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Study of Ball Valve Characteristics

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Abstract:- Ball valve is a valve with flow control in the form of a spherical disk. The ball disc has a hole right in the center. The pattern of valve use is adjusted to the needs and desired functions. The basis for valve selection is performance, flow control, and safety. The choice of valve type, design, and material type play a very important role in the performance and reliability of the valve system. Ball valves are usually used to close completely even after years of non-use. Therefore, this type of valve is an excellent choice for shut-off applications. The effect of Valve Position on cavitation pressure drop and determine the minor head loss of ball valves using different types of test methods. For testing the effect of valve position on pressure drop and cavitation using pressure test as the main test method using nitrogen as the medium. Meanwhile, to determine the minor head loss of the ball valve using a simple discharge measurement test method by pumping water from the engine to the ball valve. The variables used are fixed pressure of 1000 psi for the test method of the effect of valve position on pressure drop and cavitation and valve opening and closing of 25%, 50%, 75 and 75%. And dependent variables Pressure drop (∆P), minor loss, residual head of the pump. And the specifications of the ball valve itself. In the valve opening method with values of 25%, 50% and 75% there is no significant difference from the initial pressure drop, which is only 103 psi. And for the valve closing method with a closing value of 25%, 50%, and 75% there is no significant difference between the three data but there is a significant pressure drop from the initial pressure of 667 psi. In the 100% open valve position experiment there is a residual head of 104.9917865 and for 25% 104.6543508 then for the 50% open valve position the residual head is 104.119698 and the last for the 75% opening there is a residual head of 103.534687.

Keywords:- *Ball Valve, Pressure Drop, Head Loss Minor, Pressure Distribution*

I. INTRODUCTION

In an industry, valves have a major influence on an ongoing industrial process because a valve is a device that regulates, directs, or controls the flow of a fluid by opening, closing, or closing part of the flow path.

Valve usage patterns are tailored to the needs and desired functions. The basis for valve selection is performance, flow control, and safety. The choice of valve type, design, and material type play a very important role in the performance andreliability of the valve system.

Ball valves are usually used to close completely even after years of non-use. Therefore, this type of valve is an excellent choice for shut-off applications. Ball valves are widely used inindustrial applications because they are highly functional in pressure and temperature depending on the design and material.

In a fluid flow in the valve, there is often a pressure drop caused by the valve opening. Of course, this is detrimental to the industry that uses the valve because the greater the energy required to drain the fluid, and also the more costs required.

Cavitation is the phenomenon of forming vapor bubbles in afluid flow due to a pressure drop so that it reaches below the pressure below the vapor pressure of the fluid at a constant temperature. The ball valve design also has a cavity space which will be used to overcome the problem of residual fluid trappedwhen the valve is closed. Residual fluid is usually trapped in the hollow of the ball component or in between the seat and the ball. For this reason, with the development of technology, a single piston effect ball valve type is designed, namely a valve that can release pressure in the cavity space if the pressure is greater than the upstream side, and can also lock the pressure if the upstreampressure is greater than the pressure in the cavity space. The pressure is discharged through a hole called a vent.

In the research of Pressure Drop Analysis on Ball Valve Openings, there are several problem limitations, namely the parameters to be studied include valve openings and closures of 25%, 50%, 75% and 100%. The ball valve used has a size specification of 4x3 "type reduce bore class

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300# with forming material using ASTM A105N for the pressure drop testing method. As for the minor loss testing method, it uses a 2 "ball valve type. Pressure and time are considered fixed in each experiment, which is 1000 psi and 5 minutes and also with testing media in the form of nitrogen gas for testing methods for the effect of valve opening and closing on pressure drop in staticfluid case studies. As for the minor loss testing method using a pump machine as a water distributor, where the pump machineitself has a specification of 10.3 bar as a head.

The variation of valve opening to the initial pressure aims to determine the amount of pressure loss at the opening and closing of the valve position starting from 25%, 50% and 75%. And the residual head test method contained in the valve opening aims to determine the residual head value of the pump's ability to drain water into the valve based on the opening value of the valve starting from 25%, 50%, 75%, and 100%.

II. RESEARCH METHODOLOGY

A. Ball Valves

In the research methodology and data collection, it will discuss ball valve testing, especially with pressure testing using air or nitrogen as the main testing medium. The valve to be tested for pressure test is 4x3 "- 600# which is a reduced bore type ballvalve, namely a ball valve with a hole diameter smaller than the pipe diameter. This ball valve will later be given a pressure of 1000 psi from a pressure pump machine for the pressure test process. There are several variations that have been determined for this study, such as the initial condition / position of the ball valve or ball movement of 25%, 50% and 75% to determine thepressure drop value that occurs in this test.

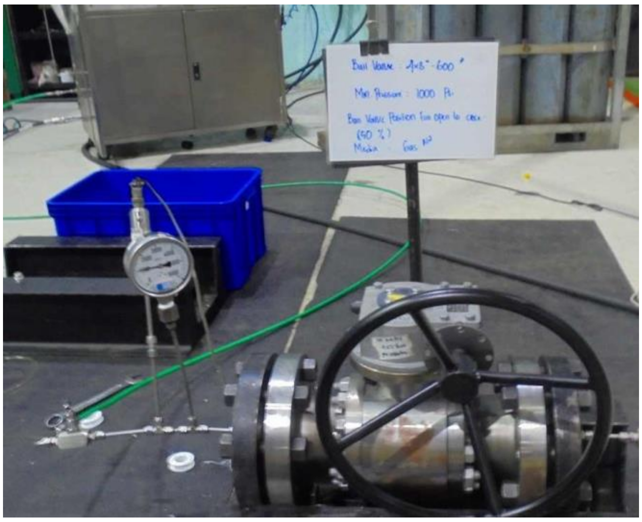

Fig 1 Ball Valve 4x3”

Valve used for measuring water discharge is a ball valve with a size of 2 ". The difference in the use of valve types in each test is because to do pressure drop testing, a valve with a rather large volume is needed to get a value or pressure drop result that can be seen clearly and for those used to measure water discharge simply because it uses water as the main test medium, a valve with a smaller size is needed so that the water storage at the end of the valve matches the storage capacity.

Fig 2 Ball Valve 2”

B. Testing Measurement Tools

In testing for comparison of pressure drop values and measuring discharge on ball valves here, several measuring instruments are used, namely, pressure gauge pressure transducer, and stopwatch. In the pressure test, a pressure gauge and pressure transducer are used to determine and monitor the pressure value on the ball valve. And a stopwatch is used to measure the holding time of the water discharge flowing from the pump engine to the shelter.

The data obtained from the pressure gauge measuring instrument to measure the pressure value given with the unit is psi and has been determined to be 1000 psi. Pressure transducer is a sensor to detect the pressure entering the ball valve.

C. Variables

First variable is the pressure drop, where can be found at pressure testing , and head loss minor for the water discharge. Controlled variables are variables whose magnitudes are controlled or made fixed during the study. In this study, the controlled variables are the type of ball valve used, the pressure,and the time used for flow stabilization.

Head Loss Total (h_{LT}) in this analysis Head Loss Minor (h_{LM}).

For Head Loss Minor (h_{LM}), it is divided into three parts, which is turns, valve (shown in green circle on Figure 2), and from venturimeter itself. Equation of h_{LM} is shown below:[6]

$$h_{L\,minor} = K\frac{v^2}{2g} \quad \text{……………………..……..…………… (1)}$$

Final part are valves. Ball valves are used on this setup.Value of K for butterfly varies between.

The valves are the most important variable. Every data and graphs that are obtained, will be done with different varieties of valve openings. There are one valve variety, and two valve variety at most.

On one variety opening of valves, there will be four different opening, which is 25%, 50%, 75% and 100% valve opened

III. RESULTS AND DISCUSSION

Valves are designed to regulate flow, besides being used to stop fluid flow but are usually used to regulate flow. Changes in the direction of fluid flow through the valve cause high pressure loss and turbulence or turmoil. The variation of valve opening against initial pressure aims to determine the smallest amount of pressure loss.

Table 1 Pressure Drop Test Results Full Close to Open Condition

Pressure In (Psi)	Pressure Out (Psi)	Opened BallValve (%)
1000	897	25
1000	898	50
1000	899	75

In the table above, it appears that there is no significant difference between the three data when the ball valve position experiment is carried out either from 25%, 50%, and also 75% of the ball movement is carried out. Because the upstream side of the ball valve that is pressurized during the test is only one side and when the ball movement is carried out by 25%, 50%, and 75% the pressure flows to fill the vacuum in the ball valve and also fills the upstream or downstream side. So the pressure on both sides of the ball valve has the same pressure and is stable after testing because the pressure has been evenly distributed on both sides of the valve.

Table 2 Pressure Drop Test Results Full Open to Close Condition

Pressure In (Psi)	Pressure Out (Psi)	Opened BallValve (%)
1000	333	25
1000	332	50
1000	331	75

In the table above, experiments carried out on the valve method starting from the full close to open position show that there is no significant difference between the three data when the ball valve opening experiment is carried out both from 25%, 50%, and also 75% of the ball movement is carried out. This is because the upstream side of the ball valve that is pressurized during the test is only one side and when the ball is opened by 25%, 50%, and 75% the pressure flows to fill the vacuum in the ball valve and also fills the upstream or downstream side. So the pressure on both sides of the ball valve has the same pressure and is stable after testing because the pressure has been evenly distributed on both sides of the valve. But the pressure drop that occurs when testing from the close to open position is a very large difference of around 667psi at each valve opening.

$$\sum Fz = ma_Z = 0 \quad \text{…………………………………...….(2)}$$

$$P_1\,\Delta x\Delta y - P_2\Delta x\Delta y - \rho g\Delta x\Delta y\Delta z = 0 \text{………………….(3)}$$

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determine the smallest amount of pressure loss [3].

The fluid used in the testing process is a fluid with μ = 0. Itis like a real motionless fluid because the only parameter is pressure (Compressive Strain). So, in an ideal fluid that is flowing, the pressure is perpendicular to the surface. At any point in the fluid, the pressure is in all directions and is equal inmagnitude.

Mass density is a derived quantity in physics that is more commonly known as density. The higher the mass density of an object, the greater the mass per volume. The average mass density of each object is its total mass divided by its total volume. An object that has a higher density will have a lower volume than an object of the same mass that has a lower density. The basic formula for mass density is as follows:

$$\rho = \frac{m}{V}. \quad \text{…(4)}$$

Evenly distributed pressure occurs during the pressure test on the ball valve where the pressure distribution is almost the same even though there is a difference in height that is not too significant because the mass density of the air 1.2 m3 /kg used is greater than the mass density of the water fluid which is only 1.0 m3 /kg at the time [4].

To get the relationship of pressure variation with depth, consider a fluid element with Δz as height, Δx as length and unit depth Δy by assuming a single fluid with the same/constant density.

Therefore, we can conclude that the pressure difference between two points in a fluid of constant density is proportionalto the vertical distance between the heights and the density of the fluid itself [5].

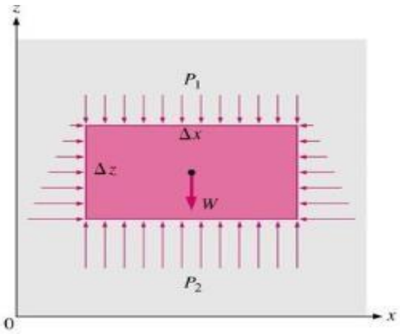

Fig 3 Free Body Diagram of a Rectangular Fluid Element in Equilibrium

Fluid flow rate is one of the quantities that exist in studying fluid movement. Flow rate is the distance traveled by one element per unit time in the fluid. Fluid flow velocity equation Q = Δx/Δt can be interpreted that an element in the fluid move as far as Δx in an interval of time Δt. To get the discharge from the ball valve is by getting the quotient of the volume of storage water that has been flowed from the pump to the ball valve with holding time.

$$Q = \frac{V}{T}. \quad \text{…(5)}$$

Where : Q = *Discharge (m^3/s)V = Volume (m^3)*

T = Time (second)

From simple discharge measurements on the ball valve using a pump as a water distributor and a stopwatch as a holding time marker for 3 minutes or 180 seconds. Then the data is obtained in the form of several positions of the ball valve opening to the amount of volume produced during the process.

Table 3 Result of Discharge Measurments on Ball Valve

Ball Valve Opened	**Holding Time**	**Volume Storage Pump Engine**	**Final Volume Shelter Flow**	**Discharge(m^3/s)**
Full Open	180 second	0.108 m3	0.00328m^3	0,00004167
25 %	180 second	0.108 m^3	0.0034 m^3	0,000041
50%	180 second	0.108 m^3	0.0034 m^3	0,000041
75%	180 second	0.108 m^3	0.00342 m^3	0,000041

Table 4 Result of Discharge Measurments on Ball Valve

Discharge(m^3/s)	**Ball Valve Coefficient**	**Final Volume Storage (m^3)**	**Position**	**Head Loss Minor**
0,00004167	0.02	0.00328 m^3	Full Open	0,002213506
0,000041	3,17	0.0034 m^3	25%	0,339649197
0,000041	8.16	0.0034 m^3	50%	0,874302034
0,000041	13,62	0.00342 m^3	75%	0,459312954

Losses are a variable that is the main discussion in this test.There are many types of losses that exist in pipe flow in axial turbines. These losses are divided into two, namely major headloss and minor head loss The equation used to find the total headloss is:

$$h = h_{Lmajor} + h_{Lminor} \quad \text{…..(6)}$$

Where : h_L = Head Loss

$h_L$major = Head Loss Major h_L minor = Head Loss Minor

In this case study using minor head loss. Because minor head loss is a loss that is considered a small loss to the variable water discharge, usually the shape of the flow, cross-sectional area, turns, to the orifice.

This type of loss provides interference in the form of a loss coefficient, which will later be sought for minor head loss or pressure drop from the formulated coefficient :

$$h_{L_{minor}} = K_L \frac{v^2}{2g}. \text{..............................(7)}$$

Where :

$h_{L_{minor}}$ = *Head Loss Minor (m)*

k = *Ball Valve Coefficient*

v = Velocity of flow (m/s)

g = gravity (m/s^2)

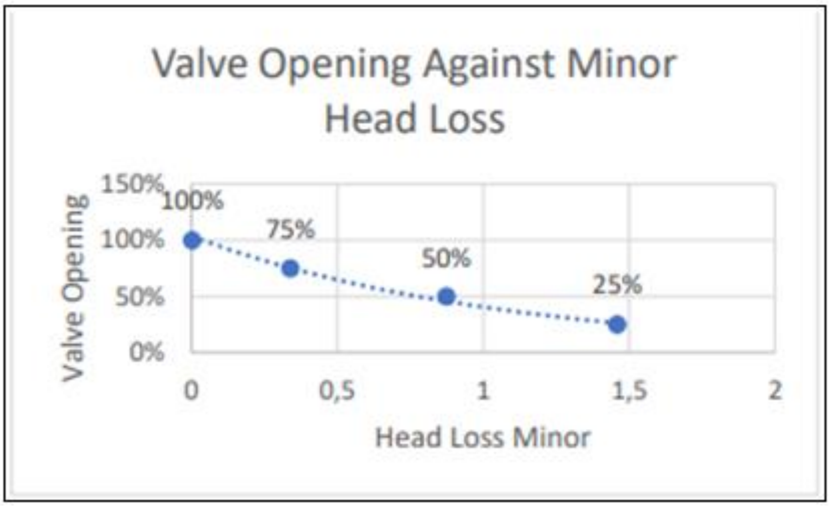

Fig 4 Valve Opening Against Minor Head Loss

The following is a comparison graph of the Minor Head Loss against the valve opening position, the higher the valve opening, the smaller the value of the minor head loss resulting from the flow because the water flows smoothly and the resistance produced is small. Because it is in accordance with the minor head loss equation, namely if the valve opening is getting bigger, followed by the ball valve coefficient getting smaller, the head loss value generated from the valve is small. To calculate the remaining Δh value of the pump then.

$$\Delta h \text{ value of the pump then} = \Delta h \text{ pump} - \Delta h \text{ minor}$$

Where the value of Δh *pump* 10,3 bar. From this value, it can be converted into head loss through the equation that can be seen below.

$$\Delta p = \gamma \ x \ H \text{..............................(8)}$$

$$10800 \ Pa = \frac{(9{,}8 \times 1000)kg}{N}.m^3 \times H = 104{,}994 \text{ m}$$

With the value of γ obtained from multiplying ρxg and ifconverted to head loss, a value of 104.994 m is obtained.

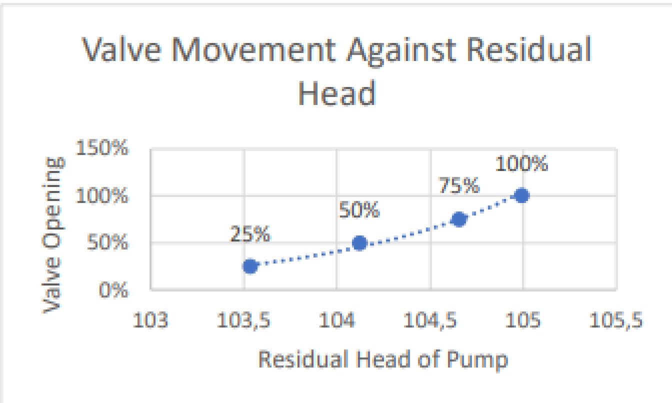

Fig 5 Valve Movement Against Residual Head

From the graph of valve movement against residual head, we can know that the pump used to drain water to the ball valve still has the ability to pump water as shown in the graph above. As for the greater the percentage of valve openings, the greater the residual head of the pump that can still be used.

IV. CONCLUSION

From the results of the research and discussion above, it can be concluded that there is no significant difference between valve openings both from 25%, 50%, and 75% openings because the time required to fill one ball valve chamber has been fulfilled, namely 5 minutes in the size of the 4x3 "-600# ball valve. So that the pressure drop does not occur significantly because there is no forward fluid flow from the valve to the connecting pipe or to the source. So the pressure on both sides of the ball valve has the same pressure and is stable after testing because the pressure has been evenly distributed on both sides of the valve.

Evenly distributed pressure occurs during the pressure test on the ball valve where the pressure distribution is almost the same even though there is a difference in height that is not too significant because the mass density of the 1.2 m3 /kg air used is greater than the mass density of the water fluid which is only 1.0 m3 /kg at the time. Thus, we can conclude, that the pressure difference between two points in a fluid with constant density is proportional to the vertical distance between the heights and the density of the fluid itself. comparison of Minor Head Loss to valve opening position the higher the valve opening, the smaller the value of minor head loss resulting from the flow because the water flows smoothly and the resistance produced is small. Because it is in accordance with the minor head loss equation, namely if the valve opening is getting bigger, followed by a smaller ball valve coefficient, the head loss value generated from the valve is small. Comparison of Head Loss Minor to the position of the valve opening the higher the valve opening followed by the ball valve coefficient the smaller the head loss value resulting from the valve is small. At 100% valve opening is worth 0.002213506m head loss while at 25% valve opening is worth 0.339649197m head loss. The greater the percentage of valve openings, the greater the residual head of the pump that can still be used. At 100% opening the residual head of the pump that can still be used 104.9917865 is still greater than the residual head of the 25% valve opening which is 104.6543508 m.

REFERENCES

[1]. Shirazi, T. N., G. Reza Azizyam and G. Hossein Akbari. (2012). CFD Analysis Of the Ball Valve Performance In Presence Of Cavitation. Life Sci J.
[2]. A. Tabrizi, M. Asadi, G. Xie, G. Lorenzini and C. Biserni. (2014). Computational of Cavitation, Journal of Engineering Thermophysics Vol. 23 No.1, pp.
[3]. Agustiyan, D. A., & Dr Bambang Lelono Widjiantoro ST, M. (2007). Simulasi Kavitasi Pada Control Valve. 1-9. Surabaya. Institut Teknologi Sepiluh Nopember.
[4]. Muhtadi, M., L, B. D., Widjiantoro, S. M., Cordova, Hendra, S. M. (N.D). (2017). Analisis Reduksi Intensitas Kavitasi Pada Kontrol Valve Akibat Pressure Drop Dengan Metode Pressure Recovery Factor di Vaco Indonesia, 1-7. Surabaya. ITS.
[5]. Syamsi Firdaus. (2017). Analisis Performa Modifikasi Propeller Ka-70 Menjadi Hubless Rim Driven Propeller. 1-108. Surabaya: Institut Teknologi Sepuluh November.
[6]. A. Aulia, N. ZA, N. Sylvia, L. Hakim, and S. Bahri, "Kajian Terhadap Kavitasi Dan Pressure Drop Pada Bukaan Control Valve Tipe Globe Valve Dengan Menggunakan Software Autodesk Cfd (Computational Fluid Dynamics)," Chem. Eng. J. Storage, vol. 1, no. 4, p. 57, 2022, doi: 10.29103/cejs.v1i4.5874.
[7]. Abdullah, M. 2016. Fisika Dasar 1. Bandung: ITB.
[8]. Ramos, Helena. (2010). CFD for hydrodynamic efficiency and design optimization of key elements of SHP. International Journal of Energy and Environment. 1
[9]. Mariano J. Savelski, 2002, Control Valves Noise Testing And Modeling, Edisi, Rowan University. Glassboro, NJ 08028, USA.
[10]. B. R. Munson, D. F. Young, and T. H. Okiishi, "Fundamentals of fluid mechanics," Fundam. fluid Mech., 1994, doi: 10.1201/b15874-2.