DESIGN AND FABRICATION OF HYDRAULIC RAM WITH METHODS OF IMPROVING EFFICIENCY

Poonam Diwan[1], Aman Patel[2], Lavish Sahu[3]
[1,3]Assistant Professor, [2]M.tech Student
Email: Poonamdiwan5@gmail.com[1], vicky999.2009@gmail.com[2], lavishkumar28@gmail.com[3]

Abstract

Pumps are among the oldest of the machines. The use of this device was suspended in the middle-ages and revived in the 16th century when a German translation of the Greek work describing the pump was published. The earliest pump to be used was the hand pump. More advanced pumps were, however, known to the Romans, as shown by the double cylinder force pump now preserved in the British museum, but their use was apparently lost in this century at the end of the Roman Empire. In the original Montgolfier design (diagram shown below), a water supply or delivery pipe feeds into a larger bored pipe that is turned up at the end and also necked down creating both a pinch point and a venturi effect causing the water to increase in speed and pressure at the exit. The iron ball, which was most probably a cannon ball that happened to be handy would fit easily into the larger bored pipe but was larger enough that it could not escape out the venturi at the end of the pipe. The force of the water flowing into the larger bore pipe would push the "cannon" ball down the bore and into the venturi suddenly stopping the flow of water. This sudden blockage of the delivery pipe would cause a dramatic increase in the water pressure behind the ball commonly referred to as "water hammer:" which in turn forced a small amount of water through a one-way valve and into the air chamber and delivery pipe. The pressure would then dissipate and release the iron ball, it would roll back into the larger bore area and the cycle would begin all over again. In operation the water would have been delivered in short pulses under high pressure into the air chamber which would act as a buffer, smoothing out the supply of water heading into the delivery pipe and on its way to the intended destination. The addition later of the snifter valve allowed a small amount of air to enter into the air chamber keeping the system operational for much longer periods of time between normal inspections and servicing. Some of these designs ended up being quite large with drive pipes exceeding 8 inches in diameter.

Keywords: Compressors, Hydraulic, Pumps

I. INTRODUCTION

The hydraulic Ram pump or hydram is a complete automatic device that uses the energy in the flowing water such as spring, stream or river to pump part of the water to a height above that of the source. With a continuous flow of water a hydram operates continuously with no external energy source.

A hydram is a structurally simple unit consisting of two moving parts. These are the impulse valve (or waste valve) and the delivery (check) valve. The unit also consists of an air chamber and an air valve. The operation of a hydram is intermittent due to the cyclic opening and cloning of the waste and delivery values. The closure of the waste valve creates a high pressure rise in the drive pipe. An air chamber is required to transform the high intermittent pumped flows into a continuous stream of flow. The air valves allow air into the hydram to replace the air absorbed by the water due to the high pressure and mixing in the air chamber.

Types of Mechanical Pumps

In mechanical pumps, the gas present in a vacuum system is transferred from a low pressure to a higher pressure region. In order to be efficient, the pump has to provide simultaneously a finite pumping speed and compression. To carry out this double task two main mechanisms have been used up to now:

- Isolation and subsequent compression of a gas volume defining a first category often named "Positive-displacement pumps".
- Transfer to the gas molecules of a preferential velocity direction introducing a mean drift of the

gas towards the high pressure region. This category is known as: "Momentum transfer pumps" having to pull fluids. Submersibles are more efficient than jet pumps.

1.2 Modern hydraulic rams

Modern hydraulic rams all work on the same principle although the "cannon" ball inside a necked down iron pipe idea has been replaced with modern steel, brass, bronze, PVC and stainless fittings that can easily be obtained from your local hardware store well as put back into use today.

The main virtue of the hydram is that its only moving parts are two valves, and it is therefore mechanically very simple. This gives it very high reliability, minimal maintenance requirements and a long operation life.

. DESIGN METHODOLOGY

Before going to design methodology let us focus on the advantages and disadvantages of hydraulic ram pump.

2.1 Advantages:

- No moving parts,
- No power requirements,
- Inexpensive,
- Quiet pumping continuously over a long period,
- Pollution free or "Green" pump,
- Simple construction and easy to install, and
- Only initial cost and very low or negligible maintenance cost.
- 7/24 operation. It operates seven days a week; 24 hours a day.
- Reliable

2.2 Disadvantages:

- The disadvantage of ram is that, through the waste valve, it throws back to ground considerable amount of water since not all water that enters the ram are pumped uphill as compared to electrically or petrol driven pumps where it has no waste water.
- It must have a continuous source of supply at a minimum height
- It cannot pump viscous fluids to a greater height. Usually used for pumping drinking water or potable water.
- The rate of water pump from the source is discontinuous.
- It is a noisy operation.

2.3 Considerations in hydraulic ram pump system design:

The following factors need to be considered in hydraulic Ram pump system design

- Area suitability (head and flow rate)
- Flow rate and head requirement
- Intake design
- Drive system
- Pump house location
- Delivery pipes routing
- Distribution system

2.4 Construction of project model:

For reducing the above disadvantages and making a model which is more efficient than the previous existing model we use the following component

Main component used in model

Main components used in the hydraulic ram model are:

- **Valve**
- **Tee**
- **Union**
- **Swing check valve**
- **Spring check valve**
- **Bushing**
- **Pipe Cock**
- **100 psi gauge**
- **Nipple**
- **Coupling**
- **PVC pipe**
- **Reservoir for storing waste water through swing chuck valve**

3.VALVE

A **valve** is a device that regulates, directs or controls the flow of a fluid (gases, liquids, fluidized solids, or slurries) by opening, closing, or partially obstructing various passageways. Valves are technically valves fittings, but are usually discussed as a separate category. In an open valve, fluid flows in a direction from higher pressure to lower pressure.

Valves have many uses, including controlling water for Irrigation, industrial uses for controlling processes, residential uses such as on / off & pressure control to dish and clothes washers & taps in the home. Even aerosols have a tiny valve built in. Valves are also used in the military & transport sectors.

Fig 3.1 Valve

Valves may be operated manually, either by a handle, lever, pedal or wheel. Valves may also be automatic, driven by changes in pressure, temperature, or flow. These changes may act upon a diaphragm or a piston which in turn activates the valve, examples of this type of valve found commonly are safety valves fitted to hot water systems or boilers.

3.1 Tees

Pipeline Engineering fabricates Barred Tees and Sphere Tees used in a pig launcher / receiver systems and / or at branches in the pipeline to ensure the safe passage of a pig or sphere past the open branch area.

Piggable barred tees incorporate simple bar sections welded across the pipeline tee branch to allow a pig to negotiate the branch opening. Piggable tees are manufactured to specific customer project specifications and International pressure vessel and piping codes such as ASME, PD5500.

Fig3.2 TEES

3.2.3 UNION

A union is similar to a coupling, except it is designed to allow quick and convenient disconnection of pipes for maintenance or fixture replacement. While a coupling would require either solvent welding, soldering or being able to rotate with all the pipes adjacent as with a threaded coupling, a union provides a simple transition, allowing easy connection or disconnection at any future time. A standard union pipe is made in three parts consisting of a nut, a female end, and a male end. When the female and male ends are joined, the nuts then provide the necessary pressure to seal the joint. Dielectric unions are unions with dielectric insulation, used to separate dissimilar metals (such as copper and galvanized steel) to avoid the damaging effects of galvanic corrosion. When two dissimilar metals are in contact with an electrically conductive solution (even tap water is conductive), they will form a battery and generate a voltage by electrolysis. When the two metals are in direct contact with each other, the electric current from one metal to the other will cause a movement of ions from one to the other, dissolving one metal and depositing it on the other.

Rotary unions are unions that allow for rotation of one of the united parts.

3.2.4 **Brass swing check valve**

A **check valve**, **clack valve**, **non-return valve** or **one-way valve** is a valve that normally allows fluid (liquid or gas) to flow through it in only one direction.

Check valves are two-port valves, meaning they have two openings in the body, one for fluid to enter and the other for fluid to leave.. Check valves are often part of common household items. Although they are available in a wide range of sizes and costs, check valves generally are very small, simple, or inexpensive. Check valves work automatically and most are not controlled by a person or any external control; accordingly, most do not have any valve handle or stem. The bodies (external shells) of most check valves are made of plastic or metal.

An important concept in check valves is the cracking pressure which is the minimum upstream pressure at which the valve will operate. Typically the check valve is designed for and can therefore be specified for a specific cracking pressure.

Fig 3.4 Brass Swing Check valve

3.2.5 Reducing Bushing

A pipe fitting with male and female threads that extends a run by joining two pipes of different diameter.

Fig 3.6 Reducing Bushing

3.2.6 100 psi Gauge bourdon gauge

The Bourdon pressure gauge uses the principle that a flattened tube tends to straighten or regain its circular form in cross-section when pressurized. Although this change in cross-section may be hardly noticeable, and thus involving moderate stresses within the elastic range of easily workable materials, the strain of the material of the tube is magnified by forming the tube into a C shape or even a helix, such that the entire tube tends to straighten out or uncoil, elastically, as it is pressurized. In practice, a flattened thin-wall, closed-end tube is connected at the hollow end to a fixed pipe containing the fluid pressure to be measured. As the pressure increases, the closed end moves in an arc, and this motion is converted into the rotation of a (segment of a) gear by a connecting link that is usually adjustable. A small-diameter pinion gear is on the pointer shaft, so the motion is magnified further by the gear ratio. The positioning of the indicator card behind the pointer, the initial pointer shaft position, the linkage length and initial position, all provide means to calibrate the pointer to indicate the desired range of pressure for variations in the behavior of the Bourdon tube itself. Differential pressure can be measured by gauges containing two different Bourdon tubes, with connecting linkages.

Bourdon tubes measure gauge pressure, relative to ambient atmospheric pressure, as opposed to absolute pressure; vacuum is sensed as a reverse motion. Some aneroid barometers use Bourdon tubes closed at both ends (but most use diaphragms or capsules, see below). When the measured pressure is rapidly pulsing, such as when the gauge is near a reciprocating pump, anorifice restriction in the connecting pipe is frequently used to avoid unnecessary wear on the gears and provide an average reading; when the whole gauge is subject to mechanical vibration, the entire case including the pointer and indicator card can be filled with an oil or glycerin.

3.2.7 Coupling

A coupling connects two pipes to each other. If the size of the pipe is not the same, the fitting may be called a reducing coupling or reducer, or anadapter. By convention, the term "expander" is not generally used for a coupler that increases pipe size; instead the term "reducer" is used.

3.2.8 NIPPLE

In plumbing and piping, a nipple is a fitting, consisting of a short piece of pipe, usually provided with a male pipe thread at each end, for connecting two other fittings.

The length of the nipple is usually specified by the overall length with threads. It may have a hexagonal section in the center for wrench to grasp (sometimes referred to as a "hex nipple"), or it may simply be made from a short piece of pipe (sometimes referred to as a "barrel nipple" or "pipe nipple"). A "close nipple" has no unthreaded area; when screwed tightly between two female fittings, very little of the nipple remains exposed.

3.3 SPECIFICATION & MATERIAL OF COMPONENTS

S No	Components	Specification	Material
1	Valve	1-1/4"	Brass
2	Tee	1-1/4"	Cast iron
3	Union	1-1/4"	Cast iron
4	Swing check valve	1-1/4"	Brass
5	Spring check valve	1-1/4"	Brass
6	Coupling	1-1/4"	Cast iron
7	Union	3/4"	Cast iron
8	Psi gauge	100 psi	Polycarbonate
9	Bushing	1-1/4"	Cast iron
10	pipe	1.5ft	P.V.C
11	Valve	3/4"	Brass
12	Tee	3/4"	Cast iron
13	Nipple	3/4"	Cast iron
14	Nipple	1-1/4"	Cast iron
15	Union	3/4"	Cast iron

FIG 3.10 FINAL ASSEMBLE HYDRAULIC RAM

WORKING OF MODEL

The concept behind the ram idea is a "water hammer" shock wave. Water has weight, so a volume of water moving at a certain speed has momentum - it doesn't want to stop immediately. If a car runs into a brick wall the result is crumpled metal. If a moving water flow in a pipe encounters a suddenly closed valve, a pressure "spike" or increase suddenly appears due to all the water being stopped abruptly (that's what water hammer is - the pressure spike). If you turn a valve off in your house quickly, you may hear a small "thump" in the pipes. That's water hammer.

Step.1

Water (blue arrows) starts flowing through the drive pipe and out of the "waste" valve (#4 on the diagram), which is open initially. Water flows faster and faster through the pipe and out of the valve.

Step.2

At some point, water is moving so quickly through the brass swing check "waste" valve (#4) that it grabs the swing check's flapper, pulling it up and slamming it shut. The water in the pipe is moving quickly and doesn't want to stop. All that water weight and momentum is stopped, though, by the valve slamming shut. That makes a high pressure spike (red arrows) at the closed valve. The high pressure spike forces some water (blue arrows) through the spring check valve (#5 on the diagram) and into the pressure chamber. This increases the pressure in that chamber slightly. The pressure "spike" the pipe has nowhere else to go, so it begins moving away from the waste valve and back up the pipe (red arrows). It actually generates a very small velocity *backward* i

Step. 3

As the pressure wave or spike (red arrows) moves back up the pipe, it creates a lower pressure situation (green arrows) at the waste valve. The spring-loaded check valve (#5) closes as the pressure drops, retaining the pressure in the pressure chamber.

Step. 4

At some point this pressure (green arrows) becomes low enough that the flapper in the waste valve (#4) falls back down, opening the waste valve again

Step 5

Most of the water hammer high pressure shock wave (red arrows) will release at the drive pipe inlet, which is open to the source water body. Some small portion may travel back down the drive pipe, but in any case after the shock wave has released, pressure begins to build again at the waste valve (#4) simply due to the elevation of the source water above the ram, and water begins to flow toward the hydraulic ram again.

Step 6

Water begins to flow out of the waste valve (#4), and the process starts over once again.

DESIGN ANALYSIS

Design Factors

The ram pump consists essentially of two moving parts, the impulse and delivery valves. The construction, basically consist of pipe fittings of suitable designed size. The main parameters to be considered in designing a hydraulic ram include

- The difference in height between the water source and pump site (called vertical fall).
- The difference in the height between the pump site and the paint of storage or use (life).
- The quantity (Q_w) of flow available from the source.
- The length of the pipe from the source to pump site (called the drains pipe).
- The quantity of water required.
- The length of pipe from the storage site (called the delivery pipe)

Determination of Design Parameters for the Hydraulic Ram

W = weight of water flowing per second into the chamber,

w = weight of water raised per second,

h = height of water in supply tank above the chamber,

H = height of water raised from the chamber.

The energy supplied by the supply tank to the ram

= weight of water supplied × Height from which the water is supplied.

= W × h.

Energy delivered by the ram

= Weight of water raised × height through which water is raised.

= w × H.

Thus

$$\text{efficiency} = \frac{\text{energy delivered by the ram}}{\text{energy supplied to the ram}}$$

$$\eta = \frac{w \times H}{W \times h}$$

The efficiency η, specified above is called as D' Aubuisson's efficiency.

Rankine gave another form of efficiency as he considered that the weight of water raised is not H, but it is (H-h).

$$\eta = \frac{w \times (H-h)}{(W-w) \times h}$$

EFFICIENCY IMPROVING TECHNIQUES

6.1 Use of Pressure vessel

It helps to increase the pressure inside the pipe. A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure.

The pressure differential is dangerous and fatal accidents have occurred in the history of pressure vessel development and operation. For these reasons, the definition of a pressure vessel varies from country to country, but involves parameters such as maximum safe operating pressure and temperature.

6.2 **Multiple ram set-up**

By using Multiple Ram set up same amount of water is increases and if they are arranged in series with single source of flow then the volumetric efficiency is increased due to increase in output flow rate.

Fig 6.2 Multiple Ram Set

6.3By using smaller Drive pipe diameter

For cost and weight efficiency, the smaller the diameter of the drive pipe, the better. However, drive pipe diameter also affects the ram's performance. A drive pipe with too small a diameter restricts the flow of water to the pump with the result that the pump delivers less water.

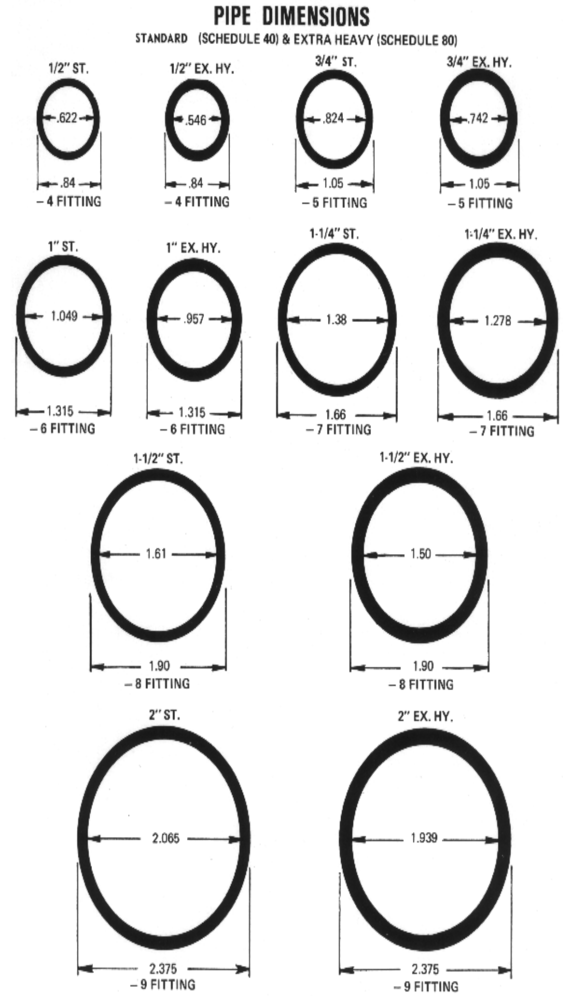

Fig 6.3Different size of pipe diameter

6.4 By Reducing the Mass of the Waste Valve Plunger

Increasing the mass of the waste valve plunger by using larger and therefore heavier components has the same effect on the pump's performance as increasing the valve stroke, i.e., it reduces the operating frequency of the ram and generally increases both the quantity of water used by the ram and the quantity delivered by the ram. But for low drive heads or for a drive pipe of too small a diameter, too heavy a plunger might prevent the operation of the pump altogether. If operating frequencies prove too high (as might be the case with drive heads much larger than 4 meters), the quantity of water delivered by the ram would be small. Though increasing the mass of the plunger would decrease the frequency and increase the rate at which water is delivered, this might possibly reduce the life of the valve because of the increased forces as the valve closes repeatedly.

6.5 Use of PVC Drive Pipe

Several trial runs were made using a 1-1/2"-diameter, class 12 rigid PVC pressure pipe (pressure rated to a head of 120 meters). Though it is known that the commonly used galvanized iron pipe is more efficient than PVC, it was felt that use of PVC could prove advantageous on occasions when ram components have to be carried on foot to remote areas. From testing, it is apparent that the PVC drive pipe is slightly less efficient. However, since durability tests have not been carried out with the PVC drive pipe, it is difficult to state here how much, if any, the life of the pipe would be reduced by the operation of the ram.

Calculation:

Calculation of discharge through supply pipe:
We used stop watch for calculation of discharge and meter scale for calculating volume

Set no.	Time (in second)	Amount of water(in litre)	Discharge Q (in litre/s)
1	10	20	2
2	10	18	1.8
3	10	18.56	1.856
4	10	19.55	1.955

Table 6.1-Calculation of discharge through supply

Supply head (h) =5ft =1.524m
Height of water raised from the chamber (H)=25ft=7.62m
Calculation of discharge through delivery pipe:

Set no.	Time (in second)	Amount of water(in litre)	Discharge q (in litre/s)
1	10	1.5	0.15
2	10	1.12	0.112
3	10	1.02	0.102
4	10	1.10	0.11

Table 6.2-Calculation of discharge through delivery pipe

Calculation of efficiency

Set no.	Q	Q	H	h	$\eta_{D'Aub}$ %	$\eta_{Rankine's}$ %
1	0.15	2	7.62	1.524	37.5	32.43
2	0.112	1.8	7.62	1.524	31.11	23.72
3	0.102	1.856	7.62	1.524	27.47	23.26
4	0.11	1.955	7.62	1.524	28.13	23.84

Table 6.3- Calculation of efficiency

Average efficiency
$\eta_{D'Aubuisson's}$=31.05%

$\eta_{Rankine's}$=25.8125%

CONCLUSION

The present study is centered towards the development of a hydraulic ram pump that would conveniently alleviate the problem of water supply to the mass populace. Ideally, different combinations of the supply and delivery heads and flows, stroke length and weight of the impulse valve, length to diameter ratio of the drive pipe, volume of the air chamber and size of the snifter valve, etc. were tried to come up with an optimum size of a hydram pump presented in this study.
From our experiment we find that the efficiency of the hydraulic ram which is designed by us is more efficient than the design developed earlier by using 1-1/4 inch valve.
This ram-pump is also use in hilly area where the source of water is continuous.

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