimal for constructing a model for experiment in flume.

4.3 RESULTS AND CALCULATIONS.

Various experimental calculations and theoretical verification were done for achieving a optimum value of efficiency as the main aim for the study was to achieve precise efficiency of the hydraulic wheel which was made best out of waste.

Instruments like Multi-Meter, Digital velocity meter, counter and stopwatch were used to calculate or obtain required data required for calculation of efficiency.

4.3.1 **Multimeter** is an instrument used to measure various electrical parameters like resonance, current, voltage etc. in this study multimeter was used to obtain the value for Voltage and current given by the dynamo or the DC Generator which was further required for calculating the power output the theoretical formula **Power(P)= Voltage(V) X Current(i) watts** .

Voltage and current being dynamic here as they fluctuated constantly taking multiple readings helped to achieve a far much accurate value for a particular head.

The probes of multimeter were connected to the output wires of the DC generator to get the output readings of voltage and current.

Fig. 4.1: Image showing Voltage output by a Multimeter.

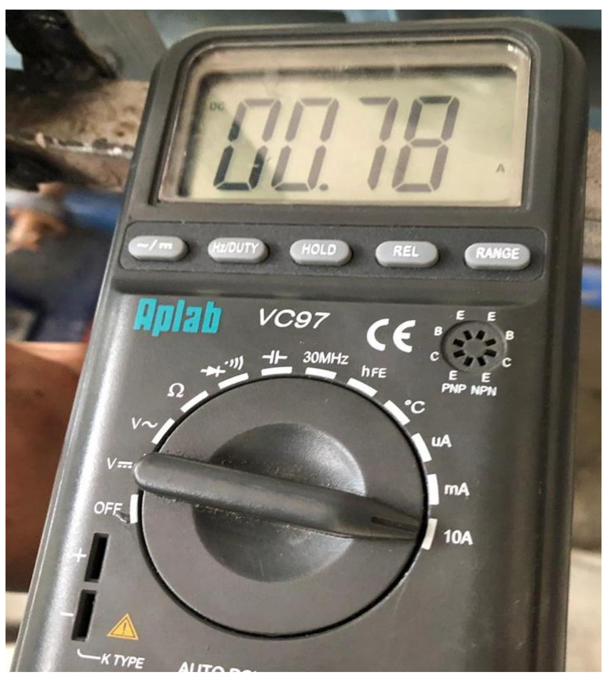

Fig. 4.2: Image of Multimeter Showing Current.

4.3.2 Digital velocity meter is an instrument used to measure the flow velocity of the flowing water for a given time and revolution which is obtained by current meter and average flow value is given the digital velocity meter.

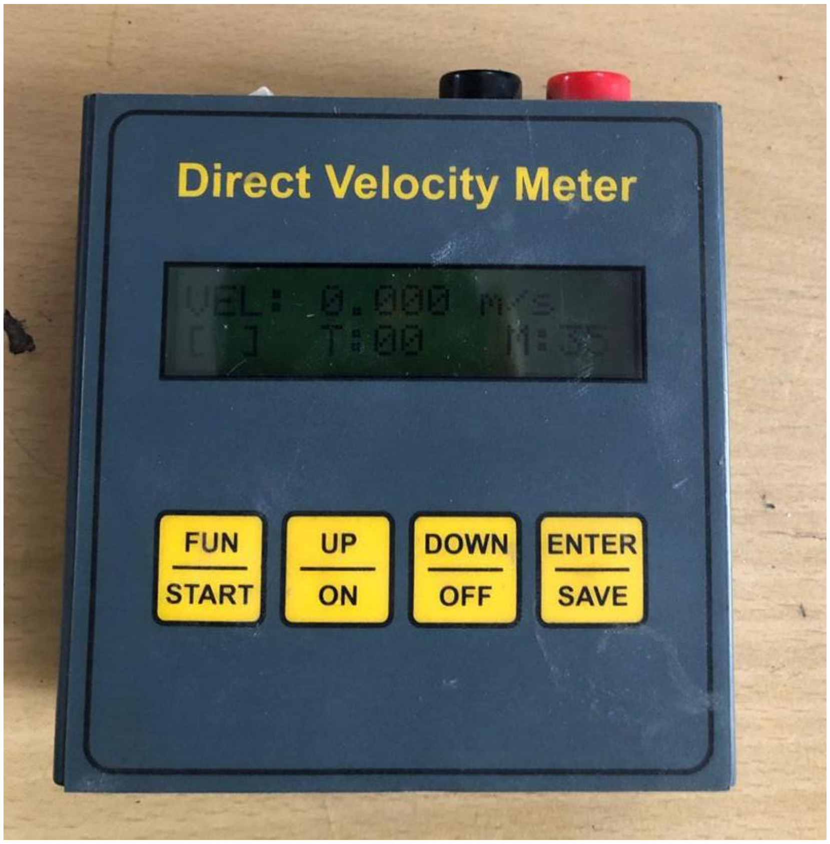

Fig.4.3: A Digital Velocity meter.

Fig.4.4: Rotating current meter which is connected to the above digital velocity meter.

4.3.3 Stopwatch and counter were used to measure the time and rpm of the wheel as rpm were counted for each 20 seconds interval during the running of the model.

4.3.4 Rectifier and battery were used to store the power generated by the hydraulic wheel so that it can give out a cumulative output of 12 volts when required during the time just like invertors.

Calculations and reading data are as follows in the table,

Table 3: Recorded data of Voltage, Current and Velocity given by the Multimeter and digital velocity meter at different head.

Serial no.	**Volts Output(V)**	**Current Output(I)**	**Velocity m/s**	**Power Output(W)**	**Head (m)**
1	0	0	0.1335	0	0.09
2	2.5	0.38	0.169	9.5	0.2
3	2.44	0.36	0.169	8.784	0.2
4	3.12	0.54	0.174	16.848	0.2
5	2.6	0.43	0.18	11.18	0.2
6	2.67	0.4	0.18	10.68	0.2
7	2.7	0.11	0.184	2.97	0.2
8	2.8	0.45	0.19	12.6	0.2
9	2.93	0.62	0.194	18.166	0.2
10	2.91	0.51	0.196	14.841	0.2
11	2.99	0.37	0.196	11.063	0.2
12	2.38	0.216	0.201	5.1408	0.2
13	0.2076	0.51	0.2076	17.595	0.24
14	0.2083	0.48	0.2083	18.432	0.24
15	0.208	0.53	0.208	18.709	0.24
16	0.208	0.58	0.208	20.3	0.24
17	0.2078	0.64	0.2078	20.48	0.24
18	0.2078	0.64	0.2078	20.544	0.24
19	0.2078	0.66	0.2078	21.582	0.24
20	0.2078	0.71	0.2078	23.288	0.24
21	0.2086	1.14	0.2086	34.2	0.24

22	0.2074	1.18	0.2074	36.698	0.24
23	0.2084	1.33	0.2084	39.9	0.24
24	2.7	0.45	0.143	12.15	0.28
25	3.14	0.48	0.143	15.072	0.28
26	2.76	0.57	0.155	15.732	0.28
27	2.89	0.63	0.159	18.207	0.28
28	3.11	0.85	0.16	26.435	0.28
29	2.29	1.46	0.162	33.434	0.28
30	2.93	0.94	0.162	27.542	0.28
31	2.83	0.39	0.168	11.037	0.28
32	3.27	1.11	0.173	36.297	0.28
33	2.52	1.65	0.173	41.58	0.28
34	3.3	1.7	0.173	56.1	0.28
35	2.7	0.45	0.143	12.15	0.28
36	3.42	0.86	0.148	29.412	0.3
37	3.39	1.29	0.151	43.731	0.3
38	3.02	1.14	0.1511	34.428	0.3
39	3.15	1.21	0.1522	38.115	0.3
40	3.14	0.99	0.1523	31.086	0.3
41	3.11	1.18	0.1523	36.698	0.3
42	3.35	1.3	0.153	43.55	0.3
43	3.47	1.33	0.153	46.151	0.3
44	3.42	1.3	0.153	44.46	0.3
45	3.28	1.33	0.1532	43.624	0.3
46	3.26	1.33	0.154	43.358	0.3

Power (Output) is calculated by the basic formulas which is **Volt x Current**.

P_{output} **= V x I**

Calculation:

Voltage for Head of 0.2 m = 2.5 Volts

Current for Head of 0.2m = 0.38 Ampere

Power$_{output}$**= 2.5 x 0.38 =** 0.95 Watts

Whereas, Mechanical or the hydraulic power is calculated via Different formula which is as follows, Power =Acceleration due to gravity (**g**) x **ρ** x Area of the cross-section of the flume (**LBH**) x Velocity at the point of contact (**V**) x Head of the water (**H**).

Formula for hydraulic/mechanical power (Input) comes out to be:

$\boldsymbol{P = H\rho g A V}$

Calculation:

Head, H= 0.2 m

Acceleration due to gravity, g = 9.8 m/s

Area of the cross section, A = 0.32 x 0.4 meter

Density of water, ρ = 1000 Kg/m^3

Velocity, V = 0.169m/s

Power input, P= 0.2 x 1000 x 0.32 x 0.4 x 9.8 x 0.169 = 42.44 Watts

These Equations were also adopted by **Lie Jasa et al (2015)** in his study of Experimental investigation of Micro-Hydro waterwheel Models to Determine Optimal efficiency.

Table 4: Experimental data for head of 0.09 m.

Serial Number	Head (m)	Velocity (m/s)	Power Output (Watt)	Power Input (Watt)	Rpm	Discharge	Efficiency
1	0.09	0.1335	0	15.087	0	0.017088	0
Average	**0.09**	**0.1335**	**0**	**15.087**	**0**	**0.017088**	**0**

Working with a head of 0.09m head was not possible as the head was too low for the designed hydraulic wheel. This could be considered as the limitation of the model as well.

Table 5: Experimental data for head of 0.2m.

Serial No.	Head (m)	Velocity (m/s)	Power Output (Watt)	Power Input (Watt)	Rpm	Discharge (m^3/s)	Efficiency
1	0.2	0.169	9.5	42.44198	11	0.021632	22.3835
2	0.2	0.169	8.784	42.44198	11	0.021632	20.69649
3	0.2	0.174	16.848	43.69766	10	0.022272	38.55584
4	0.2	0.18	11.18	45.20448	12	0.02304	24.73206
5	0.2	0.18	10.68	45.20448	11	0.02304	23.62598
6	0.2	0.184	2.97	46.20902	11	0.023552	6.427316
7	0.2	0.19	12.6	47.71584	10	0.02432	26.40633
8	0.2	0.194	18.166	48.72038	11	0.024832	37.28624
9	0.2	0.196	14.841	49.22266	12	0.025088	30.15075
10	0.2	0.196	11.063	49.22266	12	0.025088	22.47542
11	0.2	0.201	5.1408	50.47834	12	0.025728	10.18417
Avg	**0.2**	**0.184818**	**11.0705**	**46.4144**	**12**	**0.023657**	**23.851**

Table 6: Experimental data for head of 0.24 m.

Serial No.	Head (m)	Velocity (m/s)	Power Output (Watt)	Power Input (Watt)	Rpm	Discharge (m^3/s)	Efficiency
1	0.24	0.2076	17.595	62.563	13	0.026573	28.12365
2	0.24	0.2083	18.432	62.77395	16	0.026662	29.3625
3	0.24	0.208	18.709	62.68355	15	0.026624	29.84675
4	0.24	0.208	20.3	62.68355	15	0.026624	32.38489
5	0.24	0.2078	20.48	62.62327	13	0.026598	32.7035
6	0.24	0.2078	20.544	62.62327	13	0.026598	32.8057
7	0.24	0.2078	21.582	62.62327	13	0.026598	34.46323
8	0.24	0.2078	23.288	62.62327	13	0.026598	37.18745
9	0.24	0.2086	34.2	62.86436	13	0.026701	54.40284
10	0.24	0.2074	36.698	62.50273	13	0.026547	58.71424
11	0.24	0.2084	39.9	62.80409	13	0.026675	63.53089

Table 7 : Experimental data for head of 0.28m.

Serial No.	Head (m)	Velocity (m/s)	Power Output (Watt)	Power Input (Watt)	Rpm	Discharge (m^3/s)	Efficiency
1	0.28	0.143	12.15	52.07305	13	0.018304	23.33261
2	0.28	0.143	15.072	52.07305	14	0.018304	28.94395
3	0.28	0.155	15.732	56.44282	14	0.01984	27.87246
4	0.28	0.159	18.207	57.8994	16	0.020352	31.44592
5	0.28	0.16	26.435	58.26355	15	0.02048	45.37142
6	0.28	0.162	33.434	58.99185	15	0.020736	56.67563
7	0.28	0.162	27.542	58.99185	14	0.020736	46.68781
8	0.28	0.168	11.037	61.17673	15	0.021504	18.04117
9	0.28	0.173	36.297	62.99747	16	0.022144	57.6166
10	0.28	0.173	41.58	62.99747	16	0.022144	66.00266
11	0.28	0.173	56.1	62.99747	15	0.022144	89.0512
Avg		**0.161**	**26.68964**	**58.6277**	**14.818**	**0.02060**	**44.64013**

Table 8 : Experimental data for head of 0.30m.

Serial No.	Head (m)	Velocity (m/s)	Power Output (Watt)	Power Input (Watt)	Rpm	Discharge (m^3/s)	Efficiency
1	0.3	0.148	29.412	55.75219	14	0.018944	52.75488
2	0.3	0.151	43.731	56.8823	16	0.019328	76.8798
3	0.3	0.1511	34.428	56.91997	13	0.019341	60.48492
4	0.3	0.1522	38.115	57.33435	15	0.019482	66.47847
5	0.3	0.1523	31.086	57.37202	14	0.019494	54.18321
6	0.3	0.1523	36.698	57.37202	15	0.019494	63.96498
7	0.3	0.153	43.55	57.63571	16	0.019584	75.56079
8	0.3	0.153	46.151	57.63571	14	0.019584	80.07362
9	0.3	0.153	44.46	57.63571	14	0.019584	77.13967
10	0.3	0.1532	43.624	57.71105	15	0.01961	75.59037
11	0.3	0.154	43.358	58.01242	14	0.019712	74.73917
Avg		**0.1521**	**39.51027**	**57.29668**	**14.54545**	**0.019469**	**68.89544**

Above tables gives the average efficiencies at various head. For better and precise results these values are averaged and missing values for heads 0.22m, 0.26m are interpolated by using Microsoft excel and the average values of the parameters are obtained as shown in the table below.

When valve was full open following data was observed by running the water wheel at the upstream of the flume.

Table 9 : Averaged data for precise value of efficiency.

Serial Number	Head (Meter)	Velocity (m/s)	Power Output (Watt)	Power input (Watt)	Efficiency	Rpm	Discharge (m^3/s)
1	0.09	0.1335	0	15.087	0	0	0.017088
2	0.2	0.184818	11.0705	46.41445	23.85141	12	0.023657
3	0.22	0.198	15.4015	54.69742	28.15763	13	0.025344
4	0.24	0.207955	24.70255	62.66998	39.41688	14	0.026618
5	0.26	0.21133	28.3014	68.99434	41.01989	14	0.02705
6	0.28	0.21698	24.2719	76.28808	31.81611	15	0.027773
7	0.3	0.2653	19.51027	99.93957	19.52207	15	0.033958

Similarly when the Valve was half open following data was observed by running the water wheel at the upstream of the flume.

Table 10: This Table shows the average values of previous tables when valve was half open.

Serial Number	Head (Meter)	Velocity (m/s)	Power Input (Watt)	Power Output (Watt)	Efficiency	Rpm	Discharge (M^3/s)
1	0.09	0.11335	12.80982	0	0	0	0.014509
2	0.2	0.1521	38.19779	9.29668	24.33827	11	0.019469
3	0.22	0.161	44.47619	10.6277	23.89526	11	0.020608
4	0.24	0.184818	55.69734	36.4145	65.37924	12	0.023657
5	0.26	0.19225	62.76516	38.4578	61.27252	13	0.024608
6	0.28	0.207955	73.11498	42.6698	58.35993	14	0.026618
7	0.3	0.22958	86.4837	35.9372	41.55372	15	0.029386

4.4 GRAPHICAL REPRESENTATION

Graphical representation of the data when valve was full open.

4.4.1 Efficiency vs. Discharge

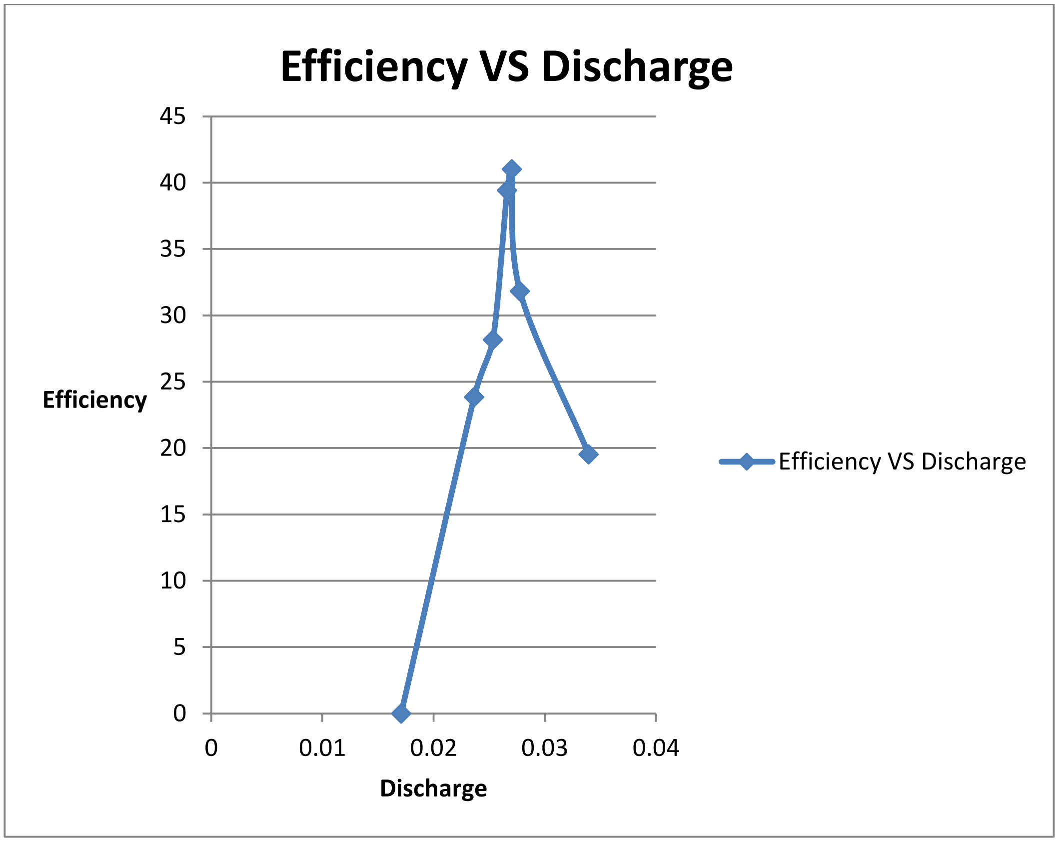

Fig. 4.5: Graphical representation between Efficiency and Discharge.

This graph follows the theoretical graph between Efficiency and Discharge as we can see that efficiency increases to a certain limit and after reaching its peak it starts decreasing this is because of the head as the designed model is for low head follows as stated in the beginning. This also states that the designed model is a undershot wheel which is for low head and low flows.

4.4.2 Power output vs. Discharge

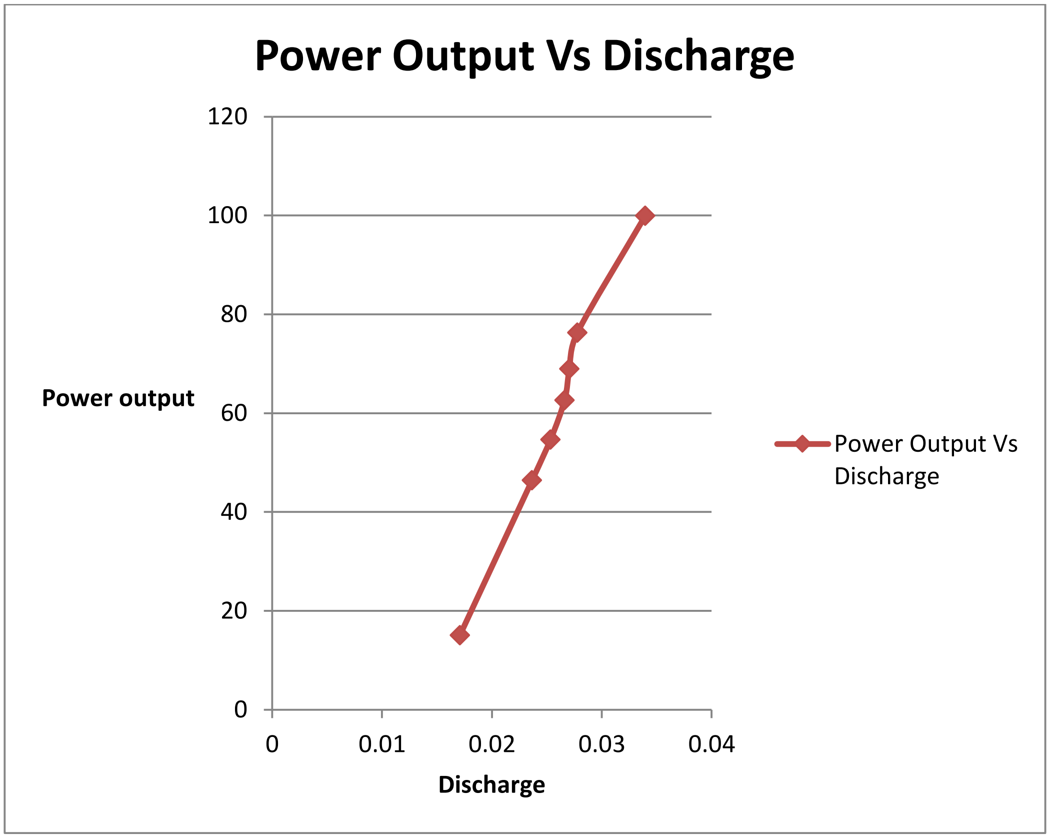

Fig. 4.6: Graphical representation between Power (Output) and Discharge.

The above graphical representation shows that the power output increases linearly ignoring the Human error or the experimental error which are unavoidable in case of model analysis as they were plenty of limitations. This result fulfils the simplified hydro power equation which is $P = \frac{\eta QH}{1.181x10^4}$. Ignoring the constant value where **H=Hydraulic head, η=Efficiency and Q is the discharge**. The graphical representation and the formula both satisfy the condition that Power is directly proportional to Head and Discharge of the flume or the open channel.

The line could be more linear or straight if human and experimental error are ignored or removed but then it would become the theoretical.

4.5 WHEN VALVE WAS HALF OPEN

4.5.1 Efficiency vs. Discharge

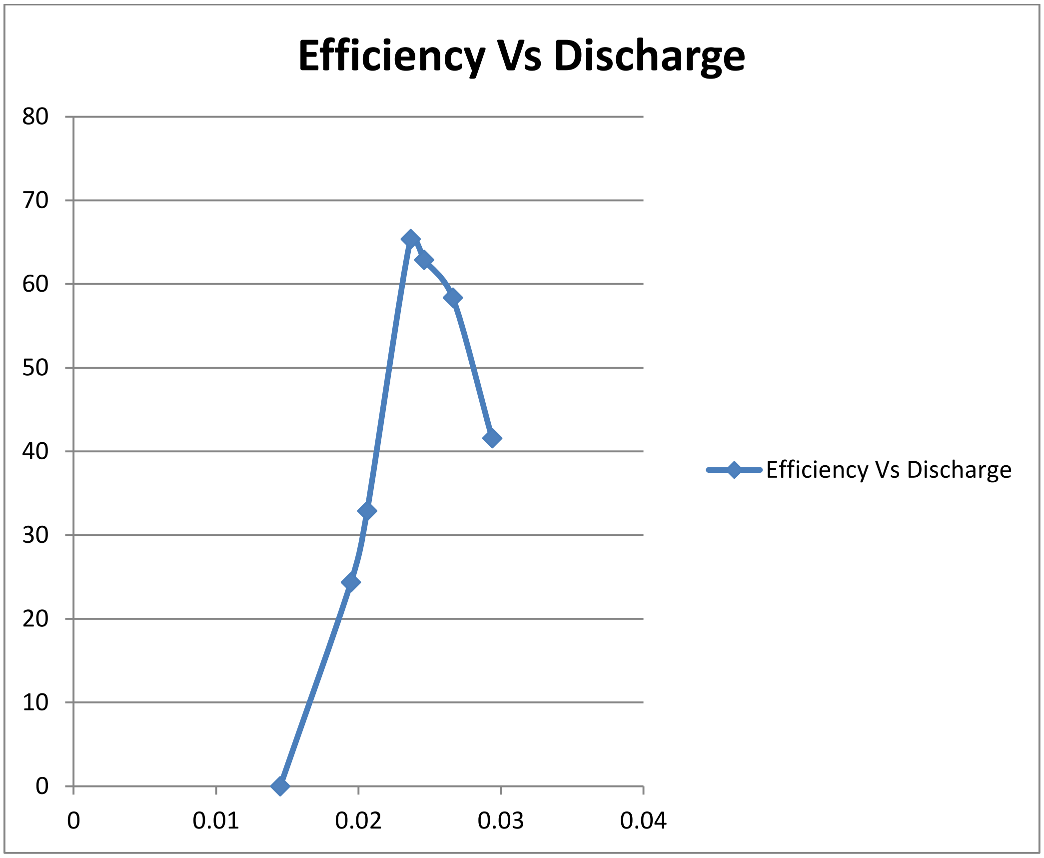

Fig. 4.7: Graphical representation between Efficiency and Discharge.

The sudden drop in the Fig. 4.7 and Fig. 4.5 Shows that Efficiency decreases after reaching a peak value this is because with increase in Velocity and Head the Hydraulic Power increases but on the other hand Power output which is derived from the product of the Voltage and Current is increasing. But the increment in power output with respect to increment in power input is small. From calculation and from the Fig. 4.7 & Fig.4.5 the ratio of power output to power input (Efficiency) is decreasing.

As stated in the above graph of efficiency and discharge, this graph follows the theoretical graph between Efficiency and Discharge as we can see that efficiency increases to a certain limit and after reaching its peak it starts decreasing this is because of the head as the designed model is for low head follows as stated in the beginning. This also states that the designed model is a undershot wheel which is for low head and low flows.

4.5.2 Power output vs. Discharge

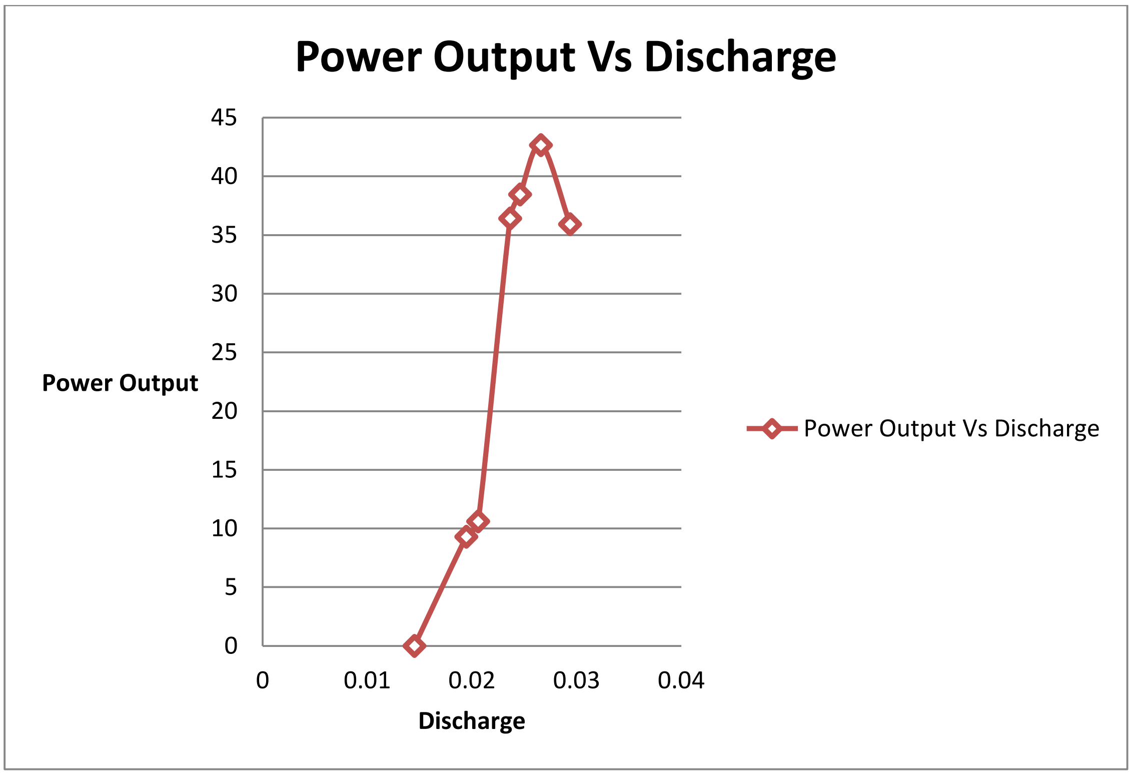

Fig. 4.8: Graphical representation between Power output and Discharge.

As stated in the same graph above**.** This graphical representation shows that the power output increases linearly ignoring the Human error or the experimental error which are unavoidable in case of model analysis as they were plenty of limitations. This result fulfils the simplified hydro power equation which is$P = \frac{\eta QH}{1.181x10^4}$. Ignoring the constant value where **H =Hydraulic head, η= Efficiency and Q is the discharge**. The graphical representation and the formula both satisfy the condition that Power is directly proportional to Head and Discharge of the flume or the open channel.

The line could be more linear or straight if human and experimental error are ignored or removed but then it would become the theoretical.

The variation of the discharge from the valve does not effect as it is for the reservoir by this we can conclude that in case of excess/inadequate flow from the feeding stream or channel carrying excess of water or insufficient of water to the reservoir tank like in case of hydro power plant with reservoir tank as discussed in previous chapters does not affect the efficiency and other parameter until and unless it is not overtopping the designed limits of the model(like in case of floods when the dam gates are opened full).

4.6 COST ANALYSIS AND BUY BACK PERIOD OF THE MODEL.

Cost estimation and analysis of it buyback is important aspect of this study as the main objective of the study was to deliver a low cost model for benefitting the local and rural grid in India.

Serial no.	**Part name**	**Price (INR)**
1	Flywheel(Rim+Blades+Shaft)	1250+400+250= 1900
2	Stand (Iron rate as per Kilo)	13x89 = 1157
3	D.C Generator (12-24 volt, Battery and rectifier)	900
4	Chain and Gear mechanism	670
5	Welding and fabrication	1500
TOTAL		**6127**

Table 10: Cost incurred for the model.

As we have connected the Hydraulic wheel with a UPS System consisting of a battery(12V) and charger cum rectifier which rectify the power from Direct current DC to Alternating Current AC. Therefore, assuming power consumption or the energy consumption from the battery to be maximum i.e. 12 volts x 40 amp-hours which gives the total 480 watts-hours.

Unit rate of power in New Delhi decided by the Discom for domestic user is Rs 1.45 per unit where 1 unit is equal to 1 kW or 1000 watts.

4.6.1 Calculation of buyback period.

Energy utilized in an hour = 480 Watt/hr or 0.48 kW/hr

Therefore, Unit consumed = 0.48 unit

Cost of Unit consumed =0.48 x 1.45= Rs 0.696/hr

Buyback period of the hydraulic wheel = Total cost/Cost of unit consumed.

= 6127/0.696

=**8803.16 hrs or 366.7 days**

The buyback period comes out to be nearly one year which can be lowered if initial cost is decreased by producing it on a large scale, using cheaper materials and high capacity UPS system. The **above cost and buyback period** is for applicable for **Delhi** as the power rates are **lowest** in this region as the federal bodies provides it a **subsidized rates** where as in other states and regions the rates vary from **Rs 1.2/unit to Rs 6/unit** for domestic consumption.

The buyback period for various approx rates are given in the following table.

Serial number	**Rate per Unit(Approx)**	**Buyback period**
1	**1.45**	**366.7 days**
2	**2.00**	**265.9 days**
3	**3.00**	**177.2 days**
4	**4.00**	**132.9 days**
5	**6.00**	**88.6 days**

Table 11: Buyback period for various unit rates.

CHAPTER 5

CONCLUSION

Hydro power plants and generation of energy is a Renewable source of energy as it does not affect or consume water throughout the process like in other non renewable sources for energy hence it is beneficiary than all for sustainable development in a eco friendly way.

It is not necessary to feed Freshwater to such modeled hydraulic wheel it can work in sewage drains and other streams present in urban areas like cities etc.

Concluding from the Experimental analysis it is fair enough to say that it hydraulic power generated from such sources like streams, rivulet and open channel stream is useful as it would lower down the load on national power grid and is extremely helpful in terrains having abundance of natural stream flows as they proves as best grounds for this model.

From the above study and experimental analysis it can be concluded which are as follows,

When valve was full open the power output at various heads 0.09, 0.20, 0.22, 0.24, 0.26, 0.28, 0.30 meter are 0, 11.07, 15.40, 24.70, 28.30, 24.27, 19.51 Watts respectively we achieved the peak value which is the highest power output at a head of 0.26 meter. Similarly Efficiency at various heads 0.09, 0.20, 0.22, 0.24, 0.26, 0.28, 0.30 meter were 0, 23.85, 28.15, 39.41, 41.01, 31.81, 19.52 respectively and we achieved a peak efficiency at a head of 0.26 meter. From this result we can observe that when discharge is increasing with increase in head. Efficiency is increasing to a certain head or to a certain discharge as shown in graph (Fig.18 & Fig.19) after reaching the peak value of 41.01 it starts declining with head and discharge.

When the valve was half open the power output at various heads 0.09, 0.20, 0.22, 0.24, 0.26, 0.28, 0.30 meter are 0, 9.29, 10.62, 36.41, 38.45, 42.66, 35.93 Watts respectively we achieved the peak value which is 42.66 at a head of 0.26 meter. Similarly efficiency at various heads 0.09, 0.20, 0.22, 0.24, 0.26, 0.28, 0.30 meter were 0, 24.33, 23.89, 65.37, 61.27, 58.35, 41.55 respectively and we achieved a peak efficiency at a head of 0.24 meter. From this result we can observe that when discharge is increasing with increase in head. Efficiency is increasing to a certain head or to a certain discharge as shown in graph (Fig.23 & Fig.24) after reaching the peak value of 65.37 it starts declining with head and discharge.

On comparing the buyback periods it proves beneficial using a hydraulic wheel for generation of power on small/micro scale as buyback period of turbines. Hydraulic wheels when connected/implemented in a series can also prove its worthiness as large output can be achieved.

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