Application Engineering to Reduce Swing Check Valve Failures

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Check Valves, unlike isolation valves have to dynamically respond to flow conditions and deliver long trouble-free performance. Hence correct selection and sizing of Check Valves based on application and line parameters is vital to system reliability.

Check Valves are probably the most misunderstood valves in a flow-control system. In simple terms, a check valve allows the flow of gas, liquid or steam in one direction and automatically prevents backflow in the reverse direction. All check valves are flow sensitive and rely on fluid pressure to open and use internal spring/hinge force to close. Check valves come in various types depending on construction and application, and the common variants are:

- Swing Check
- Lift Check
- Tilting Disc Check
- Ball Check
- Axial-flow Check
- Stop Check
- Poppet Check, etc.

Selection and Sizing of Swing Check Valve

For long trouble-free performance, check valves must be selected to suit the application. Sizing and selection of a check valve for critical applications and large sizes should be treated with as much importance as sizing of a control valve. Incorrect selection can result in premature failures.

The focus of this article is on prevention of premature failures through correct sizing and correct selection of a swing valve and material of construction that suits the application.

Typical swing check valve issues include disc chattering, slamming, tapping against the seat, cavitation, water hammer, wear, erosion etc. These phenomena can cause mechanical failure of internal parts and cause dislocation of disc from hinge, hinge pin damage, dislocation of hinge arrangement, shearing of disc shaft and damage to seat surfaces (refer figures 1 & 2). These failures can develop prematurely or develop over a period of time depending on the operating parameters.

Chattering of Disc

Repeated opening and closing of the disc is known as chattering and is one of the most common causes of swing check valve failure. Chattering occurs when the valve is oversized for the application and the disc is not firmly held against the body stop. Chattering is associated with noise generation and repeated chattering of the disc can lead to premature wear of internals like hinge pin, shearing of disc stud, spring failure, poppet damage or seat damage.

A swing check valve must be sized for flow rate that will keep the disc in a stable position against the internal stop, in fully open position. Each size

Figure 1: Swing check valve disc stud failure caused by chattering

Figure 3: Undue wear of hinge pin in a swing check valve due to chattering

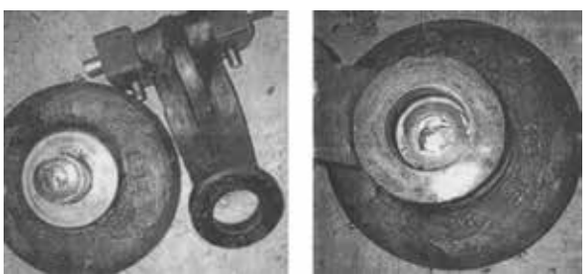

Figure 4: Disc Stud Damage

Figure 2: Seat damage caused by chattering

of check valve has a critical velocity V_{Min} which is the minimum velocity required across the valve to keep the disc in fully open position. V_{Min} depends on various parameters like flow medium (gas/ liquid), density, temperature, disc weight and moment arm distance. When a valve is sized to deliver a velocity of flow more than V_{Min}, chattering (fluttering or excess vibration) can be avoided.

Having said that, it may not always possible in industry to ensure a constant velocity above V_{Min} as flow conditions alternate from Maximum to Normal to Minimum. Modern power plants have high turndown ratio (ratio of Maximum flow to Minimum flow) and in such cases ideal sizing should ensure disc opening angle greater than 25% with minimum flow.

Further, care should be taken to ensure that there are no flow disturbances in the upstream side of the check valve and entry flow into the check valve is stable and uniform.

The wear of hinge pin (Fig. 3) was noticed before it caused any mechanical failure. This highlights the need to monitor at regular intervals the condition of check valves in critical services where the flow velocity cannot be maintained above V_{Min}.

Wrong Selection of Disc Material

In applications where fatigue loading is expected, the correct selection of disc and hinge assembly materials is of paramount importance.

For multi-phase and unstable flow conditions like in oil exploration industry, the disc material of a swing check valve should have high fatigue resistance to withstand dynamic loadings.

In a 12" Class 900 swing check valve installed in an offshore platform, the disc stud got sheared due to repeated contact of the disc against the stopper (Fig. 4).

The analysis revealed that disc material selected for check valve was a martensitic stainless steel (CA15) which has low impact strength and could not with stand the impact loading due to unstable flow.

Here, CA15 material disc was replaced with carbon steel material which is more ductile and the life of the check valve extended.

Flow Disturbances - Upstream and Downstream of Swing Check Valve

The placement and positioning of upstream and downstream equipment also play an important role in the functioning of the check valve without chattering .The upstream of the check valve should have a minimum 5D (D = pipe diameter) straight pipe length to ensure uniform flow. Presence of any control valve at shorter distance upstream will lead to non-uniform and even turbulent flow, and this could lead to chattering. Similarly,

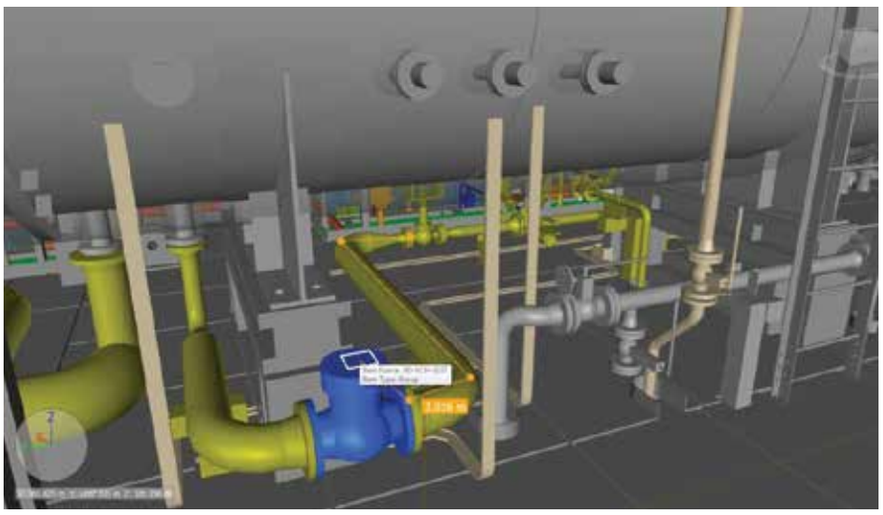

Figure 5: Pipe Layout - Refinery

Parameters		3" SCV	2"SCV
Flow medium		gas	
Flow rate	kg/hr.	281	
Actual flow velocity	m/s	4.1	9.10
V-Min (To keep Disc fully open)	m/s	29	32.7
Disc open angle for the actual flow	degree	15	25

Guidelines for Selection of Check Valve Type:

Application	Swing Check	Tilting Disc	Lift Check
Fast opening and fast closing	3	1	1
Variable flow conditions	3	2	1
Low Pressure drop	1	2	2
Disc Stability at low flow velocity and pulsating flow	3	1	1
1 - Excellent, 2 – Good/ Fair, 3 - Fair/Not Recommended			

bends, reducers, etc. on the upstream also can create non-uniform flow. The downstream of the check valve should have a straight pipe length of at least 10D since bends can cause back pressure.

Fig. 5 (Plant Layout in a Refinery) shows a check valve with upstream and downstream bends, where space constraints defy piping conventions. In this case the line fluid from bend enters the check valve in swirling streams and causes disc chattering & excessive noise.

Slamming of the Disc

Using a wrong type of check valve or a check valve of wrong size can lead to pressure pulsations and valve slamming issues. Fast closing of the disc due to back-flow pressure or pressure surge can have devastating effects on valve internals. Swing check valves which have longer travel from close from open position is more prone to slam than lift check or tiling disc check valves.

Disc Tapping

When the flow velocity through a swing check valve is too low due to oversizing, and when the disc angle of opening is less than 20 degree, there is a tendency for the disc to tap against the valve seat and bounce back. This tapping is magnified in case of gas applications with flow fluctuations. In a recent case, for gas pipeline with a flow rate of 281 kg/hr, the disc opening angle for the 3" swing check valve was only 15 degrees. Since there was a strong tendency for disc tapping, the size was changed to 2" and angle of opening increased to 25 degrees and disc tapping is avoided.

Sizing of a Check Valve for Application

Performance of a check valve depend greatly on selection and sizing based on application and operating parameters. For Sizing of the valve the following basic parameters need to be considered (list not comprehensive):

- Line fluid, and its density
- Single-phase/ multiphase
- Fluid Pressure &Temperature
- Min/ Max and normal flow rates
- Upstream and Downstream equipment

Swing check valve should be sized to obtain flow velocity sufficient to hold the disc firmly in open position. Valve manufacturer has data on V_{Min} for each valve size which can be used for sizing. Although it is preferred to operate under fully open position, the actual flow conditions in the plant may vary from low to high flow rate.

In such cases a Tilting disc check valves will perform better even when the flow velocities are below V_{Min}.

In case piping specification calls for swing check valve due to low pressure drop considerations and flow velocity ranges from low to high, size the

valve such that disc open position with low velocity flow is greater than 20 degrees to avoid disc tapping. Valve performance should be monitored at regular maintenance to avoid sudden failures. Ensure that entry into the check valve is uniform and stable by adhering to conventional wisdom of straight pipe lengths of 5D min on upstream side and 10D on downstream.

Summary

- The swing type check valves should be sized and selected for the application. Proper valve sizing will enhance system reliability, and provide long and trouble-free service.

- An oversized valve can lead to premature wear and failure of the valve internals due to chattering or excessive disc movement. An undersized valve will cause higher pressure losses and create excessive noise and vibration. Maintaining uniform flow by adhering to straight pipe distance guidelines enhance valve performance even if flow velocity is less than V_{Min}.

- Choosing a valve with short travel distance like Tilting Disc Check Valve can avoid slamming.