2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #39217

RAM Pump as a Teaching Tool in Fluid Power Laboratory

Dr. Srikanth B. Pidugu, University of Arkansas at Little Rock

Dr. Pidugu is the Interim Director and Professor of the School of Engineering and Engineering Technology. He obtained Ph.D. in Mechanical Engineering at Old Dominion University in 2001.

Dr. Ashokkumar Misarilal Sharma
Cody Capocelli

RAM pump as a Teaching Tool in Fluid Power Laboratory

Introduction

Fluid Power and Mechanics is a sophomore-level class for the Mechanical Engineering Technology (MET) program at the University of Arkansas Little Rock. The course is offered in lecture-lab format. Two hours per week were allocated for each instructional component. The prerequisite for the course is trigonometry. It is not expected that students have exposure to fluids though some students may have received instruction on fluid behavior in college physics courses. As in the case for many institutions, the thermo-fluids lab equipment used for fluid power and mechanics, applied thermal sciences, and thermal system design courses are located in the same physical space. The lecture-lab format is also used for these other two courses.

The fluid power lab has equipment purchased from commercial lab equipment suppliers and in-house built equipment. Many engineering and technology programs put considerable effort to design and develop lab equipment as a cost-saving measure [1,2]. As part of faculty research activity, a hydraulic ram pump was designed, built, and operated successfully. The mechanical engineering technology program faculty proposed to utilize the ramp pump experimental research set up in the fluid power lab to conduct a few experiments as part of the fluid power lab. This paper presents a description of lab equipment and experiments currently used, followed by the design, construction, and operation of the ram pump, and proposed experiments using the ram pump.

Summary of Current Experiments

Students conduct about ten experiments during the semester as part of the fluid power course. Over the years, faculty revised these experiments. Revising was part of the process when new equipment was added, or modifications to the existing equipment were made. As mentioned, the faculty also designed and built equipment to demonstrate some simple experiments. A brief description of the experiments is given below:

Fundamental properties of fluids: In this lab, students conduct experiments to determine various fluid properties such as density, specific weight, and specific gravity of commonly available fluids such as water, oil, and glycerin. Simple equipment available in the lab is used for this experiment.

Viscosity of fluids: Dynamic and kinematic viscosity of fluids such as water and SAE oils are experimentally determined. Two separate experiments are conducted, one using a falling ball viscometer and the second using Brookfield digital viscometer. With the second equipment, students measure the viscosity of fluids at both room and elevated temperatures.

Pressure due to fluid height: Pressure at a point in a static fluid is measured using in-house built lab equipment. Students make calculations using measured quantities and compare them with the values obtained from direct measurements from a digital pressure gauge. In this experiment, students also get an understanding of Pascal’s paradox.

Bernoulli's Experiment: Students conduct experiments to investigate the validity of Bernoulli's equation for the steady flow of water through a tapered duct. This experiment is conducted using a commercially purchased apparatus on a hydraulic bench.

Behavior of fluid flows: The goal of this experiment is to understand the laminar and turbulent behavior of fluid flows. A commercially available Reynolds apparatus is used in this experiment.

Losses due to fluid friction in a piping system: Experiments are conducted to determine the fluid friction. Both major and minor losses can be determined using a commercially available piece of equipment. Current equipment is old, and recently we had to replace the pump. We also use in-house built equipment to determine the major losses. Recently we added an inexpensive piece of equipment specifically to determine pipe friction.

Minor losses: Minor losses equipment was purchased a few years ago, but experimental results do not confirm with theory. We are trying to determine the problems with this equipment.

Centrifugal pump characteristics: Students calculate hydraulic power delivered by the pump and pump efficiency at different operating conditions. They then graph the information to understand the pump characteristics.

Experiments using a hydraulic trainer: The fluids lab has two trainers where students connect hydraulic components such as pump, manifold, needle valve, flow meter, pressure gages, directional control valve, and hydraulic cylinder to form a circuit to actuate a double-acting cylinder and calculate efficiency at different flow conditions.

Other equipment: Based on the availability of time, instructors conducted experiments using the Pelton wheel, impact of jets equipment, etc.

Ramp Pump Operation

To transport water to higher altitudes requires pumping infrastructure. In the absence of such facilities, communities that reside in isolated areas encounter water scarcity affecting drinking, sanitation, farming, and other needs. These issues can economically be solved by employing a hydraulic ram pump, which does not require electricity to function as they are powered by the water source itself resulting in a negligible operational cost. The goal of this study was to modify the design of an existing ram pump to improve its overall performance. A ram pump setup was built using various materials including valves, PVC pipe and connectors, and digital pressure gauges [3]. Many modifications are implemented to improve efficiency [3-5]. Figure 1 shows the typical components of a hydraulic ram pump system, which contains only two moving parts: the waste valve and the non-return (one-way) valve. Both of these valves operate in a cyclic pattern and create oscillating pressure waves that regulate the alternate opening and closing of both valves. This in turn results rise in the air pressure in the pressure chamber and subsequently pushes the water out from the pressure chamber into the delivery pipe. The mechanism behind the ram pump working is that it employs the kinetic energy of the falling water to lift the part of the total water supplied to a higher altitude than the source level. The flowing water can be from either a river/stream or a downhill flow from a collection source such as a pond or tank. The pump requires the pressure created from this elevation change to begin its pumping process. The main advantage of a ram pump is that it can continuously run for long periods of time as long as a water current is available. With a constant supply of water, upon priming and starting the pump, it can operate unsupervised for weeks to years pumping water to a higher elevation. Once transported to this higher elevation, it can be stored in a reservoir or water tower, or it can be further transported for other uses such as irrigation for farming. In many cases, canals are created

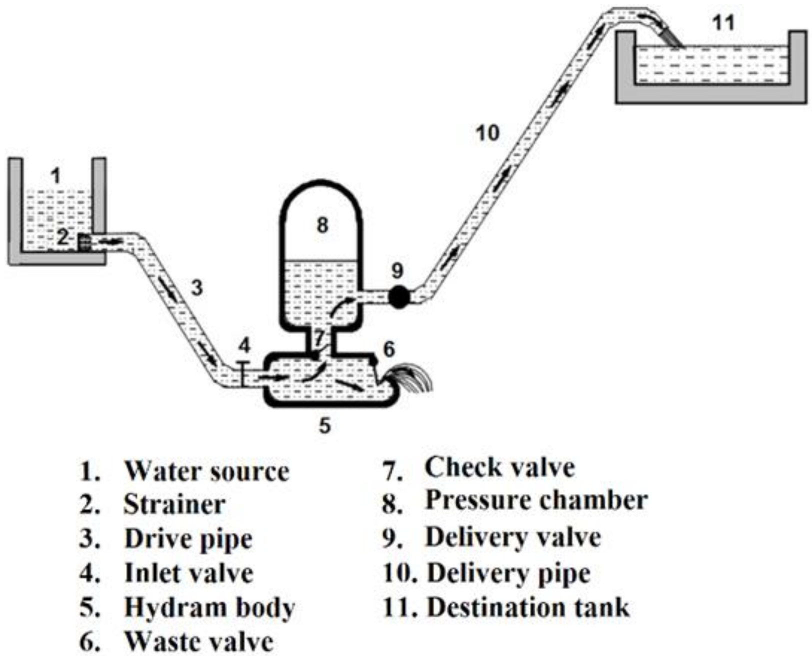


Figure 1. Schematic of hydraulic ramp pump

to divert water away from a river/stream for many reasons, but in a location with an elevation change available, a hydraulic ram pump can be a cheaper and easier solution to this problem of diverting water. Due to its simple construction and nominal running cost, ram pumps have become reasonably prevalent in many rural areas worldwide [6].

Ram Pump Design and Construction

Figure 2 shows the complete assembly of the ram pump, which includes the source tank, ram pump unit, collection tank, drive pipe, and overflow pipe. Due to low cost and durability, mostly PVC-made components were used to build the hydraulic ram pump system. One major advantage of PVC material is its specific gravity, which is one-fifth that of cast iron, making it a more suitable material for the construction of a lighter ram pump system. A 3/4 in. Schedule 40 PVC pipe was used for both the drive and delivery pipes. Flow was controlled at the inlet and outlet using a 3/4 NPT brass ball valves. The waste valve was 3/4 NPT bronze check valve. A one-way valve was incorporated between the pressure chamber and the waste valve. In the modified setup, two pressure gauges (Range: 0-30 psi) were fitted before and after the ram pump unit to measure pressure at the inlet and outlet of the pump. The pressure chamber was made of Schedule 80 PVC pipe. Upon startup, when the water pressure in the ram pump unit reaches

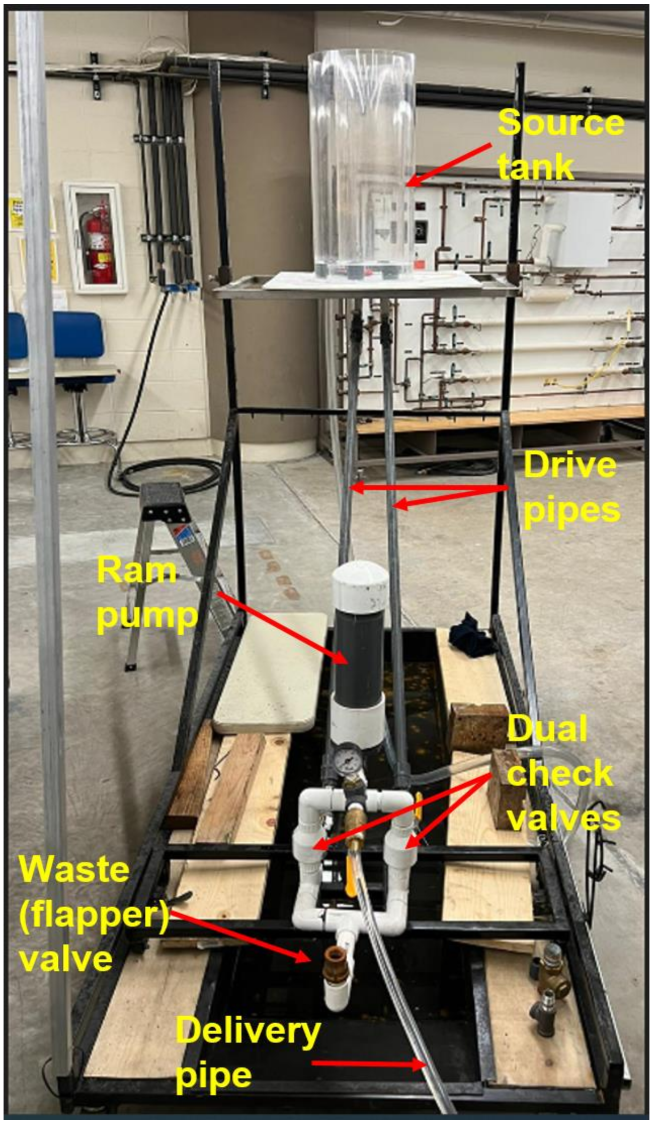


Figure 2. Hydraulic ram pump system

about 15 psi, the waste valve swings shut creating a water-hammer effect, which then directed the water through the one-way valve to the pressure chamber. This continued accumulation of water compressed the air inside the pressure chamber leading to the water being forced out from the pressure chamber to the delivery pipe. As a result, the main pressure throughout the pump decreased, causing the opening of the waste valve. The waste valve opens and closes according to pressure change. It directs water through a non-return valve. The entire cycle repeats until the water supply to the pump ends.

Proposed Experiments with Ramp Pump

There are two reasons why MET faculty wanted to add ramp pump to the existing equipment as a part of the fluid power lab. Demonstrating fluid experiments using a practical device can get the attention of students and help them to connect better with the theory. As a part of the experiments, the equipment will be used to measure pressure, volumetric efficiency, and energy efficiency. The second reason is that commercially available lab equipment is expensive as it is most often built to order. As we were building this set-up and researching operation and performance, we realized that this would be a useful teaching tool to use in the fluid power lab. With a few modifications to existing setup, students can conduct basic to advanced experiments. Interestingly, it was a student working on this research project who suggested that we use this equipment as a teaching tool in the fluid power course.

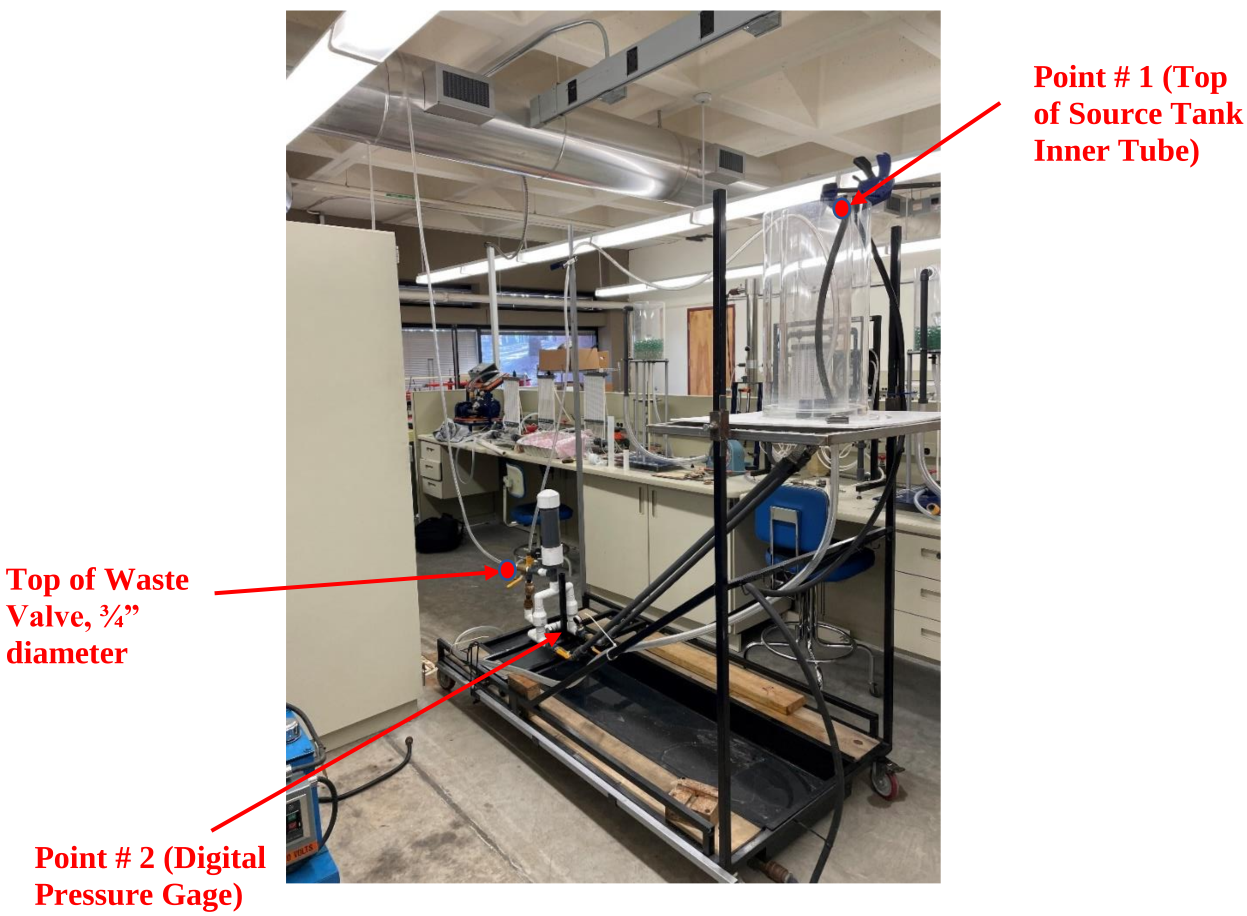
Proposed experiments include fluid pressure in column, minor losses, and validation of Bernoulli's theorem. We have found that the ram pump serves as a valuable teaching tool as students can see the importance of proper design of fluid power equipment while gaining an understanding the basic concepts. The experimental Procedure and sample calculations for validation of Bernoulli's equation is provided.

Validation of Bernoulli's equation application

Objective: To investigate the validity of Bernoulli's equation through the hydraulic ram pump.

Apparatus Required: Hydraulic ram pump with ball valve attached to wastewater outlet and digital pressure gage placed on drive line.

Ram pump with testing points and pressure gage locations:



Bernoulli's Equation:

Total head, $\boldsymbol{H = \frac{p}{\gamma} + z + \frac{v^2}{2g} \; = \text{constant}}$

Head	**Terms**
Elevation head	$\boldsymbol{z}$
Pressure head	$\boldsymbol{\frac{p}{\gamma}}$
Velocity head	$\boldsymbol{\frac{v^2}{2g}}$

At point 1, total head = z (where, velocity is negligible and gage pressure = 0)

At point 2, total head $= \boldsymbol{\frac{p}{\gamma}} + \boldsymbol{\frac{v^2}{2g}}$ (where, $z = 0$)

Experimental procedure:

1. Connect the water hose and place in the inner source tank tube.
2. To begin, close the ball valve on one drive line and close the exit valve, ensure the digital pressure gage is turned on.
3. Wait for the inner source tank to fill until water pours to the overflow tank.
4. Once full, carefully open the valve at the wastewater outlet to approximately a quarter turn. Do not open the valve beyond half turn.
5. Allow 10-20 seconds to ensure air has been purged from the system.
6. With the valve set to the designated amount, mark the pressure read from the digital pressure gage.
7. Once the pressure is marked, collect the wastewater in a graduated beaker for 20-30 seconds. Accuracy is important for volume-flow rate calculation.
8. With the wastewater collected, turn off the hose and allow the source tank to empty.
9. Repeat steps 1-8 two more times with the wastewater valve turned to different angles.
10. Measure elevation head at point 2

Calculations:

1. Calculate the volume flow rate ($\boldsymbol{Q}$)
2. Read pressure head using digital pressure gage and calculate the pressure head $\boldsymbol{\frac{p}{\gamma}}$
3. Find velocity by using formula $\boldsymbol{Q = v * A}$
4. Calculate velocity head (also known as kinetic or dynamic head): $\boldsymbol{\frac{v^2}{2g}}$
5. Calculate total head ($\boldsymbol{H}$) at point 2: $\boldsymbol{\frac{p}{\gamma} + \frac{v^2}{2g}}$
6. Repeat procedure for all five runs.

7. Compare with the total head at point 1 and calculate the percent error.

p_2 (psig)	p_2/γ (ft)	Q (ft^3)	t (s)	$v_2 = Q/A$ (ft/s)	$v_2^2/2g$ (ft)	$p_2/\gamma + v_2^2/2g$ (ft)	z_1 (ft)	% error
2.30	5.308	0.00469	14.98	1.528	0.036	5.334	5.68	6.23
2.37	5.469	0.00287	29.95	0.935	0.014	5.483	5.68	3.54
2.41	5.562	0.00112	29.85	0.366	0.002	5.562	5.68	2.08
2.42	5.585	0.00242	29.93	0.787	0.010	5.594	5.68	1.49
2.44	5.631	0.00049	30.13	0.160	0.004	5.631	5.68	0.81

Note: Report Should Include title page, objective, procedure (materials and methods), sample calculations, results (data table), data analysis and discussion, comments of validity of Bernoulli's equation, justifications of percent error, and possible ways to minimize percent error.

Conclusions

Though mostly commercially available lab equipment is used in our fluid power course, an effort is made to design and build in-house lab setups which resulted in considerable savings. To add to this effort, an attempt to use a ram pump as a teaching tool is in progress. The ram pump was initially designed and built as a research effort. One experiment is designed to validate Bernoulli's principle and a hand-out for students is developed. Experiments to investigate minor losses will be attempted in the future.