Design of a Hydraulic Ram Pumping System

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Abstract- The hydraulic ram is a mechanical water pump that suitable used for agriculture purpose. It can be a good substitute for DC water pump in agriculture use. The hydraulic ram water pumping system has ability to pump water using gravitational energy or the kinetic energy through flowing source of water. This project aims to develop the water ram pump in order to meet the desired delivery head up to 3 meter height with less operation cost. The design head of 9 m and flow rate of 1.693 m^3/s. The results from this study show that the less diameter of pressure chamber and higher supply head will create higher pressure.

Indexed Terms- Hydraulic ram, Design, Pump, Flow Rate, Head.

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. The main components of a hydraulic ram pump system is as shown in Fig.1. Water is diverted from a flowing river or taken from intake structure of a spring. A tank is usually built between the ram pump and the intake to insure constant flow of water to the ram pump. The pump lifts part of the water coming through the drive pipe to a highter level at the delivery tank.

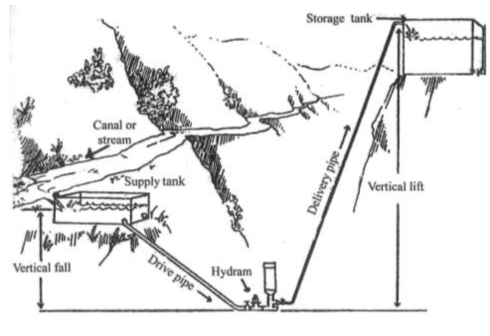

Fig.1. Hydraulic Ram Pump System

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. The system also consists of an air chamber and an air valve. Sequences processes of hydraulic ram pump are intermittent due to the opening and closing behavior of the waste and delivery valves. The behavior of hydraulic ram pump relies on water hammer phenomenon which represent on the closing and opening of the waste and delivery valves. The process begin when water entering the derive pipe coming from specific elevation height with high pressure. Therefore, the waste valve is closed by water momentum [2]. Thus, high pressure is created that will cause the delivery valve to open allowing pressurized water to rise in vacuum air chamber. Therefore, the air chamber will pressurize the water causing delivery valve to close and air valve will open allowing water to rise through delivery pipe reaching the desired place [3].

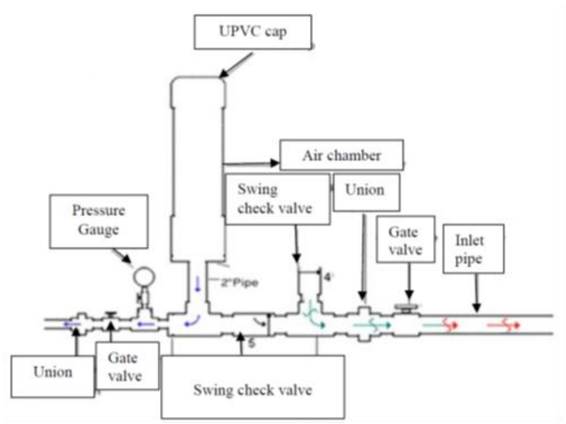

Fig 1. Hydraulic water pumping system configuration [4].

II. CONSIDERATIONS OF THE HYDRAULIC RAM PUMP SYSTEM DESIGN

When designing the hydram, there are so many parts which must be considered.Before designing the hydram, the operation and performance characteristics of hydram must be studied. The following factors need to be considered in the hydraulic ram pump system design.

Recognizing that the transient nature of hydram hydraulics, coupled with water hammer effects, makes a detailed analytical description of hydram performance virtually impossible to achieve, Dr. Slack proposed an approximate analysis based on the experimental work and subject to the following assumptions. The following assumptions are taken into account.

1 Pressure and velocity fluctuations tend to produce average caused by the supply reservoir head (i.e. drive head H), atmospheric pressure in the drive line at the impulse valve when the valve is open and by the delivery head (h) when the discharge valve is open.
2 Pipe friction remains constant.
3 Area suitability (head and flow rate)
4 Flow rate and head requirement
5 Floods consideration
6 Intake design
7 Dive system
8 Pump house location
9 Delivery pipes routing
10 Distribution system.

III. SOME DESIGN CONSIDERATIONS

Over the years many researchers have been experimenting with new materials and new methods of manufacture in an attempt to design a lightweight hydraulic ram. Most of these lightweight designs have proven unsatisfactory due to the material not being strong enough to support the high pressure which develops within the hydram. Although the hydrams have initially performed well, it is not known for how long will continue to function. It is doubtful where they will be capable of running for fifty years or more, like the traditional ones made of heavy cast steel.

The hydram is constructed from available galvanized iron pipe fittings and locally made valves. The construction requires on special skill and minimum number of tools. A drill press and some hand tools are all there are required. The cost of the hydram is very is very low compared to the cast one but its durability is needed to be determined.

The first consideration for hydram design is durability. The hydram exploits the non-compressibility of water. If water flowing at a certain speed is abruptly stopped, a high pressure (water hammer) will develop. The hydram utilizes this property by harnessing the water hammer and any pump body with a tendency to expand under pressure or is made of weak material must not be used as it will break. Although rater expensive, it is necessary to use heavy non-elastic materials. Heavy cast steel with parts of copper and brass has proved most ideal.

Another very important consideration is the internal contour of the hydram body, both from the point of view of frictional losses which will prevent the maximum spped from being achieved and air pocket which will prevent attainment of maximum pressure. Loss of speed and pressure will seriously affect the efficiency of the pump.

The success of the hydram will be guaranteed if rigid materials are used, if it is correctly made and installed and requied very little attention. The working parts, which need changing about once a year, are the rubber valve discs. Only simply maintenance required to ensure that the waterways are clear and free-flowing.

IV. 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:

a. The difference in height between the water source and pump site (called vertical fall).
b. The difference in the height between the pump site and the paint of storage or use (life).
c. The quantity (Q) of flow available from the source.
d. The length of the pipe from the source to pump site (called the drains pipe).
e. The quantity of water required.
f. The length of pipe from the storage site (called the delivery pipe)

V. DETERMINATION OF DESIGN PARAMETERS FOR THE HYDRAM

Since a hydram makes use of sudden stoppage of flow in a pipe to create a high pressure surge, the volumetric discharge from the drive pipe is given by:

$$Q = \pi r^2 L \frac{n}{60}$$

Where

Q = volumetric flow rate through the pipe,
r = pipe radius,
L = pipe length and
n = speed of revolution.

Also the velocity of fluid flow in the driven pipe is given by

$$V_d = \frac{Q}{A_d}$$

Where,

V_d = velocity of fluid flow and
A_d = area of pipe.

In order to ascertain the nature of the flow (that is whether laminar or turbulent), it was necessary to determine the Reynolds number given by

$$R_e = \frac{Vd}{\nu}$$

Where,

V = velocity of fluid flow,
d = pipe diameter and
υ= kinematic viscosity.

The friction factor *f* can be derived mathematically for laminar flow, but no simple mathematical relation for the variation of*f* with Reynolds number is available of turbulent flow. Furthermore, Nikuradse et al. found that the relative roughness of the pipe (the ratio of the size of the surface imperfection to the inside diameter of the pipe) affects the value of *f* too.

For smooth pipes Blasius suggested that for turbulent flow

$$f = \frac{0.316}{Re^{025}}$$

Where,

f = frictional factor of the pipe and
Re = Reynolds number.

The Darcy–Wersbach formula is the basis of evaluating the loss in head for fluid flow in pipes and conduits and is given by

Heat Loss = $f \frac{L}{d}\left(\frac{V^2}{2g}\right)$

Where,

g = acceleration due to gravity,
L = length of the pipe,
V= fluid velocity and
d = pipe diameter.

The velocity of fluid flow in the T–junction is given by

$$V_T = \frac{Q}{A_T}$$

Where

Q = is the volumetric fluid discharge and
A_T = pipe x-sectional area at T-junction.

Loss due to sudden enlargement at the T-junction is expressed as

$$H_{LT} = \frac{(V_d - V_T)^2}{2g}$$

Other losses of head, as in pipe fittings are generally expressed as

$$H_L = K_T\left(\frac{V^2}{2g}\right)$$

Since the head (H) contributed to water acceleration in the driven pipe, this acceleration is given by

$$H - F \times \frac{L}{D}\left(\frac{V^2}{2g}\right) - \sum\left(K \times \frac{V^2}{2g}\right) = \left(\frac{L}{D}\right) \times \frac{dv}{dt}$$

The value of K and f can be found from standard reference handbooks/textbooks. Eventually this flow will accelerates enough to begin to close the waste valve this occurs when the drag and pressure in the water equal the weight of the waste value. The drag force given by equation

$$f_d = C_d \times A_v \times \rho \times \frac{V_T}{2g}$$

The force that accelerates the fluid is given by

$$F = ma = \rho AL \times \frac{dv}{dt}$$

The pressure at point is obtained by divided the force F by the area A.

$$P_3 = \frac{F}{A}$$

The power required can k calculated using this expression

$$P = \rho gQh$$

The efficiency of the hydram is given by

$$E = \frac{Q \times h}{(Q + Qw) \times H}$$

VI. SURVEY AND PRELIMINARY DESIGN

A hydraulic ram survey must be done while considering a design. Before a design constructing, the followings are needed to know. These are;

1 Vertical fall from source to pump
2 Vertical lift from pup to delivery site
3 Amount of water available to power the pump Q_{input} or source flow
4 Minimum daily quantity of water required
5 Drive pipe length from source to pump
6 Delivery pipe length from pump to delivery site.

VII. REQUIRED DESIGN DATES FOR 30 FEET DELIVERY HEAD HYDRAM

The required design dates for 30 (feet) Delivery Head Hydram are as follow;

Drive Head, H	=1.524 m
Drive line diameter, D1	= 0.0762 m
Delivery head, h	= 9.144 m
Delivery pipe diameter, d	= 0.0254 m
Impulse valve diameter	=0.0762 m
Delivery valve diameter	=0.0762 m

VIII. CALCULATION OF THE SUPPLY HEAD AND DELIVERY HEAD

For most hydram the fall in driving water from the source to the ram must be at least one meter. But, the supply head should not exceed four meter. If the supply head is high and the drive is long, the momentum of water in the drive pipe will be very high and the pump will be damage. If the supply head is less than one meter, the momentum of water will not be enough to operate the hydram.

So, Head, H =1.524 meter

The minimum vertical lift is about two times the vertical fall and the maximum vertical lift is about twenty times the vertical fall. The ratio of the (h/H) is typically the range from 5 to 25.

Minimum vertical lift, h = 2H = 2×1.524 =3.048 m

Minimum vertical lift, h = 20H = 20×1.524 =30.48 m

The ratio of the head, (h.H) = (9.144/1.524)=6

The head ratio occurs within this range.

Therefore, Choose the delivery head h =9.144 m

IX. 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.

The best design reached target head of 9 m with and flow rate of 1.693 m3/s. The results from this study show that the less diameter of pressure chamber and higher supply head will create higher pressure.

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