Intelligent Rotary Control Valve

One Valve, Numerous Applications

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Abstract

During recent decades, rotary control valves have encroached upon the traditional territory of the linear globe valve in the petrochemical industry. Eccentric plug valves in particular have established a firm foothold in petrochemical applications. Ever increasing emphasis on environmental issues has meant that petrochemical companies are paying increased attention to emissions coming from control valves. This trend has made rotary valves more attractive because rotary valves typically have lower gland emissions than globe valves. In addition to low emissions, eccentric plug valves have proved to be suitable for numerous applications. Typical applications and opportunities, including their uses in the petrochemical industry, are considered.

Apart from versatility, the most important task of a control valve is to track the setpoint as closely as possible. In order to achieve loop performance, the control valve must perform well. This requires a high performance control valve. A novel method of studying control valve performance, based on a well-known step sequence test, is introduced.

A reliable, long-life valve solution requires careful valve selection and sizing. Factors ranging from valve sizing to maintenance are considered. Valve controllability in installed conditions is also studied. An innovative 'valve diamond', used to visualize control valve performance and evaluate valve problems, is introduced. The key component in maintaining loop performance is the smart positioner with diagnostic features. Diagnostic and device management can be handled in separate asset management software or even be integrated into the control system. An example of asset management software, based on open FDT/DTM technology, is presented.

Introduction

In the pulp and paper industry, rotary control valves are a must because a lot of applications include the control of fibrous flow media. Traditionally, only linear valves have been used as control valves in the petrochemical industry. However, rotary control valves are seen more and more often nowadays in petrochemical plants. Some major petrochemical companies have even made the decision that they prefer rotary control valves.

The high-performance intelligent valve positioner, sometimes defined as a valve controller, is an important device when a long-term control solution is required. Even though its role may sometimes be crucial, the performance of a control valve does not result solely from the smart positioner. The control valve itself must also be working well. Such problems as high friction, shaft windup and backlash have been associated with rotary control valves. However, with modern well-engineered, eccentric rotary plug valves, these issues can be minimized.

The eccentric plug valve has proven to be very suitable in many applications. The valve's ability to handle dirty service, its low emission control and its high temperature range are described.

Achieving loop performance starts with correct valve selection and sizing. Analyzing the installed flow characteristic is important in order to optimize control performance. Loop performance is maintained only if all the components in the control loop function correctly. In order to achieve performance throughout the valve life cycle, it is essential to predict when control valves should be serviced. A method based on predictive maintenance and using an intelligent valve positioner and advanced online diagnostics is discussed. Asset and device management based on FDT/DTM technology provides the means of using advanced device diagnostics and even of integrating them into the DCS system.

Intelligent Rotary Valve

Friction is one of the most common factors that may cause poor performance in a control valve. In linear valves, friction is affected mostly by the packing. In rotary valves, it is typically the sealing (or seat) that causes friction. In addition to friction, problems such as shaft wind-up and backlash are commonly associated with rotary control valves. However, backlash can be reduced by using well-engineered valve-to-actuator couplings, some of which, typically clamped designs, are even completely backlash-free. Seat friction can be eliminated in eccentric rotary plug valves because the plug detaches from the seat as soon as the plug is opened (see Fig.1). Dynamic flow forces, which can cause instability, especially at small valve openings, can also be minimized with a plug which balances flow forces.

Typically, control valves are operated by diaphragm actuators, which reduce the friction in the actuator and ensure smooth operation. Direct mounting between the actuator and the intelligent valve controller with internal pneumatic piping is preferred.

FIG. 1 INTELLIGENT ROTARY CONTROL VALVE, ECCENTRIC PLUG TYPE.

Last, but not least, an intelligent control valve should also have a high-performance, smart valve positioner. The intelligent, digital positioner is the heart of the intelligent control valve. It should be easy to use, have automatic tuning and calibration, and withstand adverse conditions like dirt, moisture and rough handling. The best of intelligent valve controllers can measure the valve's performance, store measured results in its memory, and warn the user if performance decreases. Advanced diagnostics can be utilized online without disturbing the process.

To study the performance of a control valve, the ISA open-loop step sequence test is widely used [1]. An example of such a step sequence test is shown in Fig 2. The same test method can be utilized to define for example, valve dead band or speed of response. In order to develop the method further and to find one quantity capable of characterizing variability in process variables and of controlling valve accuracy, a steady-state standard deviation relative to flow at initial travel, $Q_{2\sigma}$, is defined as follows:

$$Q_{2\sigma} = 2 \cdot Stdev(Q_N)/Q_0 \qquad (1)$$

where Stdev = standard deviation,

Q_N = steady state flow after each step back to initial signal level, N=1,2,3,4,…

Q_0 = flow at initial valve signal. (Initial signal level in Fig 2 is 50%).

Q_N is a set of steady state flow values measured after each step back to initial signal level. The steady state value is defined as an average value of a short time period just before next step is started (see definition points of the first three Q_N –values in Fig 2).The equation 1 is derived from a commonly used definition of variability (i.e. the variability is equal to 2 x standard deviation). Variability is frequently used measure of statistical dispersion. High performance control should give more accurate and consistent step responses, therefore it is expected that better control performance also gives lower $Q_{2\sigma}$ value.

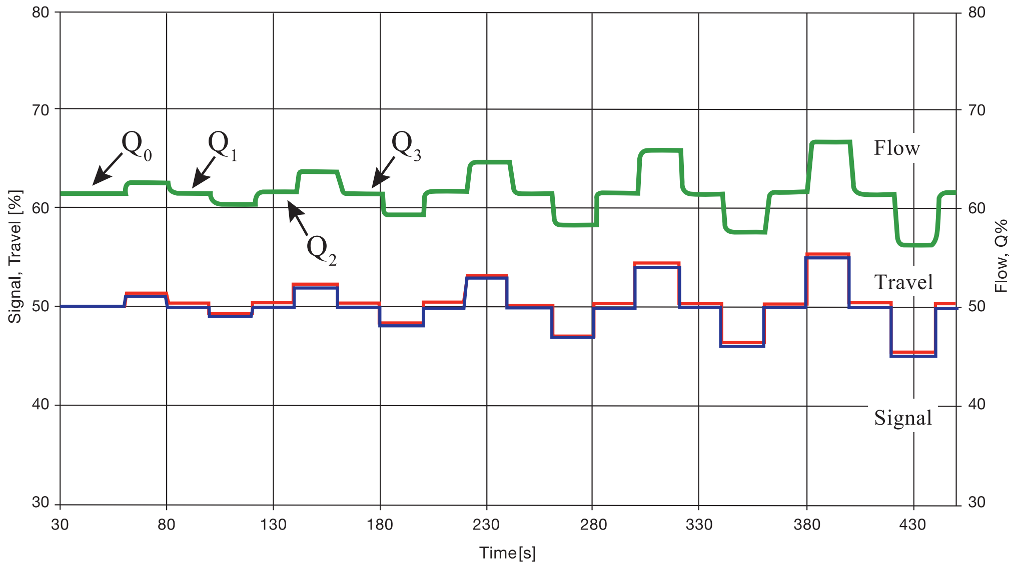

FIG. 2 STEP SEQUENCE TEST, 4" ROTARY CONTROL VALVE

Figure 3 shows an example of $Q_{2\sigma}$ values for 3 different valves. Each valve has different inherent characteristics. The test rig is comprised of a pump, a test valve, a load valve and a flow measurement device. Results show the influence of inherent characteristics on relative accuracy in the flow loop. Results indicate equal percentage (EQP) inherent flow characteristic excellence at low flow rates in this loop. As the flow rate increases, results suggest that a modified EQP characteristic valve (curve between equal percentage and linear) gives slightly better flow control accuracy than EQP.

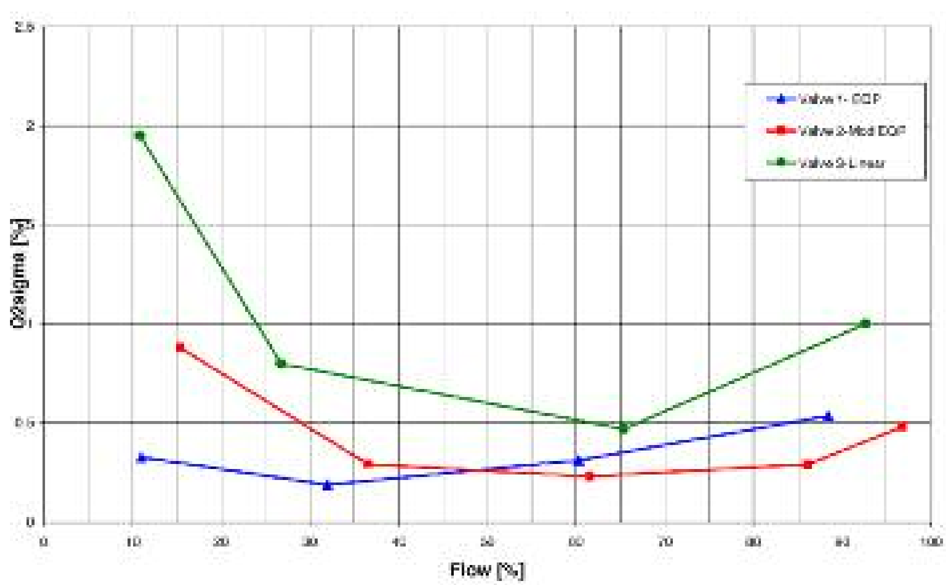

FIG. 3 RELATIVE STEADY-STATE DEVIATION IN PROCESS VARIABLES AS A FUNCTION OF FLOW RATE FOR THREE DIFFERENT CONTROL VALVES

Application Opportunities

Fluids containing impurities or dirt constitute very demanding applications for a control valve. These valves tend to 'stick' easily or become completely clogged if dirt is lodged in the valve trim, bearing or stem area. In such cases, linear valves have problems, because the rising stem tends to draw dirt into the gland packing area. This typically increases valve friction and leakage. On the other hand, rotary valves do not draw dirt into the gland or bearing area, which makes them more resistant to dirty fluids (see Fig 4). One example of such an application are the heater pass valves in a refinery [2]. Hot, dirty crude oil flows through these valves, which makes the situation very demanding for linear valves. Eccentric plug valves in particular have proved their excellence in dirty fluid service. Eccentric plug valves do not contain any cavities inside the valve where fluid can stick. Therefore, they can handle even fluids that are prone to crystallize or polymerise (see Fig 1). Process pipes may typically contain some debris, especially at startup. In such conditions, rotary valves have the unique design feature to flush away any debris when the valve is opened.

In petrochemical plants, the most critical environmental impact comes from emissions to atmosphere and to surface water. Now that petrochemical companies are promoting sustainable development, it is clear that low fugitive emissions through valve stem packing are an important factor [3]. Due to their rotary action, emission control is much easier with rotary valves than with linear valves. In laboratory tests, 10 to 100 times higher emissions have been produced using standard linear valves than with standard rotary valves [4]. It is very likely that under actual process conditions the differences are even greater, because the rising stem tends to 'pump' impurities into the gland packing area, and therefore increase the leakage.

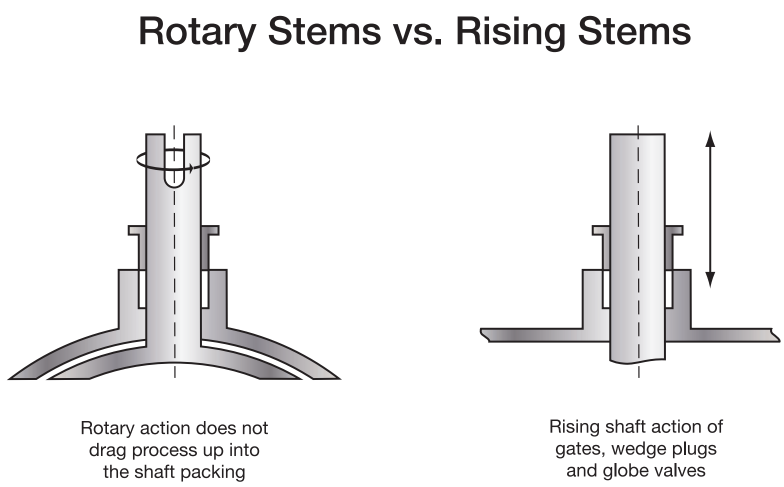

FIG 4. ROTARY STEM vs. RISING STEM.

Rotary valve manufacturers have developed live-loaded packing designs, which are almost equal to linear valves with a bellows gland. These packings have even been utilized for hazardous flow media. Live-loaded packings used in a rotary control valve are very simple designs, which require only minimal maintenance. Hence, rotary valves are an easy solution to improving overall plant emission control. On-site studies have shown that significant reductions can be achieved if rising stem valves are changed to rotary valves [5].

In general, eccentric plug valves have proven to be suitable for a very wide range of applications (for instance steam, condensate, oil, hydrocarbon, etc). Their streamlined design, whereby fluid flows around the plug, means that they can handle flashing as well as erosive services. Temperature and pressure ranges are not as wide as those in linear valves, but still wide enough to handle most of the applications found in a petrochemical plant. Temperatures from 200 to over 400°C can be accommodated. Typically, pressure classes up to ANSI 600 are available. The best of eccentric plug valves can also be equipped with anti-cavitation and noise reduction trims in order to widen their application range into high-pressure-drop ratio services. However, such valves may not be suitable for very high pressure applications (>100 bar)

Reaching Loop Performance

As can be seen in Fig 5, the control valve is only one parameter affecting loop performance. Closed control loop performance is the sum of various factors, which must be taken into account to get performance out of a control loop. However, of all the components in a control loop, the valve does the hardest work and is therefore prone to cause problems. In order to work properly, the valve must be selected and sized carefully and it should be serviced regularly. This ensures a long-lasting high-performance control solution.

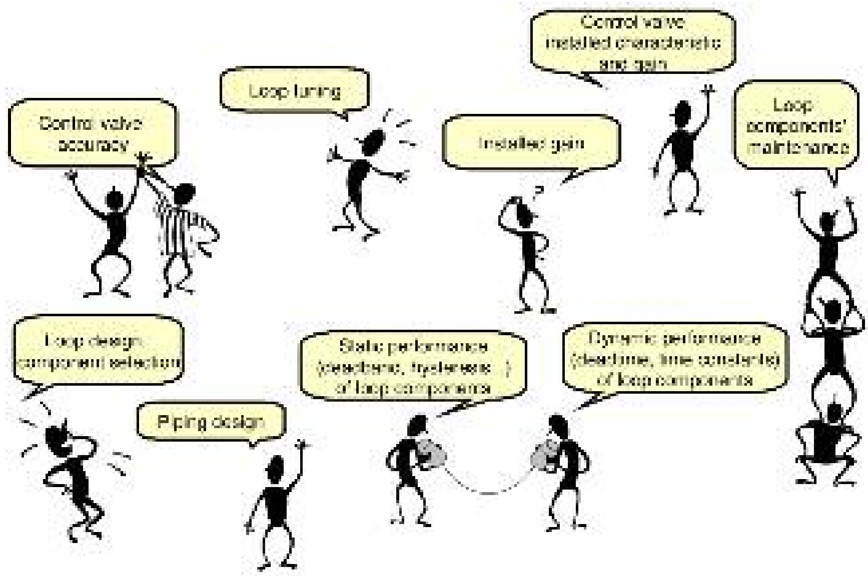

FIG 5. FACTORS AFFECTING LOOP PERFORMANCE [6]

Valve sizing and selection

The basis of control loop performance is correct control valve selection and sizing. Even an advanced control method with the most accurate transmitter cannot compensate for problems caused by poor valve selection. To optimize valve selection, the size that should be chosen should have a valve opening under normal process conditions within the range from 60 to 80%. Also important is to aim for an installed flow characteristic that is as linear as possible within the control range. Linearity of the installed flow curve can be characterized by the installed gain (i.e. the slope of the installed curve).

Installed gain can be used to estimate relative flow error with the following equation [7]

$$\Delta Q = G \cdot \Delta h \qquad (1)$$

where ΔQ = relative flow error,

G = installed gain and

Δh = relative valve travel error (e.g. valve dead band).

A common problem is an oversized valve. This means that the valve operates with openings that are too low, within a very narrow opening range and with high installed gain. As can be seen from equation 1, high installed gain means that even small changes in the control signal, and respectively in valve travel, effect relatively large changes in flow. To control such a loop accurately is very difficult. Despite the wide use of valve sizing and selection software being widely used, in many cases the installed curves has not been analyzed. Sometimes the installed curve is difficult to model, because process conditions are undefined. Typical pressure behavior in a loop consisting of a pump, pipes and a control valve, is illustrated in Fig 6. If more than one process condition is known, then the installed curve can be modeled by fitting pressure curves based on conditions. However, if only one process condition is known, then the pressure drop ratio factor, DPm, can be used to model the installed characteristic. The DPm factor describes the valve pressure loss as a proportion of the total dynamic pressure loss of the system with maximum process flow. The actual value of DPm varies and depends for example, on the length of process pipes. As rule of thumb, 0.3 can be used for liquid flow and 0.5 for gas flow. An optimal inherent characteristic depends on process conditions, but for most liquid and gas flows, an equal percentage or modified equal percentage curve gives a reasonable linear installed characteristic. On the contrary, a linear inherent characteristic usually provides a quick-opening installed curve with high installed gain.

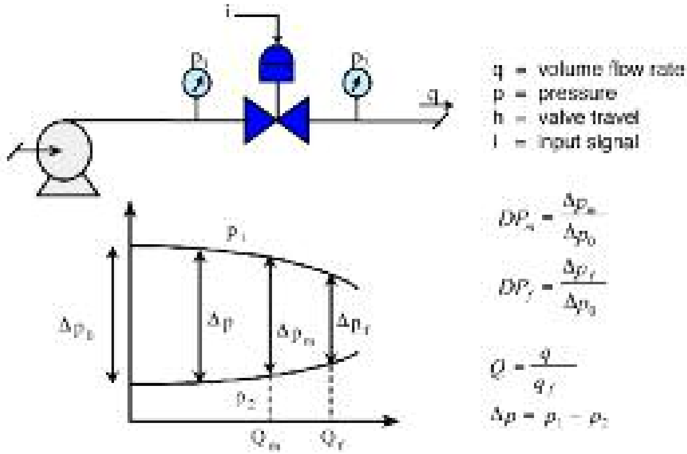

FIG 6. PRESSURE DIFFERENTIAL CHANGE ACROSS THE VALVE, DUE TO CHANGE IN THE FLOW RATE [7].

Maintaining valve performance in the control loop

It is crucial to service valves at regular intervals in order to keep the process sufficiently efficient and to maintain loop performance throughout the whole life cycle. Servicing valves before it is actually required could work, but it would be a rather expensive and time consuming way of doing maintenance. Waiting until valves fail and cause a possible unscheduled shutdown can also be very costly. Ideally, only those valves that really require maintenance should be serviced during a shutdown. To accomplish this, valve diagnostics and/or a monitoring program would have to be utilized.

During a shutdown, it is possible to monitor and analyze valves to check whether they need servicing or not by using for example, a valve signature test. However, this so called offline diagnostic can be very time consuming. Instead of this, it should be possible to analyze valve data just before shutdown, while the process is still in operation. In this way, those valves requiring maintenance can be pinpointed beforehand. This requires devices with online diagnostic capabilities. Online diagnostics make it possible to monitor valve performance while the process is running, not only during shutdowns (see Fig 7). The aim of predictive maintenance is to indicate decreasing valve performance and to warn the user before failure is so bad that it causes excessive process variability or even an unexpected shutdown. Online diagnostics can continuously monitor valve performance, but analyzing the results can be very time consuming and labor intensive. The most efficient way to carry out predictive maintenance and online diagnostics is to utilize valve controllers, which are capable of storing results in their memory and send warnings and alarms based on performance limits stored in their memory. In this way, no additional manpower is needed to analyze and study the results continuously, because the intelligent valve controller, with the help of advanced asset management software, can measure valve performance automatically.

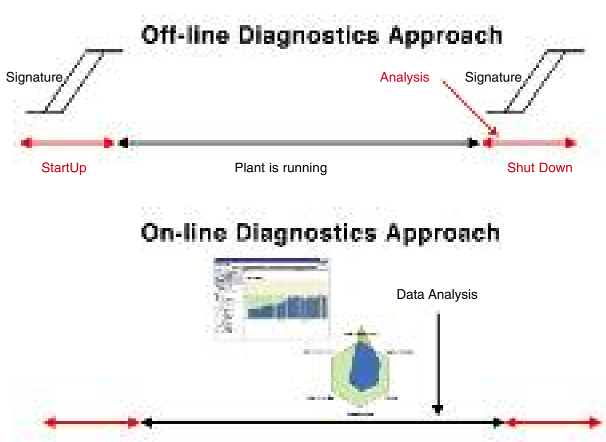

FIG 7. DIFFERENT DIAGNOSTICS APPROACH.

As discussed already, the crucial device in carrying out advanced predictive maintenance is the modern intelligent valve positioner. To get the most out of such a controller, it should include advanced device diagnostics, including online and offline diagnostics. The advanced diagnostics of the intelligent valve controller can be utilized with the help of asset management software. An example of such software, which is based on open FDT/DTM technology, is shown in figure 8.

A field device tool, FDT, is an open industry software specification for field device data management. It provides a plug-and-play integration of DTMs (Device Tool Managers) for various vendors' devices in a single tool. DTMs are devicespecific and vendorspecific software applications that provide the user interface for the configuration, calibration and diagnostics of devices. Open FDT/DTM technology provides easy utilization of advanced diagnostic features, even for complicated devices such as valves. It also provides the means to integrate these features into DCS systems.

FIG 8. AN EXAMPLE OF ASSET MANAGEMENT AND CONDITIONING MONITORING SOFTWARE.

Valve performance measurement results saved in the positioner's memory can be presented in various ways in asset management software. Results are normally shown as counters, trends or histograms. Histograms show how measured data is spread during a valve's lifetime. Histograms can be used, for instance, to detect oversized valves (Fig 9). Trends show the history of measured parameters. Trends such as valve pressure load, dynamic and static deviation, supply pressure, etc. can be collected.

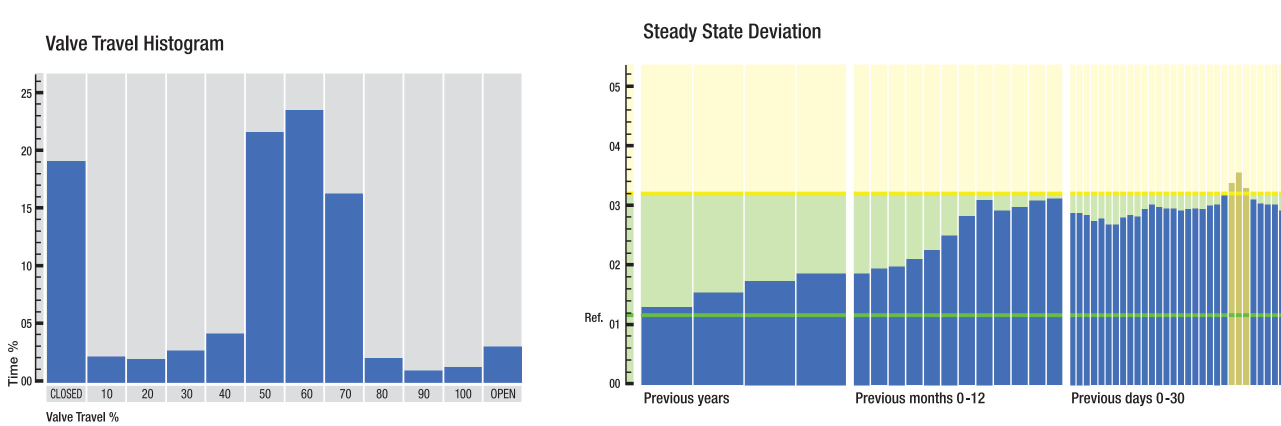

FIG 9. VALVE TRAVEL HISTOGRAM
(LEFT) AND STEADY STATE DEVIATION TREND **(RIGHT)** COLLECTED BY INTELLIGENT POSITIONER.

In order to visualize valve problem areas more clearly and to show all of the important parameters in one display, an innovative valve diamond has been introduced. The valve diamond is a visual summary of statistical diagnostic measurements, which shows at a glance the problem areas in valve performance (Fig 10). Corner points of the diamond represent the warning limit of each measured trend value. The asymmetric diamond, which is mostly inside a bigger diamond, shows the actual measured values of trends. In figure 10, the steady-state deviation has exceeded the warning limit.

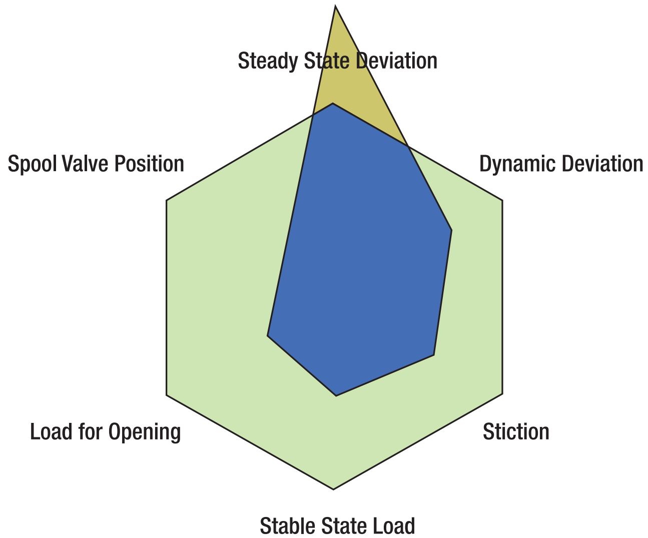

FIG 10. VALVE DIAMOND.

A real life example of how alarm limits and predictive maintenance are utilized is the case of a white water flow valve in a paper mill. A very small variation in steadystate travel deviation was seen in a white water flow valve. A travel deviation of 0.8 % is normally not significant, but in this case it had a very large effect on the basis weight of the paper. The flow was 13,000 litres per minute. This problem was traced to the presence of instrumentair impurities in the pneumatic block on the valve controller. After cleaning the pneumatic block, travel deviation was reduced to 0.3 % and the basis weight variation was correspondingly reduced. Now the travel deviation alarm for this valve is set at 0.3 %. This case clearly shows the effect of valve performance on paper uniformity and how predictive valve diagnostics and maintenance can have a positive impact on paper quality [8].

Summary

Rotary control valves have encroached upon traditional linear globe valve areas in the petrochemical industry during recent decades. Eccentric plug valves in particular have proved to be suitable for numerous applications in the petrochemical industry. Rotary valves provide excellent emission control, which gives an easy solution to the reduction of overall plant emissions. High seat friction, shaft windup and backlash associated with rotary control valve problems, can be minimized with the eccentric plug valve by using a clamped valve-to-actuator coupling. Simply due to their rotary action, eccentric plug valves can handle even very demanding dirty fluids without the risk of clogging or poor control performance.

An intelligent, high-performance valve positioner capable of measuring performance and storing results into its memory is a crucial device in ensuring long-life control-valve performance. Advanced online diagnostic features can be utilized to optimize control valve performance during the whole life cycle. Alarm limits stored in an intelligent positioner's memory provide an efficient way of carrying out predictive maintenance. A real life example of how process variability was improved with a help of advanced diagnostic and asset management software, is presented. Asset and device management, based an open FDT/DTM technology, is discussed. FDT/DTM technology provides the possibility of using advanced diagnostic features for such complicated devices as control valves. An innovative control valve diamond capable of showing valve problem areas at a glance is introduced.

The importance of correct control-valve sizing and selection from the very beginning, and the utilization of installed flow characteristic and gain, are pointed out. A method of modeling the installed characteristic, even when only one process condition is known, is described.

References

1. ANSI/ISA7525.012000 "Test Procedure for Control Valve Response Measurement from Step Inputs".
2. Jeffries, J. ,Automation 2 / 2005, Metso Automation.
3. Sears, D, "Taking Control at Nanhai", Valve World, April, 2005, KCI Publishing, p 5457.
4. Jeffries, A., EdwinScott, D., "Development of a Versatile Packing for Fugitive Emission Control, in Rising Stem and Rotary Valve", VDI 1441 2nd European Fugitive Emission Conference Proceedings, 1998, p. 315328
5. Reeves, D., Ross, J.,Wasielewski, M., "Assessing Fugitive Emission Performance in Valves and Packing", Valve World 2004 Proceedings, KCI Publishing BV, p 208228.
6. Kirmanen, J., "Control ValveDiamond in the Control Loop", Valve World 2004 Proceedings, KCI Publishing BV, p 344352,
7. Pyotsia, J. et all, " Control valve Installed Performance", Flow Control Manual, 4rd edition, Metso Automation, 2005
8. Niemela, I., Lagace, JG, Williams, M., "Valves, Transmitters verified by Desktop Diagnostic System", Praxis Profiline – The best FDT Applications, April 2005, Vogel Industrie Medien GmbH & Co, p 20 – 22.

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