Failure Analysis and Re-engineering of ANSI 2500 Water Injection Choke Valves

Background

A customer based in the North Sea on an offshore oil and gas platform was having significant performance issues with another OEM's Choke valve.

Feedback provided by the customer was that the specific reasons for the Choke valve performance issues were unclear, however, the customer did also state that numerous failures had occurred with this type of valve, with a wide range of reported issues, such as:

- Seizure
- Continuous leakage
- Loss of control
- Excessive noise

The customer reached out to Severn's team of engineering experts to identify what the issues were causing the water injection Choke valve failures and additionally identify suitable solutions.

Fig 1: Front disc (underside) showing badly damaged

As part of this investigation, the Severn team carried out a detailed failure analysis report to outline the reason for the failure of that OEM's rotary orifice choke valves and to identify bespoke engineered solutions that ensured the customer achieved their core remit of safe operations and minimum downtime.

The original choke valves installed were 6" × 4" × 6" ANSI Class 2500 angle choke valves fitted with tungsten carbide, rotating-disc-type trims. The design Cv is 42, and the valve characteristic is a variation of the standard equal-percentage characteristic. The choke valves in question had been installed for only a short period before the customer raised performance concerns with Severn.

Initial Failure Analysis Observations

Upon investigation of the valves in question, the Severn team identified multiple potential issues that were causing valve performance to deteriorate and ultimately fail. Severn's conclusions were as follows: The failure of the choke trims was due to the development of cavitation during the initial startup of the injection process.

The customer advised that the downstream pressure at startup could be as low as atmospheric pressure. Additionally, mechanical vibration was occurring.

Fracture failure of internal valve components manufactured in tungsten carbide is a common cause of failure. Failure of the material is linked to the violent change-over forces created when the vapour bubbles produced within the cavitation process collapse. Additionally, cavitation can also lead to the loss or failure of the binder in the carbide, causing the cage to crumble.

Fig 2: Top of bean with missing carbide liner

The pressure differential taken by the valve during startup conditions are generally significantly higher than operating conditions provided by the valve vendor when the original choke valve design and selection was carried out. Severn’s over 25-year experience as an OEM Choke valve manufacturer has led to the understanding that the above is a very common cause of failures on choke valves for water injection applications.

The choke valves in question were also found to generate significant levels of noise when in operation, and excessive noise is indicative that the valve is in distress and the likelihood of premature failure is high. Two primary causes of excessive noise when in operation on liquid service valves are cavitation and mechanical vibration.

Fig 3: Bore of the bean (from below)

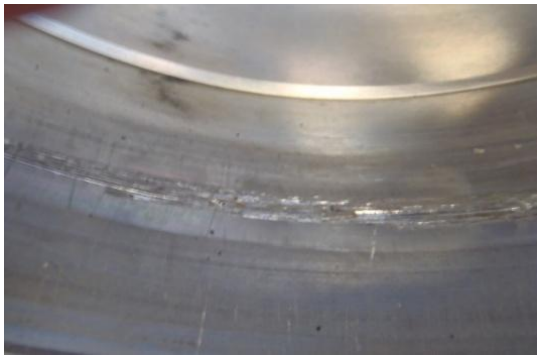


Fig 4: Scoring in bore of protecting bush

In addition to the above, the design of the choke valves in question is such that when the carbide in the front disc and the bean is in good condition, a class V shut off is achieved. However, the downside of this design is that the front disc is held in place against the bean via a spring. Should the valve be prone to vibration, it can occur that the two parts could be momentarily separated and slam back together, due to the very hard but brittle nature of the material, this can potentially result in the carbide breaking. Furthermore, debris could enter between the parts and hold them apart, further preventing shut-off and leading to future leakage.

Severn's recommendation

After the failure analysis was completed, Severn provided a list of bespoke engineered solutions for the customer to prevent future choke valve failure for the water injection application.

Severn's solutions were as follows:

On applications of this type i.e. water injection, our extensive experience shows that the valve design utilised for the desired duty should have an internal trim design which introduces a sufficient number of pressure let-down stages to the process fluid to ensure the risk of cavitation is massively reduced and/or completely eliminated during any start-up and/or low flow case conditions where the developed back pressure from the injection pipeline is relatively low.

Severn offered an additional recommendation to upgrade the areas of the valve trim exposed to the high velocities produced within the pressure letdown process. The valve trim should be manufactured in either solid tungsten carbide or ceramic to increase the valve resistance to erosion, at a point when greater volumes of produced water will be injected.

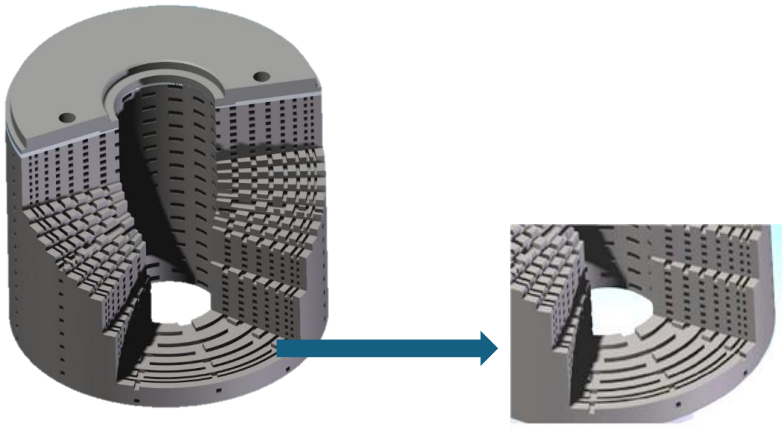
The flow path geometry from the seat bore (i.e. downstream of the trim) to the body outlet should be designed to eliminate any potential for the development of any ‘low pressure area’ (i.e. often associated with rapid flowing area changes).

The valve trim was also upgraded to ensure that the valve is capable of providing a seat leakage equivalent to ASME Class V (i.e. to prevent damage when the valve is exposed to the pump discharge pressure when operated in fully closed position).

Results

After collaboration with the customer and review of the analysis provided by Severn’s team of engineering experts, the customer was happy to proceed with Severn designing and manufacturing replacement severe service choke valves customised to suit the desired process conditions for the water injection application. Accordingly, Severn designed and manufactured multiple 6’ 2500# Angle Choke valves for water injection application in super duplex and tungsten carbide with a 12-stage CCD trim design.

Severn’s bespoke engineered choke valve solution for the end user has been in active duty for over 10 years and are still performing to the desired level with support from regular service and maintenance, therefore ensuring the customer achieves their core remit of safe operations and reduced downtime.



Solid Tungsten Carbide Alloy Valve Core (Trim)

+

Labyrinth velocity-control trim for particulate-laden service