Arab Academy for Science, Technology and Maritime Transport

College of Engineering and Technology

Mechanical Department

B. Sc. Final Year Project

Pumping (Water + Ai) Flow

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abstract

This project focuses on the investigation of the impact for flowing of water and air on the performance of a centrifugal pump. A test rig is used to study the effect of entering air in the suction line one the performance of a 1 hp centrifugal pump. This test rig consists of two acrylic tanks, about 3.5 m length pipes with elbows and joints for the pipe line construction, two inch diameter transparent PVC pipe with about 1 m length, 1700 rpm three phase electric motor, inverter, two Pressure Transducers and two flow control valves. Results show (H - Q), (eta - Q) and (shaft Power - Q) curves for the used pump in the discussed cases. From results, it can be found that as motor rotational speed increases, head and efficiency of pump increases. As mass of air entered the suction pipe increases, head and efficiency of pump

decreases. All results are found to be compatible with the previous data.

CHAPTER ONE

INTRODUCTION

1.1 History

1.1.1 History of Pumps

Today's post is a bit different from the ones we publish here on our blog. Today, we're heading back in time to take a closer look at the very start of the humble pump. Yes, though today's pumps are light-years ahead of their ancient counterparts, a travel back in history, gives us better appreciation of this simple yet ingenious device. Ever since 2000 BC, when the Egyptians invented a rudimentary device to draw water from wells, pumps have been an indispensable part of our lives. Though this first pump may seem too simple by today's standards, it has to be noted that it came about only after a thousand or so years of human existence on the planet.

1.1.2Mesopotamia – 3000 BC

The ancient empire of Mesopotamia is accredited with several modern-day inventions. The Mesopotamians were indeed an intelligent lot and had plenty of scientific thinking. Agriculture, writing, wine, the wheel, and domestication of animals are just a few of the things that this civilization introduced to the world. The ancient civilization of Mesopotamia lived in the regions of modern-day Iran, Turkey, Iraq and Syria. Though their invention wasn't a pump by today's definition, it's worth mentioning here They used a wooden lever that was placed adjacent to a water bank. On one end of the lever was a bucket and to the opposite end was attached a counterweight. When the lever was pushed down, the bucket filled with water and the counterweight bounced back the lever, bringing the bucket up. This was then emptied into a trough.

Fig.1.1. Mesopotamia.

1.1.3Egyptians – 2000 BC

The first pump invented by mankind was the Shadoof. And, the Egyptians are the ones who are credited for this invention, millennia back in 2000 BC. The Shadoof is a bucket that was tied to a rod or a rope and was used to raise water from deep wells.Though this doesn't accurately describe the workings of a pump, this is the first proof from history that states that man has always been looking for gadget to make it easy to transport water.

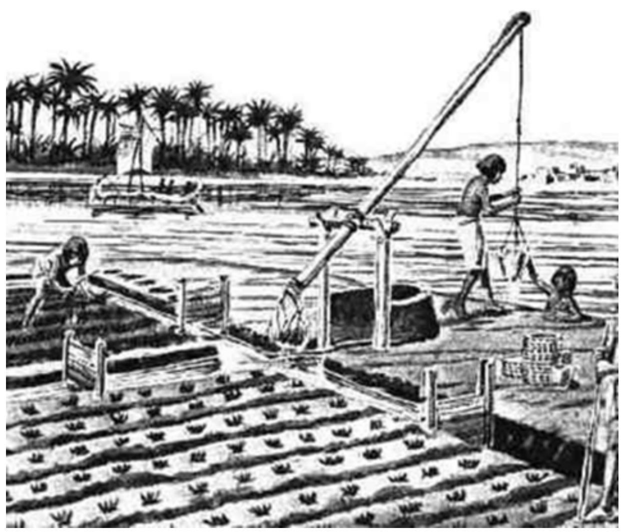

Fig.1. 2.greek pump.

1.1.4 Greeks – 3rd to 1st Century BC

The next big advances to pumps came during the era of the Greek civilization. Between the third and first centuries BC, the Greeks were at the zenith of their civilization and significant advances were made in science, technology, warfare and arts.The engineers of Hellen invented the water wheel, which was then used for irrigation and to generate power. It was during this period in history, that Archimedes came up with one of the best inventions of all mankind – the screw pump. It’s a simple but ingenious invention that is still seen today in various parts of the world. Rural areas that don’t have electricity use the screw pumps to raise water for irrigation.

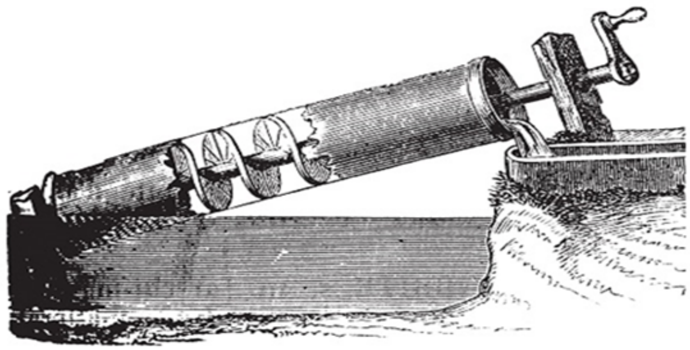

Fig.1. 3. greeks pump

1.1.5 Modern Day Pumps

After the fall of the great Roman Empire, pump technology became stagnant for nearly a millennium and a half. It was only during the Enlightenment Period that hydraulic science began to be focused on again. It was during this era that pumps had a rebirth and over the next couple of centuries, new ideas and inventions began to flood the market, all of which led to the design of modern day pumps.

Let’s take a look at few modern-day pumps and their inventors.

•Gear Pump – In the year 1593, a Frenchman named Nicolas Grollier de Serviere charted the early designs for a gear pump. Later in 1636, a German engineer named Pappenheim invented the double, deep-toothed rotary gear pump, that is still used for lubricating engines even today.

•Centrifugal Pump – This is one of the most common types of pumps used today and it was invented in the 17th century by Denis Papin, a French inventor. He used straight vanes for drainage. The centrifugal pump is a motor driven pump that pulls water by creating a suction force.

•Savery Pump – In the year, 1698, an inventor Thomas Avery created a pump that used steam for operation. The steam generated a vacuum which in turn pulled up water.

•Axial Flow Pump – Since the 1940s, axial pumps are a constant presence in water services. Apart from this application, the axial flow pump is also used extensively in the industrial and commercial sectors.

•Jet Pump – This is similar to the centrifugal pump but is mainly used to raise water up from deep wells.

•Electromagnetic Pumps – This is mainly used in advanced applications like nuclear reactors. This is because electromagnetic pumps can handle very high temperatures. Hence, it’s ideal for applications that move liquid metals and other electrically conducive liquids. It uses an electromagnetic force to displace the liquids.

•Submersible pump, deep well turbine pump, seal-less vertical pump, bush pump, peristaltic pump, metering pump, magnetic drive pump, chopper pump, circulated pump,

1.1.6 Centrifugal Pump

We will talk a little bit about the history of these pumps. They date back to the 1600s. Back in 1687, it was documented that the first true centrifugal pump that was developed by Denise Pepin. After that, there are various modifications and design changes that have gone on through the years. In 1849 we had the first all-metal centrifugal pump was manufactured. In 1851 the design of the pump started to change to make them more efficient and effective at how they displace fluid. You start to see curved vein impellers developed in the mid-1800s. Here is a diagram that was created back in 1863, where it shows some of the early centrifugal pump designs. You can see here there are casing designs. There are impeller designs and they look very similar to what we deal with today. Based on our current understanding and design capabilities, we've certainly modified vein profiles and casing designs to optimize performance. But, it's very interesting to see that these concepts existed back in the 1800s. Here's another image of an early pump this would have been a steam-powered engine pump, again showing many of the same characteristics as what you would see today.

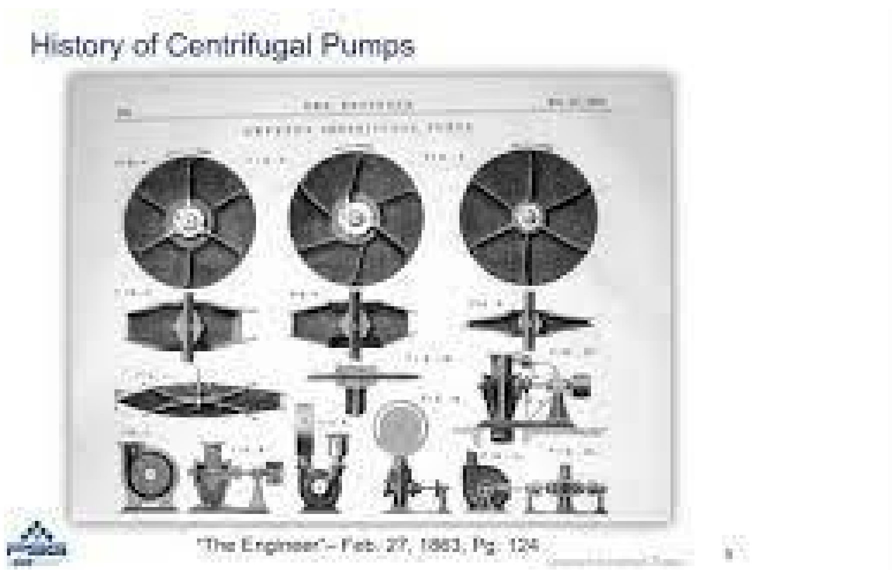

Fig.1.4.centrifugal pump.

1.2 What is a pump performance curve?

A pump performance curve indicates how a pump will perform in regards to pressure head and flow. A curve is defined for a specific operating speed (rpm) and a specific inlet/outlet diameter.

... The curve also shows the shut off head or the head that the pump would generate if operating against a closed valve.There are types of pumps can be classified by their method of displacement into positive-displacement pumps, impulse pumps, velocity pumps, gravity pumps, steam pumps and valveless pumps. There are three basic types of pumps: positive-displacement, centrifugal and axial-flow pumps.

1.2.1 How is pump performance calculated?

To determine pump efficiency you'll need to convert the capacity and head units into horsepower output. Capacity is the total water output, expressed in gallons per minute. Head is the distance from the source water to the pump's output, plus any pressure the pump places on the outlet. Head is expressed in feet. Also called a pump selection curve, pump efficiency curve, or pump performance curve, a pump curve chart gives you the information you need to determine a pump's ability to produce flow under the conditions that affect pump performance. Reading pump curves accurately helps you choose the right pump based on application variables such as:

- Head (water pressure)
- Flow (the volume of liquid you have to move in a given time period)

As you will see, you can also use pumps in parallel to increase flow. Centrifugal pump curves are useful because they show pump performance metrics based on head (pressure) produced by the pump and water-flow through the pump. Flow rates depend on pump speed, impeller diameter, and head.

1.2.2 what is head?

Head is the height to which a pump can raise water straight up. Water creates pressure or resistance, at predictable rates, so we can calculate head as the differential pressure that a pump has to overcome in order to raise the water. Common units are feet of head and pounds per square inch. (A pump curve calculator might offer different units such as Bar or meters of head).

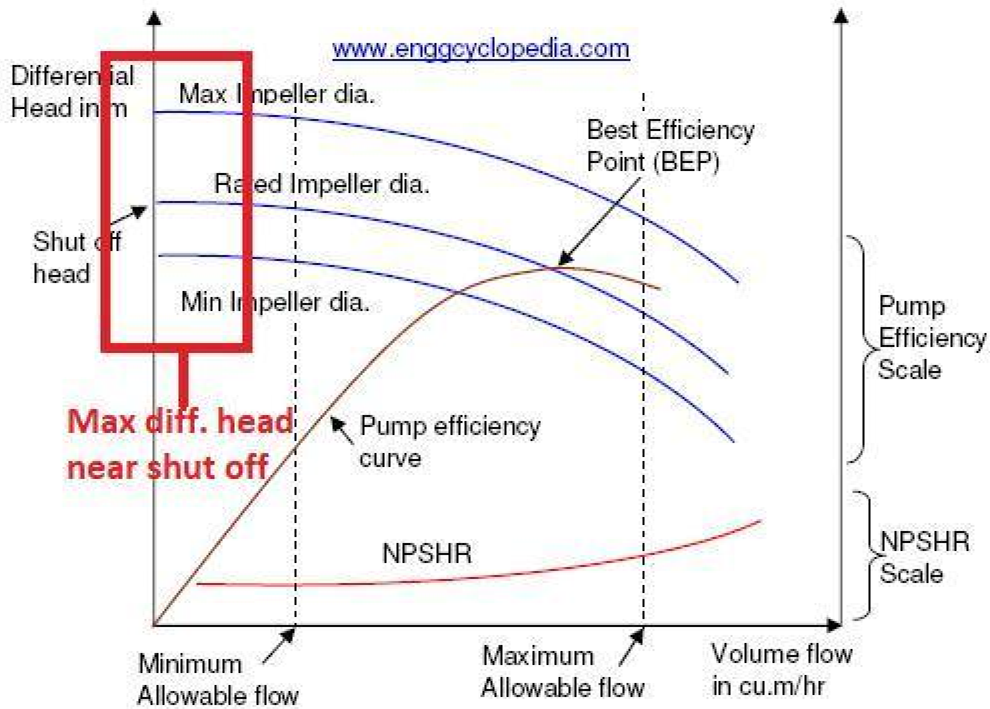

Fig.1.5.head

The equation of the pressure= rho*gh

Flow is the volume of water a pump can move at a given pressure. Flow is indicated on the horizontal axis in units like gallons per minute, or gallons per hour,

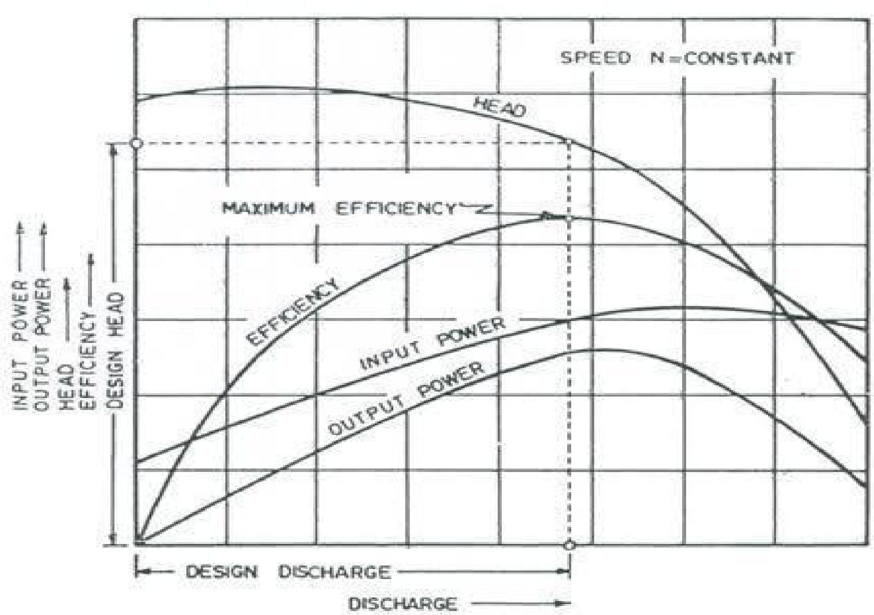

Fig.1.6.maximum head

1.2.3 what is total dynamic head ?

While pump curves help you select the right pump for the job, you first have to know the total dynamic head for the application.

Total Dynamic Head (TDH) is the amount of head or pressure on the suction side of the pump (also called static lift), plus the total of 1) height that a fluid is to be pumped plus 2) friction loss caused by internal pipe roughness or corrosion.

TDH = Static Height + Static Lift + Friction Loss

- Static Lift is the height the water will rise before arriving at the suction side of the pump.
- Static Height is the maximum height reached by the pipe on the discharge side of the pump.
- Friction Loss (or Head Loss) are the losses due to friction in the pipe at a given flow rate.

1.3Two-phase flow

1.3.1 What is two phase flow ?

multiphase flow is the interactive flow of two or more distinct phases with common interfaces in, say, a conduit. Each phase, representing a volume fraction (or mass fraction) of solid, liquid or gaseous matter, has its own properties, velocity, and temperatur

Types of two phase

1. Gas-liquid flows.

This is probably the most important form of multiphase flow, and is found widely in a whole range of industrial applications. These include pipeline systems for the transport of oil-gas mixtures, evaporators, boilers, condensers, submerged combustion systems, sewerage treatment plants, air-conditioning and refrigeration plants, and cryogenic plants. Gas-liquid systems are also important in the meteorology and in other natural phenomena.

2. Gas-Solid flow

Flows of solids suspended in gases are important in pneumatic conveying and in pulverised fuel combustion. Fluidised beds may also be regarded as a form of gas-solid flow. In such beds, the solid remains within the fixed container while the gas passes through. However, within the bed itself, both the gas and the solid are undergoing complex motions.

3. Liquid-Liquid flow

Examples of the application of this kind of flow are the flow of oil-water mixtures in pipelines and in liquid-liquid solvent extraction mass transfer systems. Solvent extraction equipment includes packed

Shapes of two flow phase

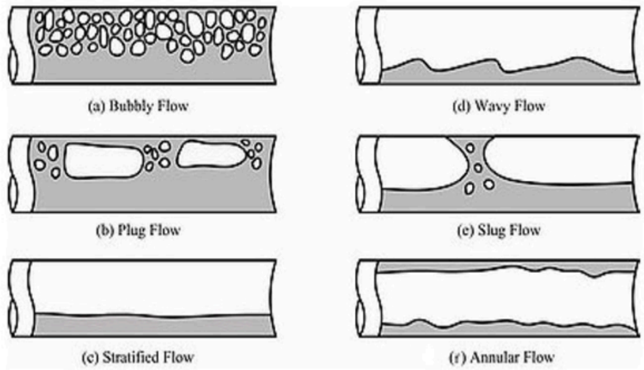

Fig.1.8.shapes of flow.

1.3.2 The fluid flow measuring

- Orifice Plate
- Venture Tube
- Flow Nozzles
- Variable Area

Fig.1.9. Orifice Plate.

1.3.2.1 Orifice Plate

Advantages:

- Orifice plate is very simplest
- Cost effective
- Have high pressure recover efficiency of 65 percent

Disadvantages:

- **It only support those fluid that are homogeneous is nature.**
- **It works under a limited viscosity of fluid**

Fig.1.10.Venture Tube

1.3.2.2 Venture Tube

Advantages:

- Perfect working behavior prediction.
- Very high pressure recovery efficiency of 90 %.

Disadvantages:

- Have high initial cost.
- Difficult to install and remove.
- Have limitation of minimum pipe diameter of 7.5 cm.

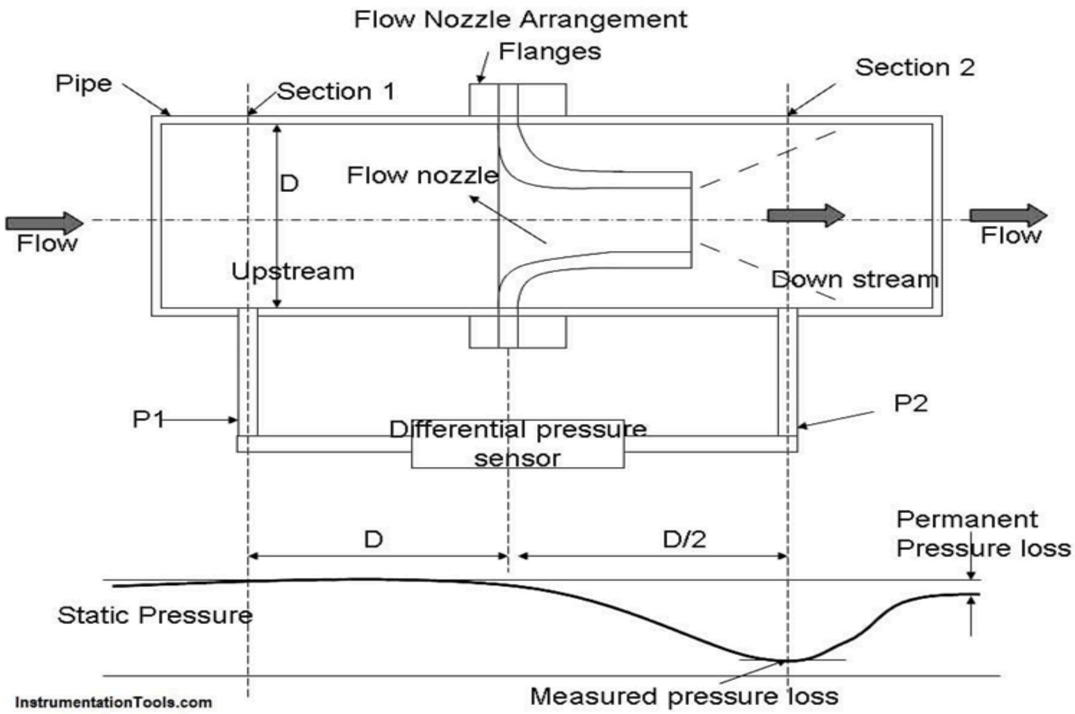

Fig.1.11.Flow Nozzles

1.3.2.3 Flow Nozzles

Advantages

- Installation is easy and is cheaper when compared to venturi meter
- It is very compact
- Has high coefficient of discharge.

Disadvantages

- Pressure recovery is low
- Maintenance is high
- Installation is difficult when compared to orifice flow meter.

Fig.1.12. Variable Area

1.3.2.4 Variable Area

Advantages

- Simple construction
- Easy to install and maintain
- Work perfectly for liquid and gas

Disadvantages

- Work only in vertical direction
- High pressure loss
- Limited rage for fluid viscosity

1.4 Introduction to three phase flow

Taitel, Barnea, and Brill (1995) noted that three phase flow stability research is rare, which is astonishing since it is so vital in the oil and gas industry. To research three phase flow, which is a comparatively untapped area of Transport Phenomena, will definitely be advantageous since this research can lead to plant optimization in the Oil and Gas industry. For example, predicting whether flow will be stable or unstable will be beneficial in the oil industry. This is because unstable flow involves high fluid velocities and, therefore, high pressures. High pressures can result in failure of pipelines. Shi, Cai, and Jepson (1999) explained that oil, if it is the continuous fluid, will lead to the pressure drop inside the pipe being high since the effective viscosity of the combined liquid phase becomes higher. These high pressures can lead to bursting of pipes.

Ghorai, Suri, and Nigam (2005) devised a model to predict hold-up as well as differences in pressure for gas-oil-water stratified flow through a horizontal pipe, which is an important initial step when examining flow stability for the stratified regime, as well as building transition characteristics. They computed the wall shear stress. Additionally, the impact of gas/liquid ratio (GLR) and pipe diameter in relation to pressure gradient and hold-up were studied. Furthermore, oil, specifically its viscosity and non-Newtonian characteristics, were investigated to observe how the hold-up and pressure gradient would be affected. A structural stability analysis was performed to investigate the developed model's sensitivity. Roscoe (1996) studied liquid holdup by the employment of a pulsed-neutron source.

1.4.1 Temperature effects

Researchers Gadelha, Neto, Swarnakar, and Barbosa de Lima (2013) studied the effect that temperature has on the thermo-hydrodynamics for the core-annular three phase passing of air, heavy-oil, as well as water, flow through a pipe that was horizontally positioned. They found that when the temperature of the fluids was increased upon entering the pipe, the superficial velocity of the oil was altered because its viscosity changed. Also, due to the reduction of the oil viscosity, the oil at the core increased in height because it was able to flow with less resistance and, thus, less oil accumulated at the core. Additionally, they also found that due to the oil and water viscosities both being decreased due to temperature increase, the resistance to flow of these liquids decreased and the pressure drop, therefore, decreased.

Three-phase flows are also of practical significance, and examples are as follows:

- Gas-liquid-solid flows: this type of system occurs in two-phase fluidised bed and gas lift chemical reactors where a gas-liquid reaction is promoted by solid catalyst particles suspended in the mixture. Another example is in froth flotation as a method to separate minerals and carry out gas-liquid reactions in the presence of a catalyst.[9]
- Three-phase, gas-liquid-liquid flows: mixtures of vapors and two immiscible liquid phases are common in chemical engineering plants. Examples are gas-oil-water flows in oil recovery systems and immiscible condensate-vapor flows in steam/hydrocarbon condensing systems.[19] Further examples lie in the flow of oil,water and natural gas. These flow can occur in condensation or evaporation of liquid mixtures (e.g. the condensation or evaporation of steam or hydrocarbons).[9]
- Solid-liquid-liquid flows: An example being sand mixing with oil and water in a pipeline.[9]

Multiphase flows are not restricted to only three phases. An example of a four phase flow system would be that of direct-contact freeze crystallization in which, for example, butane liquid is injected into solution from which the crystals are to be formed, and freezing occurs as a result of the evaporation of the liquid butane. In this case, the four phases are, respectively, butane liquid, butane vapor, solute phase and crystalline (solid) phase.

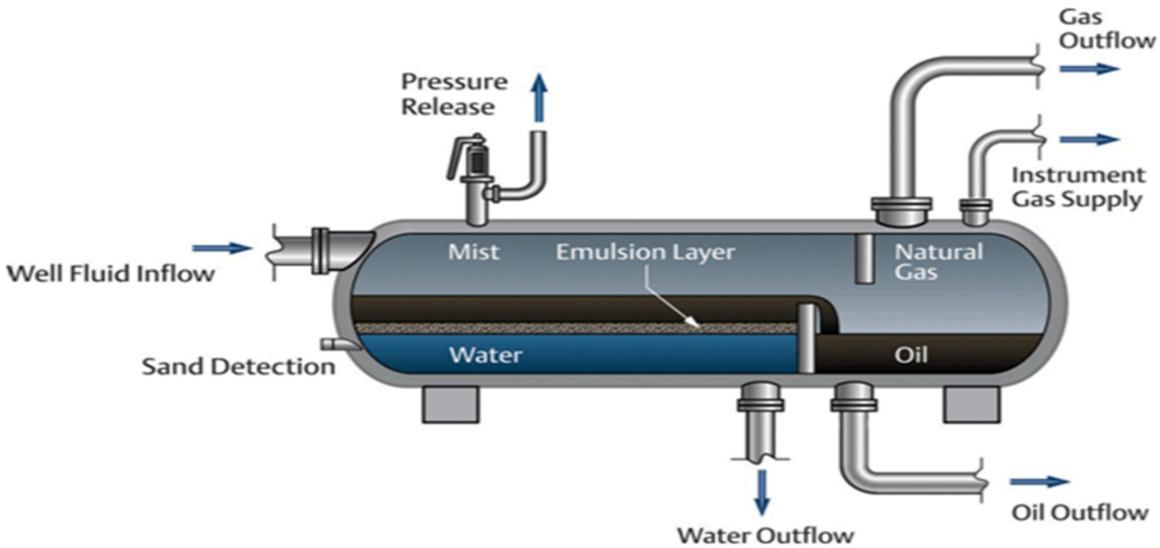

Fig.1.13

Three-phase separators differ from two-phase separators in that the liquid collection section of the three-phase separator handles two immiscible liquids (oil and water) rather than one. This section should, therefore, be

designed to separate the two liquids, provide means for controlling the level of each liquid, and provide separate outlets for each liquid. figure above show schematics of two common types of horizontal three-phase separators. The difference between the two types is mainly in the method of controlling the levels of the oil and water phases. An interface controller and a weir provide the control. The design of the second type , normally known as the bucket and weir design, eliminates the need for an interface controller.

The operation of the separator is, in general, similar to that of the two-phase separator. The produced fluid stream, coming either directly from the producing wells or from a free-water knockout vessel, enters the separator and hits the inlet diverter, where the initial bulk separation of the gas and liquid takes place due to the change in momentum and difference in fluid densities. The gas flows horizontally through the gravity settling section (the top part of the separator) where the entrained liquid droplets, down to a certain minimum size (normally 100 mm), are separated by gravity. The gas then flows through the mist extractor, where smaller entrained liquid droplets are separated, and out of the separator through the pressure control valve, which controls the operating pressure of the

separator and maintains it at a constant value. The bulk of liquid, separated at the inlet diverter, flows downward, normally through a downcomer that directs the flow below the oil–water interface. The flow of the liquid through the water layer, called water washing, helps in the coalescence and separation of the water droplets suspended in the continuous oil phase. The liquid collection section should have sufficient volume to allow enough time for the separation of the oil and emulsion from the water. The oil and emulsion layer forming on top of the water is

called the oil pad. The weir controls the level of the oil pad and an interface controller controls the level of the water and operates the water outlet valve. The oil and emulsion flow over the weir and collect in a separate compartment, where its level is controlled by a level controller that operates the oil outlet valve.

The relative volumes occupied by the gas and liquid within the separator depend on the relative volumes of gas and liquid produced. It is a common practice, however, to assume that each of the two phases occupies 50% of the separator volume. In such cases, however, where the produced volume of one phase is much smaller or much larger than the other phase, the volume of the separator should be split accordingly between the phases. For example, if the gas–liquid ratio is relatively low, we may design the separator such that the liquid occupies 75% of the separator volume and the gas occupies the remaining 25% of the volume. The operation of the other type of horizontal separator differs only in the method of controlling the levels of the fluids. The oil and emulsion flow over the oil weir into the oil bucket, where its level is controlled by a simple level controller that operates the oil outlet valve

1.5 Applications pumps

There are five applications they are discussed below

1.5.1 Sand Pumps

All of Submersible Slurry Pumps are suitable to be used for pumping sand. Sand is pumped mixed with water up to 70% of solids by weight. The mixture of liquid and particles of sand and gravel is pumped in a procedure often used as a convenient way of handling sand and gravel.

There are many applications for sand pumps: sand and gravel extraction, dredging of rivers, harbors and marines maintenance or construction, beach reclamation, filling of Geotubes, among others. Here below you can read about some of the multiple applications of sand pumps.

1.5.2 Sand and Gravel Mining

One of the most popular methods of sand and gravel extraction is by dredging the river beds or the seabed. The sand is in great demand because it is used in concrete construction and for hydraulic fracturing (fracking) in oil or gas extraction.Sand pumps are very successful in this application.

Fig.1.14 Sand and Gravel Mining

1.5.3 Harbor Maintenance

Because of sea currents and sedimentation in upstream effluents, the sea bed of harbors & marinas are frequently raised, making difficult the access of boats and vessels.Sand pumps are a convenient solution for harbor cleaning, along with our remote controlled mini-dredges and cable dredges.

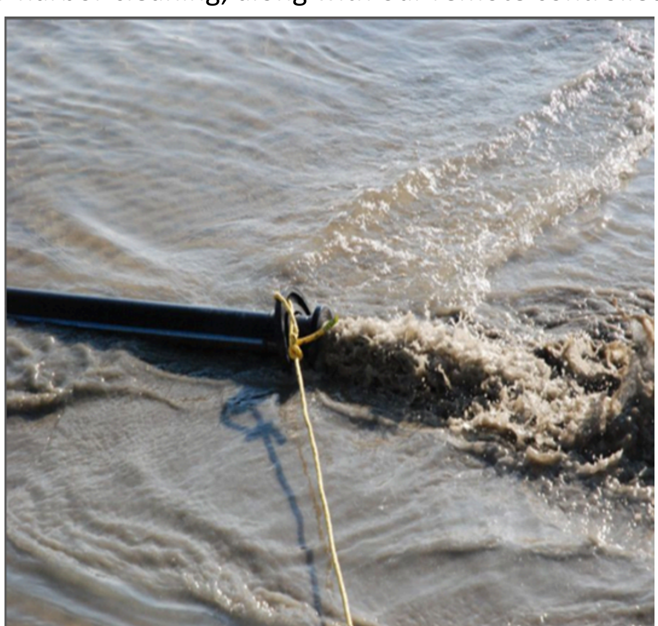

Fig.1.15

Fig.1.16

1.5.4 Beach Reclamation

Beach reclamation consist in restoring a beach adding sand to the areas of the beach affected by erosion. Sand pumps have been extensively used in beach reclamation / beach nourishments projects. Sand pumps can be combined with Cutterheads or side cutters to increase the efficiency when the sand is too compact.

Fig.1.17

1.5.5 Sand pump for Filling Geotubes

Geotubes, which are made of Geotextiles, are long tubes of permeable fabric. Filled with sand or soil, they are used to prevent coastal erosion caused by the sea, marine storms and high waves, creating a wall near the location to be protected. They are also used for slope stabilization and dewatering applications in construction sites.

Thanks to the high concentration of solids in the pumped mixture achieved when you use a Dragflow sand pump, the drainage process of the Geotube is faster. The variable rotation speed of the pump allows to easily adjust of the system production in order to guarantee best mixing with an eventual polymer and optimize fill up cycles.

Fig.1.18

1.6 Cavitation

The pump cavitation can be defined as it is the formation of a vapor bubble within the pump otherwise cavities in the fluid around an impeller at low pressure. Pump cavitation is essentially the accumulation of bubbles around an industrial pump's impeller this happens while liquid is moving through the pump. During this movement, when the liquid's bubbles burst or collapse, it creates a small energy shock wave in the liquid. Pump cavitation occurs when a pump is unable to keep up with the incoming flow of collapsing bubbles, which causes pumping capacity to decrease and the potential for overflow. Cavitation degrades the pump's performance, resulting in flow rates and discharge pressures that fluctuate. Not only does this affect productivity, it's extremely destructive to a pump's internal components.

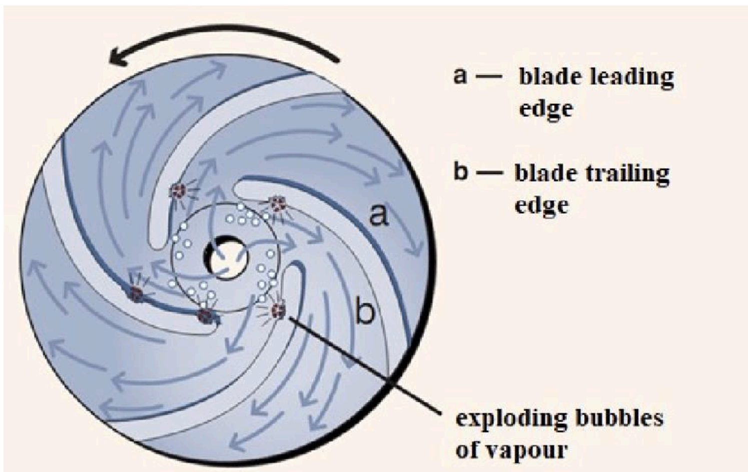

Fig.1.19.Cavitation in the pump.

1.6.1 Major factors causing pump cavitation

There are many reasons for causes of pump cavitation which include

- Impeller failure
- Extreme vibration
- Decrease of the flow, superior to required power utilization,
- Increase of the temperature of the pumped liquid.
- High fluid velocity at pump suction
- Unwanted liquid flow conditions caused by obstacles and reduced flow or force.
- Pressure drop at the pump suction nozzle.
- Objectionable flow conditions.

1.6.2 How to Recognize pump cavitation

Whenever any mechanical or structural issue occurs, it is very essential to maintain a reliable process for checking the act of pump to recognize the premature caution indications of cavitation. The following one or more symptoms can cause cavitation.

- **Noise**
- **Reduced Flow otherwise force**
- **Failure of bearing or seal**
- **Unpredictable power use**
- **The gradual destruction of an impeller**
- **Sudden vibrations**

1.6.3 What are the effects of pump cavitation

Possible reduction in pump capacity due to the vaporization, this drop in performance can be translated by drop of head at same flowrate or a change in the efficiency of the pump - Noise - Vibrations - Wear of impeller and pump housing due to the collapse of the bubbles and the pressure associated. It can decrease pump performance and lead to mechanical failure of the pump

Fig.1.20.of damage was caused by imploding air bubbles.

1.6.4 Types of cavitation

The cavitation phenomenon is generally characterized by the formation and growth of vapor bubbles in the fluid flow. The fluid-vapor interface can be under different shapes on which cavitation classification is based.

1.6.4.1 Two types of cavitation are possible:

Suction Cavitation

The suction cavitation occurs when a pump is below low-pressure otherwise high-vacuum conditions. When the pump does not receive sufficient liquid flow, then cavities otherwise bubbles will form at the impeller's eye. When the bubbles take over to the expulsion face of the pump, then the condition of fluid will change, reducing the bubble in the direction of fluid & cause it to collapse adjacent to the impeller face. An impeller has fallen victim toward suction cavitation which will include huge chunks otherwise extremely small bits of material missing, causing it to appear similar to a sponge.

This type of cavitation can cause due to some reasons which include the following.

- Clogged filters otherwise strainers
- Obstruction within the pipe
- Pump runs too far exact on the curve of the pump
- Piping design is poor
- Suction condition is poor

Fig.1.21.Suction Cavitation.

1.6.5 Discharge cavitation

The discharge cavitation occurs when the expulsion force of a pump is very high. As the expulsion pressure is high, the flow of fluid will difficult to flow out from the pump, Thus it flows within the pump among the impeller as well as the housing at extremely high velocity, that will cause a vacuum on the housing divider & the formation of the bubble. In this type of cavitation, the collapse of bubbles will activate strong shockwaves that will cause the pumps housing and the impeller tips. Then this type of cavitation is the reason for the impeller shaft toward the break.

This type of cavitation can cause due to some reasons which include the following.

- Obstruction within the pipe at expulsion side
- Strainers otherwise Clogged filters
- Pump runs too far exact on the curve of the pump
- Piping design is poor

Fig.1.22. Discharge Cavitation.

How to prevent pump cavitation

- Lower the temperature of the liquid at the pump intake.
- Reduce pump speed.
- Clean suction-side filters regularly to ensure that the flow is not restricted by blockages.
- Regularly check seals, joints and valves for leaks and wear.
- Choose pump materials that are resistant to cavitation damage 🎬 Minimize the number of bends in the suction line 🎬 Suction pipe and pump inlet connection must be of the same diameter

CHAPTER TWO

Theoretical Analysis

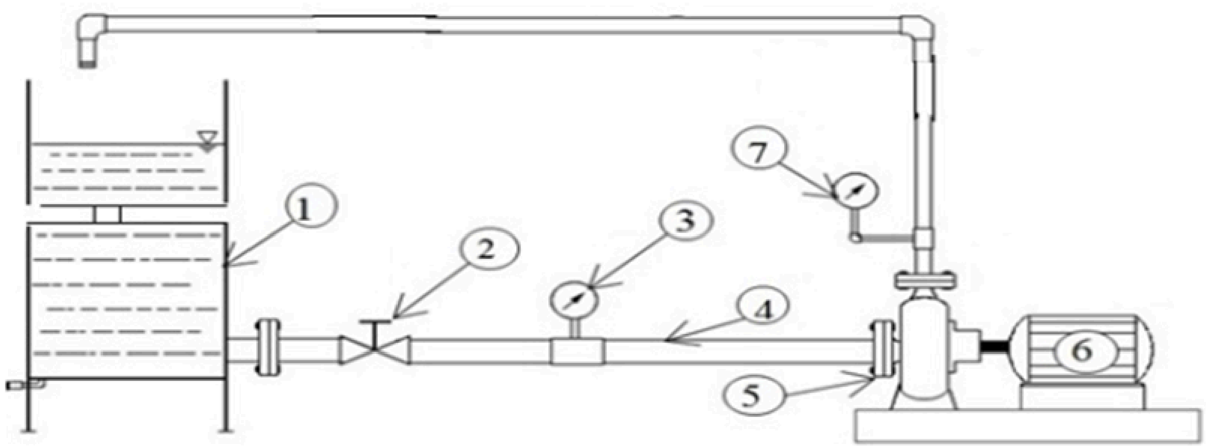

Fig.2.1 the components of the circuit.

1. Tank.
2. Gate valve.
3. Suction pressure gauge.
4. Suction line.
5. Pump.
6. Motor.
7. Delivery pressure gauge.

8. Flow control valve.

$H_{piping}=H_{st}+H_{total\ losses}+V^2/2g$

$H_{piping}=H_{st}+k_{cont.max}+F*L_1/d_1*v1^2/2g+F_{2*}L_2/d_{2*}V_2/2g$

$+K_{elbow}+f*l/d*+k_{elbow}$

$+f*ly/d*\ +K_{ent}$

$=h_{st}+v^2/2g*(K_{const}+f*l1/d*v^2/2g+$
$F*L_1/d_1*v1^2/2g+F_{2*}L_2/d_{2*}V_2/2g$

$+K_{elbow}+f*l/d*+k_{elbow}$

$+f*ly/d*\ +K_{ent}$

$+1)$

$Q=AV$

$H_{piping}=h_{st}+Q^2/2gA^2*(K_{const}+f*l1/d*v^2/2g+-+1)$

$H_{piping}=h_{st}+Q^2$

Q					
h_{piping}					

2.2-Relation between head and flow rate

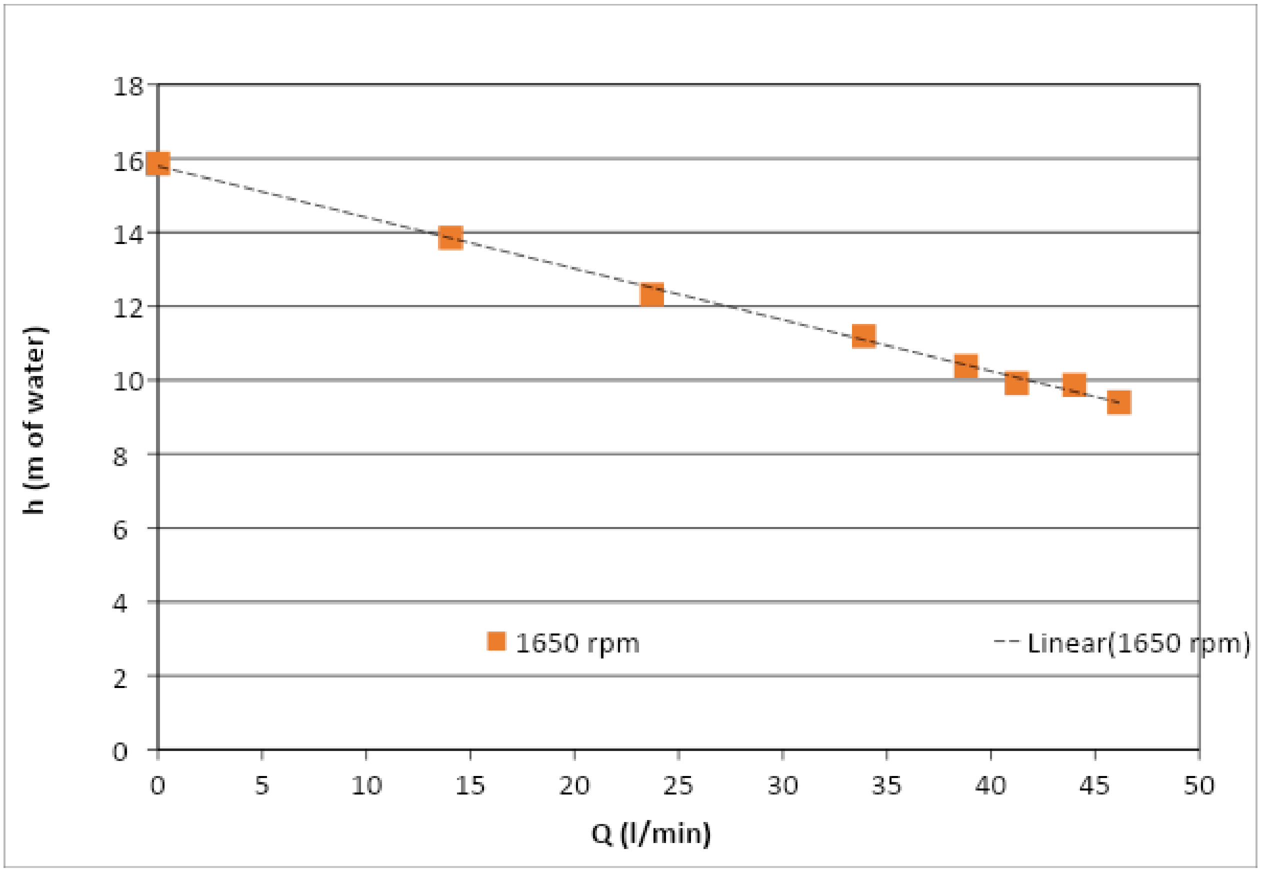

Fig 2.2

2.3-Relation between efficiency and flow rate

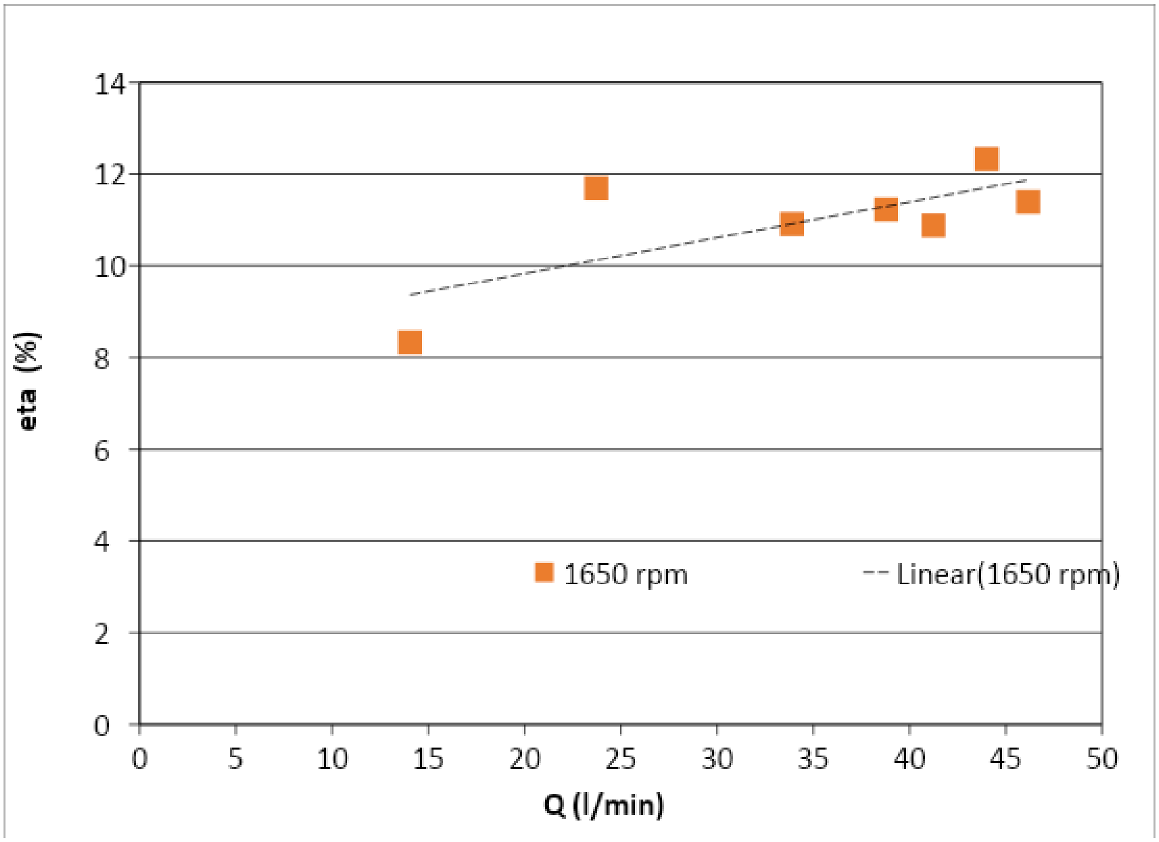
14
12
10
8
6
4
2
0
eta (%)
1650 rpm
Linear(1650 rpm)
0
5
10
15
20
25
30
35
40
45
50
Q (l/min)

Fig 2.3

2.4-Relation between shaft power and flow rate

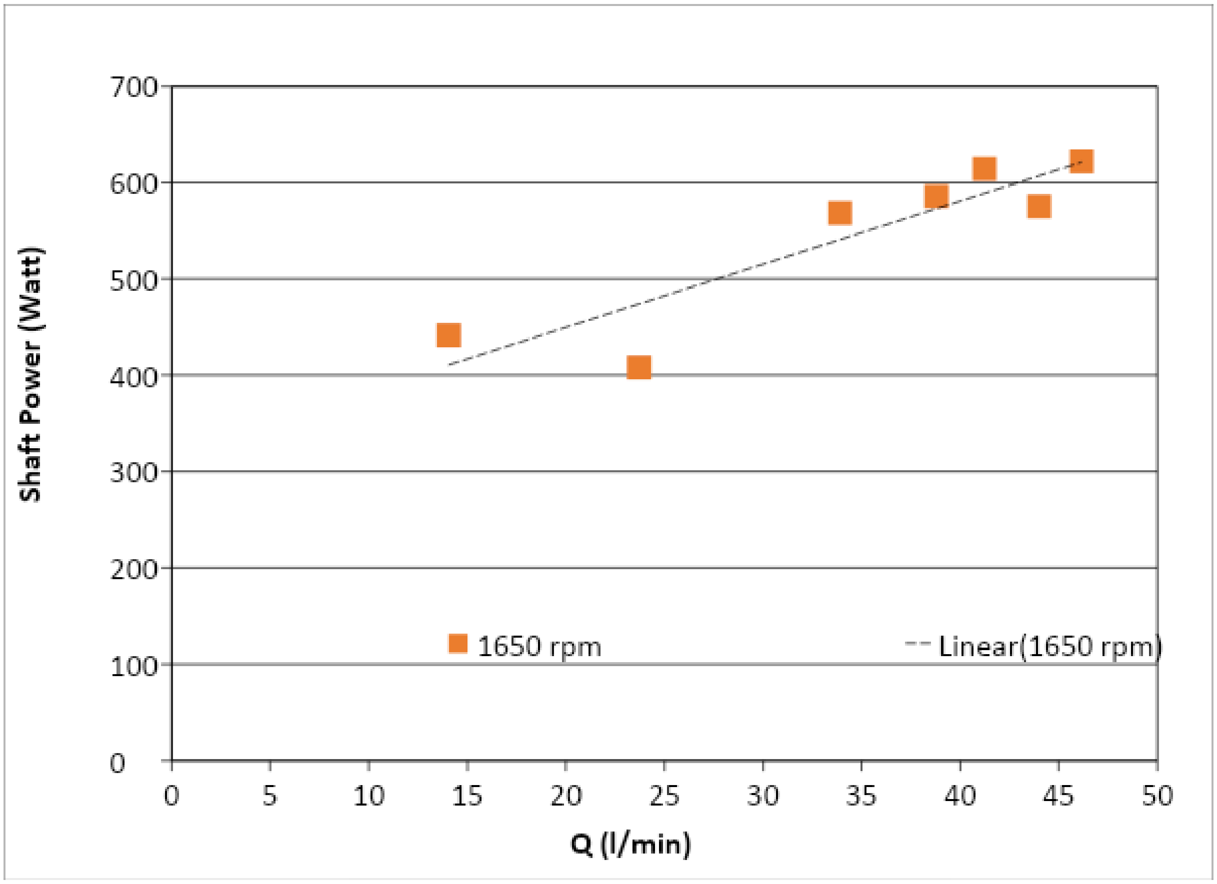

Fig2.4

Chapter 3

Experimental Analysis

Experimental Analysis

3.1 The parameters of the project

Fig3.1 the project parameters

The project idea:

Measure suction pressure and delivery pressure then calculate manometric head and calculate the flow rate by dividing volume by time then drawing the(H-Q) curve, also drawing the (shaft Power-Q) curve and finally the efficiency of the pump.

3.1.1 The project component:

1-Discharge tank:

Fig3.2 the discharge tank

This tank is used to calibrate the liquid we use in the project and the moving liquid in the pipes is to be poured into it

2-Intake tank:

Fig3.3 the main tank

This tank receives the liquid from discharge tank and passes through the pipes, we also use it to

put oil at certain concentrations of water.

3-Acrylic pipe:

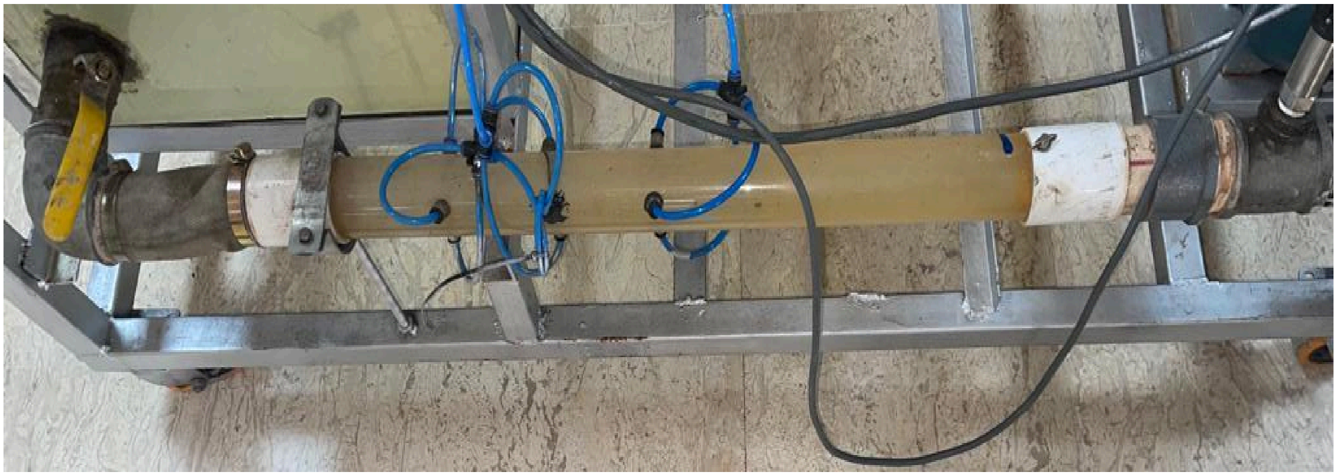

Fig3.4 the acrylic pipe

We use this pipe to see the fluid while passing through it and it contains air pipes to control the

amount of flow of air from the compressor to the pipe.

Dimensions:

Inner diameter =5cm

Outer diameter=6cm

4-Electric motor pump:

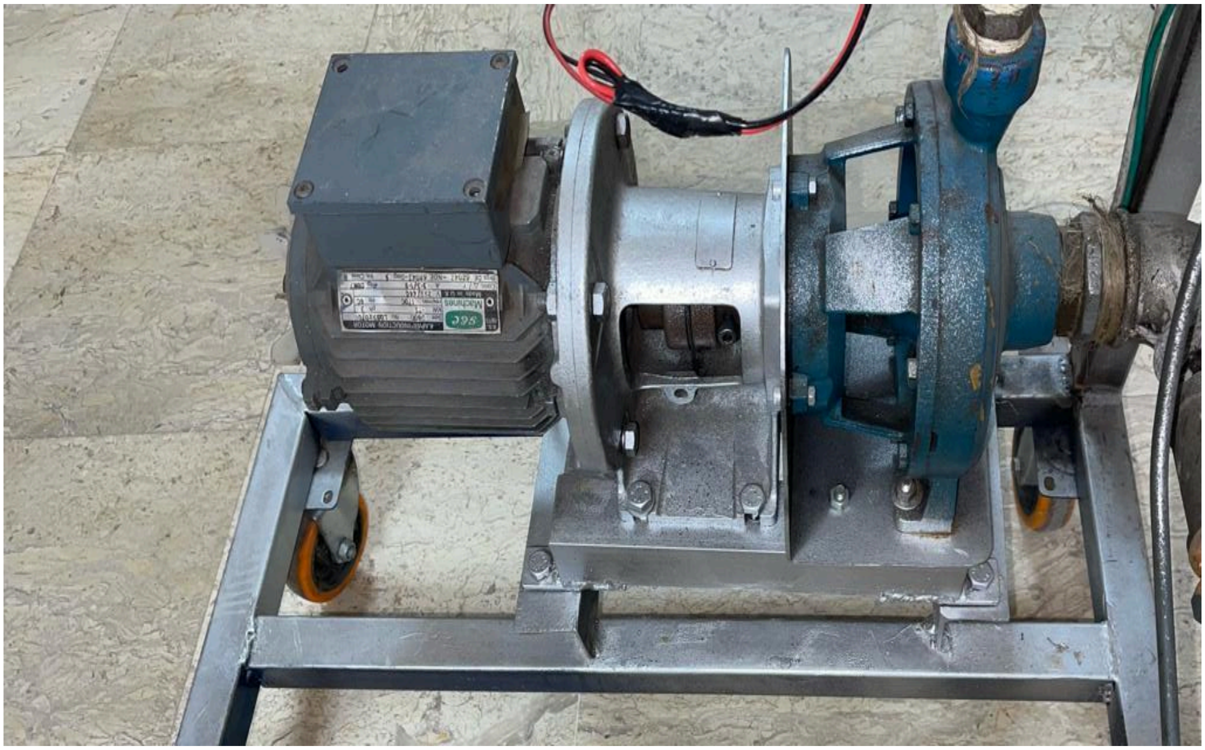

Fig3.5 the centrifugal pump

Electric motor pump is specifically designed to meet a variety of critical performance applications providing a wide range of hydraulic pressure options and we use “power pack” to operate the pump at different ranges of volts and revolutions.

Specifications:

Power=1700 Watt

Hp= 1

F=60Hz

255-440 volt

5-inverter

Fig3. 6 power pack

It is used to operate the electric pump motor at different voltages so we can operate the pump at different speeds.

6-Power supply

Fig3.7 power supply.

It is used to generate the pressure transducer and the digital air flow meter.

7- Digital Tachometer:

Fig3.8 digital tachometer

It is used to measure the number of revolutions of the centrifugal pump

8- Pressure Transducers

Fig 3.9 pressure transducers

We use them to measure suction and delivery pressures

Specifications:

scale = (0 to 4) bar

Output: from 0 to 5v

Power Dc 24 volt

Delivery pressure

Specifications:

scale = (-1 to 0) bar

Output: from 0 to 5v

Power Dc 24 volt

Suction pressure

9-Needle valve

Fig3.10 Needle valve

It is used to measure the flow rate that we want by measuring both the volume of tank and the

time needed to fill the tank

10-Flow Control Valve

Fig3.11 Flow control valve.

It is used to control the flow rate that we want to pass through pipe lines to enter the discharge

tank.

11- Air Compressor

Fig3.12 air compressor

An air compressor is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When tank pressure reaches its engineered upper limit, the air compressor shuts off. The compressed air, then, is held in the tank until

called into use

Specifications:

Power= 2 hp

Volume = 100 lit

12-Rotameter

Fig3.13 Rotameter

It is used to calibrate the digital air flow meter to minimize any measurement uncertainty by ensuring the accuracy of test equipment

3.2-Results

3.2.1-For Pure Water

Next figure shows the relation between head and flow rate for pure water at 1400, 1535 and 1650 rpm. From figure, curve of 1650 rpm shows the highest over 1535 and 1650 rpm curves.

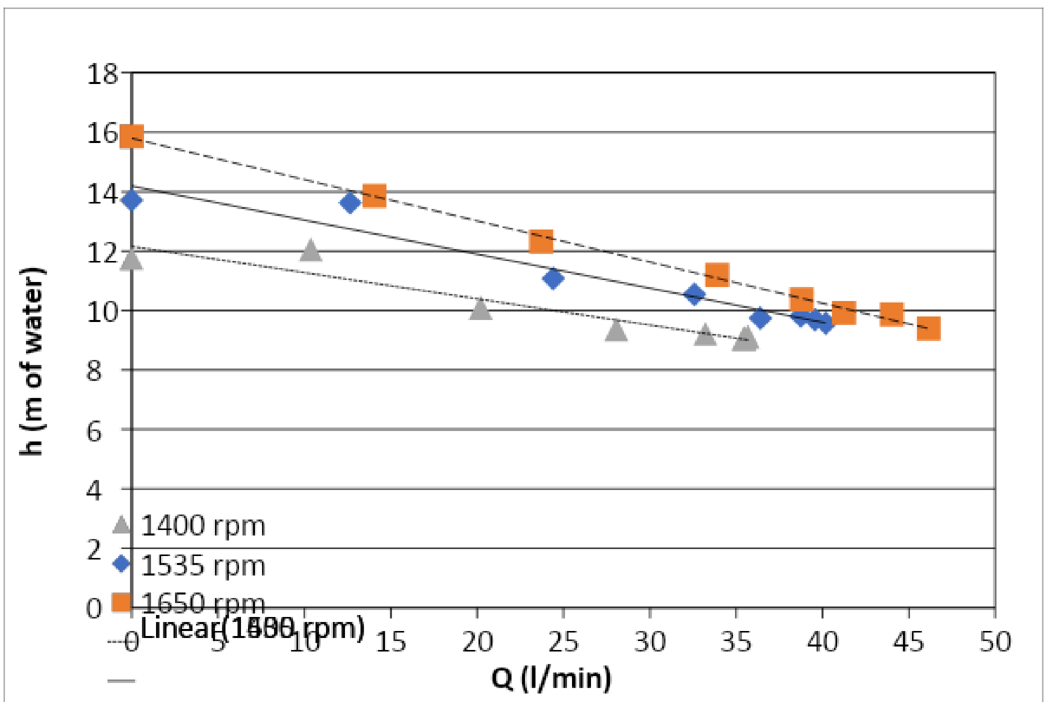

Figure3.14 : Relation between head and flow rate for pure water at 1400, 1535 and 1650 rpm.

Next figure shows the relation between efficiency and flow rate for pure water at 1400, 1535 and 1650 rpm. From figure, curve of 1650 rpm shows the highest over 1535 and 1650 rpm curves.

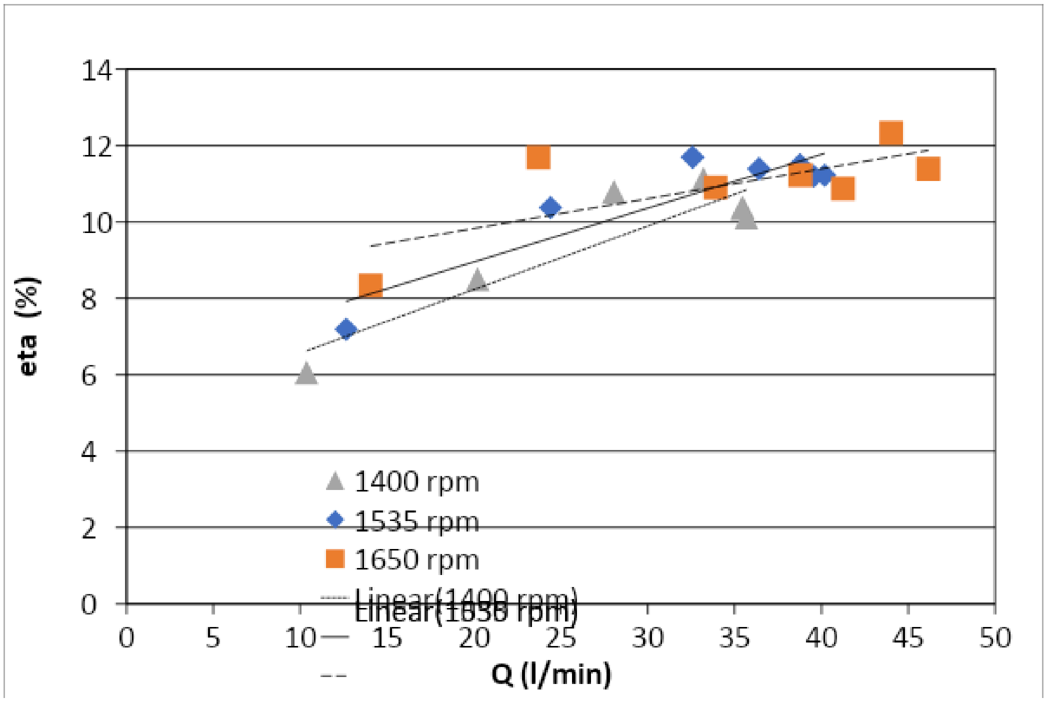

Figure3.15: Relation between efficiency and flow rate for pure water at 1400, 1535 and 1650 rpm.

Next figure shows the relation between shaft power and flow rate for pure water at 1400, 1535 and 1650 rpm. From figure, curve of 1650 rpm shows the highest over 1535 and 1650 rpm curves.

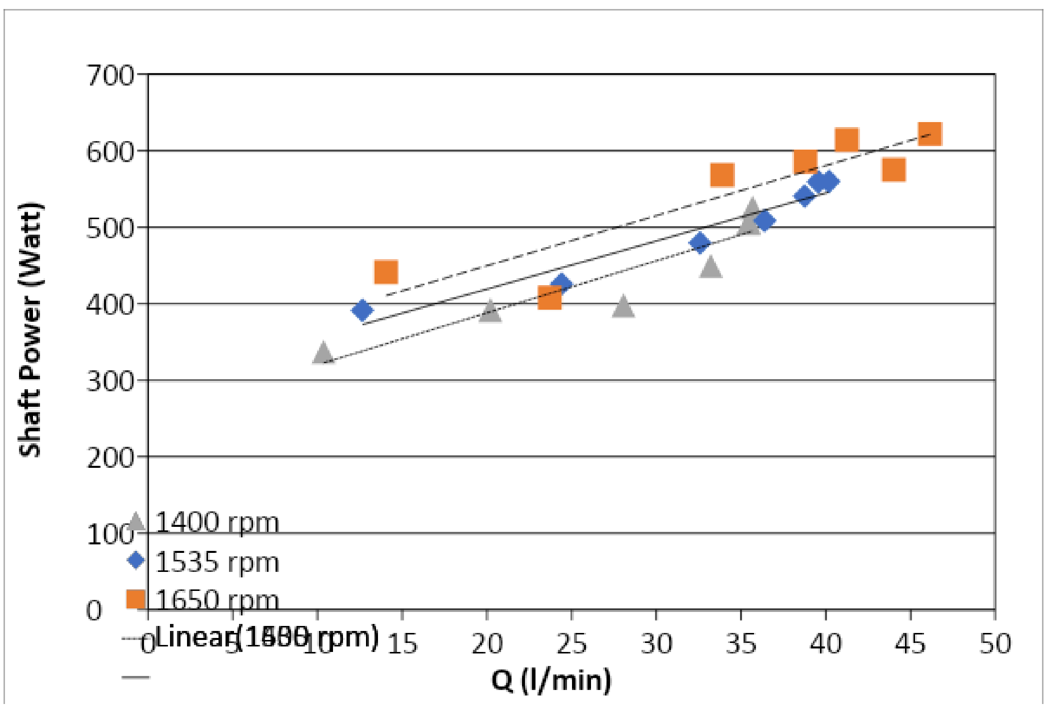

Figure3.16: Relation between shaft power and flow rate for pure water at 1400, 1535 and 1650 rpm.

3.2.2 For three stages of air at 1535 rpm

Next figure shows the relation between head and flow rate for air inserted at 1st, 2nd and 3rd stages at 1535 rpm. From figure, values of head for pure water are the highest over the other values.

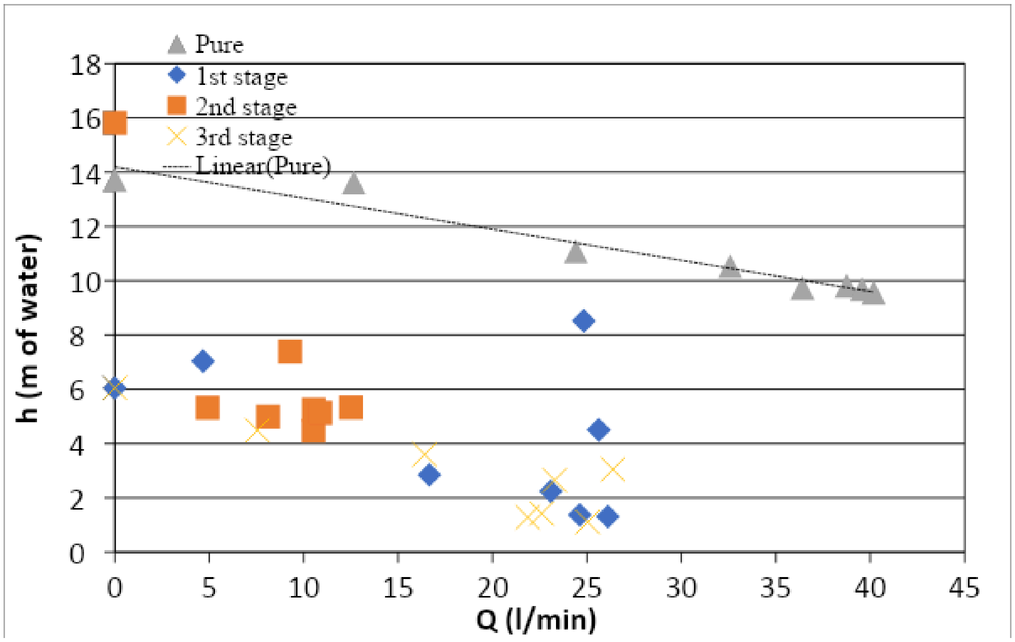

Figure3.17: Relation between head and flow rate for air inserted at 1st, 2nd and 3rd stages at 1535 rpm.

Next figure shows the relation between efficiency and flow rate for air inserted at 1st, 2nd and 3rd stages at 1535 rpm. From figure, values of head for pure water are the highest over the other values.

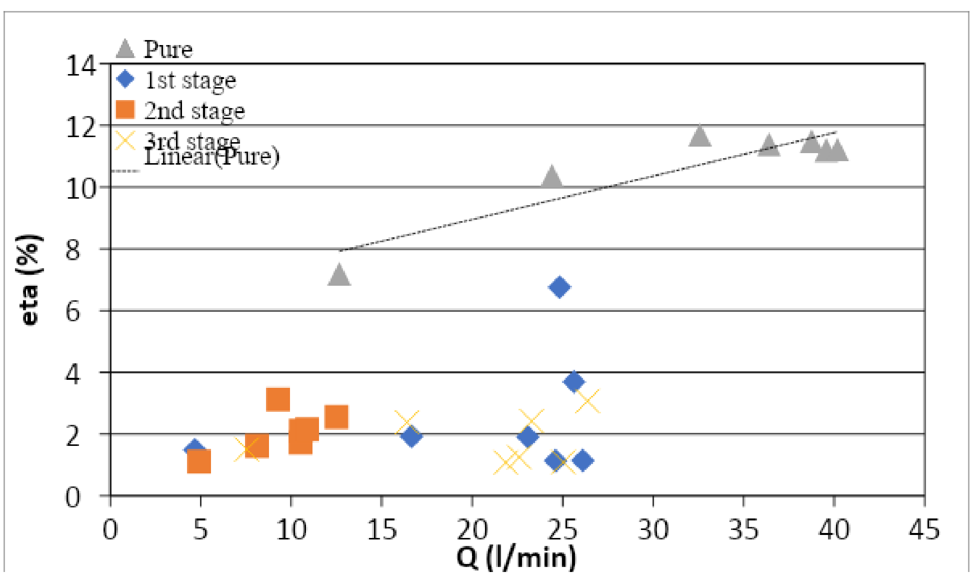

Figure3.18: Relation between efficiency and flow rate for air inserted at 1st, 2nd and 3rd stages at 1535 rpm.

Next figure shows the relation between shaft power and flow rate for air inserted at 1st, 2nd and 3rd stages at 1535 rpm. From figure, values of head for pure water have to be the highest over the other values.

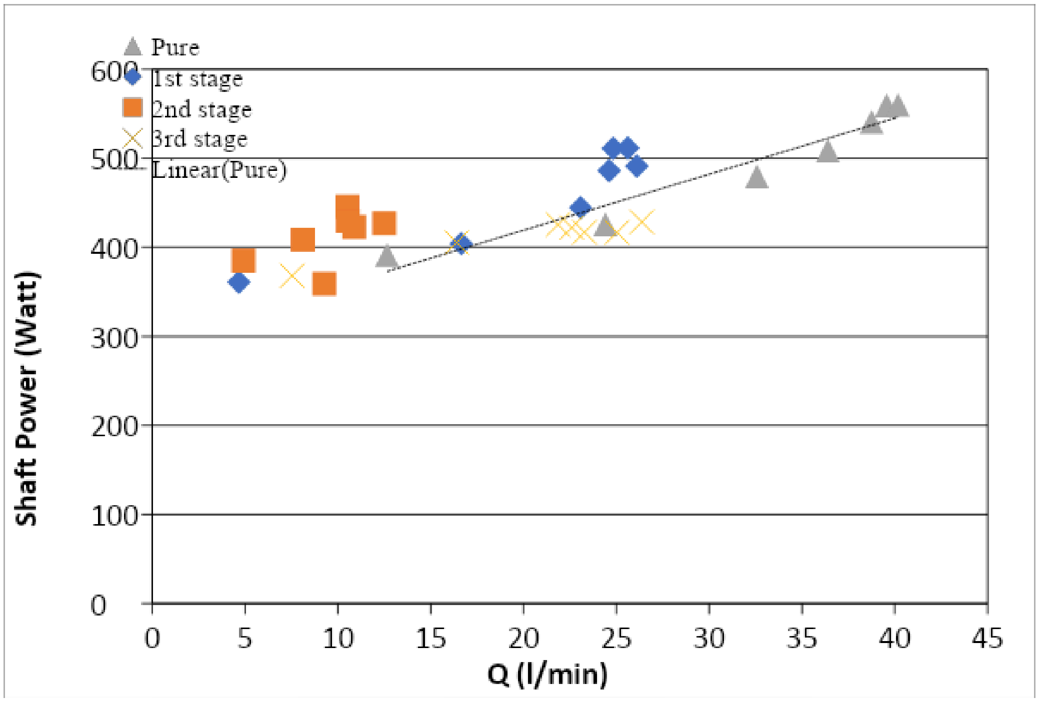

Figure3.19: Relation between shaft power and flow rate for air inserted at 1st, 2nd and 3rd stages at 1535 rpm.

3.2.3 For different air flow rate values at 1400 rpm and 3rd stage

Next figure shows the relation between head and flow rate for different air flow rate values at 1400 rpm and 3rd stage. From figure, values of head for pure water are the highest over the other values.

Fig3.20

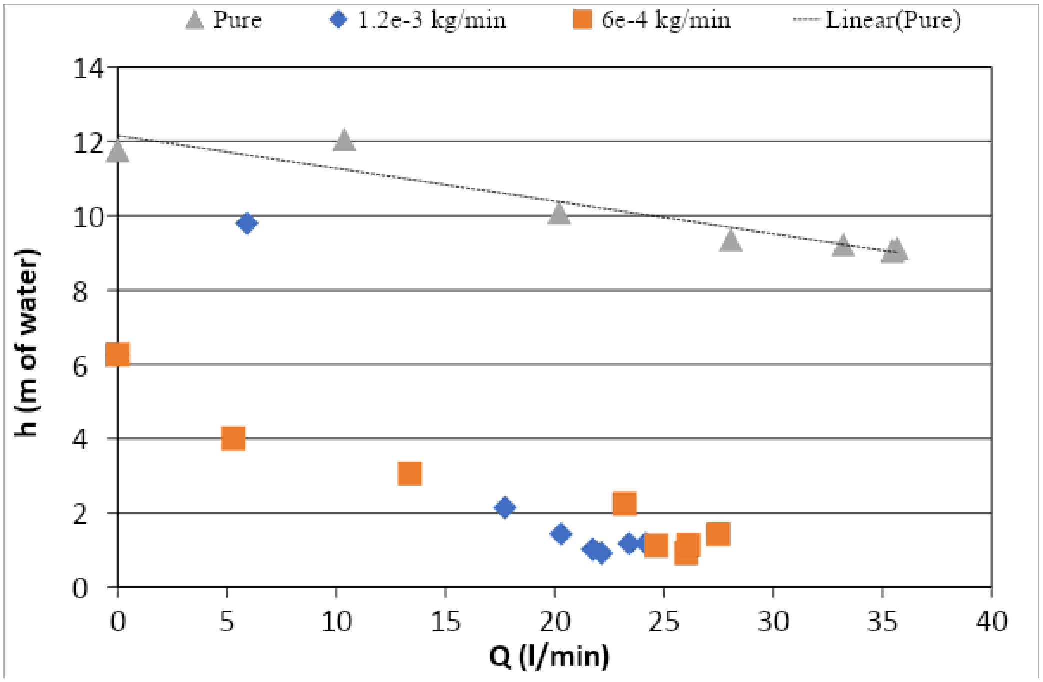

Figure3.21: Relation between head and flow rate for different air flow rate values at 1400 rpm and 3rd stage.

Next figure shows the relation between efficiency and flow rate for different air flow rate values at 1400 rpm and 3rd stage. From figure, values of head for pure water are the highest over the other values.

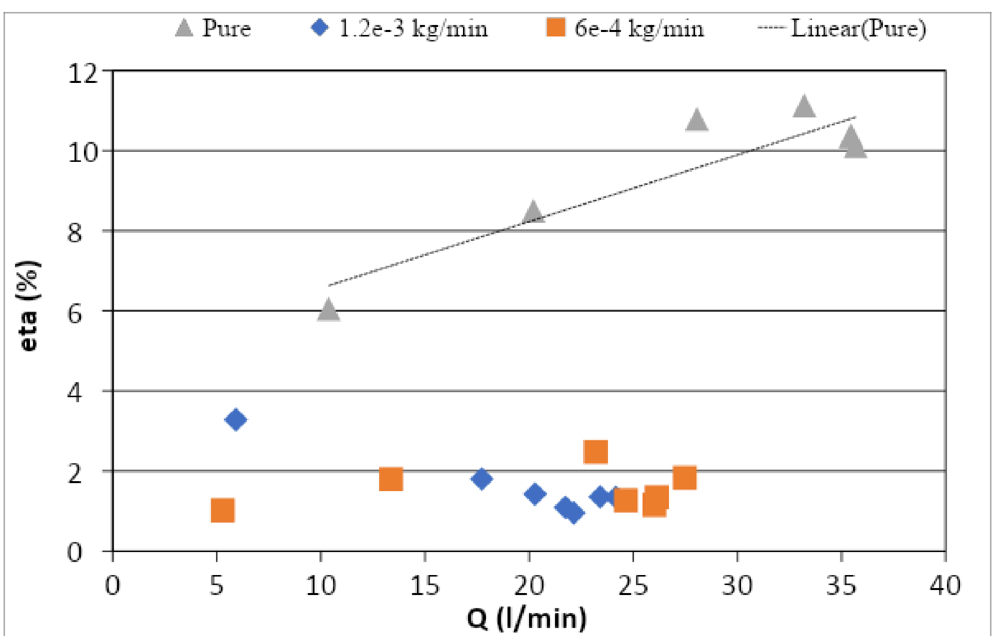

Figure3.22: Relation between efficiency and flow rate for different air flow rate values at 1400 rpm and and 3rd stage.

Next figure shows the relation between shaft power and flow rate for different air flow rate values at 1400 rpm and 3rd stage. From figure, values of head for pure water have to be the highest over the other values.

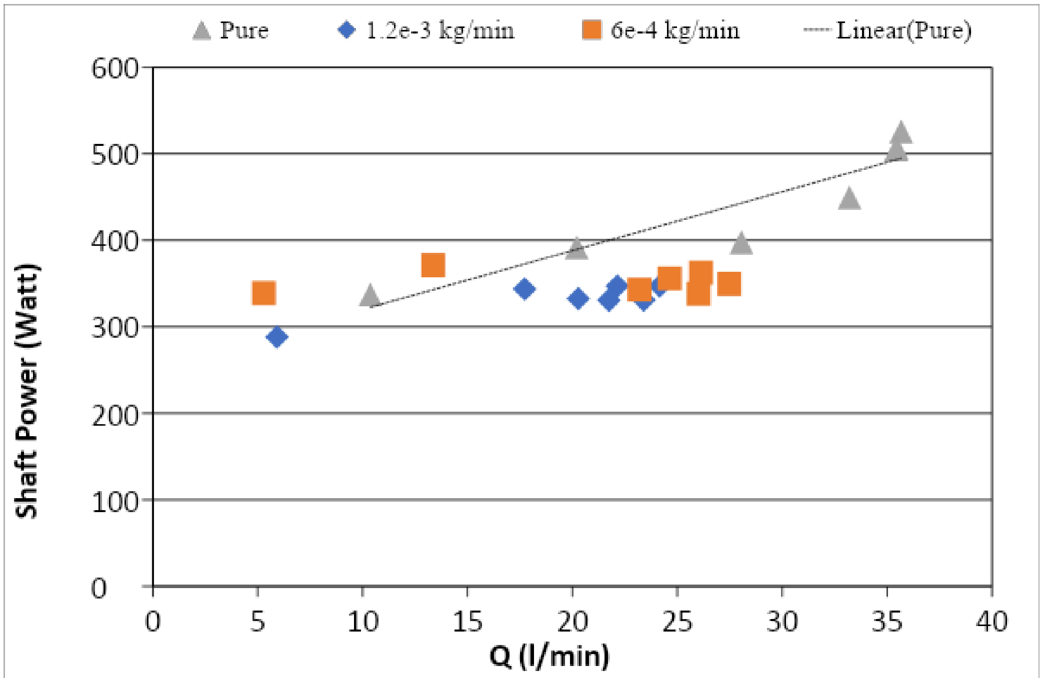

Figure3.23: Relation between shaft power and flow rate for different air flow rate values at 1400 rpm and 3rd stage.

3.2.4 For different air flow rate values at 1535 rpm and 3rd stage

Next figure shows the relation between head and flow rate for different air flow rate values at 1535 rpm and 3rd stage. From figure, values of head for pure water are the highest over the other values.

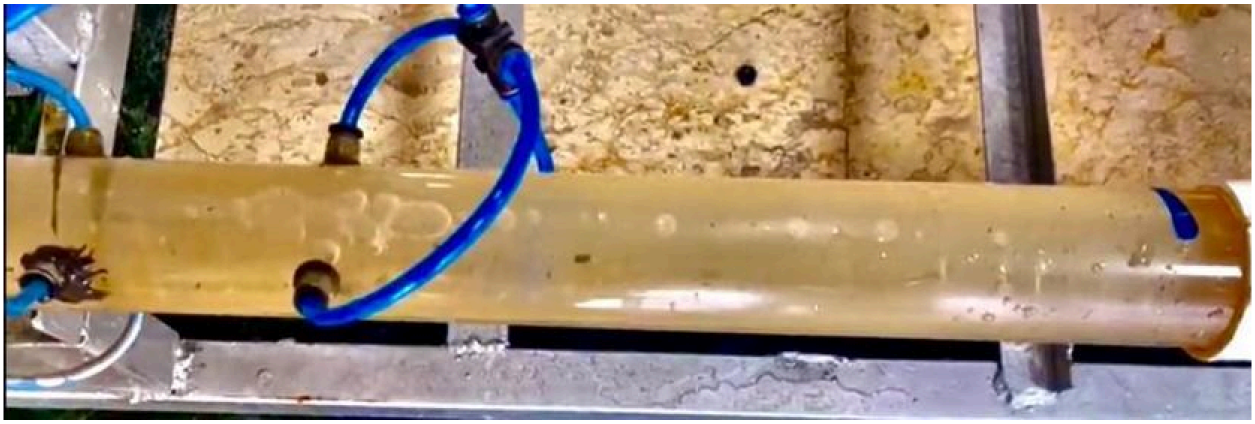

Fig3.24

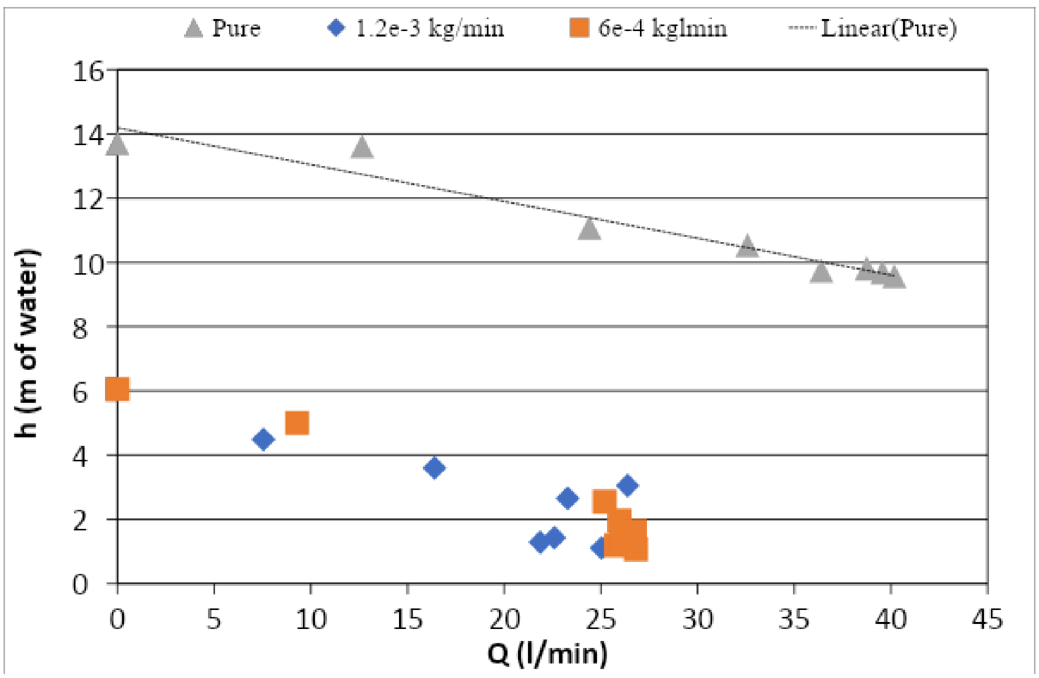

Figure3.25: Relation between head and flow rate for different air flow rate values at 1535 rpm and 3rd stage.

Next figure shows the relation between efficiency and flow rate for different air flow rate values at 1535 rpm and 3rd stage. From figure, values of head for pure water are the highest over the other values.

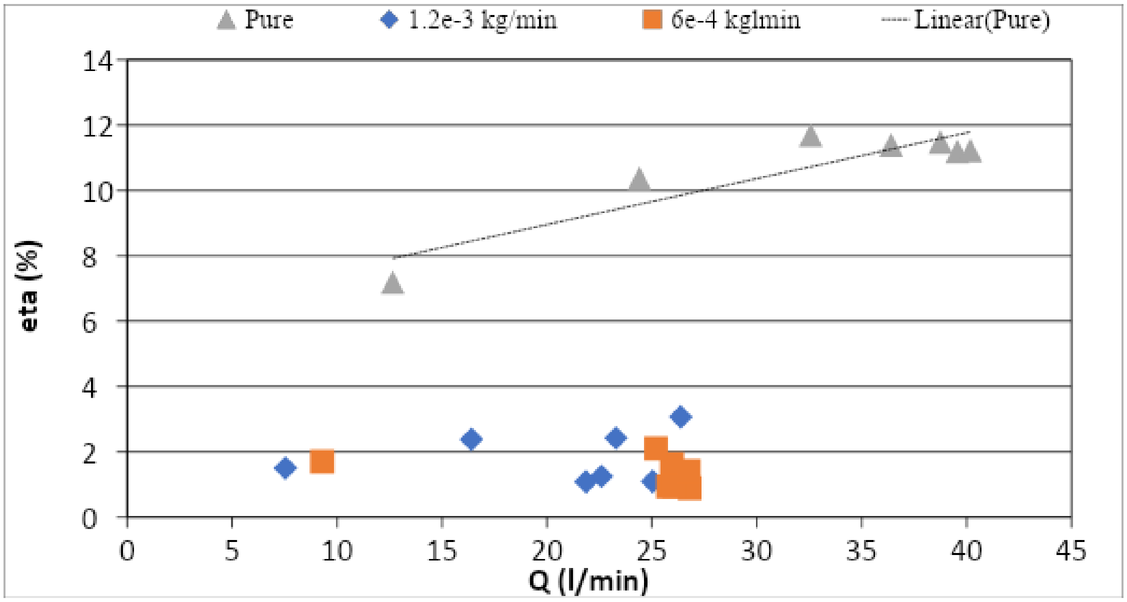

Figure3.26: Relation between efficiency and flow rate for different air flow rate values at 1535 rpm and 3rd stage

Next figure shows the relation between shaft power and flow rate for different air flow rate values at 1535 rpm and 3rd stage. From figure, values of head for pure water have to be the highest over the other values.

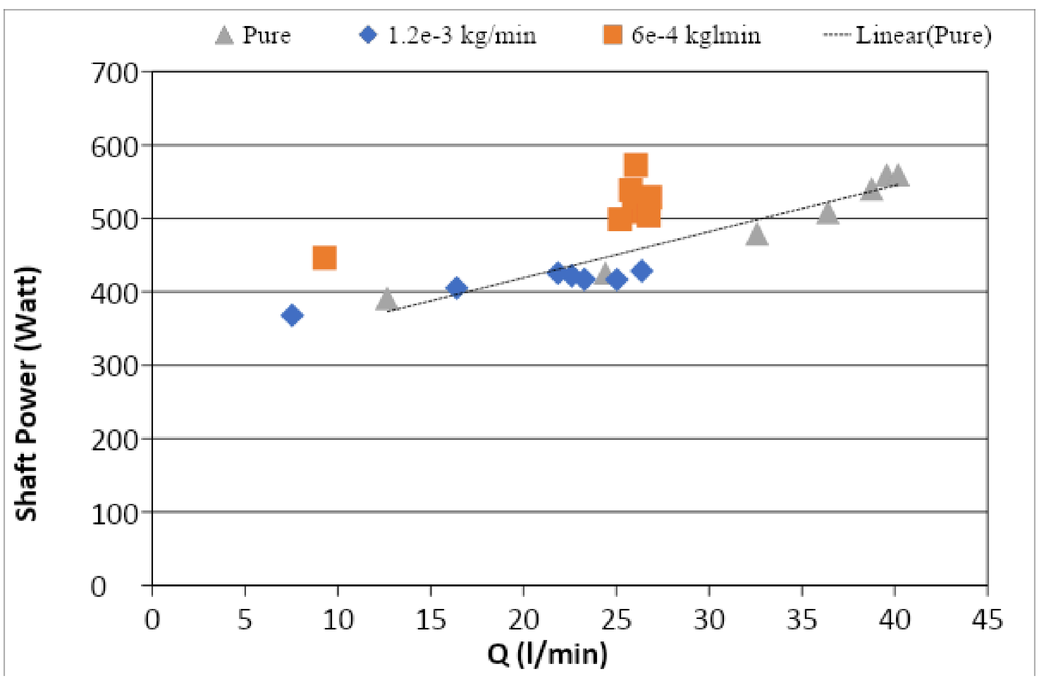

Figure3.27: Relation between shaft power and flow rate for different air flow rate values at 1535 rpm and 3rd stage.

3.2.5 For different air flow rate values at 1650 rpm and 3rd stage

Next figure shows the relation between head and flow rate for different air flow rate values at 1650 rpm and 3rd stage. From figure, values of head for pure water are the highest over the other values.

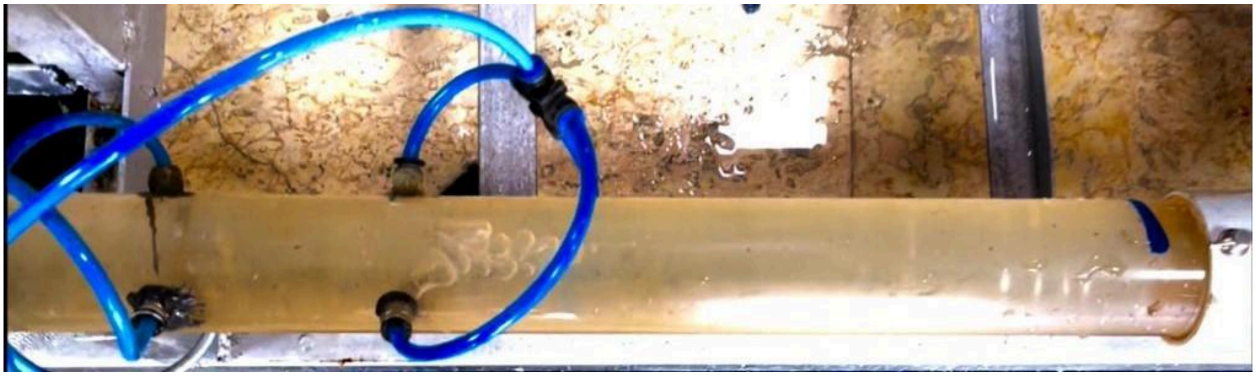

Fig3.28

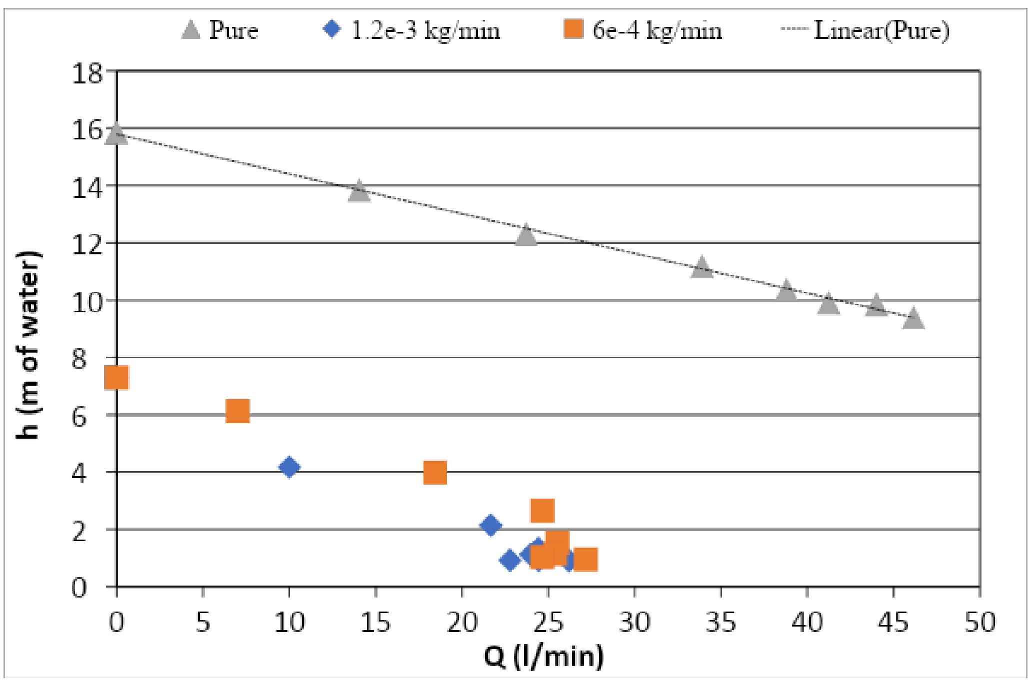

Figure3.29: Relation between head and flow rate for different air flow rate values at 1650 rpm and 3rd stage.

Next figure shows the relation between efficiency and flow rate for different air flow rate values at 1650 rpm and 3rd stage. From figure, values of head for pure water are the highest over the other values.

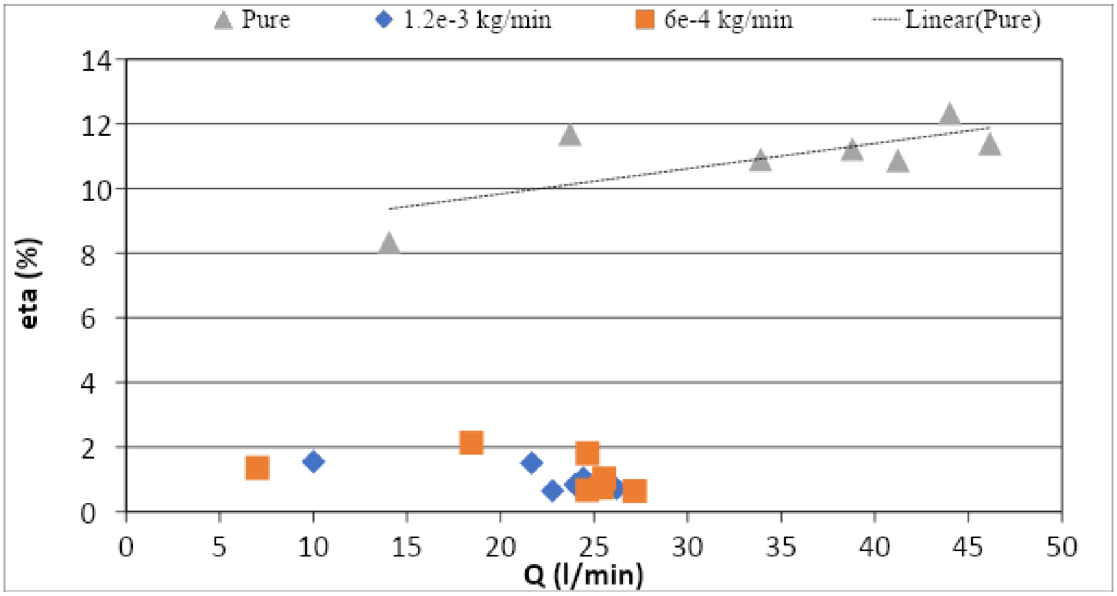

Figure3.30: Relation between efficiency and flow rate for different air flow rate values at 1650 rpm and 3rd stage.

Next figure shows the relation between shaft power and flow rate for different air flow rate values at 1650 rpm and 3rd stage. From figure, values of head for pure water have to be the highest over the other values.

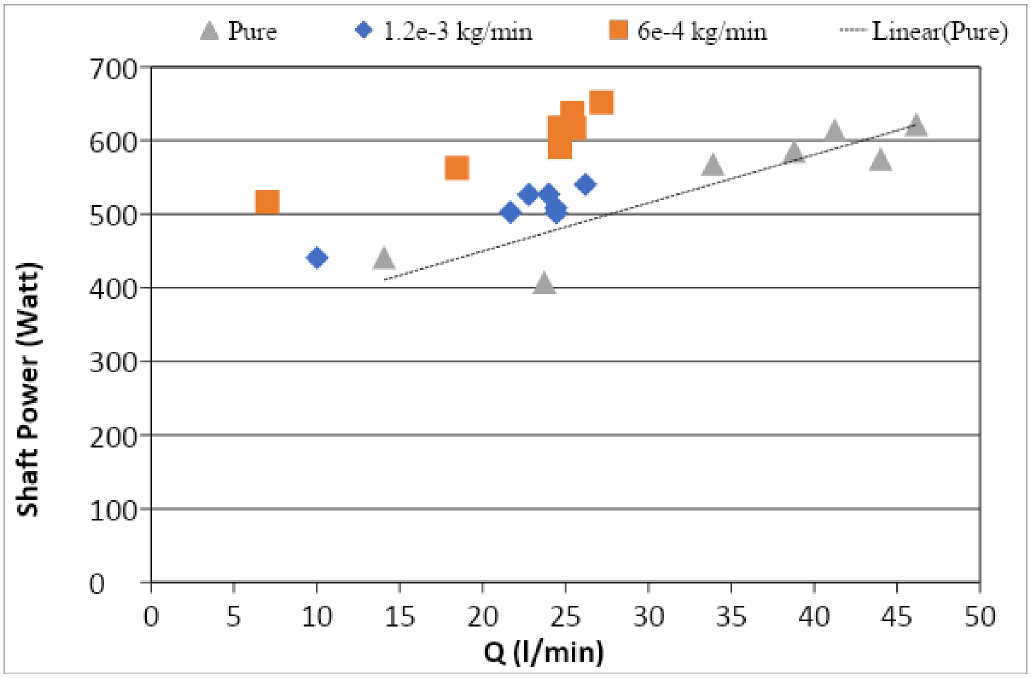

Figure3.31: Relation between shaft power and flow rate for different air flow rate values at 1650 rpm and 3rd stage.

Chapter 4

Conclusion

When the RPM increases the head increase

	1400		
RPM	1535	RPM increase	eta (%) increase
	1650	RPM increase	shaft power increase

When the distance between air inlet and the pump decrease

Shaft power increase

Eta (%) decrease

Head decrease

When the mass flow rate of air inside the pump increase

Shaft power increase

Eta (%) decrease

Head decrease