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Venturi Injector Performance with Variation of Primary Mass Flowrate to Entrainment Ratio Value

Khaeroman, Susanto, Wahyu Ari Putranto, Okpina Rochadian

Abstract— This paper discusses the testing of 3 finished venturi injector products. The purpose of this paper is to assess the effect of bypass valve opening variations on the primary flow rate on the primary mass flow rate, secondary mass flow rate and also the entrainment ratio value. The venturi injectors studied were made of PVC and plastic pipes with varying dimensions. The Venturi ejector is tested with a homemade device. In this study using 2 variables. Fixed variable volume or fluid mass flow in primary flow is 10 liters. Variable venturi injectors with diameters of 1, 3/4 , and 1 inch. Another variable used is the position of the bypass valve which is made with 5 different positions. The bypass valve variation on the primary flow inlet venturi injector affects the entrainment ratio value. The highest entrainment ratios of the 1, 3/4, and 1/2 diameter venturi ejectors were 0.1770, 0.1370, and 0.2530 respectively at the 25% bypass valve position. The best entrainment ratio is owned by a venturi injector with a smaller diameter. The size of the diameter of the venturi injector used greatly affects the value of the entrainment ratio and its suitability with the main motive fluid pressure.

Index Terms — Venturi injector, bypass valve, primary flow, mass flow rate, secondary mass flow, entraiment ratio, motive fluid pressure.

1 Introduction

Venturi injectors use a fast moving flow of motive fluid to deliver a near silent suction fluid. In a Venturi ejector, By accelerating the flow of motifs flowing through the converging section, the highest speed is achieved at the nozzle throat. The high velocity of the motive fluid creates a region of low static pressure and therefore a pressure difference between the motive fluid at the throat of the nozzle and the suction fluid. The pressure difference draws the suction flow into the nozzle, where the suction and motive streams mix before leaving the nozzle outlet. To achieve the same suction and mixing power can use a thermal ejector with several internal parts that have supersonic speeds [1]

Venturi injectors have been widely used in several large industries that use steam as their heating medium or as a power generating utility. They are devices that use the energy of a high pressure fluid to move a low pressure fluid and enable it to be compressed to a higher pressure according to the principle of energy conversion. They work like a vacuum pump but without usage of any moving part and so they can save energy. The performance of a venture injector highly depends on its geometry and operating conditions [2], [3].

In agriculture and plantations, venturi ejectors are used for spraying fertilizers. When the fluid in the form of water is flowed in the venturi ejector at high speed, the fertilizer is sucked through the suction channel and mixed with the water used for spraying. This is done in order to produce the perfect mixture [4], [5], [6].

The suction power of a venturi ejector is the most important thing in its utilization. Venturi ejectors are expected to have maximum suction capability so that they can be used for various purposes. Therefore, the test was carried out to determine the performance of the venturi ejector.

The outlet diameter of the injector nozzle has a large effect on the suction power of the secondary flow with a constant pressure on the motive fluid chest, the larger the outlet diameter, the greater the suction power generated [7].

Ejector is known as a tool technology that can produce fluid flow in the chamber at high speed. The pressure drop in the nozzle area is directly affected by the velocity of the primary fluid flowing out of the ejector nozzle. Changes in fluid flow velocity in the mixing chamber are affected by the primary flow inlet pressure, nozzle characteristics, mixing chamber volume and outlet diameter [8], [9], [10].

There are venturi injector products currently available in the market that are not equipped with venturi injector product details, so that consumers as users of these tools have not been able to determine the characteristics and performance of the venturi injector to be purchased. This paper will describe the results of testing 3 finished venturi ejector products made of PVC and plastic to assess the effect of bypass valve opening variations on the primary flow rate on the primary mass flow rate, secondary mass flow rate and also the entrainment ratio value. Another goal of this research is to create an additional practical tool on campus for the introduction of vacuum technology which is widely used in industry.

2 Experimental Procedure

2.1 Material

In this research, 3 venturi injectors have been provided made from plastic base materials which have size dimen-sions adjusted to the needs, each of which has a size of 1/2 inch, 3/4 inch and 1 inch and these venturi injectors are purchased from the market (Figure 1) which have dimensions as shown in Figure 2 and the geometry of the venturi injector in table 1.

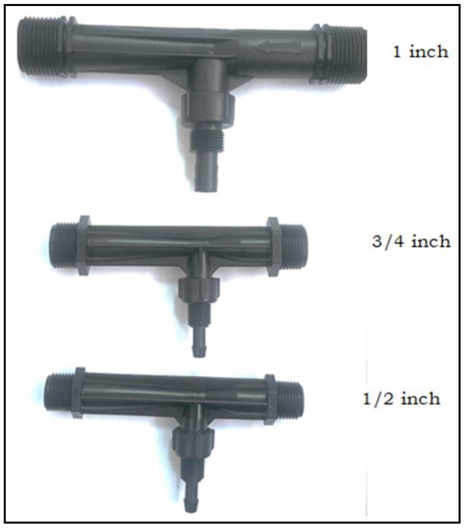

Figure 1: Venturi injector

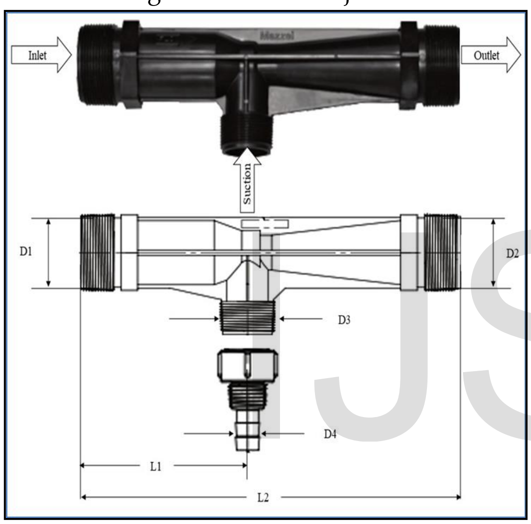

Figure 2: Venturi injector dimensions

Table 1: Venturi Ejector Geometry

Injector Code	Standard Size (Inch)	L1 (mm)	L2 (mm)	D1=D2 (mm)	D3 (mm)	D4 (mm)
Injector 1	1/2	53	117	12.7	6.35	5
Injector 2	3/4	64	150	19.05	6.35	5
Injector 3	1	94	229	25.4	12.7	5

2.2 Manufacturing of Venturi Injector Testing Equipment

The injector tester is designed to test the performance and entrainment ratio of the venturi ejector. The ability of the test equipment must be able to present the primary flow data and its effect on the mass flow rate in the secondary flow. This tool is designed to be able to make pressure variations in the primary flow. Each component of the tester is connected by 0.5 inch PVC pipe. The design and dimensions of the ejector tester are shown in Figure 3.

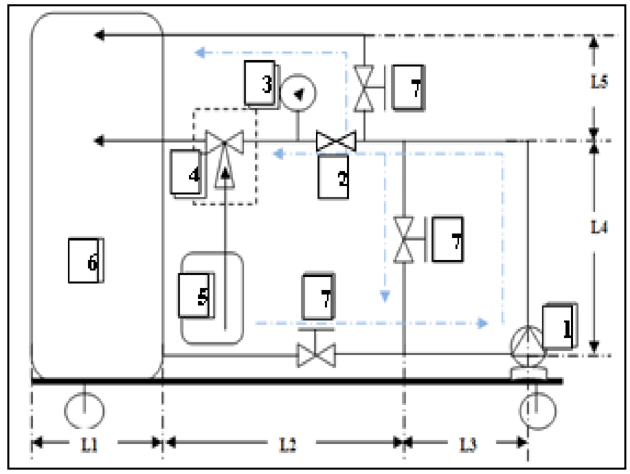

Figure 3: Schematic of the venturi injector tester

Caption:
1. Water pump
2. Manometer
3. Flowmeter
4. Venturi injector
5. Measuring cup
6. Water storage tank
7. Stop valve

The frame of the tester is made of angle iron. Figure 4 is a testing tool in 3-dimensional form made to plan the placement of the components of the testing tool.

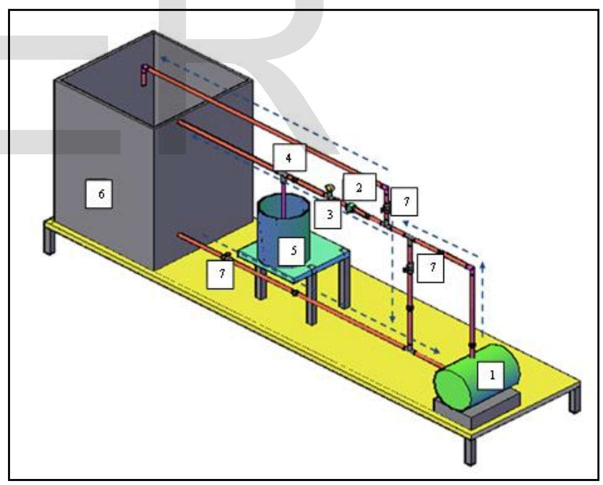

Figure 4: Testing tool in 3D drawing

2.3 Injector Venturi Testing Procedures

The test equipment is assembled using angle iron as a frame. There are wheels at the bottom for easy portability. The components are connected by 0.5 inch PVC pipe with a certain size as needed. The installation process for connecting each component is made easier by adding a watermur to each connection.

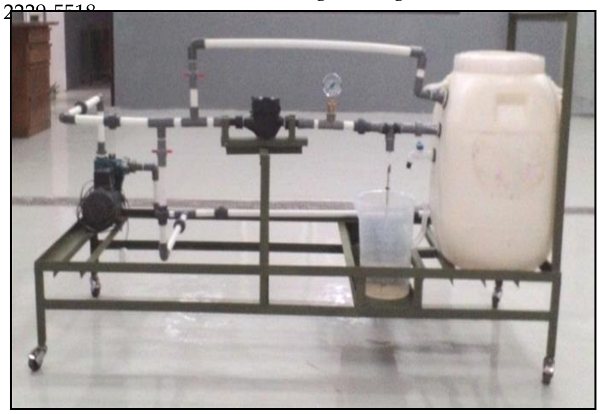

Figure 5: Injector Venturi Tester

The process of testing the tool is as follows:

1. Connect the water pump to the power source and push the switch to the ON position
2. Open all pressure regulating bypass valves
3. Move the bypass valve position to increase the pressure and make sure the manometer shows a change in pressure or the pressure rises.
4. Install one of the ejector venturi to be tested on the holder
5. Ensure the amount of flow on the flowmeter for primary and secondary flow.

The test was carried out in approximately 10 minutes. The measuring cup is always considered during testing, if there is a decrease in the volume of water, it is ensured that the tool is working and ready to be used for testing.

3 Test Result and Discussions

3.1 Ejector Test Data Calculation Results

Table 2: Calculation of Ventiri Injector Test Data

Venturi Injektor (inch)	Bypass Valve Position	*Primary Pressure* (Bar)	*Primary Flow Rate* [$Q_P = (V_P/t).10^{-3}$] (m^3/s)	*Secondary Flow Rate* [$Q_s = (V_s/t).10^{-3}$] (m^3/s)
1	0	0.00	$1.0870x10^{-4}$	$1.1196x10^{-5}$
	¼	0.00	$1.4925x10^{-4}$	$2.3433x10^{-5}$
	½	0.10	$2.0408x10^{-4}$	$3.4082x10^{-5}$
	¾	0.15	$2.3256x10^{-4}$	$4.1163x10^{-5}$
	1	0.15	$2.3256x10^{-4}$	$4.1163x10^{-5}$
¾	0	0.00	$0.5780x10^{-4}$	$0.5954x10^{-5}$
	¼	0.30	$0.8264x10^{-4}$	$1.6529x10^{-5}$
	½	0.50	$1.0869x10^{-4}$	$1.6630x10^{-5}$
	¾	0.60	$1.2820x10^{-4}$	$2.9487x10^{-5}$
	1	0.70	$1.2987x10^{-4}$	$1.7792x10^{-5}$
½	0	0.00	0.00	0.00
	¼	0.10	$1.1905x10^{-4}$	$2.1785x10^{-5}$
	½	0.30	$0.0621x10^{-4}$	$7.0186x10^{-5}$
	¾	0.40	$0.0621x10^{-4}$	$1.5714x10^{-5}$
	1	0.50	$1.4925x10^{-4}$	$3.5820x10^{-5}$

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Table 3: Calculation of Venturi Injector Entrainment Ratio

Venturi Injektor (inch)	Bypass Valve Position	*Primary Mass Flow ($\dot{m}P = \rho. Qp$) (Kg/s)*	*Secondary Mass Flow ($\dot{m}s = \rho. Qs$) (Kg/s)*	*Entrainment Ratio ($\omega = \dot{m}s/\dot{m}p$)*
1	0	0.00	$1.0870x10^{-4}$	$1.1196x10^{-5}$
	¼	0.00	$1.4925x10^{-4}$	$2.3433x10^{-5}$
	½	0.10	$2.0408x10^{-4}$	$3.4082x10^{-5}$
	¾	0.15	$2.3256x10^{-4}$	$4.1163x10^{-5}$
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¾	0	0.00	$0.5780x10^{-4}$	$0.5954x10^{-5}$
	¼	0.30	$0.8264x10^{-4}$	$1.6529x10^{-5}$
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	¾	0.60	$1.2820x10^{-4}$	$2.9487x10^{-5}$
	1	0.70	$1.2987x10^{-4}$	$1.7792x10^{-5}$
½	0	0.00	0.00	0.00
	¼	0.10	$1.1905x10^{-4}$	$2.1785x10^{-5}$
	½	0.30	$0.0621x10^{-4}$	$7.0186x10^{-5}$
	¾	0.40	$0.0621x10^{-4}$	$1.5714x10^{-5}$
	1	0.50	$1.4925x10^{-4}$	$3.5820x10^{-5}$

The average venturi ejector test results of 1, 3/4, and ½ inch are calculated and presented in the test data calculation table. The results of these calculations are used to obtain the value of the mass flow rate and entrainment ratio.

The calculated values for the mass flow rate and entrainment ratio are entered into the nozzle test data calculation table. The final result of the entire calculation process is presented in the table for calculating the entrainment ratio value so that it is easy to analyze. Tables 2 and 3 present the results of the calculation of test data for venturi injector diameters of 1, 3/4, and ½ inch.

3.2 Effect of Bypass Valve Opening Variations on Motive Fluid Pressure (P)

Based on Figure 6, the graph of the variation of the Bypass valve opening against the motive fluid pressure is presented with data on venturi ejectors with diameters of 1, 3/4, and 1/2 inch. The motive fluid pressure increases as the bypass valve opens. The graph shows that the smaller diameter of the injector venturi has a higher motive fluid inlet pressure value than the larger diameter.

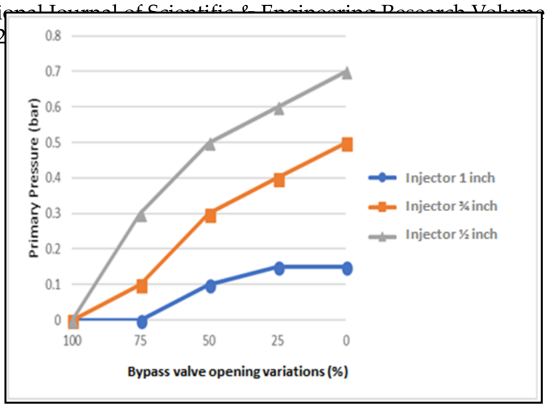

Figure 6: The graph of the variation of the bypass valve opening against the motive fluid pressure

3.3 Effect of Bypass Valve Opening Variations on Time (t)

Based on Figure 7 the graph on the vertical line shows the length of time for testing. The valve position is 100% open while 0% is closed. The longest testing time on a ¾ inch diameter venturi injector with a 100% bypass valve variation position with a time of 92 seconds. The shortest test time on the 1 inch diameter venturi injector at the position of the 0% bypass valve variation with a time of 43 seconds. The graph shows that if the diameter of the venturi injector is smaller, it takes longer time for 1 test with the same variable.

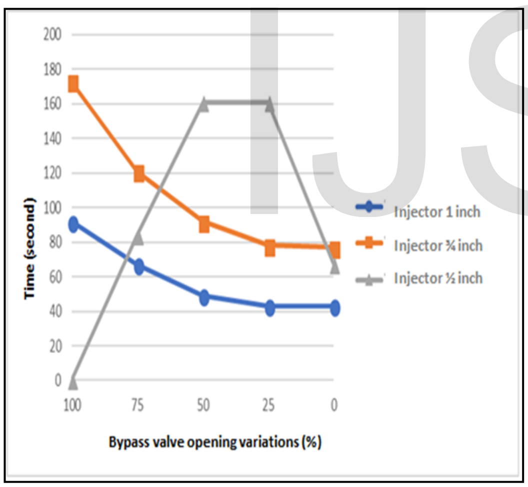

Figure 7: Graph of variation of bypass valve opening with time.

3.4 Effect of Bypass Faucet Variation with Primary Mass Flow

Based on Figure 8, the 1 inch diameter venturi injector experienced the largest increase in mass flow rate at the 25% bypass valve position. The flow rate of the 1 inch diameter venturi ejector is higher than the 3/4 and 1/2 diameters. Figure 7 show that the value of the primary flow mass flow rate is strongly influenced by the diameter of the venturi injector. The 1 inch diameter ventsuri injector has the highest mass flow rate at the 0% bypass valve position.

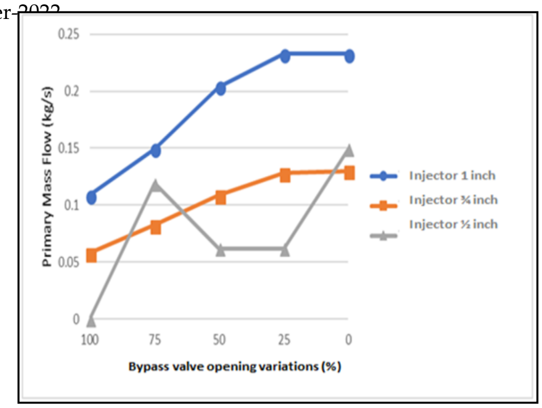

Figure 8: Graph of variation of bypass valve opening to primary mass flow

3.5 Effect of Bypass Valve Variation with Secondary Mass Flow

Based on Figure 9, the 1 inch diameter venturi injector experienced the largest increase in mass flow rate at the 25% bypass valve position. The flow rate of the 1 inch diameter venturi ejector is higher than the 3/4 and 1/2 diameters. Figure 7 shows that the value of the secondary flow mass flow rate is strongly influenced by the diameter of the ejector venturi. The 1 inch diameter venturi ejector has the greatest mass flow rate at the 0% bypass valve position. The secondary flow mass flow rate is strongly influenced by the nozzle diameter and the fluid flow from the primary flow.

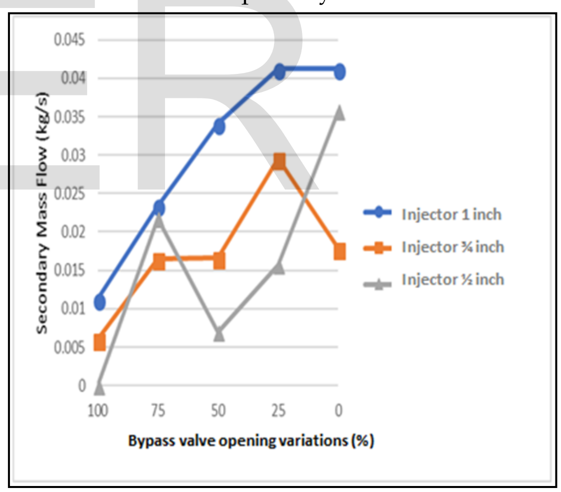

Figure 9: Graph of variation of bypass valve opening against secondary mass flow

3.6 Effect of Bypass Valve Variation with Entrainment Ratio

Based on Figure 10, the highest entrainment ratios for venturi ejector diameters of 1, 3/4 and 1/2 respectively are 0.1770, 0.1370, and 0.2530 at the 25% bypass valve position. The best entrainment ratio value is owned by the venturi ejector with a smaller diameter. The value of the entrainment ratio is strongly influenced by the diameter of the venturi ejector used and the suitability of the pressure of the primary motive fluid.

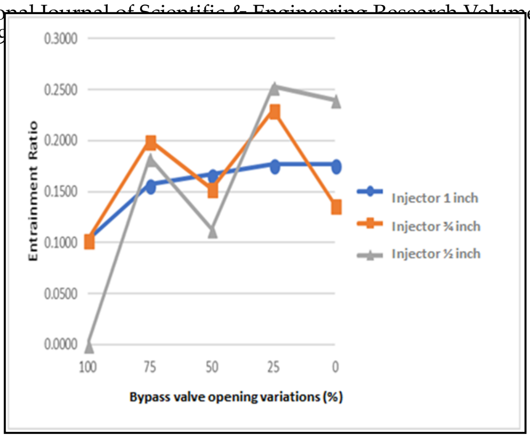

Figure 9: Graph of variation of bypass valve opening to entrainment ratio

4 Conclusion

In accordance with the results and discussion of testing variations in the position of the primary flow bypass valve and the diameter of the venturi ejector, it is concluded that there is an effect on the mass flow rate and the value of the entrainment ratio. These conclusions include:

1. Variations in the opening of the primary flow venturi ejector inlet pressure regulating bypass valve have an effect on the mass flow rate in the primary flow and secondary flow. When the bypass valve is closed, the inlet pressure of the venturi ejector increases.
2. Variations in the diameter of the venturi ejector affect the mass flow rate. The highest mass flow rate occurs in the 1 inch diameter venturi ejector. The mass flow rate of the 1 inch diameter venturi ejector at the primary flow is 0.2326 kg/s. The mass flow rate of the 1 inch diameter venturi ejector at secondary flow is 0.0412 kg/s.
3. Variations in the opening of the bypass valve inlet pressure, primary flow inlet to the venturi ejector, have an effect on the value of the entrainment ratio. The highest entrainment ratios for venturi ejector diameters of 1, 3/4, and 1/2 respectively were 0.1770, 0.1370, and 0.2530 at the 25% bypass valve position. The best entrainment ratio value is owned by the venturi ejector with a smaller diameter. The value of the entrainment ratio is strongly influenced by the diameter of the venturi ejector used and the suitability of the pressure of the primary motive fluid.

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