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Investigation and analysis on the performance of hydraulic ram pump at various design its snifter valve

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Investigation and analysis on the performance of hydraulic ram pump at various design its snifter valve

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Abstract. Hydraulic ram pumps are equipped with air vessel to reduce the pulsation of the pumping water flow and the acceleration head loss. In their operation, the amount of air available in the air vessel will be decreased continuously flowing out with delivery water. In order to replace the air volume in the air vessel, the hydraulic ram pump is equipped with a snifter-valve. However, in its implementation, this valve is a hole or orifice with a diameter of 2 mm at a distance of about 2 cm below the delivery valve on the body of the hydraulic ram pump. On the other hand, this will reduce the water hammer pressure that occurs, furthermore, it reduces the performance of the hydraulic ram pump. Based on its working principle, a snifter-valve is an automatic anti-vacuum valve or a non-return valve or check valve. Therefore, the work has been carried out to investigate and analyze the performance of a hydraulic ram pump without a hole or any snifter-valve, with a hole of 1 mm diameter, and equipped with a check-valve of 1 mm orifice diameter. The results showed that the snifter-valve with check-valve of 1 mm orifice diameter gives the best hydraulic ram pump performance for the hydraulic ram pump model that has been investigated.

1. Introduction

The hydraulic ram pump is a device that utilizes available energy in the water stream to pump some of the water to a higher elevation without using electric or fuel [1,2]. The hydraulic ram pump was first designed in England at the end of the 18th century by John Whitehurst, originally called the "pulsation engine". The next generation design was done by Joseph Michel Montgolfier and patented in 1797. Hydraulic ram pumps in the history of its development are used as irrigation equipment to provide water at the locations where the electrical energy is unavailable. The main advantage of the hydraulic ram pump is its simple structure, using renewable and reliable sources of energy.

The components of a hydraulic ram pump are water supply tank, drive pipes, pump body, waste or impulse valve, delivery valve, snifter valve, air chamber, and delivery pipe [3]. The working mechanism of the waste valve results in the occurrence of a water hammer when the waste valve closes suddenly. This water hammer pressure energy is utilized in the hydraulic ram pump cycle [4]. The waste valve primarily affects the magnitude of the impulse force generated [5]. At the operation of the hydraulic ram pump, within a certain period of time the air volume in the air chamber will gradually decrease out with the pumped water, therefore it needs to take the air supply into the pump body through a snifter-valve.

In its implementation, this snifter-valve valve is generally only a hole with $1 \div 2$ mm diameter at a distance of about 2 cm below the height of delivery valve of the hydraulic ram pump body, as shown in Figure 1. This will result in a decrease of water hammer pressure due to a leakage of flow through the hole, and then it will also be able to reduce the performance of the hydraulic ram pump. Based on the working concept of the snifter-valve is an automatic anti-vacuum valve which will close during the compression phase and open when pressure back takes place in drive pipe at the recoil phase. Therefore, the concept of this valve should be a one-way valve (non-return valve or check valve). Hence, a non-return valve design has been investigated in this research. A ball shape design is chosen considering the ball is easier to move open and close than the form of a disc.
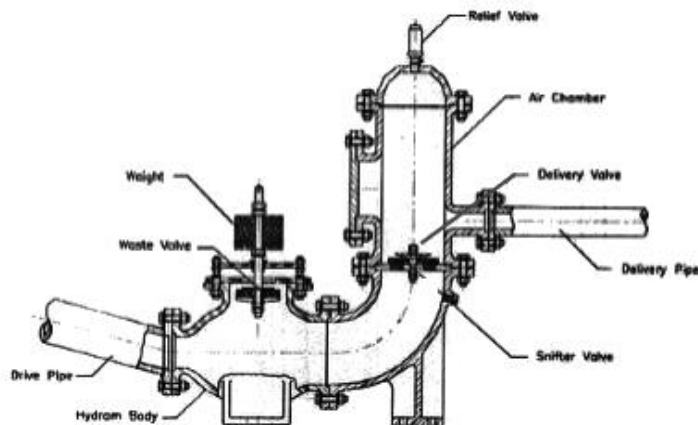
Figure 1. The main components of the hydraulic ram pump [6].

Figure 2. Orifice/hole of snifter-valve on the hydraulic ram pump.

In the second millennium, this hydraulic ram pump has been widely used by the communities. Suarda and Sukadana have implemented hydraulic ram pumps with membrane press valves for pumping water for community service (see Figure 2) in Belantih village, Kintamani sub-district, Bangli district, Bali province [7].

In addition, the hydraulic ram pump is constructed using a flange and bolt-nut connection system to simplify the assembly and disassembly, especially when repairing the valves. In line with the construction design, Yang proposed a novel design of hydraulic ram pumps with the note that it is advisable not to use a conical enlargement on the valve portion of the waste but cambered diffuser with an angle between 25° and 90°, to avoid the asymmetric pressure distribution on the disk valve waste [8]. Given the hydraulic ram pump, there are only two moving parts, namely waste valve and delivery valve. Their design determines the performance of the hydraulic ram pump. Therefore, Suarda has examined the forces that occur on both valves with algebraic analysis [9]. In general, methods that can be used in the main considerations of planning and application in various ways have been proposed by Balguda [10]. However, according to Nambiar, the waste valve is a key component of the hydraulic ram pumps, hence, it is requiring attention in the development and further optimization in improving the total efficiency of the hydraulic ram pump system [11].

Grygo develops mathematical equations of the performance stream of a water ram with regard to the height of water delivery [12]. The main aim of this work is to define the mathematical relationship that allows determination of the impact of the height of water on the performance of water ram. the obtained mathematical dependence (regression equation) shows that by increasing the height of water delivery it will reduce the performance. Then, Harith et al study how to determine the effect of improved design to significant effect on flow analysis and simulation study [13]. They confirmed that by adding a control mechanism to the new design component delivery and waste valve have enhanced about 20% more efficient than the current design. Moreover, they study on waste and delivery valve design modification to the pump performance [14]. The results of the investigation show that the projection of the velocity vector for every details case and pressure contour.

In addition, Mondol built a design, manufacture and test a hydraulic ram [15]. Then, he observed that if the water in the tank decreased the time taken between strokes increased and the pump ceased to work. Shortening the stroke increased the frequency of strokes. Thus, a certain amount of water has to be maintained in order to pump water via the ram pump satisfactorily. Furthermore, Guo et al develop a method for the optimal design and performance analysis of a hydraulic ram pump with numerical simulation and model experiment [16]. They argue that when the delivery head is less than 50 m, the efficiency of the new product ranges from 50% to 70% while the delivery flow is the largest.

Therefore, it is necessary to conduct research to investigate the performance of the hydraulic ram pumps without and/or equipped with snifter-valve. This research is very important because of the lack of research and development of the hydraulic ram pump design, especially the reference in determining the dimensions of its valves. With a more appropriate snifter-valve design, it is expected to produce more optimal hydraulic ram pump performance. Furthermore, with the availability of the design is expected to develop the manufacture and utilization of hydraulic ram pumps in the community.

2. Research Methods

2.1. Experimental Setup

Considering that in its implementation in community, the snifter-valve of hydraulic ram pump is only a small hole with a diameter of about $1 \div 2$ mm, hence, the research was conducted to compare the performance of the hydraulic ram pump system which is unequipped with a snifter-valve, equipped with snifter-valve which is only a 1 mm diameter hole and a snifter-valve design/model of non-return valve with 1 mm orifice diameter, as shown in Figure 3. The investigation will be conducted experimentally on the hydraulic ram pump model that has been installed in the laboratory of Energy Conversion of Mechanical Engineering Department of Udayana University.
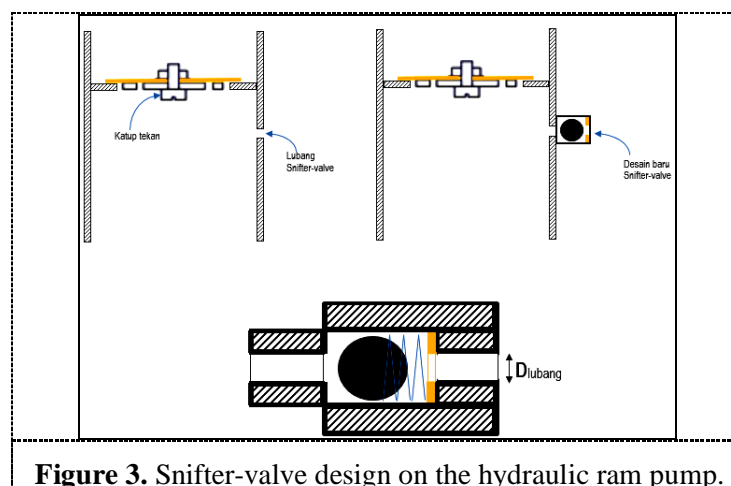

Figure 3. Snifter-valve design on the hydraulic ram pump.

In this experiment, the work was performed on the hydraulic ram pump installation system as shown in Figure 4. This research was conducted on the hydraulic ram model with the following specifications:

1) The supply water level is a drive head, $Z_s = 1.82$ m
2) Delivery head $Z_d = 2.02$ m, the addition of variation of the delivery head is adjusted by arranging the control valve opening on the delivery pipe.
3) Drive pipe diameter $D_s = 36$ mm with length $L_s = 12.2$ m.
4) The diameter of delivery pipe $D_s = 12$ mm with a length of 1.36 m.
5) The diameter of the waste valve disk is 47 mm, and the stroke length is 6.0 mm.
6) Snifter-valve model: no hole, 1 mm diameter hole, and a non-return valve with 1 mm orifice diameter.
7) Waste valve mass (moving parts) 490 grams
8) The volume of the air chamber is 0.0083 m^3

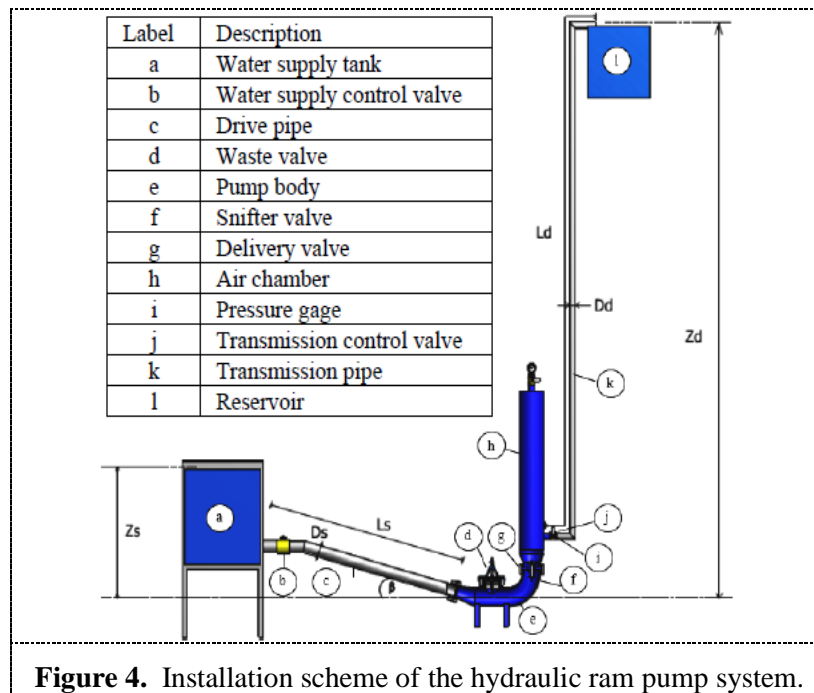**Figure 4.** Installation scheme of the hydraulic ram pump system.

2.2. Experimental Procedure

The V-notch weir discharge equation used is the Kindvater-Shen equation [17], i.e.:

$$Q = \tag{1}$$

Where Q is the water flow rate (cfs), C is the flow coefficient, θ is the V-notch Weir angle, h is the hight of the water flow through V-notch Weir (ft), and k is the V-notch Weir flow correction factor.

The general method used to calculate the efficiency of the hydraulic ram pump installation is the Rankine method [18]:

$$\eta_R = \frac{Q_d H_d}{(Q_d + Q_w)H_s}100\% \tag{2}$$

Where η_R is the total efficiency of the hydraulic ram system (%), Q_w is the water outflow from the waste valve (m³/s), Q_d is the pumping water flow rate (m³/s), H_s is the head of the driving water supply (m), and H_d is the pumping head (m).

Investigating the snifter-valve in the pump hydraulic ram system in the laboratory is carried out through the testing stages as follows:

1) Preparation of pumps and valve models, with water supply height Z_s = 1.82 meters, the diameter of the drive pipe D_s = 1¼ inch and the length of L_s = 9 meters.
2) Setup hydraulic ram pump without hole or snifter-valve.
3) Setup of pumping height Z_d = 2.02 meters
4) Flowing the water into the drive tank to full and be kept in an always-over-flow condition so that the height of the driving head is constant
5) Open the water supply control valve, to drain the water from the supply tank to the pump body.
6) Start the pump work by opening and closing the waste valve so that the pump can work and let the pump run for a while
7) Setup head of pumping pressure (P_d) of 0.5 bars
8) While the pump is working and it has been stable do data recording such as height of the water flow on V-notch weir (hvw) coming out from the waste valve, time for collecting of 1 liter of water volume coming out of the delivery pipes (Td), pressure on the delivery pipe manometer (Pd), and the frequency of the pump work cycle (F).
9) Repeat step 8 for 3 (three) times

10) Repeat steps 7 through 8 for pumping pressure heads (Pd): 1.0, 1.5, 2.0, 2.5, and 3.0 bars
11) Repeat steps 3 through 10 for a snifter-valve design/ model of 1 mm diameter hole, and the non-return snifter valve with a 1 mm orifice diameter.

3. Results and Discussions

Based on the data of the results of the experiment, then the performance of hydraulic ram pumps on the variation of the design of the snifter-valve hydraulic ram pumps tested at various ratios of pumping head to the static head of the hydraulic ram pump water supply can be illustrated as in Figure 5 to Figure 8.
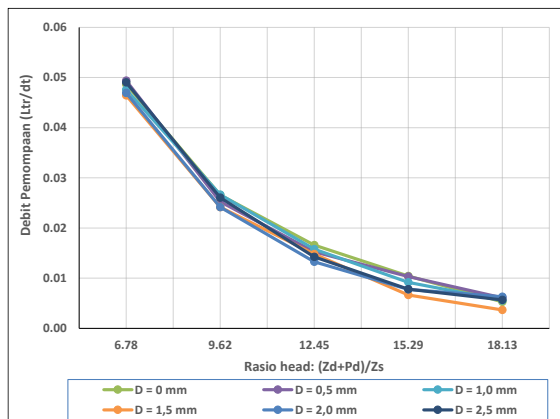

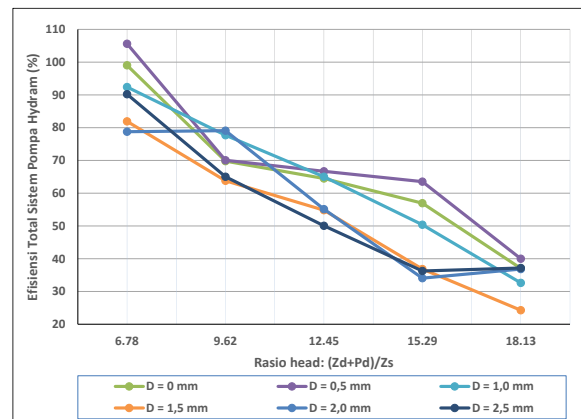**Figure 5.** Pumping discharge at various of snifter-valve hole diameter.

Figure 6. The total efficiency at various of snifter-valve hole diameter.
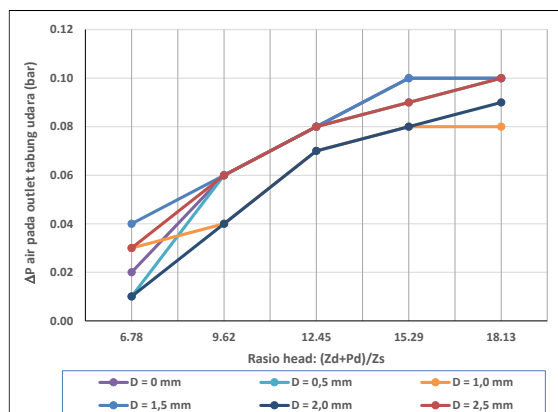

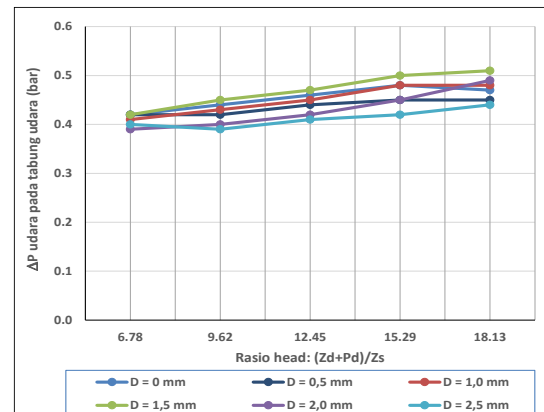**Figure 7.** Pressure fluctuation of water at air vessel outlet.

Figure 8. Pressure fluctuation of air in the top of air vessel.

Figure 5 shows that in general, the higher the pumping pump hydraulic pumping pump's pumping head is getting smaller, and the larger the snifter-valve pumping diameter of the pumping pump is relatively smaller. However, snifter-valve with a 0 mm (without hole) provides the highest pumping discharge. However, it should be noted that for pump operation within a certain period of time the amount of air in the press tube will be discharged and discharged thus disrupting the pump operation even stop operating. For that 1mm diameter, snifter-valve is the best alternative choice. Furthermore, Figure 6 shows that the higher the pumping head the smaller the total efficiency of the hydram pump generated. In addition, the smaller the Snifter-valve hole diameter the higher the total efficiency produced. Considering the function of the snifter-valve, then, snifter-valve with hole diameter 0.5 mm to 1.0 mm is the best alternative choice.

The larger the pumping head causes the slower the pumping cycle occurs, and the larger the diameter of the Snifter-valve hole results in a decrease in the frequency of the hydram pump cycle, as shown in Figure 7. This is due to the reduced back-pressure occurring in the moving pipe as a result of the greater pressure leakage water through the snifter-valve. Then the higher the pumping head results in the greater pressure fluctuation that occurs in the tube outlet tube to the delivery pipe, due to the higher pressure heads that occur in the compressive tube, as shown in 8. In addition, the small diameter hole-shaped snifters relatively result in fluctuations greater pressure.
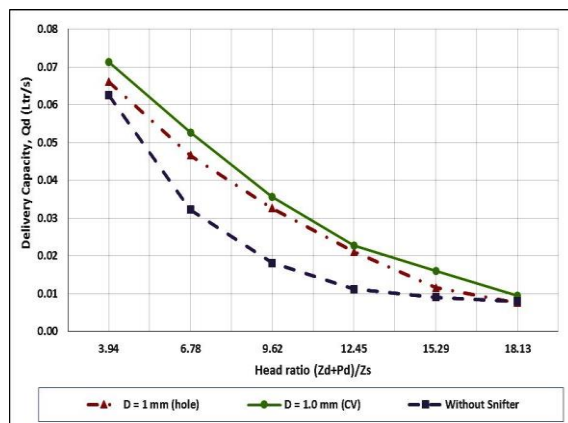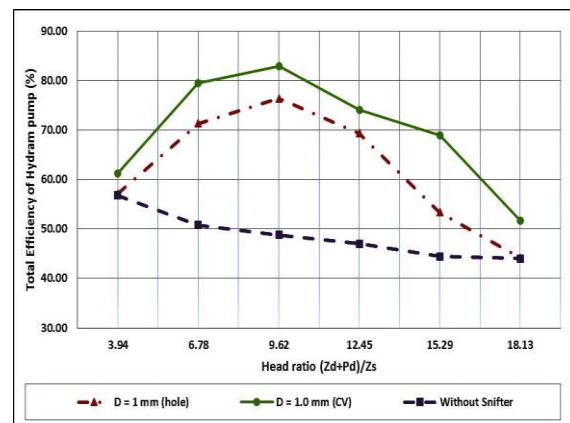

Figure 9. Pumping discharge.
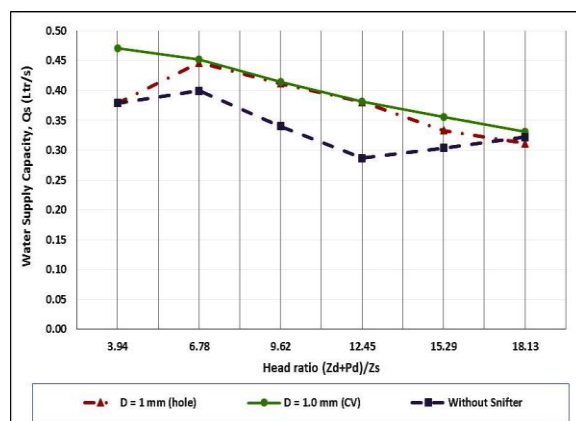

Figure 10. The total efficiency.

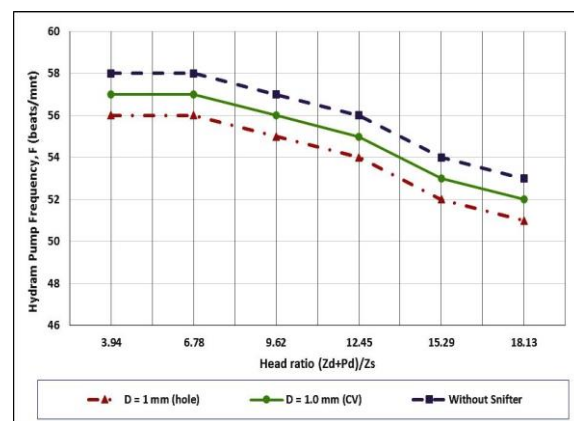**Figure 11.** Water supply to drive the hydraulic ram pump.

Figure 12. The frequency of the hydraulic ram pump cycle.

Figure 9 shows the effect of the snifter-valve design on the pumping discharge of the hydraulic ram pump. In general, the higher delivery head then pumping capacity of the hydraulic ram pump is getting smaller. This is because of the higher pumping head requires the greater of pumping power. The non-return snifter-valves (CV) with 1 mm orifice diameter results in greater pumping discharge compared to snifter-valve which is only a hole of the same diameter of 1 mm. It is due to leakage of flow through the hole during the compression phase. Furthermore, hydraulic ram pumps which are without equipped with snifter-valve produce the smallest pumping discharges, because most of the water hammer pressure occurs to cause higher back pressure on the drive pipe.

Figure 10 shows the effect of the snifter-valve design on the total efficiency of the hydraulic ram pump system. The hydraulic ram pump which is without equipped with snifter-valve has the lowest total efficiency, due to the minimal pulsation in the pump body. A 1 mm orifice diameter of the non-return snifter-valve provides greater total efficiency compared to the 1 mm diameter of the only hole of snifter-valve, because of there is no loss of pressure through the orifice of the snifter-valve at the

time of compression phase. Furthermore, the highest efficiency of the tested hydraulic ram pump system is achieved at a pumping head ratio of 9.62. This means that if the head or high water source of the hydraulic ram pump is 2 meters then the highest efficiency is achieved at the head or pumping height of about 20 meters.

Moreover, Figure 11 shows that the hydraulic ram pump which is without equipped with snifter-valve requires the least discharging of the pump driving water flow, since in addition to the absence of waste water flow through the snifter-valve's hole, also due to the high pressure back on the drive pipe resulting in obstacles water flow on the drive pipe during acceleration phase.

The hydraulic ram pump cycle of the hydraulic ram pump which is without equipped with a snifter valve is the highest, due to the highest pressure back on the drive pipe resulted in delayed acceleration of water flow in the drive pipe, as shown in Figure 12 Conversely, the hydraulic ram pump equipped with a hole of snifter-valve produce the lowest pumping cycle due to the lowest pressure back that occurs in the drive pipe. While the hydraulic ram pump equipped with non-return snifter-valve model produces a pumping cycle that occurs between the without any snifter-valve and the hole snifter-valve model. In addition, the higher the pumping head will result in decreasing frequency of the hydraulic ram pump cycle.

As a result, a snifter-valve design with non-return valve system (CV) provides significantly improved pump performance. This is because it can optimize the utilization of water hammer pressure that occurs during the compression phase and the external air suction process during the recoil phase. However, further study is needed over a longer period of time, for instance, one week or more to determine the reduction or addition of air volume in the air chamber of the hydraulic ram pumps.

4. Conclusion

The snifter-valve model with non-return valve system has significantly improved the performance of the hydraulic ram pump compared to the only hole of snifter-valve and/or without any snifter-valve. However, further work is necessary to study the performance of hydraulic ram pump which is equipped with non-return snifter-valve model on the variation of orifice diameter in order to get the design reference of the snifter-valve sizing on various dimensions of hydraulic ram pump.

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