SUDAN UNIVERSITY OF SCIENCE & TECHNOLOGY

COLLEGE OF GRADUATE STUDIES

WATER PUMPING BY USING NATURAL FLOW ENERGY OF STREAMS

ضخ المياه باستخدام طاقة الانسياب الطبيعية للتيارات المائية

A thesis Submitted in Partial Fulfillment of the Requirement for the Master of Science (M.Sc.) Degree in Mechanical Engineering

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قال تعالى :

"إن في خلق السموات والأرض واختلاف الليل والنهار لآيات لأولي الألباب"

صدق الله العظيم

الآية (190) - سورة آل عمران

DEDICATION

To my parents, who are the reasons of my existence in life-after Allah the Almighty-, and who I will not ever be able to satisfy in return what they have done for me.

To all teachers who have taught me even a letter, through all my education years everywhere.

To everyone I knew in my whole life.

ACKNOWLEDGEMENT

Praise (be) to Allah the Almighty... Who bestowed grace and wisdom,

I am deeply grateful to my supervisor Dr. Yousif H. M. Ali, for his patience with me, when I visit him at his office or through phone calls wherever and whenever he was, paving the way for me to conduct this research,

I am thankful also for my friend, Eng. Ahmed Hasan Ahmed for his valuable assistance in the system simulation which made my research processing much easier... May Allah bless them all.

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LIST OF SYMBOLS

Symbol	***Meaning or dimension***
GWT	Ground Water Table
H	Head
V	Velocity
g	Gravitational acceleration
π	Bi
D	Wheel diameter
Dw	Working diameter
Cw	Working circumference
S	Space between blades
n	Number of blades
w	Wheel width
t	Annulus width
r	Wheel radius
Vw	Working velocity
Nw	Working rotation speed
ω	Angular velocity
Vrelaive	Relative velocity
Vfinal	Final velocity
Q	Volume flow rate
A	Sectional area
L	Stroke length
d	Pump diameter
ṁ	Mass flow rate
ρ	Density
Fn	Force normally to stream
Fx	Force horizontally with stream
Fxt	Total force

ABSTRACT

This research aimed to utilize the natural flow energy of streams through design of a mechanical system consists of a wheel with rectangular blades attached to asteel structure installed with two separated floating platforms on the stream, this wheel spins naturally by impulse of stream and transmits the rotational motion to a crank shaft linked with two reciprocating pumps deliver the water directly from the source up to storage or direct use according to need.

Velocities, torques and power have been calculated based on the lowest available realistic assumptions with different directions and efficiencies, withsimplicity of design and durability for easier operation and maintenance, that is done by the selection of manufacturing materials that fulfill these requirements to maintainsystem continuity in water pumping for different activities as long as possible.

المستخلص

هدف البحث إلىمحاولة استغلال طاقة الانسياب الطبيعية للتيارات المائيةوذلكبتصميم منظومةميكانيكية هي عبارة عن عجلة ذات ألواح مستطيلة مرتبطة بهيكل فولاذي مثبتعمنصتين منفصلتين قابلتين للطفوعلى المجرى المائي، هذه العجلة تدور طبيعيا باندفاع التيار المائي وتنقل الحركة الدورانية إلى عمود مرفق مرتبط بمضختين ترددية تنقلان المياه من المصدر مباشرة إلى الاعلى اما للتخزين أو الاستعمال المباشر وذلك حسب الحاجة.

تم حساب السرعات والعزوم والقدرة على أساس أقل افتراضات واقعية متاحة بمراعاة الاتجاهات والكفاءات، مع التقيدبالبساطة في التصميم والمتانة قدر الإمكان لتسهيل عمليتي التشغيل والصيانة، وذلك باختيار مواد التصنيع التي تفي بهذه المتطلبات، مما يسهم في استمرارية عمل المنظومة بضخ المياه للاستفادة منها في مختلف النشاطات لأطول فترة ممكنة.

Chapter {1}

The Theoretical & Conceptual Framework

(1-1) Introduction: -

Energy is an essential part of daily life, since all of applications almost are relying on it. Getting energy is coming through many types of power generation. Although the most important one is the thermal generation as it forms about eighty percent of the power generation in the world, but it has many different effects on all aspects of life (environmental, social, economic, political, .., etc.). The proven world oil reserves are equal to (1200 billion) barrels, and the world natural gas reserves are (180 trillion) m^3,according to numbers was recorded in (2005). Also the current production rate is equal to (80 million) barrels per day for oil, and about (8 billion) m^3 per day for natural gas, therefore, these proven reserves of oil and gas, at current rates of consumption, would be adequate to meet demand for only (41 & 67) years respectively, and coal reserves for (230) years.[1] The implications of these limited reserves that the price of energy that gained from fuels will accelerate as the reserves are decreased, withthe uncontrolled increasing of population which is very significant factor. In the middle of this complicated situation, the research about resources of renewable energy has been a general concern, since that can reduce remarkable amount of these effects directly or indirectly. So, the developing and using of a sustainable, green and clean source of energy and power is the only way to overcome these issues. There are many types of renewable energy like hydraulic, solar, wind, geothermal, waves and tide energy. All of these energy kinds are available in abundance and can be used effectively.

(1-2) Problem statement:-

There are many natural resources of energy and water at some locations that are not utilized effectively, these places are mostly inhabited by grazers and farmers who get the water from the streams around by pumps that work by fueled engines or electrical motors, which are costly options since they take considerable time in maintenance and exhaust a lot of efforts at following up, in addition to the contribution in the environmental problems, therefore, they need a permanent solution for their issues to keep up the production process at a satisfying rate.

(1-3) Significance of research:-

Natural flow energy of streams at some locationscan be utilized by fabricating a system that can take advantage of this energy effectively to provide a considerable quantity of water for different uses, and encourage the settlement at these areas and expand their activities. Simplicity ofsystem design with using of a renewable source of energy would be economic and save a lot of time at maintenance and following up, as a result, the concentration shall be on getting the maximum benefit of this application.

(1-4) Objectives:-

(1-4-1) General objectives:-

*To find out a cost effective alternative that cover important related fields.

*Contribution in the activities that reduce the impacts on environment.

*Forming a ground for making the sustainable designs of useful applications.

*Spreading the culture of renewable energy using and developing, like natural flow energy of streams.

(1-4-2) Specific objectives:-

*To employ the popular techniques used nowadays in the specified design.

*Using the simplest techniques and available materials for manufacturing the system for the desired area.

*Put practical options for operation and maintenance with the minimum design requirements.

*Utilization of the maximum available quantity of natural flow energy in the specified location.

(1-5) Theoretical methodology:-

*Investigate the operation of hydraulic power generation process, and the obtained quantity.

*Study the current followed techniques of using hydraulic energy with different applications.

*Examine of the corresponding procedures for the most popular techniques.

*Determine the minimum requirements of the design at the specified location.

*Calculate the velocities, torques and power that gained at the application area.

*Specify the characteristics of the mechanical and physical attributes of design according to the minimum circumstances.

*Utilize the available power with the actual requirements and make the design adjustable for any additions or improvements.

*Simulate the design of application with the related elements of indicated area.

Chapter {2}

LITERATURE REVIEW

(2-1) Introduction: -

The first reference to the use of the waterwheel dates back to about four thousand years B.C. by Greek people, the device was used for crop irrigation, grinding grains, supply drinking water to villages and later to drive sawmills, forge bellows, tilt hammers and to power textile mills. The same applications were existed in ancient China,India, Europe, Africa and Middle East civilizations.[7]

(2-2) Previous studies: -

*Sara Salomonsson and others have developed a windmill driven water pump for irrigation and domestic use.[8] The objective was to redesign and to build a small-scale irrigation system in Tanzania. The methodology began with limited changes in the original design to fit the situation. They included strength of materials calculations on the windmill construction. The type and size of the irrigation system was dependent on actual field conditions at the project area and the system was designed for fields with area of 4000 m^2. Irrigation system has reduced the need to water by hand and gives an opportunity to grow crops all year around.The pump has reduced the need for a diesel driven pump. They recommended that making some improvements in the parts of the system like pipes and bearings would make it more efficient.

*Vince Ginter and others have developed a water current turbine.[9] Their study aimed to using the hydro-energy for gaining electricity without using dams. The methodology began by specifying the energy thatcan be gained and then design a vertical axis wheel to harness the kinetic energy in the river to spin an electricity generator.

They identified important aspects of the turbine, optimized performance and understood system with its operational characteristics that required for getting a robust yet highly functional system to market. Their plan consisted of three components, theoretical modeling, model verification through experimental testing, and longer term field testing. They found thatapplications and installation of the En-Current Turbine brings another set of technical and regulatory challenges and early installations of the turbine have focused on man-made water channels, industrial outflows and irrigation canals, as this reduces the technical and environmental requirements for the installation.

*Stefan Tkac and others investigated about the use of water element in the micro-urban structures.[10] Thesis objective was to deal with using seemingly energy uninteresting water sources by applying the new structural design of water turbine for producing electricity. The principal idea of the methodology is to get the most satisfactory outcomes to design the system according to them. They considered the transformation principle of energy by using a water turbine with the smallest losses as possible depends on the suitability of applied device. By summarizing this knowledge from the field of study and setting critical points of current practice they designed the solution for existing applications. They considered an important solution that includes a proposal which leads to reduction of acquisition and operating costs, given the low efficiency of concrete resource. From the analysis of data they gathered, they came up with the solution that cut the current to the streamlines, using self-stabilizing floating rotor and turning flow. They found that their results are in theoretical faze and their strengths and weaknesses are demonstrable in the subsequent period of research including realization, individual laboratory tests and final practical applications.

*Kari Sornes created small scale water current turbines for river applications.[11]The objective of this report was to get an overview of the existing technology of water current turbines with a unit power output of about (0.5-5 kW). The researcher summarized the commercial market which exists in this field and considered some previous experiences in rural areas. Several companies from different parts of the world were presented with their concept. They found thatsmall-scale water current turbines can be a solution for power supply in remote areas. Also because of low investment costs and maintenance fees, this technology is cost effective in comparison to other technologies, and this kind of small-scale hydropower is considered environmentally friendly, meaning that the water passing through the generator is directed back into the stream with relatively small impact on the surrounding ecology. Because of the low cost and durability of this kind of hydro power, developing countries can manufacture and implement the technology to supply the needed electricity to small communities and villages.

(2-3) Hydrological concepts: -

*Streams flow Components:

Precipitation water infiltrate into the ground, some portion may evaporate, and some flow as a thin sheet of water over the land surface which is termed as overland flow. If there is a relatively impermeable stratum in the subsoil, the infiltrating water moves laterally in the surface soil and joins the stream flow, which is termed as underflow (subsurface flow) or interflow,if there is no impeding layer in the subsoil the infiltrating water percolates into the ground as deep seepage and builds up the Ground Water Table(GWT)[Figure (2-1)]. The ground water may also contribute to the stream flow, if the (GWT) is higher than the water surface level of the stream, creating a hydraulic gradient towards the stream, sothe overland flow reaches the stream channel, then the interflow. The term direct runoff is used to include the overland flow and the interflow. The portion of runoff in a rising flood of a stream, which is absorbed by the permeable boundaries of the stream above the normal phreatic surface, is called bank storage.

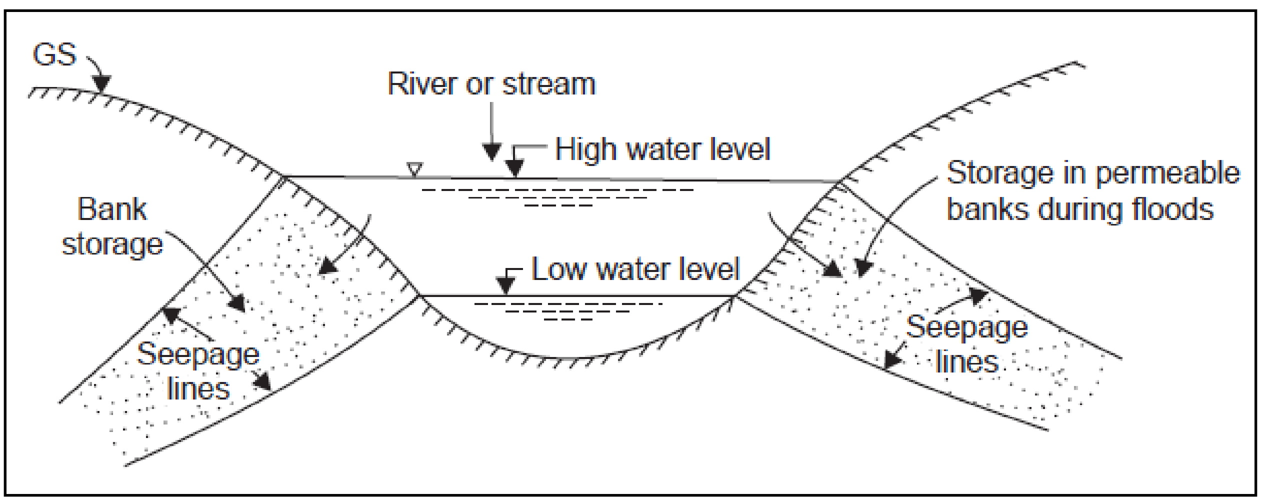


Figure (2-1)-Ground Water Table (GWT).[4]

*Streams Classification:

(i)Influent and Effluent streams:

If the (GWT) is below the bed of the stream, the seepage from the stream feeds the ground-water resulting in the building up of water mound. Such streams are called influent streams. Such streams will dry up completely in rainlessperiod and are calledephemeral streams which are generally seen in arid regionsand the flow is only for few hours after the rainfall, so they are not used for conventionalhydropower.When the (GWT) is above water surface elevation in the stream, the ground water feeds the stream. Such streams are called effluent streams. The base flow of surface streams is the effluent seepage from the drainage basin. Most of the perennial streams are mainly effluent streams.

If the (GWT) lies above the bed of the stream during the wet season but drops below the bed during the dry season, the stream flows during wet season due to surface runoff and ground water contribution but becomes dry during dry seasons. Such streams are called intermittent streams. While in the case of perennial streams, even in the most severe droughts, the (GWT) never drops below the bed of the stream and therefore they flow all the year. For power development a perennial stream is the best, power can also be generated from intermittent streams by providing adequate storage facilities.[4]

*Factors affecting runoff:

Runoff is that portion of total precipitation (rain, snow or other sources) that does not infiltrate into the soil but instead flows over the soil surface and it is part of the water cycle.There are many characteristics that affect runoff divided as following:

-Storm characteristics: Type or nature of storm season, intensity, duration, distribution, direction, frequency and antecedent precipitation.

-Meteorological characteristics: Temperature, humidity, wind velocity and pressure variation.

-Basin characteristics: size, shape, slope, altitude, orientation, topography, vegetation, soil type and land use.

(ii)Intermittent and Perennial streams:

-Storage characteristics: ground water storage in pervious deposits(aquifers), check dams (in gullies) and flood plains swamps.[4]

*Flow measurement:

There are many methods commonly suggested for measuring the flow in small or medium sized streams. It is essential that the presence of the sensing device in the flow stream does not affect the flow being measured. Velocity is usually measured indirectly by measuring the difference between the stagnation and static pressures (Pitot tube) or by the rotational speed of wheels (vane anemometer).

Velocity is also measured directly, in some instances, by determining the distance travelled by a group of fluid particles during a measured time interval.The float method[Figure (2-2)] of testing stream flowis the easiest test to conduct and will yield satisfactory data,basically the cross section of an unobstructed area of the stream is measured and a weighted float such as a bottle weighted with pebbles is timed as it floats down a 100 foot course.

The weir method [Figure (2-3)] is more time consuming but may be the most satisfactory test if the stream is very small, shallow, rocky and obstructed, or if there is an existing dam, a weir is a dam with an opening or notch through which the entire stream flows. The flow may be calculated by precisely measuring the depth of water flowing over the crest of the weir. The selected references give more detail on how to measure stream flow by the weir or float method. [2]

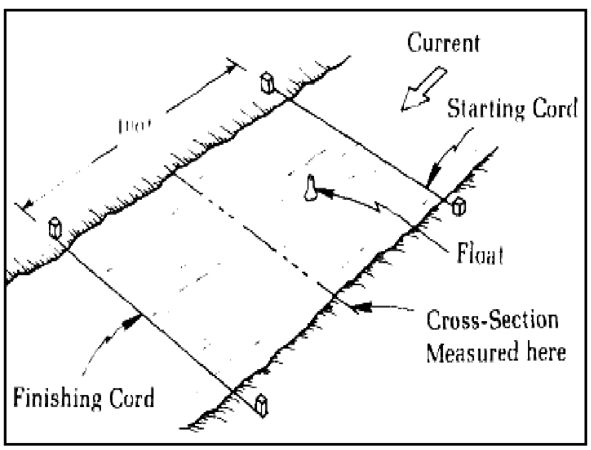


Figure (2-2) –Float method.[2]

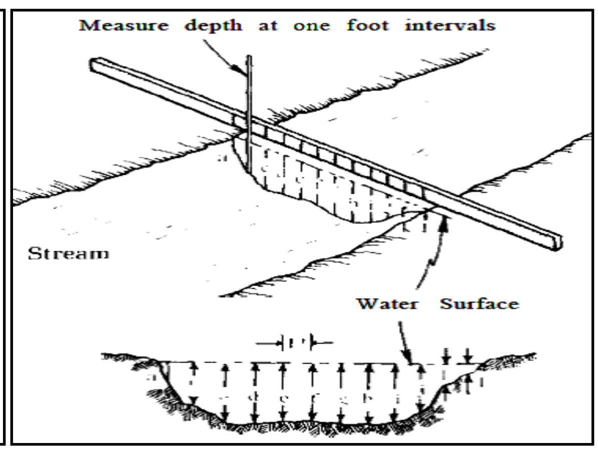


Figure (2-3)-Weir method.[2]

(2-4)Hydraulic turbines:-

Water wheels:

A water wheel is a machine for converting the energy of free flowing or falling water into useful forms of power. Wheels are used in conjunction with axles, either the wheel turns on the axle, or the axle turns in the object body. The mechanics are the same in either case. A water wheel consists of a large wooden or metal wheel, with a number of blades or buckets arranged on the outside rim forming the driving surface. Most commonly, the wheel is mounted vertically on a horizontal axle. Vertical wheels can transmit power either through the axle or via a ring gear and typically drive belts or gears. Horizontal wheels usually directly drive their load. Bearings are used to help reduce friction at the interface, in the simplest and oldest case the bearing is just a round hole through which the axle pass (a plain bearing). There are wheels that were used for water lifting, in these water raising devices rotary motion is typically more efficient than machines based on oscillating motion. The compartmented water wheel comes in two basic forms, the wheel with compartmented body (Latin "tympanum") and the wheel with compartmented rim or a rim with separate, attached containers. The wheels could be either turned by the flow of water, men treading on its outside or by animals and means of what is known by "Saqia". While the "tympanum" had a large discharge capacity, it could lift the water only to less than the height of its own radius and required a large torque for rotating. These constructional deficiencies were overcome by the wheel with a compartmented rim which was a less heavy design with a higher lift. [7]

**Categories:*

Water wheels are classified by the way in which water is applied to the wheel, relative to the wheel's axle. Overshot water wheels are suitable where there is a small stream with a height difference of more than two meters, often in association with a small reservoir. Breast-shot and undershot wheels can be used on rivers or high volume flows with large reservoirs.

(i) Overshot wheels:

A vertically mounted water wheel that is rotated by falling water striking paddles, blades or buckets near the top of the wheel is said to be overshot. In true overshot wheels the water passes over the top of the wheel, but the term is sometimes applied to back-shot wheels where the water goes down behind the water wheel. A typical overshot wheel has the water channeled to the wheel at the top and slightly beyond the axle. The water collects in the buckets on that side of the wheel, making it heavier than the other "empty" side. The weight turns the wheel, and the water flows out into the “tail-water” when the wheel rotates enough to invert the buckets. The overshot design can use all of the water flow for power (unless there is a leak) and does not require rapid flow. Overshot wheels gain a double advantage from gravity. Not only is the momentum of the flowing water partially transferred to the wheel, the weight of the water descending in the wheel's buckets also imparts additional energy. The mechanical power derived from an overshot wheel is determined by the wheel's physical size and the available head, so they are ideally suited to hilly or mountainous country. Overshot wheel uses sixty three percent of the energy in the flow of water.

(ii) Breast-shot wheels:

A vertically mounted water wheel that is rotated by falling water striking buckets near the center of the wheel's edge, or just above it, is said to be breast-shot. It is the most common type in the United States of America and are said to have powered the American industrial revolution. The individual blades of a breast-shot wheel are actually buckets. It requires a good trash rack and typically has a masonry "apron" closely conforming to the wheel face, which helps contain the water in the buckets as they progress downwards. Breast-shot wheels are preferred for steady, high volume flows.

An undershot wheel[Figure (2-4)] (also called a stream wheel) is a vertically mounted water wheel that is rotated by water striking paddles or blades at the bottom of the wheel. The name undershot comes from this striking at the bottom of the wheel. This type of water wheel is the oldest type of wheel. The undershot wheels are cheaper and simpler to build, and have less environmental impacts as they do not constitute a major change of the river, and they can be used where the flow rate is sufficient to provide torque. Undershot wheels are also well suited to installation on floating platforms or to be mounted immediately downstream from bridges where the flow restriction of arched bridge piers increased the speed of the current. There are subtypes of undershot wheels [Figure (2-5)] like the “Poncelet” wheel, “Sagebien” wheel and “Zuppinger” wheel, and they allow greater efficiencies than the traditional undershot wheels. [7]

(iii)Und

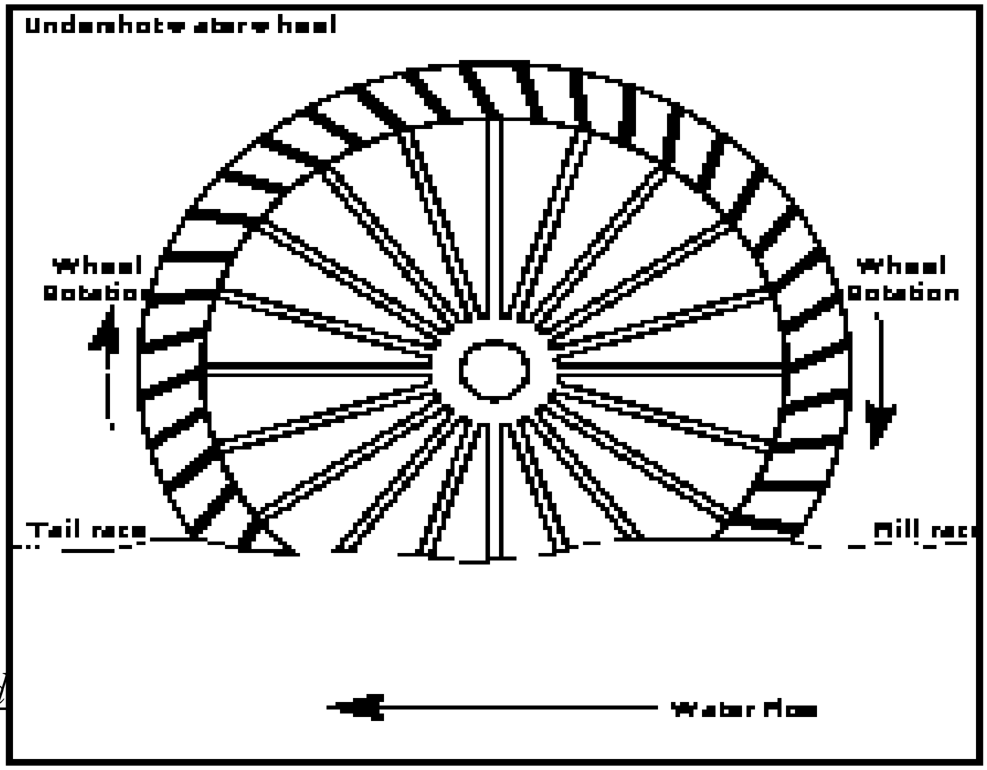


Figure (2-4)-Undershot water wheel

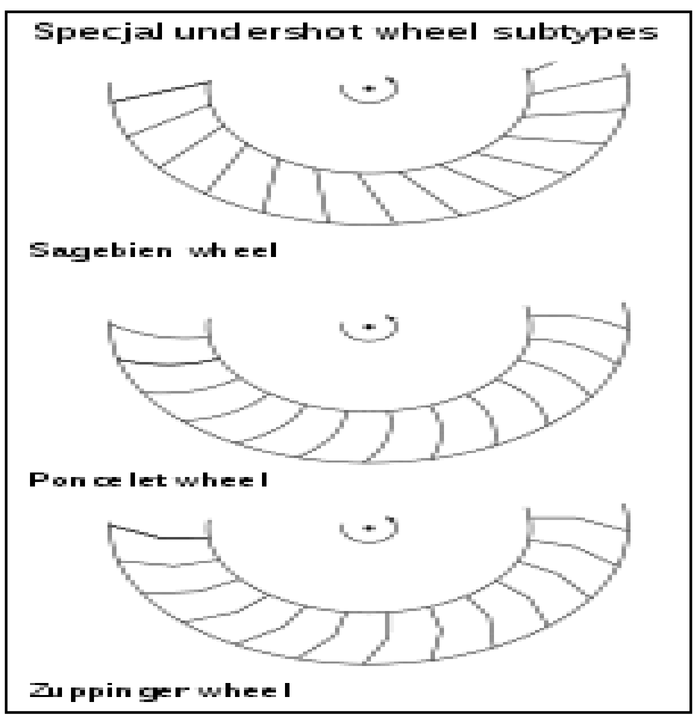


Figure (2-5)-Special undershot wheel subtypes

Chapter {3}

POWER TRANSMISSION

(3-1) Theory of Transmission:-

Transmission of power from a source, such as an engine or motor, through a machine to an output actuation is one of the most common machine tasks. An efficient means of transmittingpower is through rotary motion of a shaft that is supported by bearings. Gears, beltpulleys, or chain sprockets may be incorporated to provide for torque and speed changesbetween shafts.

(3-1-1) Shafts:-

Shaft is a rotating member, usually of circular cross section, used to transmit power or motion. Most shafts are cylindrical and include stepped diameterswith shoulders to accommodate the positioning, support and provide the axis of rotation, or oscillation, of elements such as of bearings, gears, pulleys, flywheels, cranks, sprockets, and control the geometry of their motion[Figure (3-1)]. An axle is a nonrotating member that carries no torque and is used to support rotating wheels or pulleys. The automotive axle is not a true axle and this term is a carry-over from the horse-and-buggy era, when the wheels rotated on nonrotating members. A non-rotating axle can readily be designed and analyzed as a static beam and the rotating shafts are subject to fatigue loading. Most shafts serve to transmit torque from an input gear, pulley or any element through the shaft, to an output element. Of course, the shaft itself must be sized to support the torsional stress and torsional deflection. It is also necessary to provide a means of transmitting the torque between the shaft and the gears. Common torque-transfer elements are keys, splines, setscrews, pins, press or shrink fits and tapered fits.

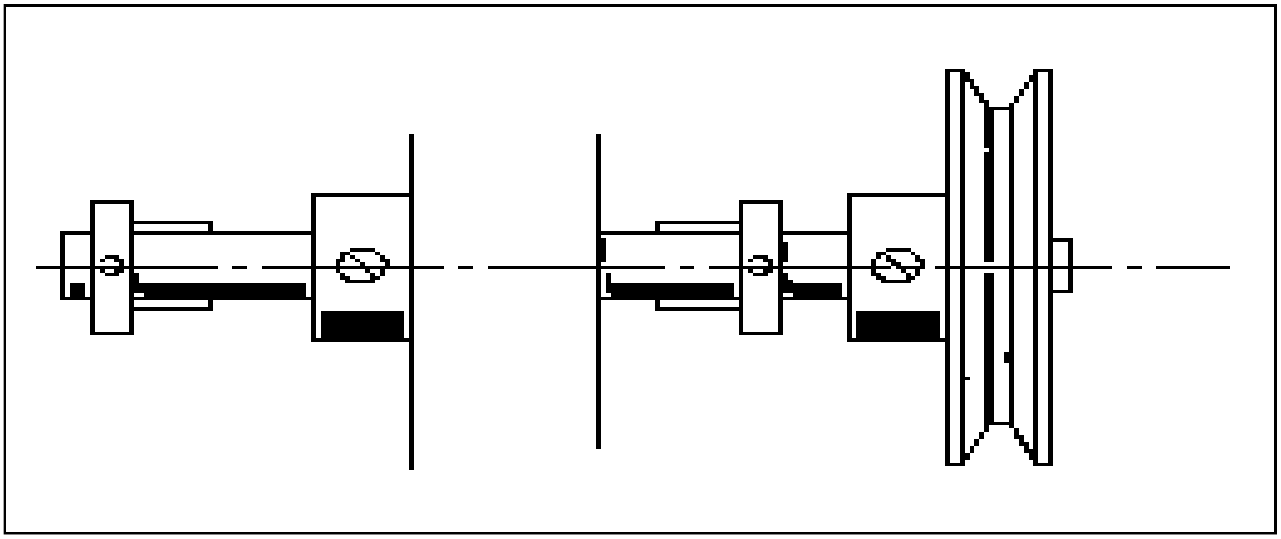


Figure (3-1)-Side view of a transmission shaft

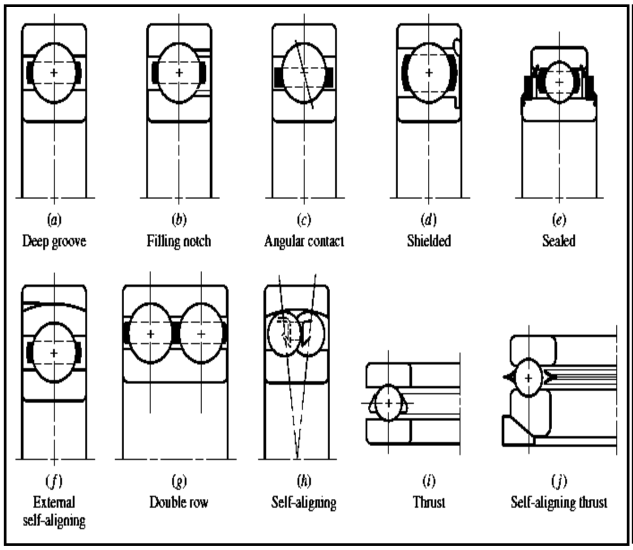
In addition to transmitting the torque, many of these devices are designed to fail if the torque exceeds acceptable operating limits, protecting more expensive components. One of the most effective and economical means of transmitting moderate to high levels of torque is through a key that fits in a groove in the shaft and gear. Keyed components generally have a slip fit onto the shaft, so assembly and disassembly is easy. The key provides for positive angular orientation of the component, which is useful in cases where phase angle timing is important. Tapered roller bearings used in a mowing machine spindle. This design represents good practice for the situation in which one or more torque transfer elements must be mounted outboard. A bevel-gear drives in which both pinion and gear are straddle-mounted. Most shafts will transmit torque through a portion of the shaft. Typically the torque comes into the shaft at one gear and leaves the shaft at another gear. A free body diagram of the shaft will allow the torque at any section to be determined. The torque is often relatively constant at steady state operation. The shear stress due to the torsion will be greatest on outer surfaces.[2]

(3-1-2) Bearings:-

Bearings are manufactured to take pure radial loads, pure thrust loads, or a combination of the two kinds of loads.Some of the various types of standardized bearings that are manufactured are:

****Ball bearings:*** The balls are inserted into grooves by moving the inner ringto an eccentric position[Figure (3-2)]. The balls are separated after loading, and the separator is then inserted. The use of a filling notch in the inner and outer rings enables a greater number of balls to be inserted, thus increasing the load capacity. The thrust capacity is decreased, however, because of the bumping of the balls against the edge of the notch when thrust loads are present andthe angular-contact bearing provides a greater thrust capacity,all these bearings may be obtained with shields on one or both sides.

****Roller bearings:***Straight roller bearings will carry a greater radial load than ball bearings of the same size because of the greater contact area[Figure (3-3)]. However, they havethe disadvantage of requiring almost perfect geometry of the raceways and rollers. A slight misalignment will cause the rollers to skew and get out of line. For this reason, the retainer must be heavy. Straight roller bearings will not, of course, take thrust loads. Helical rollers are made by winding rectangular material into rollers, after which they are hardened and ground. Because of the inherent flexibility, they will take considerable misalignment. If necessary, the shaft and housing can be used for raceways instead of separate inner and outer races. This is especially important if radial space is limited.



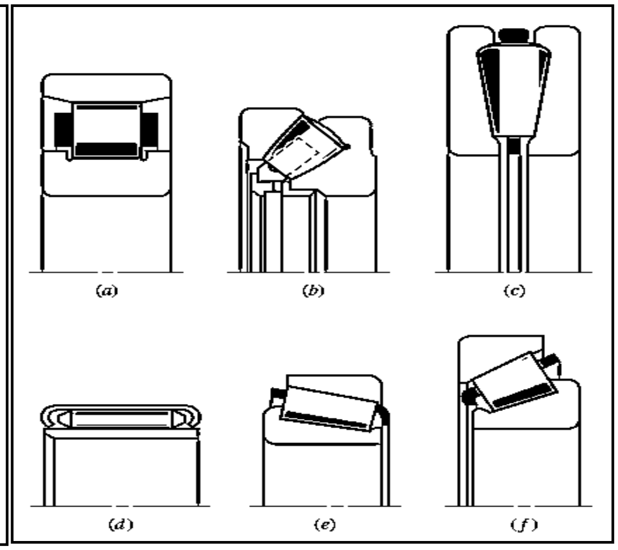


Figure (3-2)-Types of ball bearing

Figure (3-3)-Types of roller bearing

The spherical-roller thrust bearing is useful where heavy loads and misalignment occur.Needle bearings are very useful where radial space is limited. They have a high load capacity when separators are used, but may be obtained without separators. The tapered roller bearing is designed so that all elements in the roller surface and the raceways intersect at a common point on the bearing axis.

The bearings described here represent only a small portion of the many available for selection. Many special-purpose bearings are manufactured, and bearings are also made for particular classes of machinery. Typical of these are:

- ***Instrument bearings:*** which are high-precision and are available in stainless steel and high-temperature materials
- ***Non-precision bearings:*** usually made with no separator and sometimes having split or stamped sheet-metal races
- ***Ball bushings:*** which permit either rotation or sliding motion or both
- ***Bearings with flexible rollers.***[2]

(3-2) Classification of Pumps:-

The more basic system of classificationis to define the principle by which energy is added to the fluid, goes on to identify the meansby which this principle is implemented, and finally delineates specific geometries commonlyemployed. This system is therefore related to the pump itself and is unrelated toany consideration external to the pump or even to the materials from which it may beconstructed.Under this system, all pumps may be divided into two major categories, **Dynamic**, in which energy is continuously added to increase the fluid velocities within the machineto values greater than those occurring at the discharge so subsequent velocity reduction within or beyond the pump produces a pressure increase, and **Displacement**, in which energy is periodically added by application of force to one or more movable boundaries of any desired number of enclosed, fluid-containing volumes, resulting in a direct increase in pressure up to the value required to move the fluid through valves or ports into the discharge line. Dynamic pumps may be further subdivided into several varieties of centrifugal and other special-effect pumps. Table (3-1) presents in outline form a summary of the significant classifications and sub-classifications within this category. Displacement pumps are essentially divided into reciprocating and rotary types, depending on the nature of movement of the pressure-producing members. Each of these major classifications may be further subdivided into several specific types of commercial importance, as indicated in Table (3-2).

Table (3-1)-Types of displacement pumps

<table>
<tr><th colspan="4">Displacement Pumps</th></tr>
<tr><th colspan="2">Reciprocating</th><th colspan="2">Rotary</th></tr>
<tr><td>Piston</td><td>Diaphragm</td><td>Single</td><td>Multiple</td></tr>
<tr><td>Steam</td><td>Simplex</td><td>Vane</td><td>Gear</td></tr>
<tr><td>Single</td><td>Multiplex</td><td>Screw</td><td>Lobe</td></tr>
<tr><td>Double</td><td>Fluid operated</td><td>Peristaltic</td><td>Circumferential</td></tr>
</table>

Table (3-2)-Types of dynamic pumps

<table>
<tr><th colspan="7">Dynamic Pumps</th></tr>
<tr><th colspan="3">Centrifugal</th><th colspan="4">Special effect</th></tr>
<tr><td>Axial</td><td>Mixed</td><td>Peripheral</td><td rowspan="5">Jet</td><td rowspan="5">Gas left</td><td rowspan="5">Hydraulic Ram</td><td rowspan="5">Electro-magnetic</td></tr>
<tr><td>Single stage</td><td>Single suction</td><td>Single stage</td></tr>
<tr><td>Multistage</td><td>Double Suction</td><td>Double Stage</td></tr>
<tr><td>Closed impeller</td><td>Self-priming</td><td>Self-priming</td></tr>
<tr><td>Open impeller</td><td>Non-priming</td><td>Non-priming</td></tr>
</table>

(3-2-1) Positive displacement pumps:

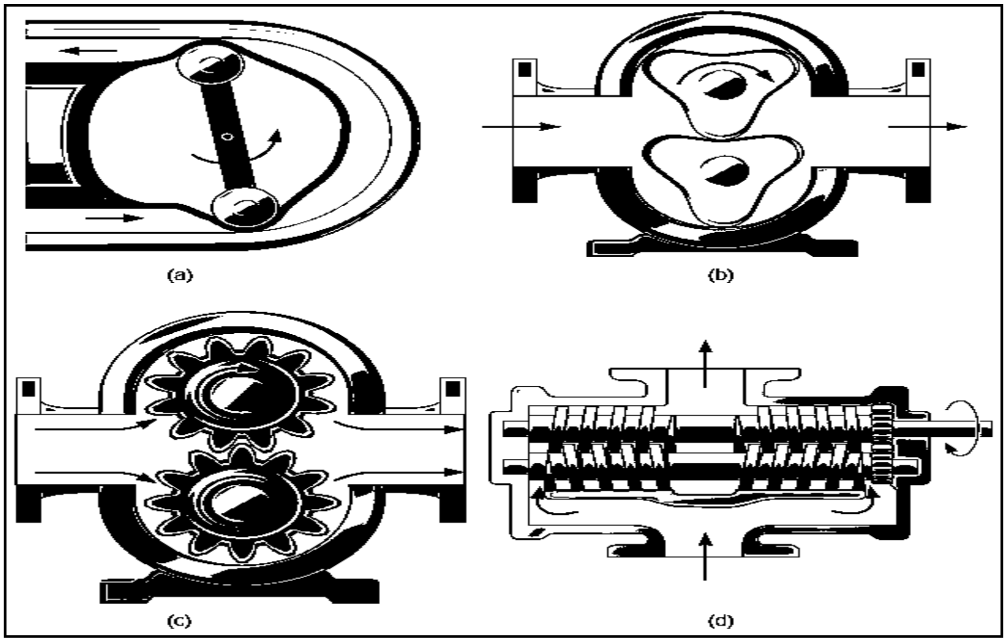


Figure (3-4)-Types of positive displacement pumps

In these pumps, fluid is sucked into an expanding volume and then pushed along as that volume contracts, but the mechanism that causes this change in volume differs greatly among the various designs. Some designs are very simple, like the flexible-tube peristaltic pump (Figure 3-4 a) that compresses a tube by small wheels, pushing the fluid along. Others are more complex, using rotating cams with synchronized lobes (Figure 3-4b), interlocking gears (Figure 3-4 c), or screws (Figure 3-4 d). Positive-displacement pumps are ideal for high-pressure applications and where precise amounts of liquid are to be dispensed or metered.A well-sealed positive displacement pump can create a significant vacuumpressure at its inlet, even when dry, thus it is able to lift a liquid from several meters below the pump and known byself-priming pump. The rotor of a positivedisplacementpump runs at lower speeds. Their volume flow rate cannot be changed unless the rotation rate is changed.

(3-2-2) Dynamic pumps:

There are three main types of dynamic pumps that involve rotating blades called impeller blades or rotor blades, which impart momentum to the fluid. For this reason they are sometimes called roto-dynamic pumps or simply dynamic rotary pumps. There are also some non-rotary dynamic pumps, such as jet pumps and electromagnetic pumps. Dynamic rotary pumps are classified by the manner in which flow exits the pump: centrifugal flow, axial flow, and mixed flow. In a centrifugal-flow pump, fluid enters axially (in the same direction as the axis of the rotating shaft) in the center of the pump, but is discharged radially (or tangentially) along the outer radius of the pump casing. For this reason centrifugal pumps are also called radial-flow pumps. In an axial-flow pump, fluid enters and leaves axially, typically along the outer portion of the pump because of blockage by the shaft, motor, hub, etc. A mixed-flow pump is intermediate between centrifugal and axial, with the flow entering axially, not necessarily in the center, but leaving at some angle between radially and axially.[6]

Chapter {4}

SYSTEM DESIGN

(4-1) General description:

To design the system by specific characteristics, real assumptions must be made for accuracy. The systemwill supposed to be installed on streamby an average velocity of (3 m/s), the maximum depth of the stream surface under the bank level is (6 m), and the minimum depth is (0.5 m).Generally, the system consists of many parts connected and dependent on each other [Figure (4-1)]. The wheel is supported by a holding rack close to the stream bank and attached with two separated floating platforms for every two columns parallel to stream direction, and the wheel with the other parts (shaft, bearings, pumps) are installed on a square planchthat can be moved up and down with the holding rack according to the stream level. The shaft and pumps are connected with the wheel horizontally and supported by three bearings which are more close to the wheel and pumps. The pump is joined with the shaft closely to minimize loss of energy between system parts. The pumps draw and deliver the water by hoses to adjust with movement of the main planch. The suction hose has a strainer on the part that inside the stream [Figure (4-2)]. The discharge hose is connected to a steel pipe on the stream bank, which divides into two branches one of them is connected up to a storage tank and the other goes toward for direct use. Over flow pipe is connected up to the storage tank and discharge in the stream. Valves are used to control the usage of extracted or stored water, two valves just after the main pipe point ofdividing, one of them in the pipe that goes up to the storage tank and the other in the pipe goes toward, and another valve in the discharge pipe of the storage tank.

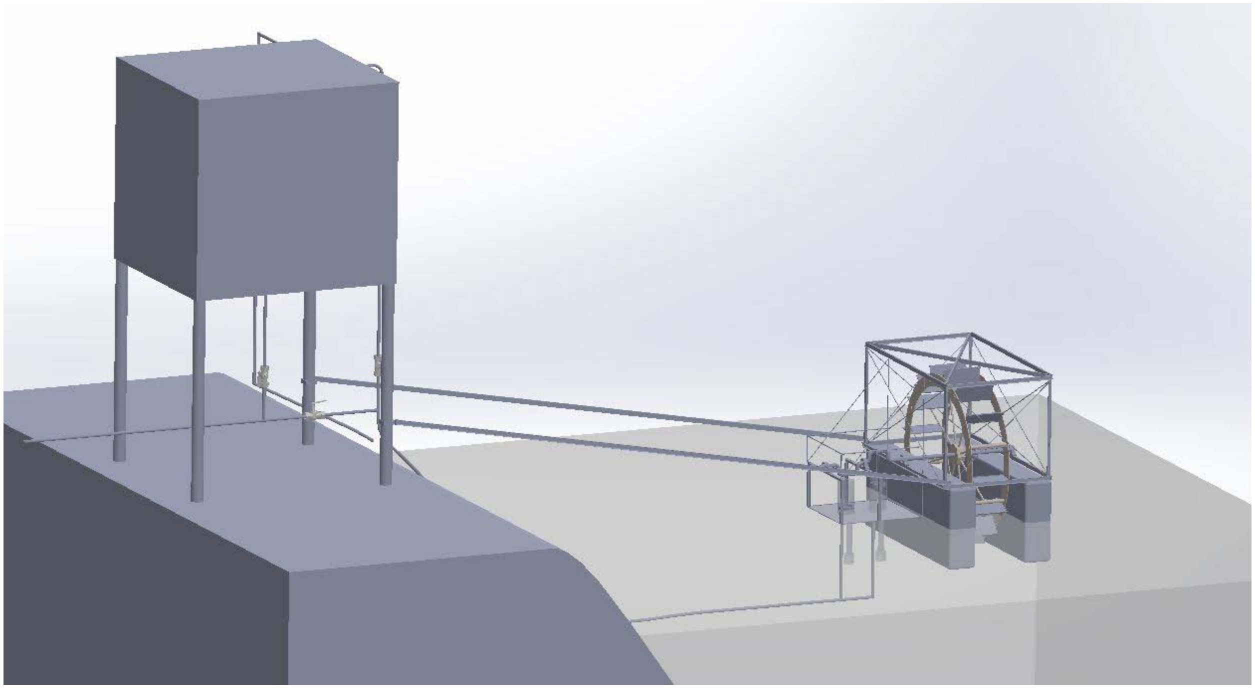


Figure (4-1)-Simulation of system general design

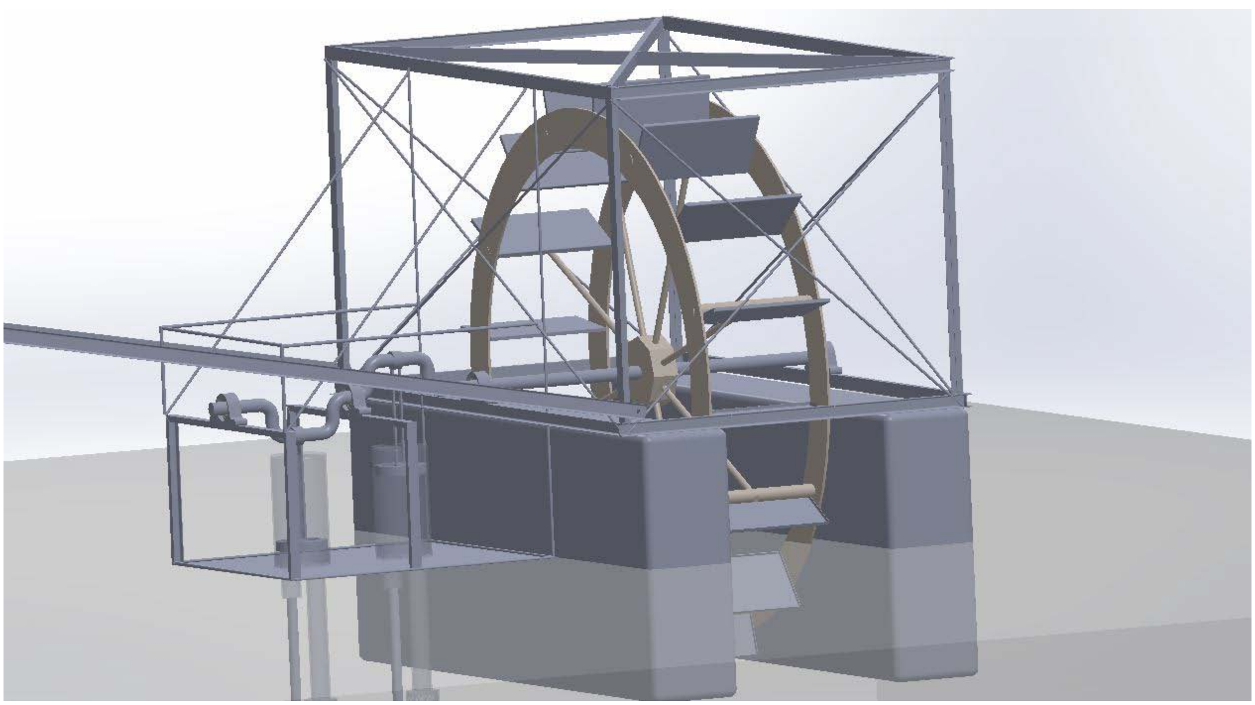


Figure (4-2)-Simulation of wheel with rack assembly

(4-2) Wheel design:

In the case of swift moving stream, the equation for spouting velocity describes the speed of any moving mass "velocity squared divided by two times a gravitational constant". This will convertvelocity into a "head". When designing an undershot wheel the "head" must be known,since the optimum diameter of the wheel equal to(3 to 6 multiplied by the head).[7] The stream velocity in this case is (3 meters per second), so:

$H = V^2 / (2*g) = 3^2 / (2*9.81) = 0.46$ m

In other words, the water is moving as fast as it would if it had fallen (0.46 meter). The wheel should then be at least:

$D = 3 * 0.46 = 1.38$ m to $D = 6 * 0.46 = 2.76$ m

Whenever possible, the wheel is better to be as large as possible. However, there would be no improvement in performance if it were larger than (2.76 m). The working diameter is:

$Dw = D – H = 2.76 – 0.46 = 2.3$ m

Working circumference is:$Cw = \pi * Dw = 3.14 * 2.3 = 7.22$ m

The blades shall be submergeda distance equal to the head.[7] Therefore, the spacing between the blades shall be less than head ($S < 0.46$m), ($S = 0.45$ m), so, the blades number is:

$n = Cw / S = 7.22 / 0.45 = 16$ blades

The wheel width (w) shall be less than the ratio (1/2 * Dw), so, (w = 0.8 m). The annulus width (t) must be at the range of(t/r = 0.05 to 0.25), so, (t = 0.15 * 1.15 = 0.173 m).[7] Part of every blade shall be out of the annulus by (0.15 m)and they will be radial, so, (blade width = wheel width = 0.8 m)&(blade length = 0.3 m)[Figure (4-3)].

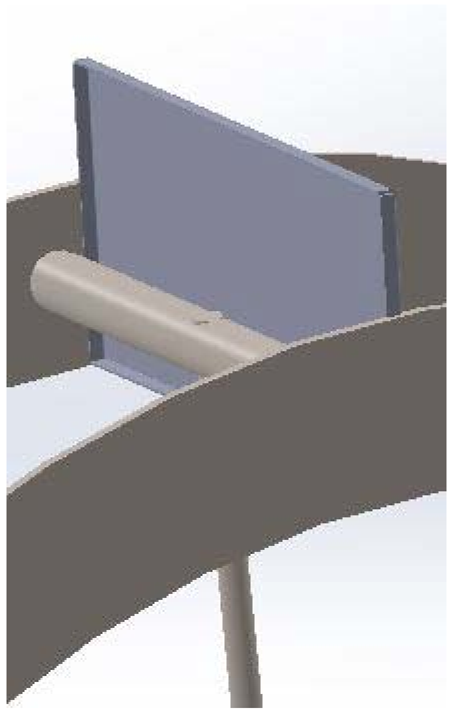


Figure (4-3)-Sample of a blade with the holder and annulus.

The most efficient energy transfer occurs when the wheel speed is between 67% and 90% of the water speed.[7]

$Vw = V * 0.67 = 3 * 0.67 = 2.01$ m / sec = 120.6 m / min

$Nw = 120.6 / 7.22 = 16.7$ rev / min(rpm)

$\omega = (2*\pi*Nw) / 60 = 1.75$ rad / sec

The effective power or torque is calculated according to the angles of the 5 blades inside the stream at every moment, one of them is normal to the free stream, two of them are inclined by an angle of (45°), the others areinclined by an angle of (30°), so, the calculations are as following:[5]

For the blade that is normal to the stream, the relative velocity with which the water strikes the blade is:

$V_{relaive} = V – V_w = 3 – 2.01 \approx 1$ m/sec

Volume of water striking the blade per second is:

$Q = A * V_{relaive} = (0.3*0.8) * (1) = 0.24$ m³/sec

Mass of water striking the blade per second is:

$\dot{m} = \rho * Q = 10^3 * 0.24 = 240$ kg/sec

For the blade that is normal to the stream, Force exerted by water on the blade in the direction of the stream is:

$F_x(90°) = \dot{m} * (V_{relaive} - V_{final}) = 240 * (1-0) = 240$ N

For the blade that is inclined by an angle ($\theta = 45°$) to the stream, theforce exerted by water on the blade in the direction normal to the stream is:

$F_n(45°) = \dot{m} * [(V_{relaive} * \sin\theta) - V_{final}) = 240 * [(1 * 0.7) – 0] = 168$ N

Force exerted by water on the blade in the direction of the stream is:

$F_x(45°) = F_n(45°) * \sin\theta = 168 * 0.7 = 117.6$ N

For two blades: $F_x(45°)_t = 117.6 * 2 = 235.2$ N

For the blade that is inclined by an angle (θ= 30°) to the stream, the force exerted by water on the blade in the direction normal to the stream is:

Fn(30°) = ṁ * [(Vrelaive * sin θ) -Vfinal)

= 240 * [(1 * 0.5) – 0] = 120 N

Force exerted by water on the blade in the direction of the stream is:

Fx(30°) = Fn(30°) * sin θ = 120 * 0.5 = 60 N

For two blades: Fx(30°)t = 60 * 2 = 120 N

Fxt = Fx(90°) + Fx(45°)t + Fx(30°)t = 240+235.2+120= 595.2 N

Power = Fxt * Vw = 595.2* 2.01 = 1196.352N.m/sec or (Watt)

= 1.196≈ 1.2 Kw ≈1.58 HP

Torque = Power / ω = 1.2 / 1.75 = 0.686kN.m (KJ)

Blade attachment to the side wall will be made by attaching strips to the inside of the side wall to fasten the buckets to. The annulus shape is of side wall and the inside of the bucket is accessible from the inside. This makes closing off the inside of the bucket simpler because the necessary pieces can be inserted through inside.

The two side walls shall be attached to each other by eight horizontal welded solid pipes distributed evenly (with the blades) from each other in the inside diameter of the annulus, their length is equal to the wheel width (0.8 m) and their diameter is (5 cm). Each one of these solid pipes is welded in the middle to a radial solid pipe by the same diameter and length of (1 m), and they gathered together in the wheel center and welded to an octal sleeve by an inside diameter of (55 cm), thickness of (20 cm).

All the wheel components will be made of Aluminum alloy, because they are subject all the time to the water and the design must satisfy the weight, hardness and water resistance requirements.

Table (4-1)-Properties of aluminum

Property	***Value***
Atomic Number	13
Atomic Weight (g/mol)	26.98
Valency	3
Crystal Structure	FCC
Melting Point (°C)	660.2
Boiling Point (°C)	2480
Mean Specific Heat (0-100°C) (cal/g.°C)	0.219
Thermal Conductivity (0-100°C) (cal/cms. °C)	0.57
Co-Efficient of Linear Expansion (0-100°C) ($x10^{-6}$/°C)	23.5
Electrical Resistivity at 20°C (&#937.cm)	2.69
Density (g/cm^3)	2.6898
Modulus of Elasticity (GPa)	68.3
Poissons Ratio	0.34

(4-3) Transmission shaft:

The shaft withstands the wheel weight, in addition to the rotational movement, so,the bearing is located as close as possible to the wheel. Bearings that hold the shaft at the two opposed sides are supported by crossed steel bars attached in each side to the vertical steel bars compose the holding rack. The distance between the wheel bearings is (2 m). Shaft diameter is (6 cm). The shaft is attached to the sleeve by a bolt radially through the sleeve and shaft center with length of (0.6 m) and diameter of (3.5 cm).

Slider and crank mechanism is used because there is no way for attachment of the wheel directly to the piston rod because of design movability requirements and to prevent bending moments on the pump piston. The beginning offirst crank part in the shaft is at a distance of (0.3 m) from the last wheelbearing, with horizontal length of (0.4 m) and vertical length of (0.3 m) for each one of them, for consideration of stroke length for the pump piston.

Stroke is easily adjustable by attaching the crank pin to the shaft via a flange plate with holes drilled at various distances from the rotation axis, through which the crank pin can be fixed.

Shaft material is stainless steel because of its hardness and sustainability properties.

Table (4-2)-Mechanical Properties of stainless steel

Property	***Value***
Grade	303
Tensile strength (MPa)	500
Proof stress 0.2% (MPa)	190
Elongation A5 (%)	35
Hardness Rockwell (HB)	262max

Table (4-3)-Physical Properties of stainless steel

Property	***Value***
Density (g/cm^3)	8.03
Melting point (°C)	1455
Modulus of elasticity (GPa)	193
Electrical resistivity (Ω.m)	$0.072 * 10^{-6}$
Thermal conductivity at 100°C (W/m.K)	16.3
Thermal expansion at 100°C (/K)	$17.3 * 10^{-6}$

(4-4) Pumps& pipes:

The most reasonable type to use in this system is thepositive displacement pump since we have a relatively slow rotation speed for the wheel. The design is trying to get ashigh capacity and high head as possible with considerations ofdurable, well manufactured unitat low cost, bore size, stroke length and head capacity. The speed surge on the wheel can be partially overcome by usingtwo single acting pumps that can be attached to the cranks of the wheel shaft.Such use will improve the overall efficiency of the system.In general the pressure peak will be a function of the peak piston velocity the pump bore size, the suction and delivery pipes size, length of and type used. The head required at the pump outlet will be made up of the actual change in elevation to the delivery pipe exit, friction loss in the pipes and the friction loss inside the pumps.There shall be speed fluctuations in the wheel which may be pronounced in smaller wheels working near their capacity. This is no particular disadvantage as long as the stall torque capacity of the wheel exceeds the minimum torque necessary to keep the pump moving.

Power calculated at the minimum average velocity of stream, by consideration of efficiency and losses during power transmission through the wheel, transmission shaft, pumps and other attached parts, the calculations shall be as following:

Power extracted from the wheel (efficiency of 67%) = 1.2 kW

Power extracted from the shaft (efficiency of 90%) = 1.08 kW

Power extracted at the pump (efficiency of 85%) = 0.918 kW

The peak head required for the pump will be the sum of the maximum depth of the stream below the bank level (6 m), the intake pipe length (1m), the average value of connections friction loss head is about (3 m) and the tank height above the bank level (9 m) so, there is a sum of (19 m) total head the pumps must deliver the water for it. So, according to the available power, design and head requirements the pump will be with diameter of (0.2 m), stroke length (0.5 m), so:

$Q = (\pi * d^2 /4) * L * N/60 = (\pi * 0.2^2 /4) * 0.5 * 16.7/60 = 0.0044 m^3/s$

$H = Power / (\rho * g * Q) = 918 / (10^3 * 9.81 * 0.0044) = 21.27$ m

It is obvious that the available head satisfies the system requirements. There are pressure variations in the delivery line but as long as they do not exceed the capacity of the pump and related mechanism thesevariations will cause no harm.Side loads on designed profile are very small and the sliding bearing on the outboard end of the pumps rod on the crank would easily absorb it. The pumps and cranks part of the shaft shall be covered by rectangular box with four side holes and movable upper side for maintenance. Twointake pipes with length of (2 m), diameter of (6 cm) with a strainer at their terminal are connected to the pump[Figure (4-4)].Delivery hoses by diameter of (6 cm) and length of (8 m) is used to adjust with the movable planch that holds the pumps. Non-return valves with the same diameter of pipes are mounted to the two intake pipes, the two outlet pipes of the two single acting pumps, also for the intake and outlet main pipes.

Galvanized iron pipes are used in this design for their hardness and sustainability.

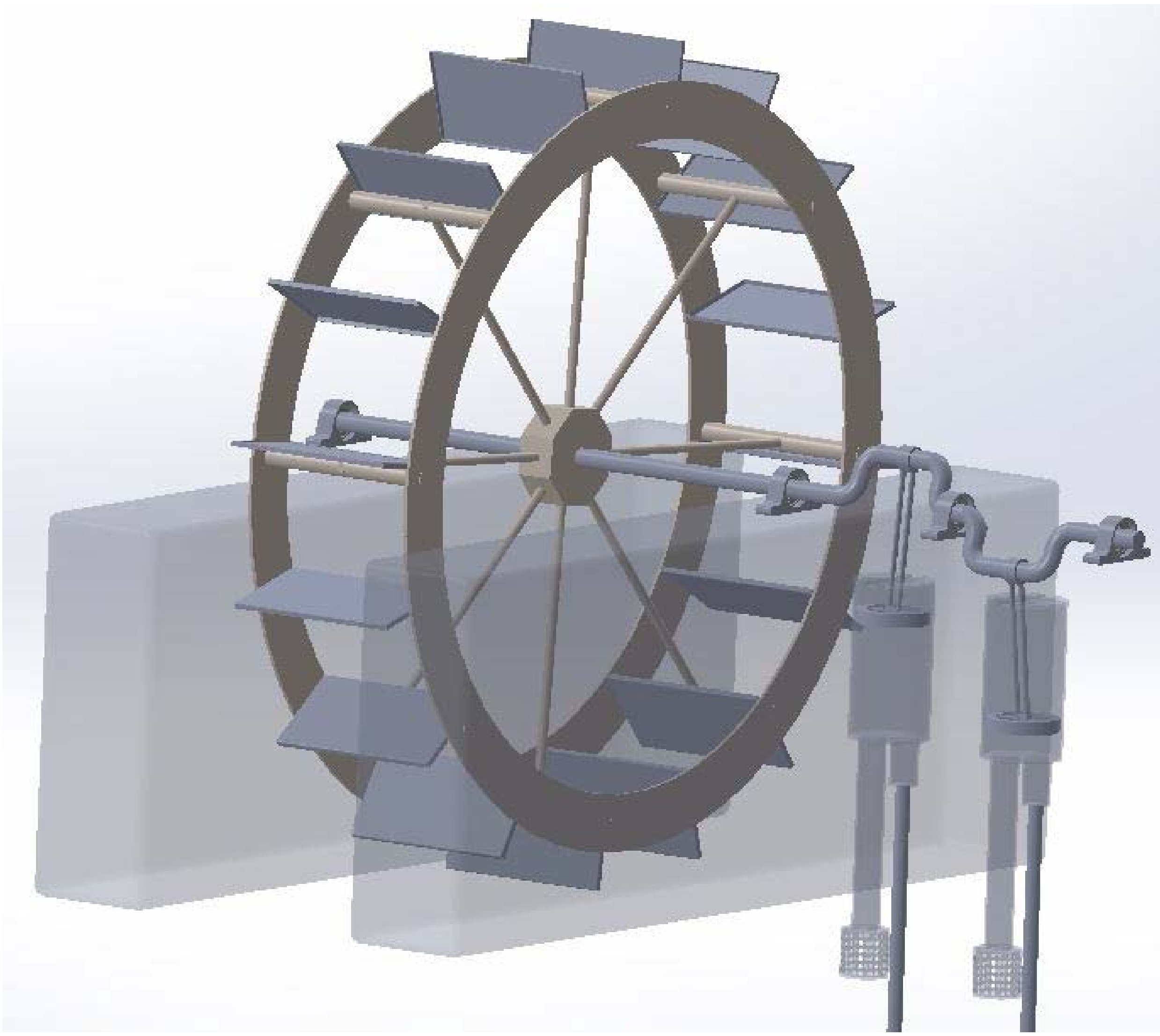


Figure (4-4)-Simulation of pumps with the crank shaft and bearings.

(4-5) Bearings:

Bearings are the most component that can keep the balance of the system. There will be four bearings in the system, two of them for the wheel part of the shaft and two for the pumps part of the shaft which attached to the piston inside the cylinder.

The most suitable bearing type for the system is the normal ball bearing since it can hold the weight and rotational movement of the shaft. According to the power load (1.58 HP), rotational speed (16.7 rpm) and diameter of the shaft (6 cm), the bearing size is (5.85 cm)to make considerations of clearance.

The bearings shall be welded from the bottom to the horizontal steel bars in the holding rack and the planch attached to it inside the rectangular box covering these parts to make sure of continuity and reliability for all the components.

(4-6) Holding rack:

The undershot wheel is normally set down on top of the stream with virtually no preparation of raceway necessary, but in many streams the rise and fall with heavy local rainfall is spectacular, so flood protection would be a major consideration for the design process. The simplest flood protection is a channel leading from the river to the installation, with inlet to the channel controlled to keep flood water in the main stream, but this option is not suitable since it would increase the cost of creating such design. So, the permanent solution is to make a holding rack by the simplest components with consideration of rigidity, flexibility and movability.

The foundation of the rack consists from two floating cubic platforms parallel to the stream running way andform like a channel, with dimensions of (3 m length, 0.5m width and2 m depth) to hold the weight of the system components.To withstand the stream flowing power, four main vertical steel bars are mounted on the bank (1 m) apart from each other with four cylindrical small bars on each side (the bank and the holding rack) attached with four horizontal steel bars move vertically with the stream level. The wheel cube beginning from wheel center with (1.5 m width, 3 m length and 1.5 m height).

Cubic cover box withthe bars holding the other two bearings of the crank shaft with the planch (that holds the two pumps and crank shaft) is welded to the wheel cube to move with it up and down.

(4-7) Storage tank:

The importance of this component is that it keeps the operation continuity of the system and regulates the water flow to the desired need. According to the available head and quantity of water per day, the dimensions of the tank would be as much as possible to store the most quantity of water in the maximum head that the pump can reach.

Since average water quantity rate is (15.84 m^3/hour) thentank storage capacity of(64 m^3) with length, width and height (4 m) for each dimension would be suitable. Tank inlet pipe is branched vertically from the main outlet pipe from the pump with length of (9 m), diameter of (6 cm) with normal valve at the beginning. The tank outlet pipe comes down vertically from the middle of the tank bottom with length of (8 m), diameter of (6 cm) with a normal valve at the end. Direct use pipe comes as an extension of the main outlet pipe with length of (8 m), diameter of (6 cm) with normal valve in the middle[Figure (4-5)].

Concrete or steel can be used for the tank to withstand water weight and environmental changes during different seasons of the year.

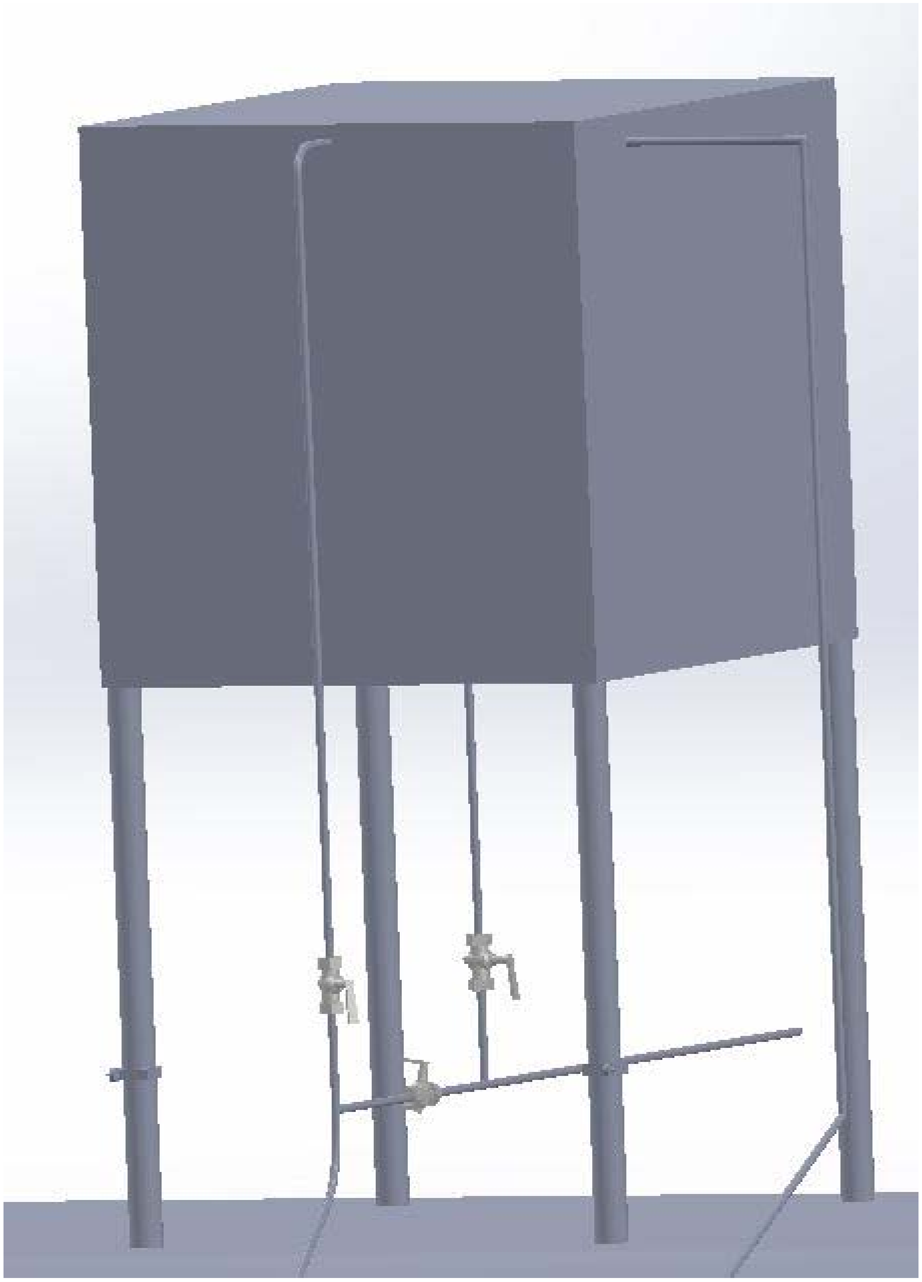


Figure (4-5)-Simulation of storage tank with distribution pipes and valves.

(4-8)Maintenance:

Local construction suggested the desirability of design details requiring only simple construction techniques. Since the installation is kindly remote, the maintenance operation must be clear and simple. The device should be such that repair, if any, could be carried out on site with parts and necessary tools light enough to be carried easily to the site. The usual considerations of safety must be applied.Pressure grease fittings using suitably wash resistant grease are used for bearings and parts need forlubrication. Precautions of protection can limit somewhat the exposure to water in these parts.

The parts used may be painted or varnished for a protective coating. This will obviously extend the life of these parts. Periodic repainting, if desired, can be carried out. The decision on painting must be made on purely economic grounds.

Packing box style lubrication with oily felt or rags could also be successful. Both methods rely on periodic attention, which could be of an intolerable frequency. There are also the crank pin and clevis pin at the slider to be lubricated. Finally, alignment is a potentially tricky problem because of the narrow tolerance allowable on parallelism of the wheel shaft and crank pin and on perpendicularity of the plane of the slider crank mechanism with the wheel shaft. There is the potential danger of excessive wear and short life if the lubrication is insufficient. This is not generally a suitable mechanism for unattended use in harsh conditions.

Chapter {5}

CONCLUSION &

RECOMMENDATIONS

(5-1) Conclusion:

There are changes in the surrounding circumstances with low limits of velocity and power extracted from flow energy of the specified stream, the considerations of minimum and maximum situations have been taken into account. Considering the long term benefits of low maintenance and operation costs,the system is relatively economic.

(4-1) Recommendations:

*Specific recommendations:

-Manufacturing a prototype for the system to get the results realistically.

-Finding more reliable and available materials alternatives.

-Developing of research results by designing more options for the system components.

-Making a financial proposal for the study and trying to market the system as a cost effective product.

*General recommendations:

-Spreading the application of this research to the public for getting more benefits.

-Research about moreresources ofclean energy available in the nature that can be utilized effectively beside flow energy.

REFERENCES

1- Zobaa, A. & Bansal, R. (2011). **Handbook of Renewable Energy Technology.** Singapore: World Scientific.
2- Da Rosa, Aldo V. (2005). **Fundamentals of Renewable Energy Processes.** USA: Elsevier Inc.
3- **Mechanical Design Fundamentals.** (2006). USA: McGraw-Hill.
4- Kothandaraman, C. &Rudramoorthy, R. (2007). **Fluid Mechanics & Machinery.** 2ndEd. New Delhi: New Age International.
5- Rajput, R. K. (2005). **Fluid Mechanics & Hydraulic Machines.**3rd Ed. India: S. Chand & Company Ltd.
6- Karassik, Igor; Messina, Joseph; Cooper, Paul &Heald, Charles. (2001). **Pump Handbook.** 3rd Ed. USA: McGraw-Hill.
7- http://en.wikipedia.org/wiki/Waterwheel (March 2014)
8- http://his.diva-portal.org/smash/get (January 2014)
9- http://www.newenergycorp.ca(January 2014)
10-http://www.zero.no/(January 2014)
11-http://www.ier-institute.org(January 2014)