ABSTRACT

After some long period of production, the well may not be able to lift the hydrocarbons by its natural energy. Therefore artificial lift system is applied. Sucker rod pump as one of the artificial system commonly used, is a pumping system using a surface power source to drive a downhole pump assembly. Its components are: beam, crank assembly, sucker-rod string, plunger, and valve assembly to convert the reciprocating motion to vertical fluid movement. This sucker rod is very common and widely used on onshore platforms where the reservoir pressure is not adequate to lift the Hydrocarbon by its natural force. Even though sucker rod pump is commonly used, there is still weakness which can be improved through this proposed project.

In this study, it is proposed that the stationary ball valve at the bottom of the pump must be developed in a manner that the ball valve will be immediately closed as the downstroke begins and similarly, the travelling valve is opened. It is proposed that energy to close and to open the valve is added by the energy generated by the motor. In this way, the motor will help to pull and push the ball up and down therefore the closing and the opening period will be reduced and also the motor will also help to avoid leakage at the valve.

The development will give great benefit in increasing the pumping capacity and also as well as to maximize the profit of production company.

CHAPTER I: INTRODUCTION

I.1. BACKGROUD OF STUDY

The present era has seen great importance towards energy reserves and towards different steps involved in utilizing those reserves economically and extract the source to its maximum recovery. As for production engineer, producing hydrocarbon at minimized cost and maximized profit is the core responsibility. To achieve such, the production engineers do concern not only on the nature or the performance of the reservoir but also on the equipment used in their production system.

Sucker rod pump is widely used in onshore platform where the reservoir pressure is not adequate to lift the hydrocarbon by its natural energy. Even though sucker rod pump is commonly used in production companies, yet there is still a development which is needed to increase the pumping capacity. Understanding its operation and mechanism in pumping the hydrocarbon, can yield a suggestion to improve on the stationary ball valve to get a better pumping performance. The proposed development is in this proposal with a very detailed procedure.

I.2. PROBLEM STATEMENT

When the rod is operating, at the valve assembly, the ball valve whose main functions are to open and close and also to seal the leakage at the valve, gives great effect on the pumping capacity. Once the valve starts to close and open, there is a time delay which can lead to an escape of hydrocarbon from the pump barrel. Therefore there is a need of development to better the ball valve in a manner that the delay period is reduced as much as possible.

I.3. OBJECTIVES

The objectives of this study are:

- To design a modification on the ball vale of sucker rod pump which can reduce the closing and opening time period

I.4. SCOPE OF STUDY

- To study and determine possibility of development on the stationary ball vale of the sucker rod pump
- To study the flow behaviour of Hydrocarbon at the inlet of the stationary ball vale of the sucker rod pump.
- To study the possibility design of modification on the ball vale of sucker rod pump to increase pumping capacity

I.5. RELEVANCY OF STUDY

This study will prove the ability of new modification on the sucker rod pump to increase the pumping capacity.

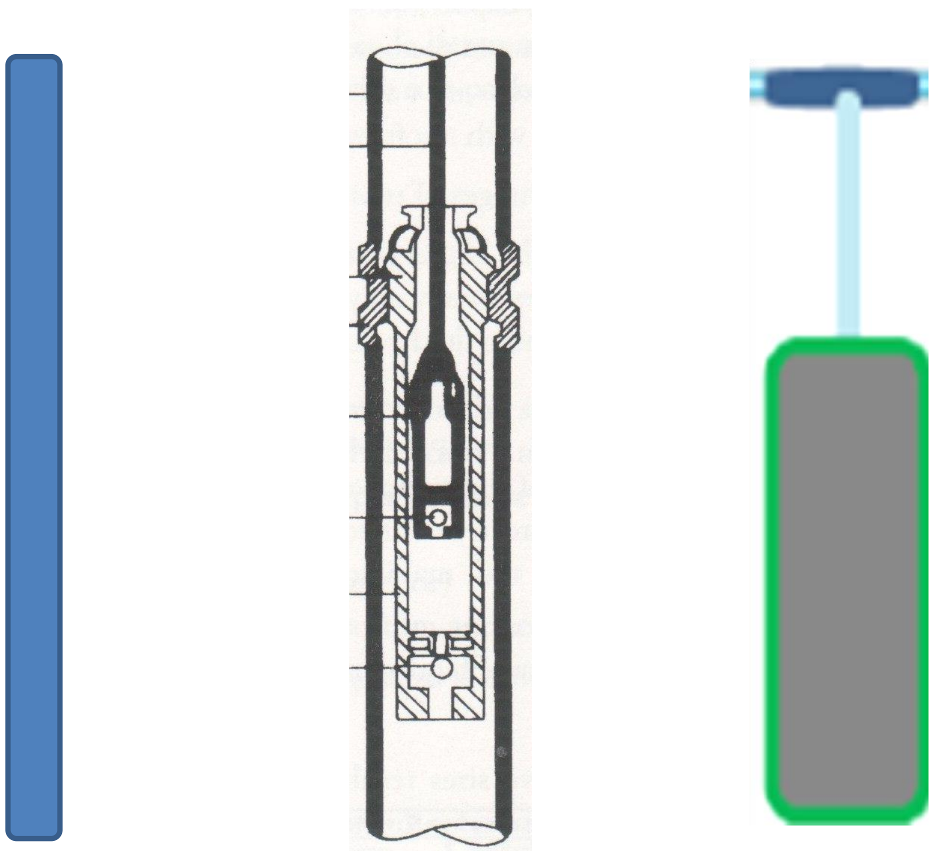
I.6. Feasibility of Study within the Scope and Time Frame

The study is expected to be feasible based on the below:

- The readability of experiment's instrument for this project.
- Plenty of related literature review on this topic.

I.7. Equipment and Tools

- Pump Barrel, Motor, rod, and Hydrocarbon.

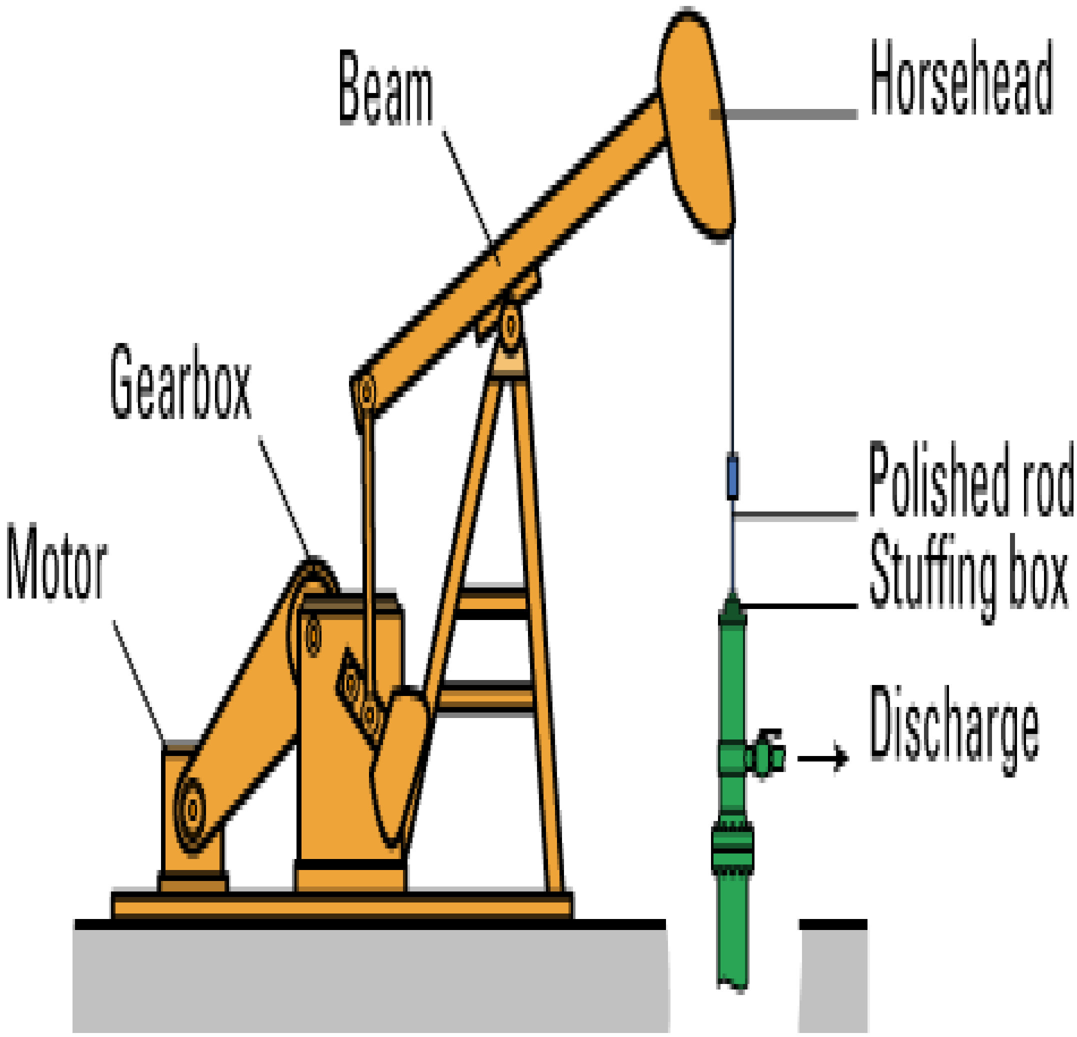


(Rod) **(Pump barrel)** **(Motor)**

(Figure 1: Tools)

CHAPTER II: LITERATURE VIEW

II.1. SUCKER ROD PUMP

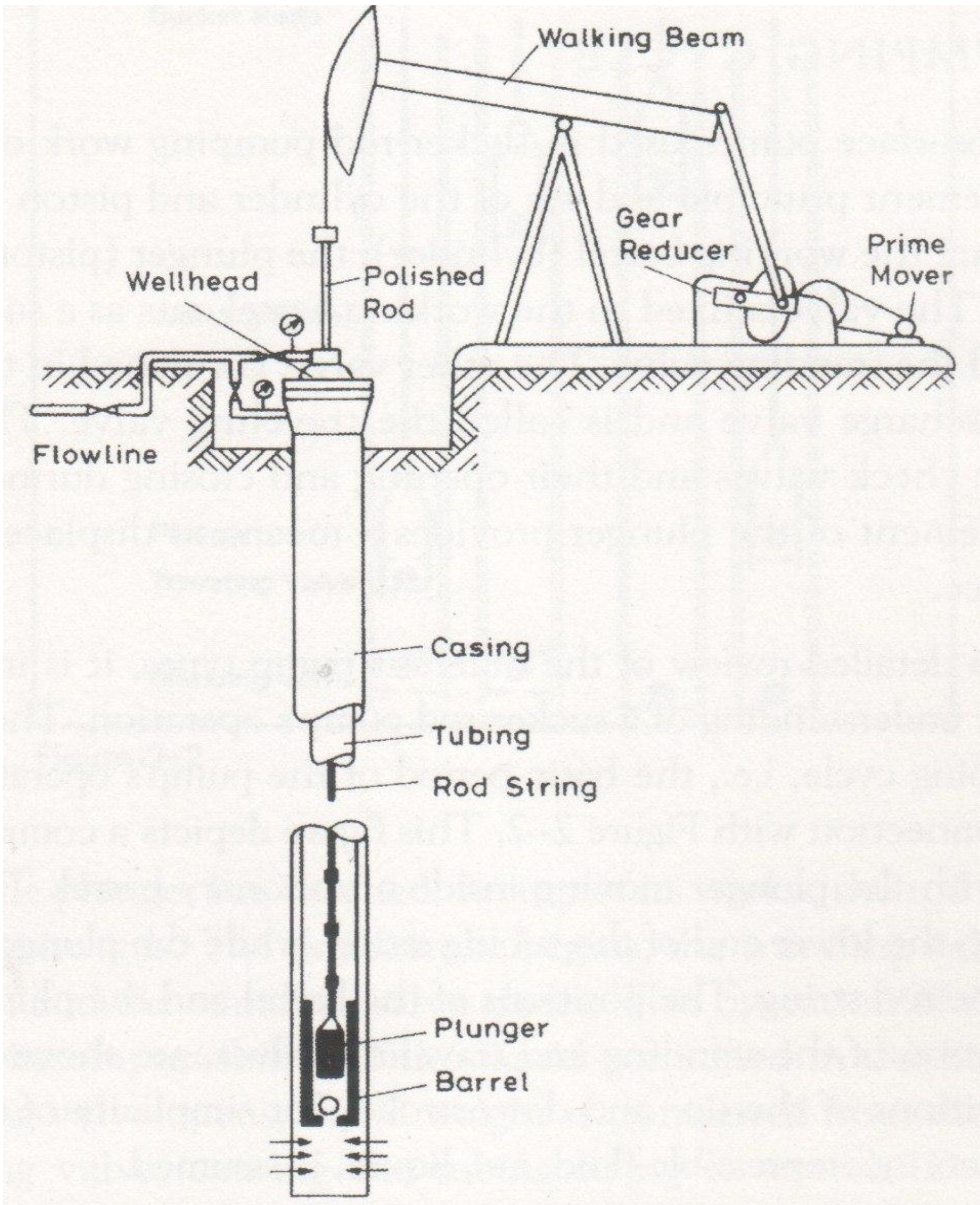


(Figure 2: Sucker rod pump)

Sucker rod pump is an artificial-lift pumping system using a surface power source to drive a down hole pump assembly. Its components are: beam, crank assembly, sucker-rod string, plunger and valve assembly to convert the reciprocating motion to vertical fluid movement. Sucker rod pump is often used on onshore platform where the reservoir pressure of the wells is not adequate to lift the Hydrocarbon by its natural energy.

II. 1.1 COMPONENTS OF SUCKER ROD PUMP

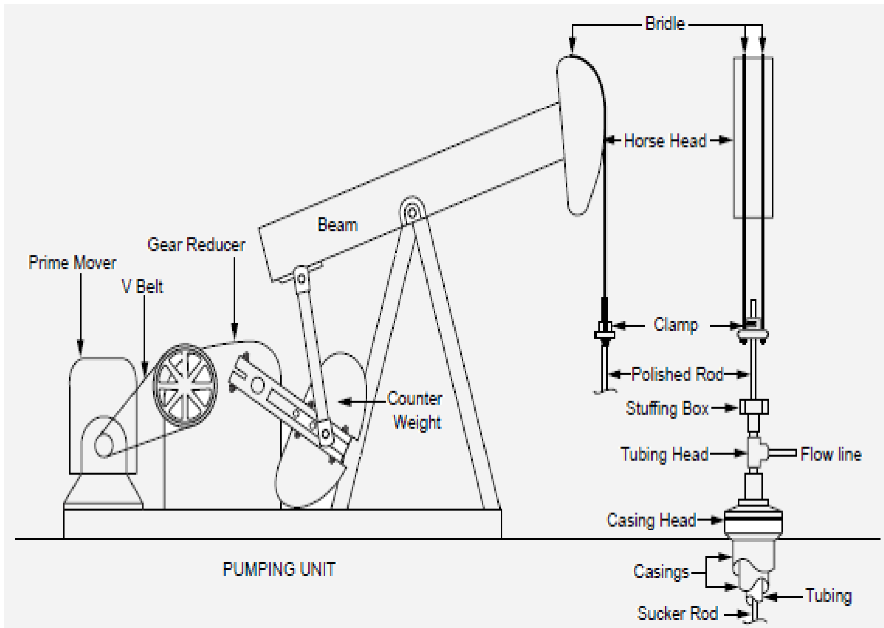
The individual components of a sucker rod pump can be divided onto two major groups: surface equipment and downhole equipment as illustrated in the figure below:



(Figure 3: Components of Sucker rod pump)

The surface equipment includes:

- **The prime mover:** provides the driving power to the system and can be an electric motor or gas engine.

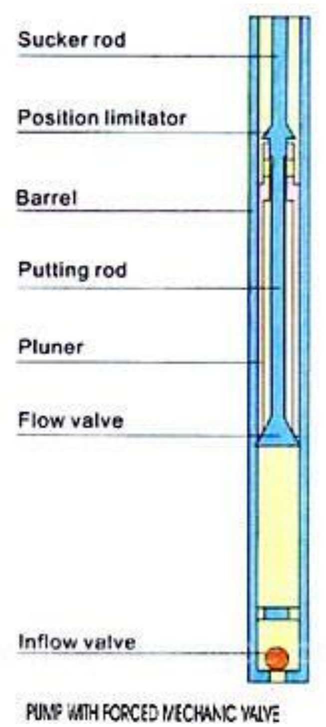


(Figure 4: Surface Equipment)

- **The gear reducer or gearbox:** reduces the high rotational speed of the prime mover to the required pumping speed and, at the same time, increase the torque available at its slow speed shaft.
- **The pumping unit,** a mechanical linkage that transforms the rotatory motion of the gear reducer into the reciprocating motion required to operate the downhole pump. Its main element is the walking beam, which works on the principal of mechanical lever.
- **The polished rod:** connects the walking beam to the sucker rod string and ensure a sealing surface at the wellhead to keep the well fluids within the well.
- **The wellhead Assembly:** contains a stuffing box that seals on the polished rod and a pumping tee to lead well fluids to the flowline.

The download equipment includes:

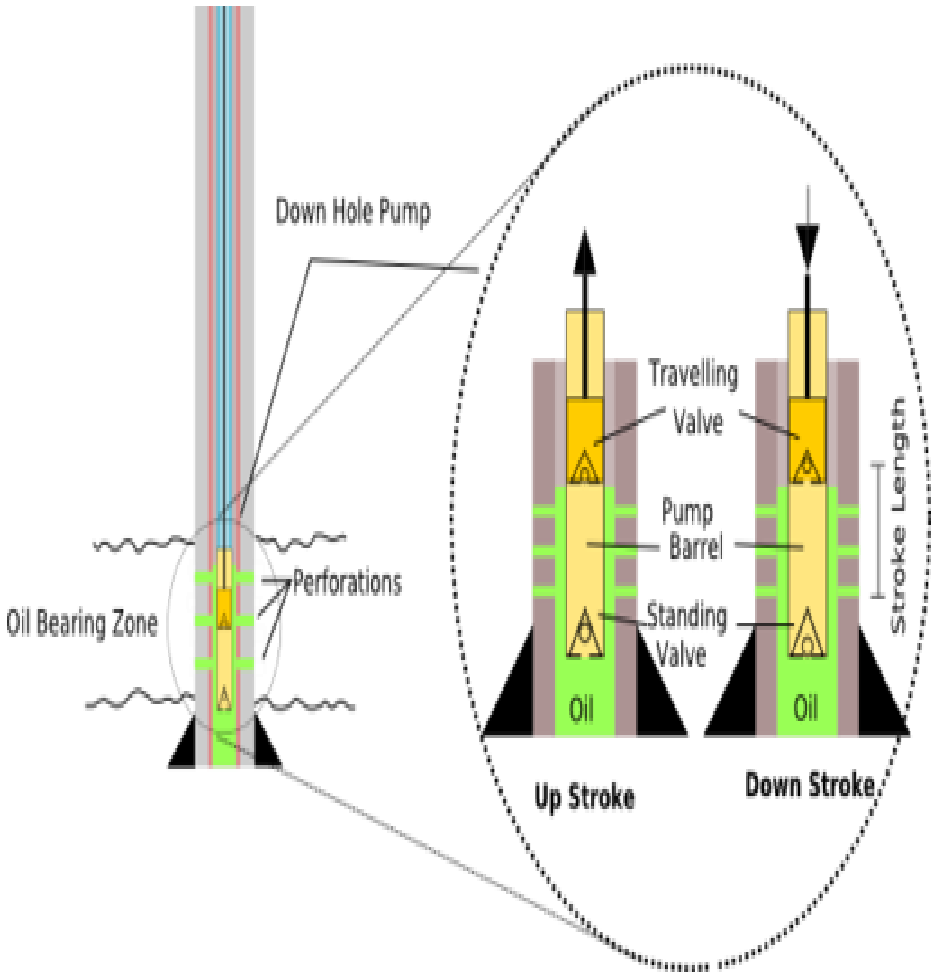
- **The rod string:** composed of sucker rods, run inside the tubing string of the well. The rod string provides the mechanical link between the surface drive and the subsurface pump.



(Figure 5: Downhole Equipment)

- **The pump plunger:** The moving part of the usual sucker rod pump is directly connected to the rod string. It houses a ball valve called the travelling ball valve. During the upward movement, it lifts the fluids contained in the tubing.
- **The pump barrel or working barrel:** is the stationary part (Cylinder) of the subsurface pump. Another ball valve, the standing valve is fixed to the working barrel. This acts as suction valve for the pump, through which the well fluids enter the pump barrel during upstrokes.

- **The ball valves assembly:** The valve assembly has two valves; the travelling ball valve and stationary ball valves.

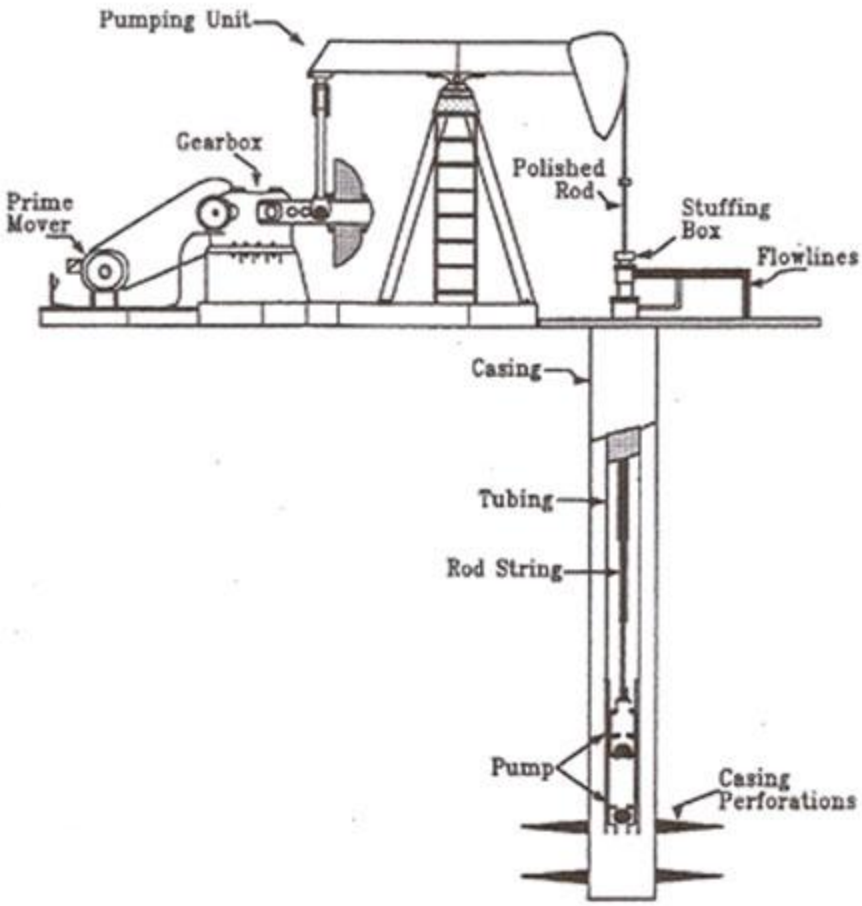


(Figure 6: Downhole vale)

The ball valves have function of closing and opening the pump barrel while the sucker rod pump is operating. When it is closed, it acts as seal to prevent the fluid from flowing downward from the pump barrels. And when it opens, it allows the fluid to go into the pump barrels and the pump barrels then carry the fluids to the surface.

II.1.2. THE OPERATION OF SUCKER ROD PUMP

Sucker rod pump operates simply and not so complicated to understand. Its operations can be described simply as follows:

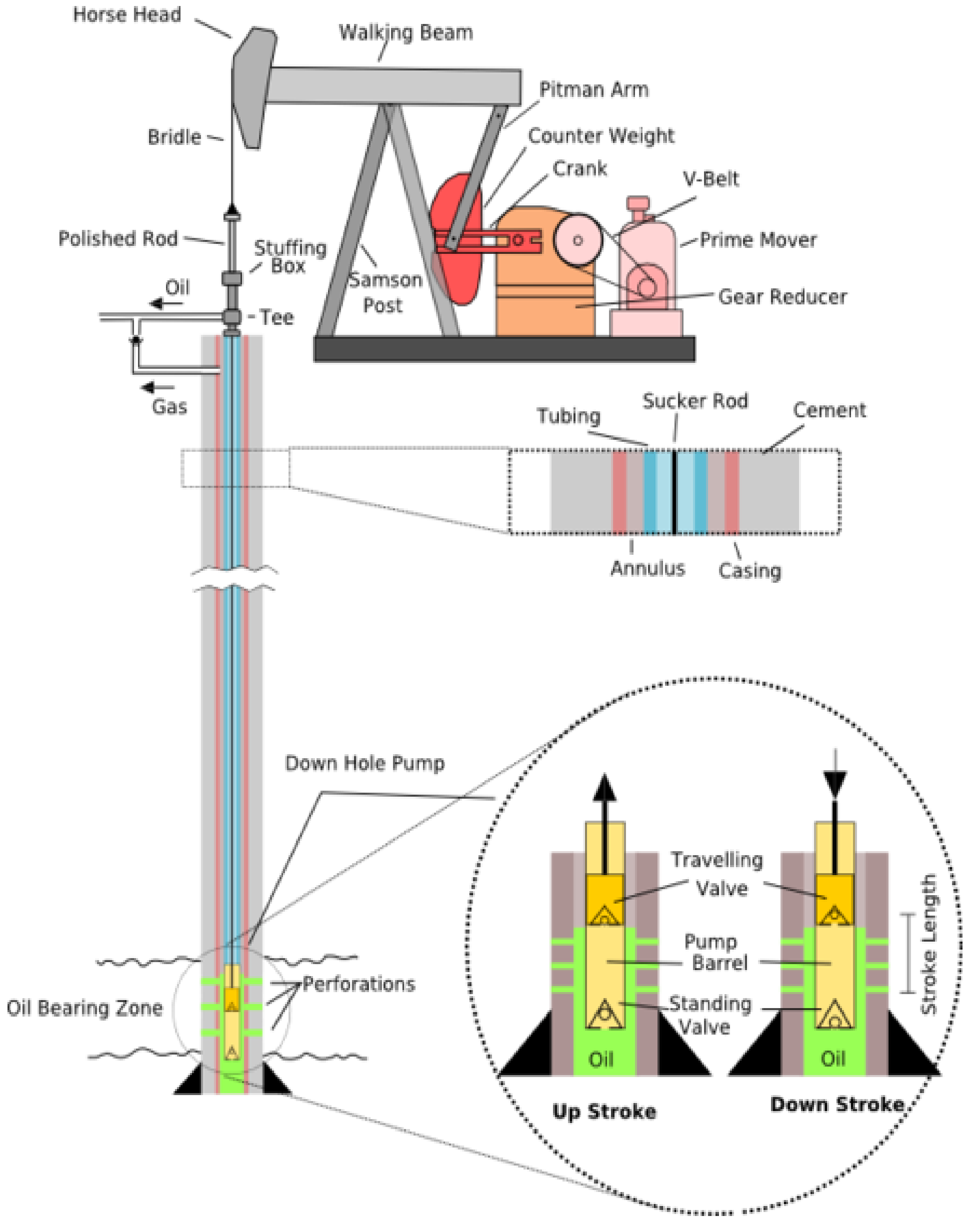


(Figure 7: Operation of sucker rod pump)

- **Prime Mover**, usually run by electric motor or gas engine, runs a set of pulleys to the transmission which in turn drives a pair of cranks, generally with counterweights on them to assist the motor in lifting the heavy string of rods.

(Figure 8: Prime mover)

- **Cranks,** raise and lower one end of an I-beam which is free to move on an A-frame. On the other end of the beam, there is a curved metal box called a Horse Head or Donkeys Head, named so due to its appearance. A cable made of steel (or, occasionally, fiberglass) called a bridle, connects the horse head to the polished rod, a piston that passes through the stuffing box.
- **Rod:** The polished rod has a close fit to the stuffing box, letting it move in and out of the tubing without fluid escaping. (The tubing is a pipe that runs to the bottom of the well through which the liquid is produced.) The bridle follows the curve of the horse head as it lowers and rises to create an almost completely vertical stroke. The polished rod is connected to a long string of rods called sucker rods, which run through the tubing all the way to the down-hole pump, usually positioned near the bottom of the well.

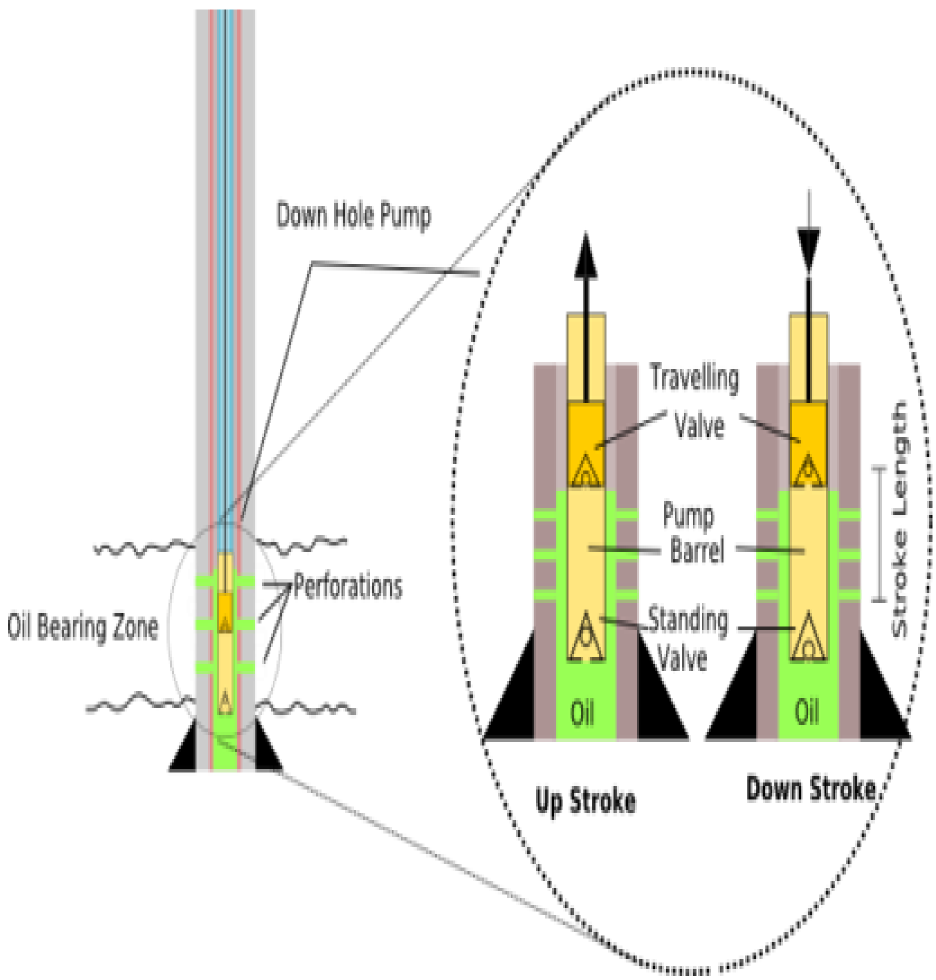


(Figure 9: Operation of sucker rod pump)

- **Valve Assembly** consists of two:
  - Stationary Ball Valve
  - Traveling Ball Valve

When the rode goes up, the traveling valve is close and the stationary valve is open due to the drop in pressure of the pump barrels. Consequently, the pump barrel fills with the fluid from the formation as the traveling piston lifts the previous contents of the barrel upwards.

When the rod goes down, the traveling valve is open and the stationary valve is close due to the increase in pressure of Pump Barrel. The traveling valve drops through the fluid in the barrel (which had been sucked in during the upstroke). The piston then reaches the end of its stroke and begins its path upwards again.



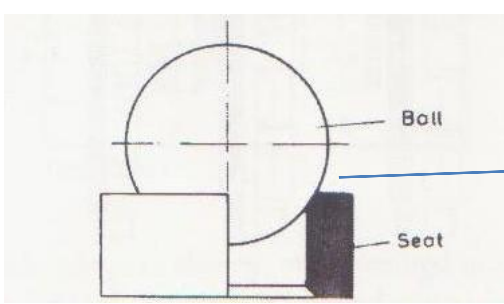
(Figure 10: Operation of valve Assembly of Sucker rod pump)

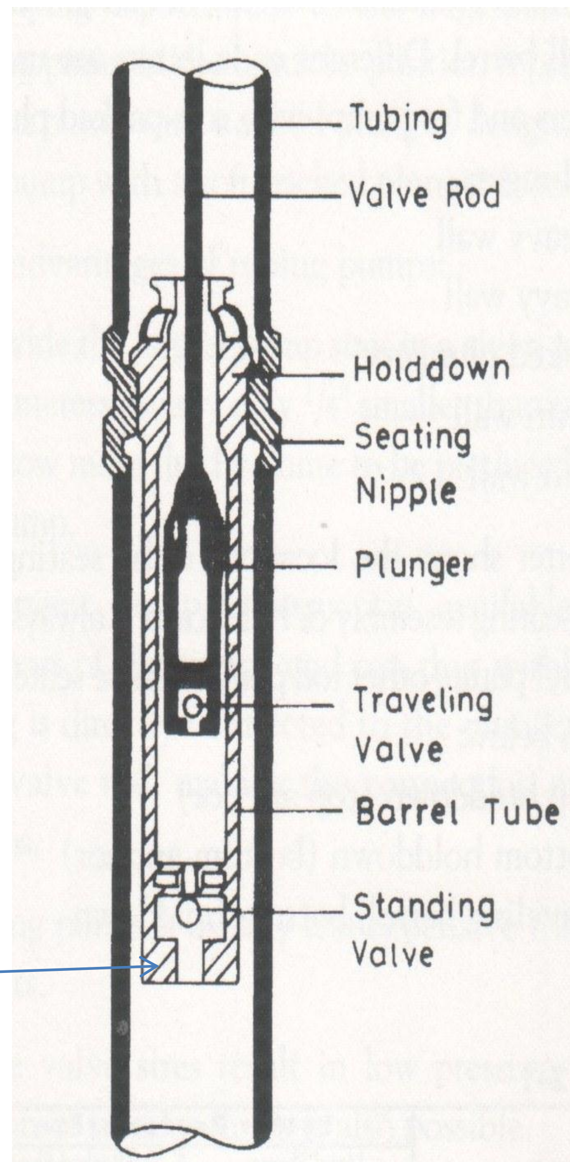
II.2. THE PROPOSED DEVELOPMENT ON BALL VALVE OF SUCKER ROD PUMP

II.2.1 THE BALL VALVE OF SUCKER ROD PUMP

At the vale assembly, the ball valve is placed as stationary and traveling valves. Its working mechanism is totally dependent on the pressure inside the pump barrel due to the fluids inside the pump barrels.

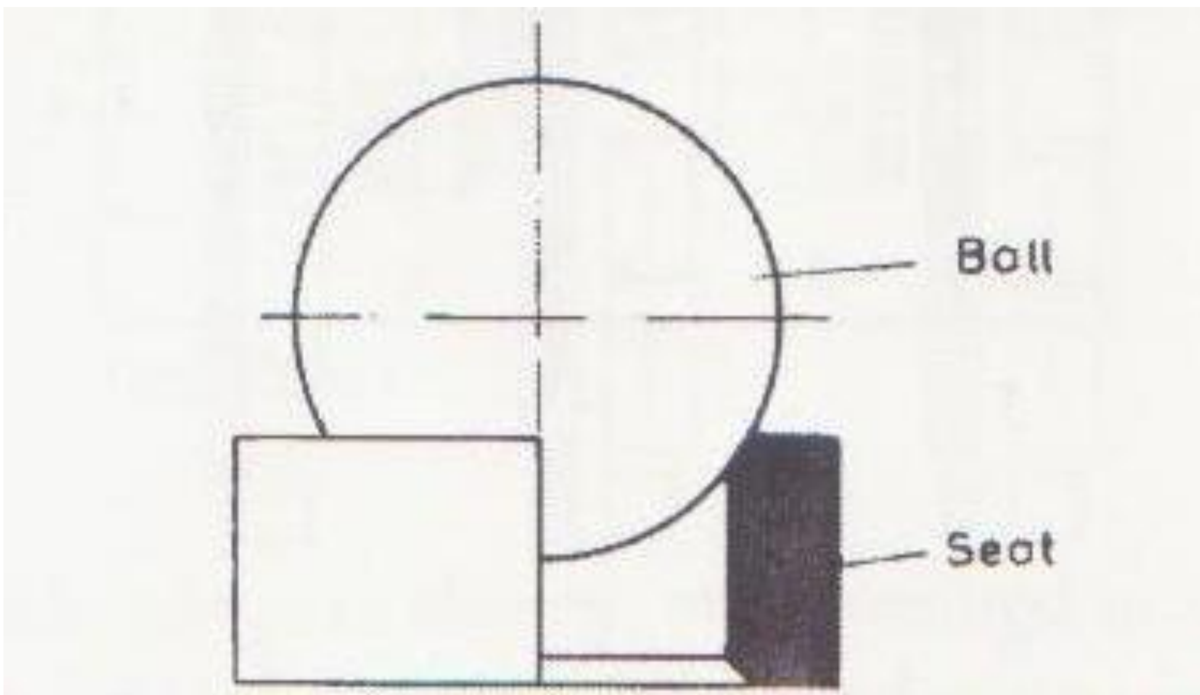
During down stroke, the ball valve of the traveling valve is open due to the reduce in pressure inside the pump barrel and during the up stroke due to the increase in pressure of the pump barrel, the ball valve of the traveling valve is closed and seals the valve.





(Figure 11: The ball valve of sucker rod pump)

Ball vales are considered as the heart of the sucker rod pump, an efficient sucker rod pump is dependent on the proper action of the stationary and the travelling valve. These are simple check valves, and operate on the ball and seat principles. Seats are machined, precision ground, and finished from corrosions, and erosion resistant metals. They are usually reversible and can be used for both sides. The metal balls are precision finished, and each ball and seat combination is lapped together to provide a perfect seals.



(Figure 12: The ball and seat of ball valve)

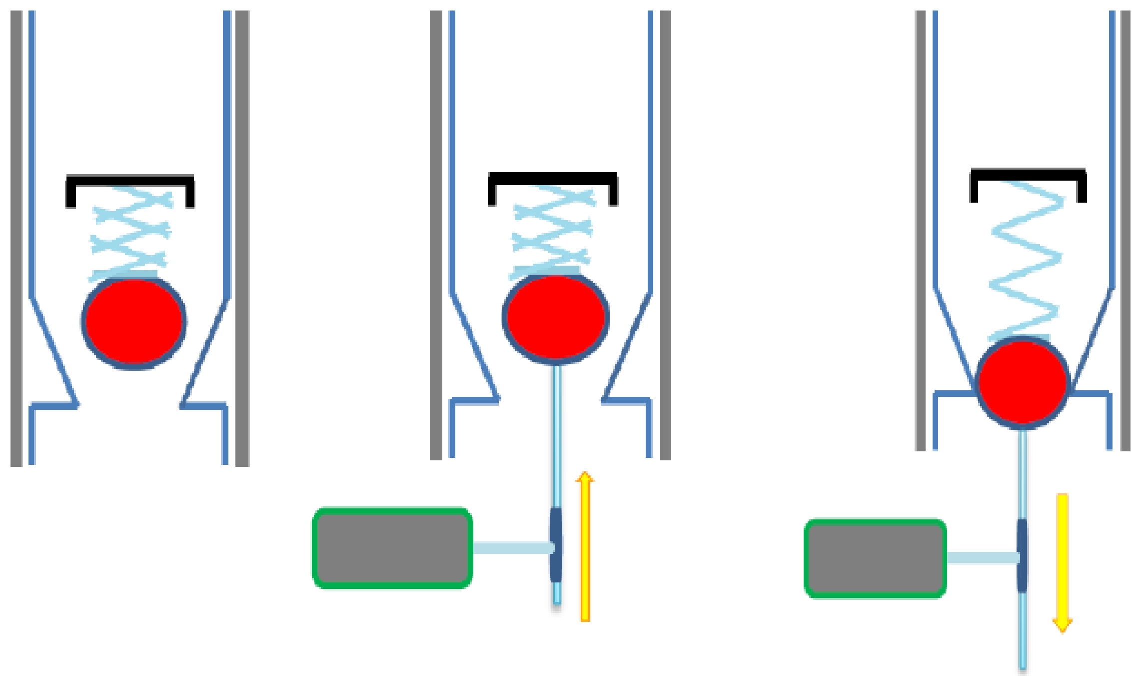
II.2.2 THE PROPOSED DEVELOPMENT ON THE BALL VALVE

In conventional sucker rod pump, the working mechanism of the ball valve is mainly dependent on the pressure of the pump barrel arising from the fluids inside the pump barrel. Therefore this leads to a delay in the closing period which can let the fluids escape from the pump barrel before the valve is perfectly closed. In this project, it is proposed that the stationary ball valve at the bottom of the pump must be developed in a manner that the closing period will be reduced to almost zero.

- It is proposed that energy to close and to open the valve is added by the energy generated by the motor.

- The motor will help to pulls and push the ball up and down therefore the closing and the opening period will be reduced.

- This motor will also help to avoid leakage at the valve.



(Figure 13: The proposed development of ball valve)

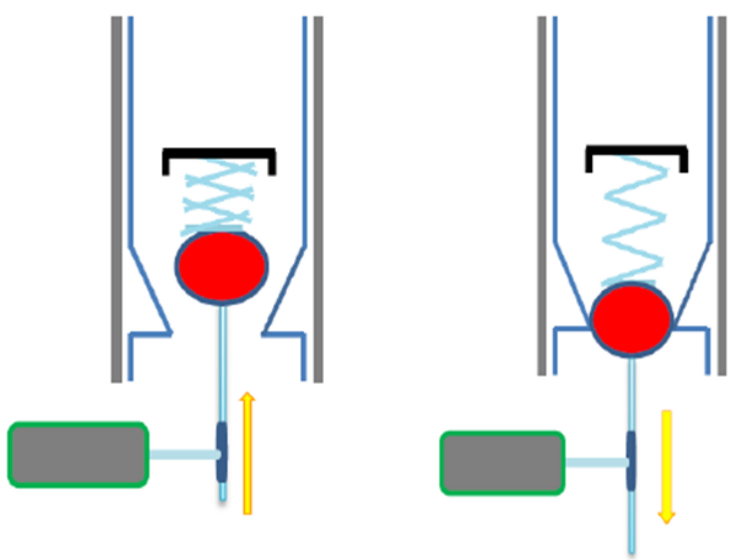
CHAPTER III: RESEARCH METHODOLOGY

III. 1. METHODOLOGY IN THE DEVELOPMENT

A simple methodology is used to develop modification on the ball valves of the sucker rod pump. In this modification, the motors are attached to the ball valves and the motors will be giving the energy to the ball valves and help the closing period to be reduced. The modification on the ball valves help not only to reduce the closing period but also to seal the valve so the leakage is avoided. The figure of the development is as above in the previous page.

III. 2. MODIFICATION ON THE BALL VALVE

The modification will be done on the ball valve in such a way that the motor connected to the ball valve will help to give energy to the ball valve so that it will help to accelerate to close the valve. This leads to a reduction in closing time period and consequently reduces the amount of hydrocarbons escaping from the pump barrel.



(Figure 14: The proposed modification on ball valve)

III. 3. DESIGNING ON THE MODIFICATION ON THE BALL VALVE

III. 3.1 EQUIPMENT USEED

To design this modification, the following equipment is needed:

Steel bar: the steel bars are used to make the piles attached below the ball valves and also to connect to the balls as to pull and push the ball up and downs.

(Figure 15 : the bar used)

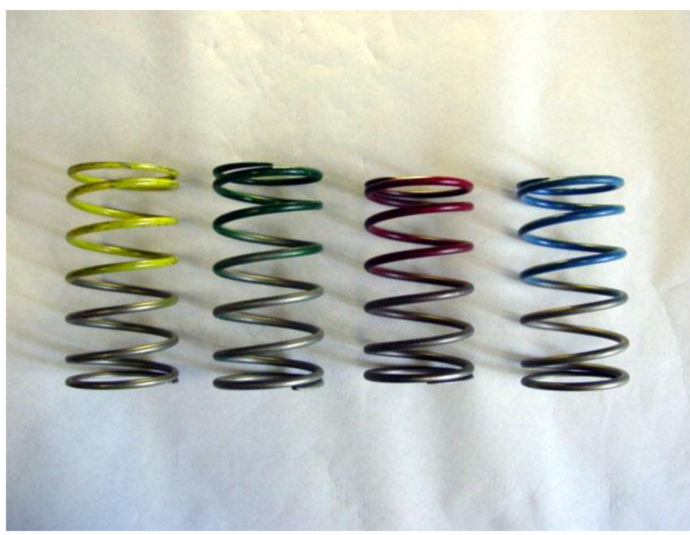
Motor: The motors are used as the force generators to pull and push the ball up and down so that the closing time period is reduced.

(Figure 16: The Motor used)

Bolt and nuts: bolts and nuts are used to strengthen and hold the design structure and they will help the design to be able for the operation mechanism.

(Figure 17: Bolts and nuts used)

Spring: The spring is used to attach at the bottom of the plate which is used to connect the pile and hold the structure tightly.



(Figure 18: The spring used)

The steel round plate: The round steel plates are used to make the structure strong and hold the structure tightly at the bottom, the middle, and the upper next to the balls.

(Figure 19: The plate used)

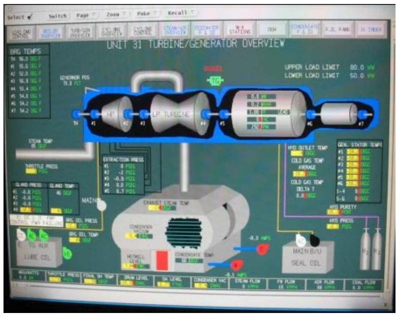
The steel balls: The balls are designed and used as the valve balls which act as the valve ball for the stationary valve.

(Figure 20 : The steel ball used)

III. 3.2 TOOLS USED

In this project, several tools are required to design the modification. These tools include:

1. **Power generator:** A electricity generator that provides the electricity for the welding and drilling of the holes required for the design.



(Figure 21: The power generator)

2. **The welding machine:** Welding machine is used to weld the metal material to integrate them together to get the structure as designed.

(Figure 22: The welding machine used)

3. **The drilling machine:** The drilling machine is used to drill the hole for the structure design.

(Figure 23: The drilling machine used)

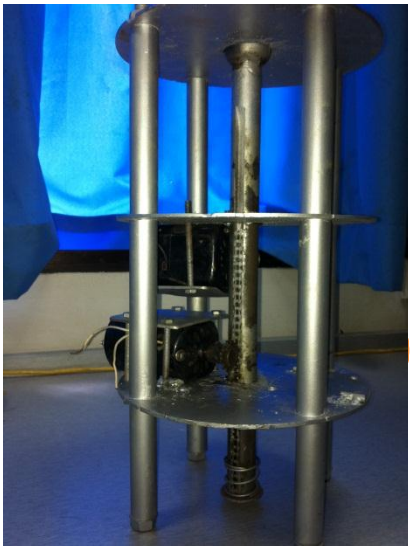
4. **The spanners and adjustable wrench:** They are used for tightening and losing purposes of the bolts and nuts. They help in tightening the bolts and nuts to hold the structure.

(Figure 24 : The spanners and adjustable wrench used)

III. 3.3 THE DESIGN ON THE BALL VALVE OF PROTOTYPE

Using all the equipment and tools as described above, the prototype was successfully made into real thing. And its working mechanism is as working principle as designed.

It has taken almost 5 weeks to complete the prototype because it requires a lot of mechanic work and also some skill of welding and measurement.



(Figure 25: The designed prototype)

The motors are attached at the bottom of the ball valve and they operate to pull up and down the small rod which attached to the ball.

When the pump is at the upstroke and it reaches maximum height, the downward motor will operate to open the traveling valve, so that the fluid can enter into the pump.

When the pump is downward and it reaches its minimum height, the upper motor will operate to close the traveling valve and seal the ball and the opening inlet so that the pump barrel holds the fluid inside the pump barrel.

The overall prototype was completed at the middle of the semester.

(Figure 26: The overall designed prototype)

III. 3.4. THE POWER CONSUMED BY THE MOTORS TO OPERATE

(Figure 27: The motor used)

The electrical power consumed by the motors used can be calculated using the formula:

W = P (T)

Where W, is the electrical energy, J

P, is the power of motor, w

T, is the time, s.

In our operation of 6 strokes per minute, with each of the two motors operates only 1 second to help close and open the valve. So in one stroke, the total time is 2 seconds.

In one day, the sucker rod pump operates

$$N = 24(60)(9) = 12960 strokes$$

So the total operating time for the two motors in one day is

T = 12960 x 2

= 25 920 seconds

The motors used have the electrical power of P = 900W, so the electrical energy used by the motors is:

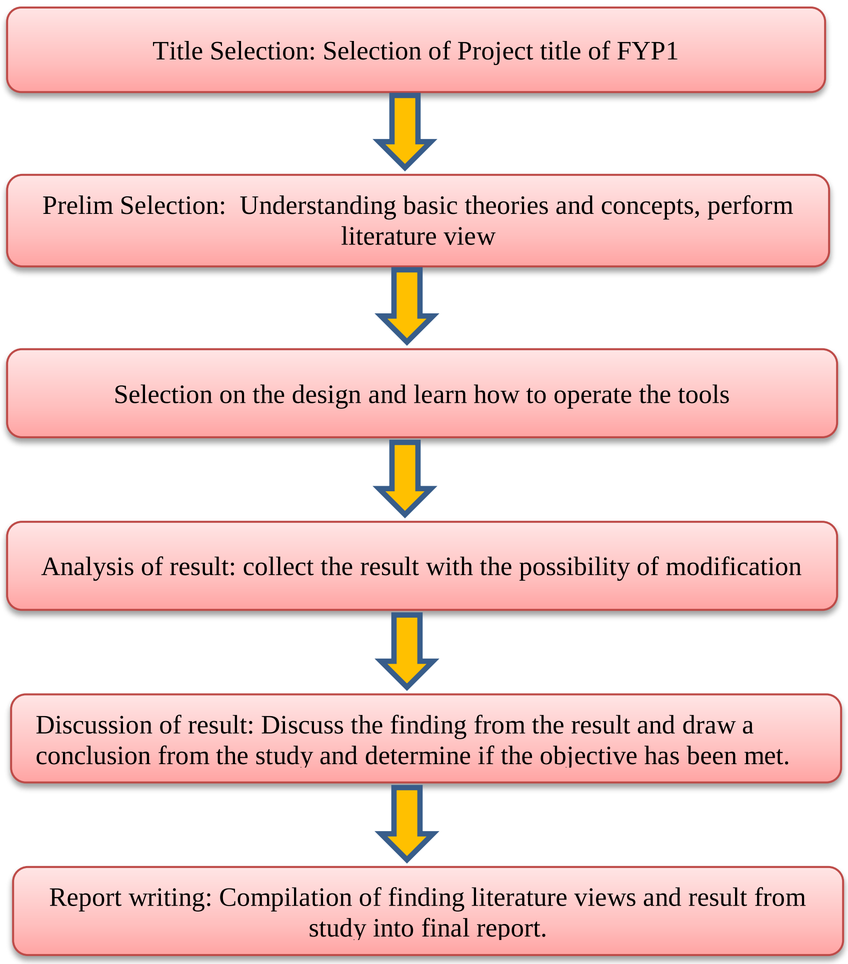
W = 25920 X 900

= 23,328,000 J

= 6.48Kwh.

III.4. THE PROJECT FLOW

The project is done with accordance to the follows:



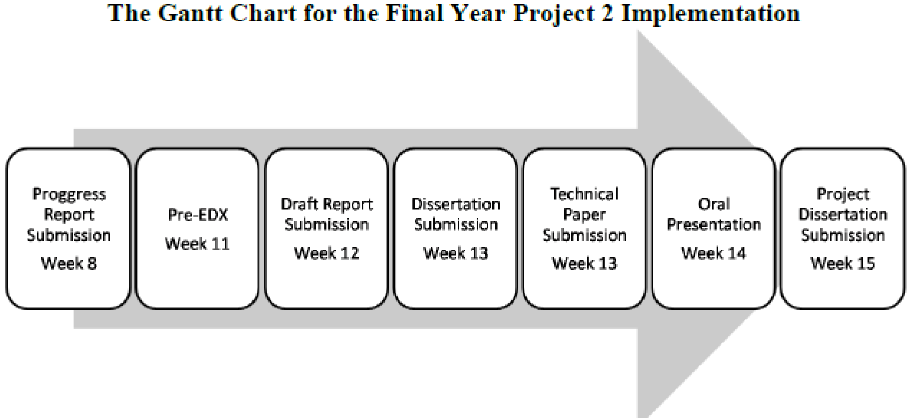
(Figure 28: The project flow)

III. 5. KEY MILLSTONE AND PLANNING FOR THE PROJECT

The project is aimed to finish within the timeframe and the planning as follows:

FINAL YEAR 2nd SEMESTER (May 2011)																	
No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1.	Looking for tools	■							Mid-semester break								
2.	Looking for equipment	■	■	■													
3.	Modification on Ball valve and prototype		■	■													
4.	Study the theory of Force			■	■	■											
5.	Study the theory of Motion					■	■	■									
6.	Submission of Progress report									■							
7.	Testing on the prototype									■	■	■	■	■			
8.	Pre-EDX												■				
9.	Submission of Draft report													■			
10.	Submission of Dissertation														■		
11.	Submission of Technical Paper														■		
12.	Oral Presentation															■	
13.	Submission of Project Dissertation (Hard bound)																■

The Gantt Chart for the Final Year Project 2 Implementation



(Figure 29: The project Millstone and planning)

CHAPTER IV: RESULT AND DISCUSSION

RESULT

IV.1. METHOD OF CALCULATION

In this research project, as the topic suggests, we are trying to make a development that can reduce the closing and opening time period for the ball valves.

To calculate the pumping efficiency increase, basically we have to calculate the reduction time that can reduce the closing and opening period of the ball vale during its operation. To do that we have to use the Newton's law which states that "The acceleration of a body is parallel and directly proportional to the net force F and inversely proportional to the mass m, i.e. $\sum F = ma$,". This law will be used with combination with the equation for the speed and the motion of a body in fluid. The general equation will be: $h = ½ at^2+v_0t+h_0$.

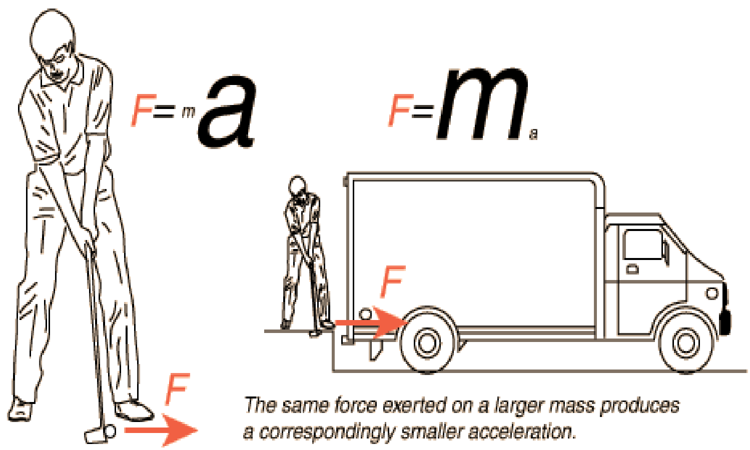


Figure 30: Newton's second law

The Newton's law suggests that we have to consider and study all the forces acting and exerting on the ball during its moving to get to the calculation. The forces contribute to the overall calculation can be, **the gravitational force of the ball, the buoyancy force of the ball, the drag force of fluid acting on the ball, and also the velocity of the pump barrel relative to the fluid inside.**

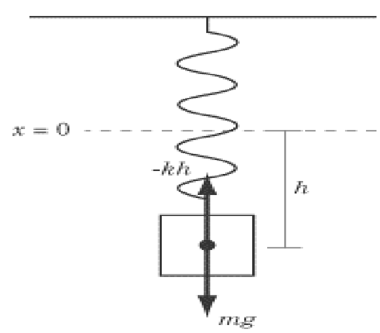


Figure 31: Gravitation Force of a body

1. GRAVITATIONAL FORCE

Gravitation, or **gravity**, is a natural phenomenon by which physical bodies attract with a force proportional to their mass.

In everyday life, gravitation is most familiar as the agent that gives weight to objects with mass and causes them to fall to the ground when dropped.

Gravitation is responsible for keeping the Earth and the other planets in their orbits around the Sun; for keeping the Moon in its orbit around the Earth; for the formation of tides; for natural convection, by which fluid flow occurs under the influence of a density gradient and gravity; for heating the interiors of forming stars and planets to very high temperatures; and for various other phenomena observed on Earth.

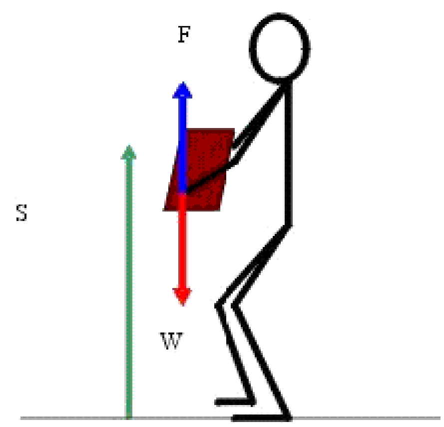


Figure 32: Gravitational force Indicator

Every planetary body (including the Earth) is surrounded by its own gravitational field, which exerts an attractive force on all objects.

Under an assumption of constant gravity, Newton's law of universal gravitation simplifies to $F = mg$, where m is the mass of the body and g is a constant vector with an average magnitude of 9.81 m/s^2. The acceleration due to gravity is equal to this g.

For example, a man whose weight is 78Kgs has a gravitation force of:

$$W = mg = 78 \times 9.81 = 765.18 \text{ N}$$

2. BUOYANCY FORCE

Since the valve ball will be submerged in the fluid, the buoyance force will exist and the consideration of its existence must be taken into account for the calculation.

Principle of the Buoyancy force is stated as: "**A body floating or submerged in a fluid is buoyed upward by a force equal to the weight of the fluid that would be in the volume displaced by the fluid." And this force is called Buoyancy force**.

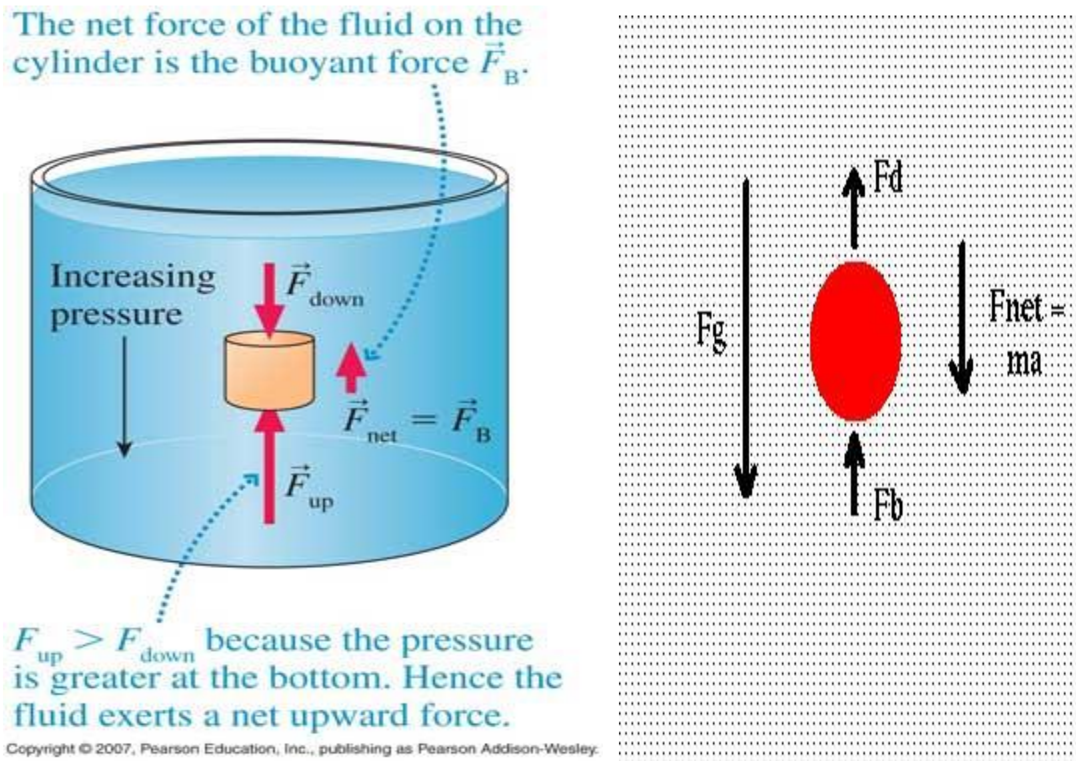


Figure 33: Buoyancy Force

Archimedes' Principle – A fluid exerts an upward buoyant force buoyant on an object immersed in or floating on the fluid. The magnitude of the buoyant force equals the weight of the fluid displaced by the object.

Example a block of wood which has a volume of 1 m^3 submerged in water whose density is 1000kgs/m^3, experiences buoyancy force of:

$$W= F = mg= V\rho g = 1 \times 1000 \times 9.81 = 981 \text{ N}$$

3. Drag Force exerted on the valve ball

In fluid dynamics, drag (sometimes called air resistance or fluid resistance) refers to forces that oppose the relative motion of an object through a fluid (a liquid or gas). Drag forces act in a direction opposite to the oncoming flow velocity.

In fluid dynamics, the **drag equation** is a practical formula used to calculate the force of drag experienced by an object due to movement through a fully-enclosing fluid.

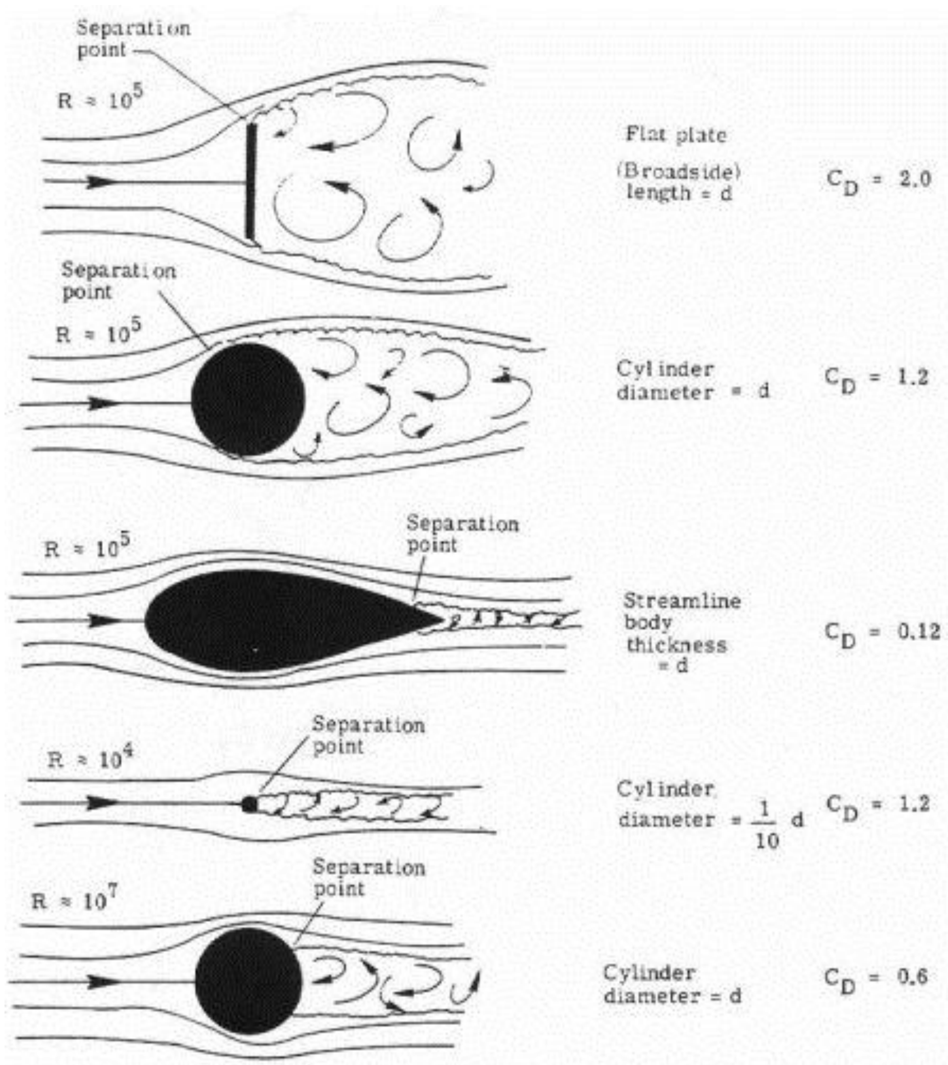


Figure 34: Drag force of submerged body

The equation is attributed to Lord Rayleigh, who originally used L^2 in place of A (with L being some linear dimension). The force on a moving object due to a fluid is:

$$F_D = \frac{1}{2} \rho v^2 C_D A$$

Where

F_D is the force of drag, which is by definition the force component in the direction of the flow velocity, (N)
ρ is the mass density of the fluid, (Kg/m^3)
v is the velocity of the object relative to the fluid, (m/s)
A is the reference area, (m^2)
C_D is the drag coefficient — a dimensionless constant,

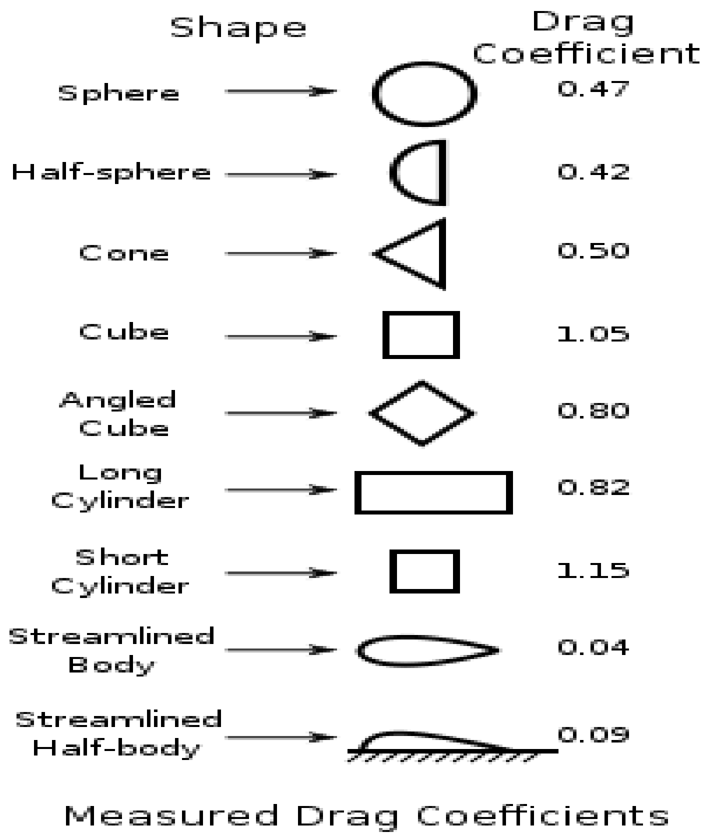


Figure 35 : Drag coefficients

The coefficient Cd of drag force is dependent on the shape of the body emerged in the fluid. It has great effect on the drag force.

The accurate calculation will have to consider on the shape of the body.

The figure on the right is showing the value of the drag coefficient for different types of shape of the body submerged in the fluid.

Some irregular shapes, it is hard to know their values of drag coefficient. The assumption sometime has to be made for the calculation of their drag force.

5. THE FORCE GENERATED BY THE MOTOR

The force generated by the motor is calculated using the formula:

Figure 36: Motor

F = P x T

Where:

P is the power (w)

T is the time (s)

F is the force (J)

For example,

A motor which has power of 900 w, in 1 minute will generate force of

F = 900 x 60 = 54 000 J

IV.2. CALCULATION OF THE EFFECIECIENCY INCREASE IN CAPACITY

CASE STUDY: Determine the efficiency of the pump capacity before and after the modification in this example:

A sucker rod pump pumps oil whose density is 915 kg/m^3 from a well at a rate of 800 Bbl/Day. The pump operates at 6 stokes per minute and it is stoke length S = 9 m, wiith a diameter of the pump barrel of 2.5 in. The ball is metal steel whose has a density of 8000 kg/m^3 and has a diameter of 1.5 in. Assume that when the valve is maximized open, it moves 6 cm from the seal where it deposits when the valve is closed.

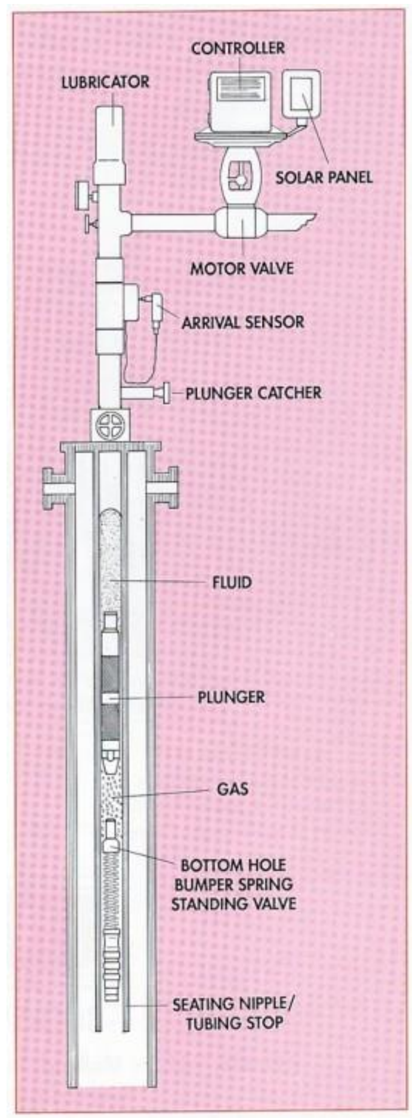


Figure 37: Downhole valve

<u>Before the modification:</u>

Actual pumping rate:

Qactual = 800 BBL/D

Maximum pumping rate:

- Number of stokes in one day

  N = 24 x 60 x 6 = 8640

- Maximum fluid the pump can carry per stoke = The volume of overall pump barrel for one stoke length

  $Qs = S \times A_{barrel}$

  Where S is the stoke length

  A_{barrel} is the area of the barrel

  $Qs = 9 \times 3.14 \times (2.5 \times 0.0254)^2/4$

  $Qs = 0.028487\ m^3$

  $Qs = 28.487\ dm^3$

  Maximum pumping rate per day

Qmax = Qs x N

= 28.487 x 8640

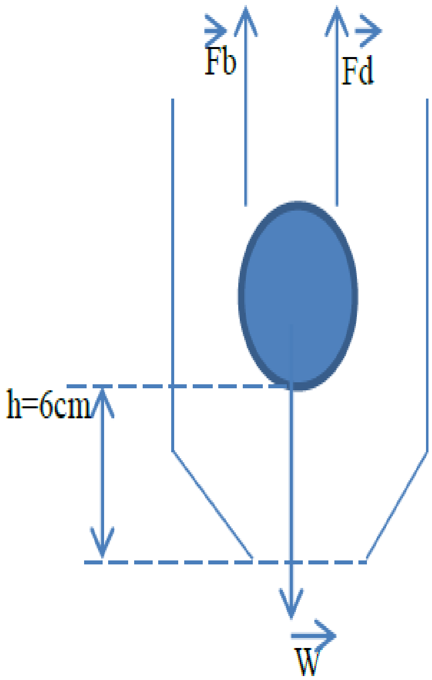
= 246 135 dm^3

= 246 135/ 158.987

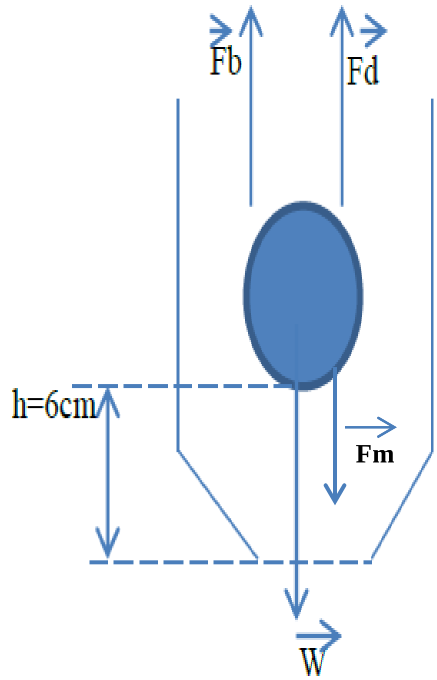
= 1548.145 BBL/Day

Efficiency = 800/1528.145 = 51.67 %.

After the modification:



Before modification



After modification

- Time taken to close properly before the modification

In this case, the ball experiences the motion

$h = ½ at^2$

where

a is the acceleration in (m/s^2)

t is the time taken (s)

h is the height (m)

Newton's law:

$$\sum F = ma$$

In this case $\sum F = W - Fb - Fd$

And $Fd = ½ \gamma V^2 CdA$

$A = \pi D^2/4$

$= 3.14 \text{ x } (1.5\text{x}0.0254)^2/4$

$= 1.14 \text{ x } 10^{-3} \text{ m}^2$

For this shape Cd= 0.47

$\gamma = 925\ Kg/m^3$

V = 6 x 9 x 2 / 60

= 01.8 m/s

Fd = ½ x 915 x 1.8^2 x 0.47 x 1.14 x 10^{-3}

Fd = 0.794 N

Fb = $4_{/3}\pi r^3\ \gamma_{oil}$ x g

= 4/3 x 3.14 x $(0.75x0.0254)^3$ x 915 x 9.81

= 0.26 N

W = $4_{/3}\pi r^3\ \gamma_{Steel}$ x g

= 4/3 x 3.14 x $(0.75 \times 0.0254)^3$ x 8000 x 9.81

= 2.27 N

$\sum F = W - Fb - Fd$ = 2.27 – 0.26 – 0.794

= 1.216 N

m = $4_{/3}\pi r^3\ \gamma_{Steel}$

= 4/3 x 3.14 x $(0.75x0.0254)^3$ x 8000

= 0.232 Kg

But

$$\sum F = ma$$

a = F/m

a = 1.216/.232

= 5.24 m/s^2

And

h = ½ $a_1 t_1^2$

$t_1 = \sqrt{\frac{2h}{a_1}}$

$t_1 = \sqrt{\frac{2\ x\ 0.06}{5.24}}$

t_1 = 0.15 s

- The time taken to close after the modification

The forces generated by motor in 0.01 second is

$F_m = P \times T$

$= 180 \times 0.1$

$= 18$ N

In this case, the Force generated by the motor will be added at to the total force experience by the ball, so

$$\sum F = W + Fm - Fb - Fd = 2.27 + 18 - 0.26 - 0.794$$

$= 19.216$

$a_2 = 19.216/0.232$

$= 82.82$ m/s^2

And

$h = ½ a_2 t_2^2$

$$t_2 = \sqrt{\frac{2h}{a_2}}$$

$$t_2 = \sqrt{\frac{2\ x\ 0.06}{82.82}}$$

$t_2 = 0.03$ s

Hence the time reduction is

$$\Delta t = t_1 - t_2$$

$= 0.15 - 0.03$

$= 0.12$ s

The travelling speed of the rod pump is

V $= 6 \times 9 \times 2 / 60$

$= 0.9$ m/s

If the valve is open, in one minute, the pump barrel can lose fluid of

Vm $= V \times A_{Pb}$

$= V \times \pi D^2/4$

$= 0.9 \times 3.14 \times (2.5 \times .0254)^2/4$

= 0.002848 m^3

So if the closing time is reduced by $\Delta t = 0.12$, so the pump can carry more fluid by the amount of :

Qs (increase) = 0.12 x 0.002848

= 0.0003418 m^3

Since the pump operates N = 8640 stokes in a day,

So in a day it can help increase in pumping more fluid by

Qd (Add) = Qs x N

= 0.0003418 x 8640

= 2.9531 m^3/d

= 2953.1 dm^3/d

= 2953.1/158.98

= 18.6 BBL/d

So with modification, the overall production will be

Qt = 800 Bbl/d + 18.6 Bbl / d

= 818.6 Bbl/d

This time the capacity efficiency is

Efficiency = 818.6 / 1528.145

= 53.56%

Therefore the percentage increase in capacity efficiency is 53.56 – 51.67 = 1.89 %

RESULT AND DISCUSSION

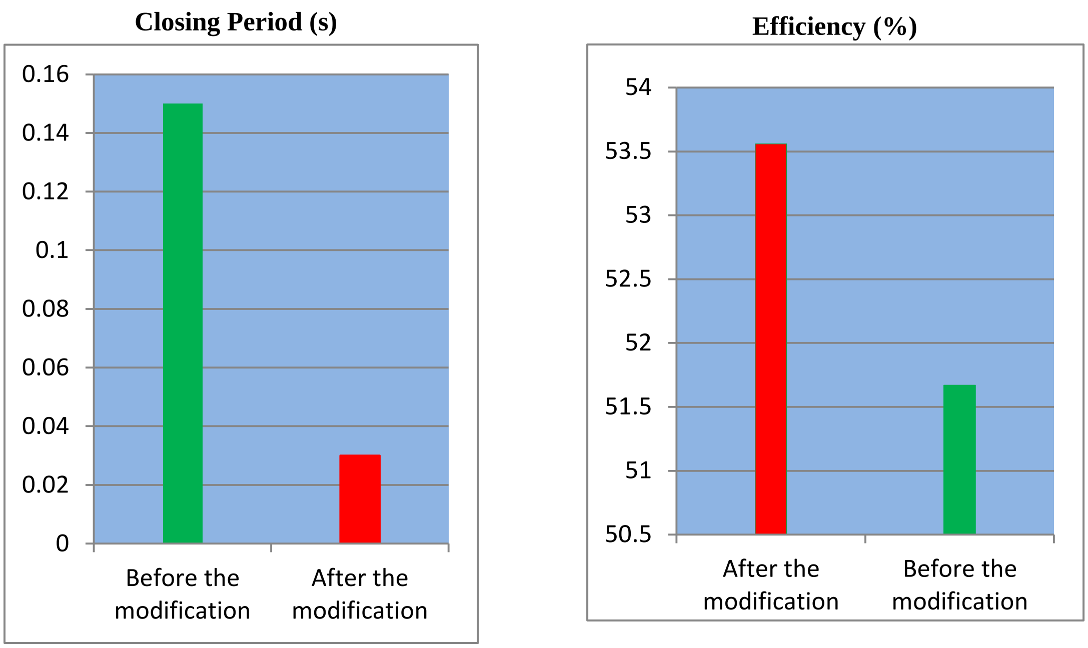


Figure 38: Closing Period and Pump Efficiency

From the calculation, we can see that, the usage of the modified ball valve of the sucker rod pump will lead to an increase a production of 18.6 barrels per day which can be translated as 1.89 % increase in the capacity efficiency.

In one day, it can help to increase the production of 18.6 barrels; this can be interpreted to a sum of 18.6 barrels x 365 = 6789 barrels in a year.

If the current price is 100 $ per barrel, so in one year it can help to add profit to the operating company of 100 x 6789 = 678 900 $ which is almost 1 million USD in each year.

CHAPTER V: CONCLUSION

The development on the ball valve of sucker rod pump helps a lot in increasing the pump capacity. Therefore, the future development should be done on this project to get the idea into the reality of the modifying on the pump to increase its capacity efficiency to serve the production company to maximize their profit.

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APPENDIX

1. **The Newton's Second Law of Motion**

$\sum F = ma$

Where m is the mass of body in (Kg)

a is acceleration in (m/s^2)

2. **The motion equation**

$h = ½ at^2+v_ot+h_o$

Where h is the height in (m)

a is acceleration (m/s^2)

t is the time in (s)

v_o is the velocity at t = 0s

h_o is the height at t = 0s

3. **The Electrical Energy**

W = P (T)

Where W, is the electrical energy, (J)

P, is the power of motor, (w)

T, is the time, (s).

4. **Weight of a body**

W = m (g)

Where m is mass in (kg)

g is gravitational acceleration, (m/s^2)

5. **Buoyancy Force**

Fb = Vρg

Where V is the volume emerged in the liquid, (m^3)

ρ is the density of body, (Kg/m^3)

g is the gravitational acceleration (m/s^2)

6. Drag force

$$F_D = \frac{1}{2} \rho v^2 C_D A$$

Where FD is the force of drag, which is by definition the force component in the direction of the flow velocity,

ρ is the mass density of the fluid, (Kg/m3)

v is the velocity of the object relative to the fluid, (m/s)

A is the reference area, (m2)

CD is the drag coefficient — a dimensionless constant.

7. Drag Force Coefficient With Different Shape of Bodies