Damage scenarios for valves: Identifying the potential for optimisation

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Ideally, valves used in the production process would go unnoticed and remain problem-free throughout a line's entire functional lifetime. But valve integration cannot be ignored quite so easily; after all, these components are indispensable for automated production processes to ensure the appropriate routing paths and to shut off product flows. They are required to exhibit maximum reliability in terms of design and function, and to be sturdy enough to effortlessly cope with any events occurring in the production process.

Where exactly are the potential problems associated with valves? Moving parts for opening and closing the shut-off components, duty limits of seal materials as well as product characteristics, and the temperatures encountered in the production and cleaning processes all demand a lot from the components involved and influence their useful lifetimes. Then there are the imponderables, such as water hammers or human error in handling the individual components when removing and installing wear parts. By designing a radically new series of valves, Krones has taken on board the empirical feedback from operating aseptic and non-aseptic production lines, and has created a family of valves that exhibit salient improvements for many of the problems encountered in valve design. This involves valve design that contributes to safe and contamination-free product routing, and incorporates features that simplify the operator's work and enhance personnel safety.

Seal design for butterfly valves

Numerous cases of damage when using valves are associated with the seal. In the case of a butterfly valve, for instance, volume changes will occur, caused by rises in temperature. These swellings on the seals protrude into the product compartment, so that during the opening and closing operations for the valve disc, the increased level of friction causes small particles to be abraded, which are then entrained in the product or the cleaning agent (Figure 1).

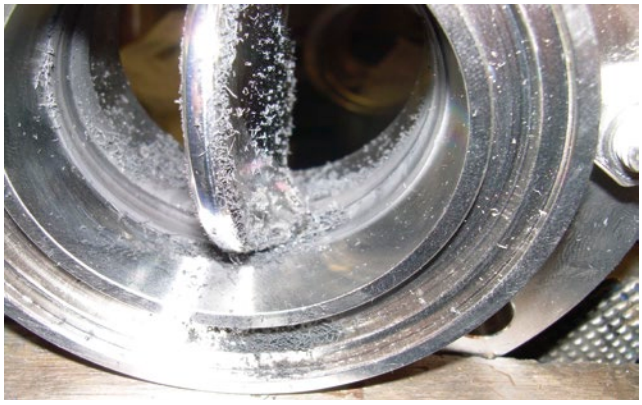

Figure 1. Seal abrasion at the disc.

The result is that the valve no longer closes properly, which means that the liquids are no longer dependably separated, resulting in product contamination. For example, if the flap is no longer being positioned in a 90° configuration, the feedback signal from the proximity sensor is not being sent, and the system goes into fault mode, which entails substantial costs in terms of lost production output (Figure 2).

Figure 2. Swelling of the seal, with tear, in conjunction with imprecise closing of the butterfly valve.

With a seal design that incorporates two expansion grooves the expansion caused by a change in temperature can be purposefully confined to the seal's installation space in the housing, and the abrasion or damage in areas coming into contact with the product can thus be avoided (Figure 3).

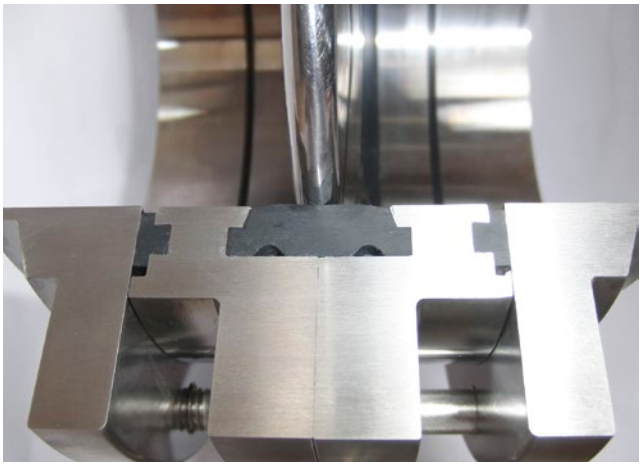

Figure 3. Cross-sectional view of a butterfly valve with optimum installation situation for the seal.

And in order to prevent wear phenomena due to valve flap movements, a smooth surface has been provided in the product compartment, thus relocating the dividing line to outside the product area. A lead-in chamfer on the seal

supports the switching mechanisms of the disc, so that all switching operations are performed with minimum stress on the material.

Extensive tests on the capability of the valve design to withstand pressure chock (or water hammer) also provide precise data on the production conditions under which the valves can be operated. Thus, in the event of unexpected water hammers (which cannot be entirely ruled out in any production operation), a clear statement can be made on the state of the seal. (Figure 4).

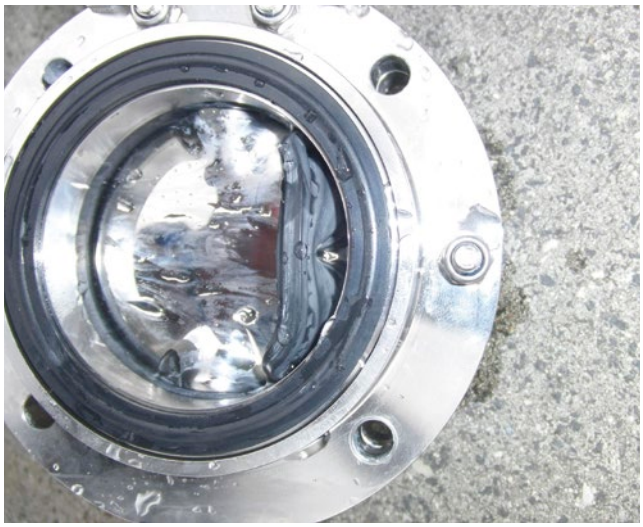

Figure 4. Seal torn out after a water hammer.

Weak point: Valve stem and seat seal

In the case of seat valves, it is not uncommon for traces of wear at the valve disc and the valve shaft to be responsible for entraining dirt into the product area and for leaks (Figure 5).

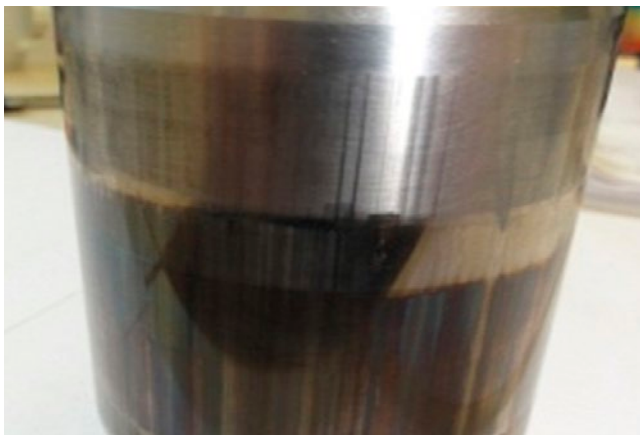

Figure 5. Traces of wear on the valve disc.

This is prevented by integrating a second shaft seal, which strips off any dirt, and avoids any damage to the valve shaft from wear traces. Leakage detection according EHEDG is warranted between housing and seat ring. (Figure 6)

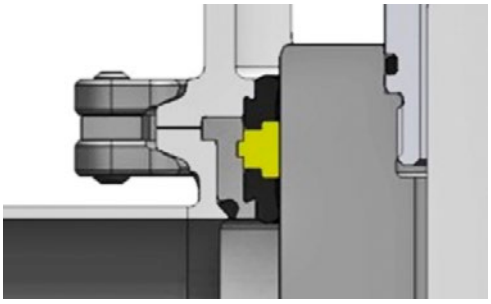

Figure 6. Sealing configuration at the valve plate.

In the event of damage to the valve disc, safe and contamination-free operation of the production line can only be restored by a time-consuming and expensive replacement of the valve plate.

The frequently observed phenomenon of the seat seal's tearing out at the opening and closing movements of the valve discs is manifested with one-piece valve discs, where installation of the seal is, in most cases, not easy, and in actual practice is also accompanied by a bit of "helping out" with the use of grease or washing up liquid.

The design of a two-part screwed-together valve disc with a defined installation space for the seal ensures significantly more precise installation conditions, and concomitantly, reliable positioning of the seal. This provides concomitant gains in terms of reliability against pull out and fluid behind the seal. Leakage detection according EHEDG is warranted between the parts of the valve disc. (Figure 7).

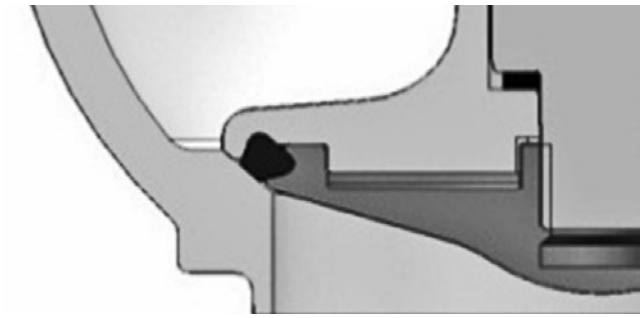

Figure 7. Sealing configuration at the seat.

Similar phenomena can be observed with mix proof valves. Damage to the radial seal and traces of wear at the valve disc can be prevented by providing a defined installation space for the seal, and by designing the seal with a support ring (Figure 8).

Figure 8. Traces of wear on the valve disc.

Moreover, since the seals are identical, there is no possibility that the product paths will be shut off incorrectly due to confusion between the axial and radial seals (Figure 9).

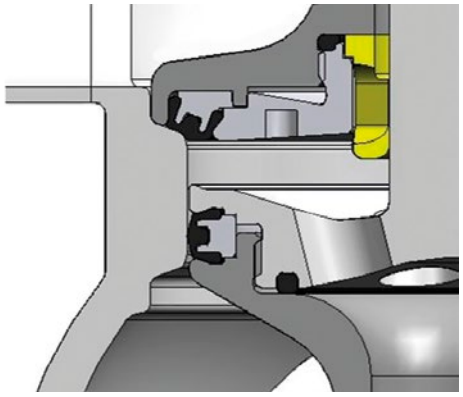

Figure 9. Identical seals for radial and axial sealing of the valve disc at a mix proof valve.

Compounds for high operating temperatures

It holds true for all valve designs that newly developed high-performance compounds have led to higher temperature resistance. Whereas 10 years ago temperatures of up to 160°C were customary for the steam involved, in systems designed today the temperature spectrum has to be extended up to 210°C, which means the seal has to possess significantly enhanced performance capabilities. By utilising the finite element method (FEM), the framework conditions were simulated by Krones during the design phase, and the stress limits and expansion reproduced under defined temperature conditions and with specified installation spaces. A comparison with a seal of conventional design revealed definite advantages for the newly chosen seal construction.

Aseptic – strong bellows essential

The requirements involved are even more stringent in aseptic operations. Dependable separation of the product from its surroundings has been the strategy pursued for many years now. Integrating the bellows elements as a seal at the valve disc can indeed create the desired separation; however, this introduces a not-inconsiderable source of possible malfunctions. Defective bellows and the concomitant possibility of rear infiltration may be responsible for contamination phenomena not amenable to easy detection, causing substantial losses of productivity in actual operation quite apart from a contamination of the product involved (Figure 10).

Figure 10. Damage to the bellows means that contamination is inevitable.

A study of the stresses acting on the stainless-steel bellows under a flow of p = 7 bar shows unequivocally (with different process parameters and stroke positions) what vibrations occur in the bellows construction. This quickly reveals why a bellows breaks after only a very brief period of operation. In the newly designed valve series, this is remedied by an integrated support body (Figure 11), which ensures that the bellows is properly guided and dampens the vibrations at the individual pleats. Moreover, this also avoids damage to the bellows due to overstressing at removal.

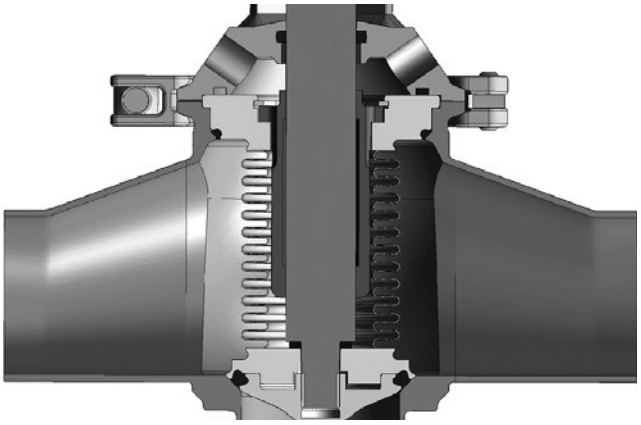

Figure 11. Support body for guiding the bellows.

The conditions for operators and maintenance staff

Besides replacing any worn seals, staff are also involved in maintenance work on the valves and the actuators. So maximised safety has to be assured. The foundations for this are in place: clients, and thus the valve manufacturers too, have to ensure that the design of their systems and components is such as to fundamentally rule out any risk of injury during operation, and conforms to the requirements of the EU's Machinery Directive (2006/42/EC) and the EU's Pressure Equipment Directive (97/23/EC).

With a welded version of the actuator (designed for one million switching cycles), the amount of maintenance work required is minimised, while the accident risk from opening up an actuator is eliminated as well. In this context, special attention has been paid to easy handling of the actuators, as evidenced by the weight of < 25 kg in the case of nominal diameters of up to ND 100. In addition, accident prevention in production mode is enhanced by covers for moving parts (valve yoke, feedback system) (Figure 12).

Figure 12. Personnel safety – protective feature at the valve yoke and feedback system

With a component inspection conducted by the TÜV Süd technical control board, comprising a pressure test, a safety test and a strength test, the new series of valves has been subjected to all tests designed to document operational safety down to the tiniest detail.

Besides safety considerations, of course, features designed to facilitate care and maintenance work have also been integrated, such as quick and easy seal replacement in the product compartment without needing any special tools, and (as already mentioned) eliminating any risk of confusion when replacing seals.

Summary

New methods for determining the performance capabilities of components, plus a rigorous scrutiny of damage occurrences, are indispensable as a basis for design enhancements. State-of-the-art components offer possible approaches for optimising the useful lifetime and for reducing cases of damage in actual production conditions.

This new designs also score in terms of financial aspects, since with lower compressed-air consumption, fast lifting time and free cross-sectional areas in the product flow energy costs can be meaningfully reduced.

Of the utmost importance are improvements in terms of hygienic design of valves. It is an excellent idea to confirm the cleanability of valves in the process through certification by the European Hygienic Engineering & Design Group.