UNIVERSITI PUTRA MALAYSIA

OPTIMIZATION OF FLOW IMPACT TO DETECT THE DEFECT FACTOR ON BALL VALVE

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OPTIMIZATION OF FLOW IMPACT TO DETECT THE DEFECT FACTOR ON BALL VALVE

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November 2014

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Cavitation is a phenomenon which frequently creates fear within the engineering industry as the violent and critical attacks by cavitation can cause a lot of damage to ball valves. The damage in term of erosion, vibration and noise (e.g. water hammer) is a biggest challenge especially for the valve and pump industry. The energetic bubbles bring very high pressure to implode in a metal surface. The bubbles implosions will consistently digging the surface. Consequently, the failure and damage cannot be avoided. In this research, the aim for the study is to find the best solution to reduce the cavitation attack. The numerical tools embedded inside the simulation software combined with the novel design idea, was applied to enhance the ball valve performance. Moreover, the Pugh method matrix was applied to select the best groove design. The developed groove for ball valve was simulated under same boundary condition with existing experimental and simulation ball valve. The results done by previous researcher for the standard ball valve was compared with results data for develop ball valve. The convincing outcome was obtained, all three develop ball valve produce a better results compare with the standard ball valve. Evidently, in average percentage for energy loss performance error, all develop new design ball valve record the increment percentage of performance starting with D2 (32.96%), followed by D1(30.34%) and D3 (12.38%). In general, the cavitation index average performances for develop new design ball valve performed better than existing standard ball valve. Noticeably, develop design ball valve D2 recorded increasing 46.40% on average performance, this value is the highest increasing performance if compare with D1 model 36.32% and D3 model 34.32%. Thus, the goal to solve the violent cavitation effect was successfully achieved.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PENGOPTIMUMAN KESAN ALIRAN UNTUK MENGESAN FAKTOR KEROSAKAN KEPADA INJAP BEBOLA

Oleh

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Peronggaan merupakan satu fenomena yang sentiasa menjadi kebimbangan kepada industri kejuruteraan, kehadiran fenomena peronggaan ini akan menyebabkan banyak kerosakan kepada injap bebola. Kerosakan dari segi hakisan, getaran dan bunyi bising (contohnya kesan tukul air) adalah satu cabaran yang paling besar terutama kepada industri pam dan injap. Fenomena peronggan ini terhasil apabila gelembung udara yang bertenaga membawa tekanan yang sangat tinggi meledak di permukaan logam. Letupan secara konsisten daripada gelembung udara ini akan menghakis permukaan logam. Oleh itu, kegagalan kepada system kawalan bendalir dan kerosakan injap tidak dapat dielakkan. Dalam kajian ini, tujuan utama nya ialah untuk mencari penyelesaian terbaik bagi mengurangkan serangan peronggaan. Persamaan model matematik yang dibangunkan di dalam perisian simulasi, digabungkan dengan idea reka bentuk yang asli oleh pengkaji, digunakan untuk meningkatkan prestasi injap bebola. Selain itu, kaedah matriks Pugh telah digunakan untuk memilih reka bentuk terbaik untuk injap bebola yang dihasil kan. Injap bebola yg dibangun kan telah di analisis dengan kaedah simulasi di dalam persekitaran atau keadaan sempadan yang sama dengan injap bebola uji kaji makmal yang sedia ada. Keputusan diperolehi oleh pengkaji terdahulu untuk injap bebola sedia ada telah dibandingkan dengan data simulasi injap bebola baru dibangunkan. Hasil yang meyakinkan diperolehi, ketiga-tiga injap bebola baru dibangunkan mencatat keputusan yang lebih baik berbanding dengan injap bebola sedia ada. Buktinya, purata peratusan untuk ralat prestasi kehilangan tenaga bagi semua rekaan terbaru merekodkan peningkatan. Bermula dengan ciptaan D2 (32.96%), di ikuti oleh D1 (30.34%) dan yang terakhir ialah D3 (12.38%). Secara umumnya, purata prestasi indek peronggaan untuk ciptaan baru injap bebola merekodkan keputusan yang lebih baik berbanding dengan injap yang sedia ada. Rekod simulasi memaparkan, purata prestasi untuk ciptaan baru bagi indek peronggaan meningkat didahului oleh D2 (46.40%), diikuti oleh D1 (36.32 %) dan di akhiri oleh D3 (34.32%). Oleh itu, daripada semua perbandingan data antara ciptaan injap bebola baru dengan injap bebola sedia ada, boleh di rumuskan bahawa matlamat untuk menyelesaikan masalah hakisan kesan daripada fenomena peronggaan telah berjaya dicapai.

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APPROVAL

I certify that an Examination has met on **date** to conduct the final examination of **Nik Syamsul Bahari Bin Che Yusof** on his **degree** thesis entitled **"Improved Design Of A Ball Valve Due To Cavitation Defect Using Cfd Simulation"** in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the student be awarded the Masters of Science.

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LIST OF NOMENCLATURES

X_F	:	Pressure Ratio
X_{FZ}	:	Valve – Specific Cavitation Coefficient
P_i	:	Inlet Pressure
P_o	:	Outlet Pressure
P_V	:	Pressure Vapor
D_p	:	Different Pressure
ρ	:	Water Density
$P\infty$	:	Fluid Pressure
CI	:	Cavitation Index Range
CFD	:	Computer Fluid Dynamic
SWF	:	Solidworks Flow Simulation
FVM	:	Finite Volume Method
F	:	Applied Force
V	:	Velocity
V_i	:	Inlet Velocity
S	:	Control Surface
D1	:	Design one
D2	:	Design two
D3	:	Design Three
K	:	Loss Coefficient
α	:	Ball Valve Closing Angle
CI	:	Cavitation Index

CHAPTER 1

1 INTRODUCTION

1.1 General Overview

Fluid dynamic is a wide area of study. The knowledge and deep understanding of it will give a lot of advantages for an engineer to control or to manipulate the fluids (e.g. liquid and gases). Valve is a piece of equipment to control the flow of fluid, most of the time it apply to direct or control the gases or liquids by opening, closing or in some measure obstructing various passageway. Valve in principle is a pipe fitting device but are usually discussed as a separate category. In an open valve, fluid flow in a direction from a high concentration to a lower concentration. Valves are commonly used in piping systems (Chern & Wang, 2004). There are varieties of purposes for using valve, but the main function of valves is to control the flow rate in a piping system.

Valve is used in a multiplicity of circumstance including industrial, commercial, military, residential and transportation. Majority valve used in oil and gas industries, power generation, chemical manufacturing and water reticulation. People uses valve in routine activity such as shower, gas control valves on cookers and washing clothes, there have a lot of plumbing valves which is allowed people control the fluid volume or fluid flow rate. Valve can be operated manually either by a handle, lever or pedal. But in industries which focus to precision, most of the time valves operate automatically by changes in pressure, temperature or flow rate.

In the industry, valve plays a very important division to transport fluid from one point to another such as drinking of water or control of ignition in an engine. More complex control valve system will require an actuator to automatically control the valve operation based on an external input such as the regulating flow through a pipe an actuator will act upon a diaphragm or a piston which in rotation activates the valve, the general example for this system we can found at safety fitted hot water system or boiler.

Valve have a multi range in size from as small as ½ inch to as large as 30 feet in diameter and have a different complexity from simple brass valve at the local hardware store to a precision design equip with highly sophisticated coolant system control as used in the nuclear reactor. After a hundred years of improvement when it was started develop in 19th century, the enhancement of the valve capability makes it possible to control flow of all types from the thinnest gas to highly corrosive chemical, superheated steam, abrasive slurries, toxic gases and radioactive materials.

Besides that, valve also very useful to regulate the rate, the volume, pressure or to direct liquids, gases and slurries through a pipe line. Valves are able to run in any condition from a cryogenic region to molten metal and pressure from high vacuum to thousands of pounds per square inch. Valves are the heart of the hydraulic and pneumatic system. The damage of valve would expect the whole system will fail. In the long run, a cheap valve will have proved to be the most expensive, skimping on valve is the wrong way to reduce a cost.

Previously, it was difficult to investigate the flow pattern inside the piping system or valve because those two items are not physically visible from outside. In this study, ball valve is the main focus to analyze the flow impact. A ball valve is a valve with a spherical disc, the part of the valve which controls the flow through it. The sphere has a hole, or port, through the middle so that when the port is in line with both ends of the valve, flow will occur. When the valve is closed, the hole is perpendicular to the ends of the valve, and flow is blocked. The handle or lever will be in line with the port position; it designs to let people know the position of it.

Ball valves are used extensively in industrial applications because they are very versatile, supporting pressures up to 1000 bars and temperatures up to 200°C. Sizes typically range from 0.5 cm to 30 cm. They are easy to repair and operate.

The unpleasant enemy for the ball valve industry is cavitation. The physical phenomenon for cavitation existed undetected until year 1893 by speed trial naval research. The study applied mathematical model developed by Euler as early as year 1754 to calculate the possibility of cavitation attack (Boddéus, 1999). The cavitation attack will create a fatal damage to the ball valve which kills the heart of hydraulic and pneumatic working system.

1.2 Problem statements

Valve performance has a dramatic effect on process plant efficiency and valve life cycle. All control valves have an inherent flow characteristic that defines the relationship between valve opening and flow rate. Valve opening at several inlet angles will provide a different flow conditions, the conditions of a flow are related with the characteristic coefficient, the loss coefficient represent the energy loss due to a valve. It also will provide vortices for the flow pattern the vortex flow will cause the cavitations phenomena and always appears at the edge of the vortex behind the ball valve. When the cavitations happen, it will come together with noise. As the opening of the valve decreases, these vortices grow and may cause more pressure drop or in other word more energy loss due to these growing vortices (Chern & Wang, 2004). Figure 1.1 shows the characteristic of the fluid flow in the upstream and the downstream of the ball valve.

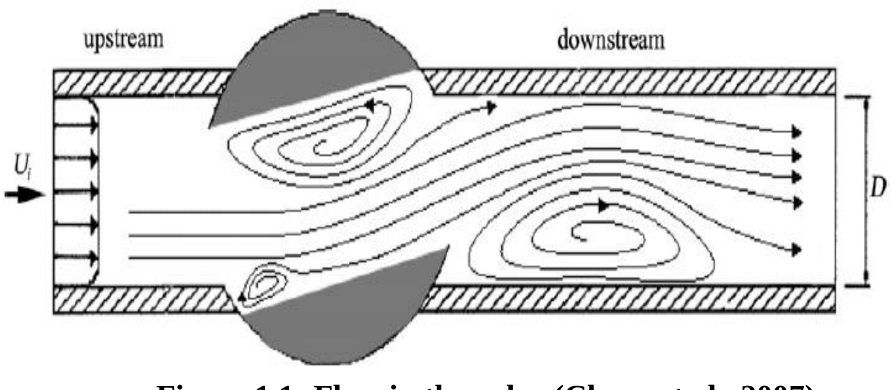

Figure 1.1: Flow in the valve (Chern et al., 2007)

Based on Figure 1.1, the high flow velocities from the upstream region cause the local hydrostatic pressure to drop to a critical value at the downstream region which roughly corresponds to the vapor pressure of the fluid. This causes small bubbles filled with stream and gases to form. These bubbles finally collapse when they reaches the high pressure areas as they carried along by the liquid flow (Shirazi et al.., 2012). These pressure peaks lead to mechanical vibration, noise (e.g. water hammer effect) and material erosion in walled areas. When the cavitation bubble collapses in a valve surface, it produces a unique low level sound such as erratic popping or crackling. The noise volume will gradually increase when the pressure drop increases. If cavitations are severe, the hydraulic valve coefficient as well as the fluid properties changes (Chern & Wang, 2004).

Cavitations abolishes both pipeline and ball valve, the hazardous consequences occurred when the ball valve leak by eroding surface, it will form a damage to a rough surface initiate with small micro sized of depth, it will steadily drill holes until the part is either repaired or failed. In certain cases, part of the liquid vaporizes resulting by outlet pressure is below the upstream vapor pressure, the liquid pressure will not arise above the vapor pressure again, this change in state known as flashing. The damage due to cavitations usually more severe or consider worst then flashing.

In this research, the best answer to stop the cavitations attack is to reduce the pressure drop from inlet to outlet gradually or avoiding a large pressure drop when the fluid flows through the ball valve. Cavitations can be eliminated totally by not allowing the pressure to fall below the vapor pressure, thus eliminating any bubble formation and subsequent collapse. Additional method that can be used to stop the cavitations is dissipating the energy of the imploding bubbles by divorcing them away from the metal surfaces. This impressively reduces the amount of energy that the exposed surfaces of a valve need to absorb and allowing the components to resist damage. Therefore, the new models for ball valve are developed to fulfill all decision criteria made to avoid the cavitation.

1.3 Research Objectives

i. To develop new groove design at critical area region to reduce the valve defect.
ii. To simulate the new developed groove for ball valve, comparing with the standard ball valve experiment data.

1.4 Scope of Study

This research will only develop simple new ball valve design in 3D model. There is no physical model fabricated. The analysis elements will use air/water as a sample study of fluid. Study only focus on design at the critical area. All ball valve models will simulate using Computer Fluid Dynamic software and compare with previous laboratory experiment results.

1.5 Thesis Outline

In this first chapter, a brief description about valve is introduced, which is focused to present what is a ball valve in general. Apart from that problem statement and objective of the research are also presented.

Chapter 2 presents literature review which includes the previous and current researches on the improvement of flow impact to detect the defect factor on Ball valve.

Chapter 3 discusses the methods used in this study. It covers the ball valve details, the justification of selected ball valve as a main focus to study the cavitations effect and the way to reduce the cavity attack. Moreover, the simulations data based on the built model and the improvement ball valve design reveals here. The results data collect from the simulation, compare with existing results were examined. Besides that, the evidence Computer Fluid Dynamic (CFD) software able to perform develop model simulation are presented. Thus, the new software tool for simulations introduced.

Chapter 4 exhibits all the results obtain from simulation. The cavitation index number, loss coefficient value, table and graph are discussed in details here.

The conclusion is drawn in Chapter 5, the arguments and issues are reaching to the final judgment at this chapter. Some suggestions are given for future research works.

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