Computational fluid dynamic analysis of flow coefficient for pan check valve

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Abstract: This paper describes the computational fluid dynamic analysis of flow coefficient for pan check valve. This work is focused on determine the length of supporting beam by pressure drop analysis and evaluate flow coefficient. And then in case of design of pan check valve, predict flow head loss with different flow rate. The method of computational fluid dynamic analysis provides a greater insight into the flow visualization aspects through this pan check valve. By using computational fluid dynamic analysis, pressure and velocity description can be easily observed and the pressure drop and flow coefficient can be exactly predicted. The length of supporting beam gives an important effect on the fluid performance of the check valve and the optimum length for the supporting beam is 32mm, the pan disc supported at this distance yields the minimum pressure drop and maximum flow coefficient. This research improved the understanding of the fluid flow performance of check valve. The method can also be applied to design the other part of this valve and/or other different valves.

Key-Words: Pan check valve, Flow coefficient, Pressure drop, Head loss, Computational fluid dynamic analysis

1 Introduction

The check valve is one of the typical components being extensively used in the safety system of pipelines [1]. Check valve normally allows fluid to flow through it in only one direction. Check valves are two-port valves, meaning they have two openings in the body, one for fluid to enter and the other for fluid to leave [2]. There are various types of check valves used in a wide variety of applications. Check valves work automatically and most are not controlled by a person or any external control, accordingly, most do not have any valve handle or stem.

There are a number of reasons for using check valves, which include:
• Protection of any item of equipment that can be affected by reverse flow, such as flow meters, strainers and control valves.
• To check the pressure surges associated with hydraulic forces, for example, water hammer. These hydraulic forces can cause a wave of pressure to run up and down pipe work until the energy is dissipated.
• Prevention of flooding.
• Prevention of reverse flow on system shutdown.
• Prevention of flow under gravity.
• Relief of vacuum conditions.

The pan check valve consists of four main components as shown in Fig. 1: the body, a disc, a spring and a spring retainer. The disc moves in a plane at right angles to the flow of the fluid, resisted by the spring that is held in place by the retainer. The body is designed to act as an integral centering collar that facilitates installation. When the force exerted on the disc by the upstream pressure is greater than the force exerted by the spring, the weight of the disc and any downstream pressure, the disc is forced to lift off its seat, allowing flow through the valve. When the differential pressure across the valve is reduced, the spring forces the disc back onto its seat, closing the valve just before reverse flow occurs. The presence of the spring enables the pan check valve to be installed in any direction. The design of pan check valves allows them to
be installed in any position, including vertical pipelines where the fluid flows downwards [3]. An important concept in valves is the flow coefficient which is a relative measure of its efficiency of fluid flow across the valve. Flow coefficient is related to pressure drop across a valve [4]. Typically the check valve is designed for and can therefore be specified for a specific flow coefficient. The objective of this research is optimization of flow coefficient for pan check valve by computational fluid dynamics. This work is focused on determine the length of supporting beam by pressure drop analysis and evaluate flow coefficient. And then, in case of optimum design of pan check valve, predict flow head loss with different flow rate.

2 Flow coefficient and head loss

The flow coefficient of a device is a relative measure of its efficiency at allowing fluid flow as shown in Fig. 2. The check point of pressure in pipeline is form 2 times of pipe diameter before valve and 8 times of pipe diameter after [5].

It describes the relationship between the pressure drop across an orifice, valve or other assembly and the corresponding flow rate. Mathematically the flow coefficient can be expressed as follows:

\[ Cv = F \sqrt{\frac{SG}{\Delta P}} \] (1)

Where, \( Cv \) is the flow coefficient or flow capacity rating of valve, \( F \) is the rate of flow (US gallons per minute), \( SG \) is the specific gravity of fluid (Water = 1), and \( \Delta P \) is the pressure drop across valve (psi). The part is focusing on the prediction of the head loss under different flow rate conditions. The head loss mathematically can be expressed in as:

\[ H = \frac{\Delta P}{\rho g} \] (2)

Where, \( H \) is head loss through the check valve, \( \Delta P \) is pressure drop across valve, \( \rho \) is density of fluid (Water = 997Kg/m³), \( g \) is gravitational constant.

The use of the head loss offers a method of calculating the head loss or pressure drop through the check valve under different flow rate conditions. The use of the flow coefficient and head loss offers a standard method of comparing valve capacities and sizing valves for specific applications that is widely accepted by industry.

3 Computational fluid dynamic analysis

3.1 Flow coefficient of pan check valve

The objective of this research is to find the optimum length of supporting beam to make the flow coefficient biggest. Since this valve mainly works at its maximum opening determined by the length of supporting beam as shown in Fig. 3, thus the fluid dynamic analysis with different beam length are carried out under the same working condition to find the optimum length using commercial software ANSYS CFX version 11.0.

Fig. 2 Calculation check point of pressure drop

Fig. 3 Length of supporting beam

Fig. 4 Grid of valve and pipe model
Fig. 5  Velocity distribution for beam length of 32mm

Turbulence is accounted through high Reynolds number k–ε with standard wall functions. The reference pressure of fluid is defined to be 101,325 Pa. Water flow with specified capability of 56m³/hr is entering the inlet, and leaves through outlet, where atmosphere pressure is prescribed. And it’s assumed that the wall of pipe and valve are No-slip and Smoothing.

(a) beam length L is 30mm

(b) beam length L is 32mm

(c) beam length L is 33mm

(d) beam length L is 34mm

Fig. 6 Pressure distribution for different beam length

The velocity distribution of cross section valve and pipe for beam length of 32mm is shown as fig. 5. Fig. 6 shows the pressure distribution at the middle plane for three beam length. It can be found that the pressure drops very obviously due to the resistance of the valve. Comparison of these figures shows the pressure distributions change differently for various beam length. To exactly compare the fluid performance of nine case different models of beam length from 28mm to 42mm, the pressure drops and coefficients are calculated as shown in Table 1. Fig. 7. It’s obvious that beam length 32mm leads to the best fluid performance of valve. That is, when the beam length L is 32mm, the valve has the least pressure drop and biggest flow coefficient. Thus, the beam length is adopted as the optimum beam length.

Table 1. ΔP and flow coefficient(Cv) with different L

<table>
<thead>
<tr>
<th>L (mm)</th>
<th>Q (m³/hr)</th>
<th>ΔP (Psi)</th>
<th>Cv</th>
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<tbody>
<tr>
<td>28</td>
<td>9.405</td>
<td>140.935</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>9.041</td>
<td>143.739</td>
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<td>33</td>
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<td>143.375</td>
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<td>34</td>
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</tr>
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<td>38</td>
<td>10.997</td>
<td>130.333</td>
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<td>42</td>
<td>16.040</td>
<td>107.918</td>
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</tbody>
</table>

Fig. 7: Flow coefficient Cv vs. beam length L

3.2 Head loss of pan check valve

The head loss variation of pan check valve with optimum beam length 32mm are calculated by eq.(2). The head
loss of the valve are shown in Table 2 and Fig. 8. It can be found that the head loss is the minimum 0.693m at flow rate 24 m$^3$/hr. Head loss is increased at flow rate 32 m$^3$/hr.

<table>
<thead>
<tr>
<th>L (mm)</th>
<th>∆P (Psi)</th>
<th>Head loss (m)</th>
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<tbody>
<tr>
<td>28</td>
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<td>16.040</td>
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Fig. 8   Variation of head loss with different beam Length

4 Conclusion
The application of CFD method provided a greater insight into the flow visualization aspects through this pan check valve. By using CFD analysis, this pressure and velocity distribution can be easily observed, and the pressure drop and flow coefficient can be exactly predicted. Results show that the length of supporting beam give an important effect on the fluid performance of the valve. And the optimum length for the supporting beam is 32mm, the pan disc supported at this distance yields the minimum pressure drop and maximum flow coefficient.

This research improved the understanding of the fluid performance of check valve, the method can also be applied to optimize the other part of this valve and/or other different valves.

In addition, this research has not considered cavitation and dynamic performance of this valve. It’s necessary to consider those for check valves design in the future work.

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References: