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Linear Sliding Stem Control Valve Hunting Analysis and Extrapolation of Valve Monitoring Features

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Abstract— Control Valve is one of the major final control elements used in industries and plays a vital role in enhancing the productivity of a plant. Optimization of control valve depends on the effective preventive maintenance schedule. Control valves may be overhauled from the pipeline when there is a suspicion of fault. Almost 80% of the control valve maintenance relates to the diagnosis of valve in service to detect any abnormality. When a fault is identified the preventive maintenance process shifts to the breakdown maintenance process. During this process the control valve components are tested to determine the cause of the problem and to establish a corrective course of action. With the developments in microprocessor based control valve instruments along with their diagnostics capabilities has allowed engineers to simplify the maintenance activities. These digital devices can identify problems related with instrument air quality, leakage, supply pressure restriction, excessive friction, dead band, and calibration shift. Troubleshooting control valves after installing in the field is a tedious process as it is difficult to discriminate whether the problem is in the control valve or in the controller tuning. This article presents a novel method using sensors to identify the problems related with the control valve hunting, to pinpoint the source of error and present the performance results to end user. The objective of this research is to reduce manual intervention in troubleshooting of control valves and to enhance the predictive maintenance resulting in cost effective production.

Index Terms— control valve, diagnosis, hunting, maintenance, positioner, stiction, troubleshooting.

I. INTRODUCTION

Control valve hunting is a condition when the valve closes and opens at an uncontrolled rate. It denotes that the control valve is unable to find the correct position in order to maintain the set process conditions. In a closed loop this causes the process variable to move around its set point. This phenomenon of hunting is caused by various reasons. The problem can be with the controller or due to defects in certain parts of a control valve or even due to process conditions.

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Continuous hunting of valve will lead to damage in gland packing and large deviations from the required set point. To properly address and improve control loop performance, it is necessary to establish what the real cause of the poor performance is, and then to take appropriate corrective action.

Oscillations can originate from within the control loop or be caused by external factors. This article discusses about the various causes of hunting and how to diagnose it. Also a novel method is proposed to pinpoint the cause of hunting in an industrial scenario and convey this information to the engineer.

II. LOOP PROBLEMS

The traditional method to find out whether the problem is within the loop the controller mode is changed from auto to manual and the response is verified. If the oscillation stops then the problem rests with the loop. These types of problems are usually encountered in non linear process. Another cause for hunting may be due to hysteresis effect. This causes the process loop to behave in a sluggish manner. This is a mechanical problem which cannot be solved by controller tuning. Proper tuning of controller is the solution to control valve hunting due to loop problems. If it is not hunting in manual then the reason could be due to other factors like actual variations in process variable, valve sizing etc which are discussed in the forthcoming chapters.

III. VALVE SIZING

Control valve sizing is a critical factor in deciding the controllability of the valve. Sizing is determined by the flow coefficient denoted as Cv which is the number of US gallons per minute of 60^0F water that will flow through a fully open valve with a pressure drop of 1 psi. The Cv is determined by the construction of the valve and will remain constant. Control valves of the same size may have different Cv if the valve body style or valve trim is different. Control valve sizing problems exist when the overall process gain is very less or very high. Control valves are often sized to accommodate additional flow rate in future. This leads to buying a valve which is slightly oversized for the application which can lead to imprecise control. An oversized valve will cause hunting, packing damage and imprecise control due to excessive opening and closing. Under sizing a valve will require large pressure drop across the valve to maintain the appropriate flow and may not provide the required capacity.

This results in additional load to the pump and also leads to cavitations. Cavitation and Flashing are the two major problems which leads to damage in control valve trim which thereby produces fluctuations in process control.

IV. POSITIONER

All Valve positioner is an instrument used to increase or decrease the air pressure to the actuator of the control valve until it reaches a balanced position desired for controlling the process variable. It consists of a spool valve to regulate the air flow which eventually wears with continuous operation or due to dust particles in the air. As a result of this the spool valve will get stuck at a particular point which can cause the air pressure to build. This build up of air pressure will release the spool piece from its position which leads to overshoot. Hence the position of the valve becomes unpredictable and control over the valve is lost which leads to hunting.

Another cause of control valve hunting due to positioner is the exposure of the positioner to high temperature due to radiation from nearby process tanks. This will lead to damage in positioner seals and tubing's. A positioner uses a feedback link to assess the actual position of the valve and allows the positioner to change its output. If the feedback link is disconnected or damaged the valve may not operate at the desired position due to fluid forces, friction etc. Modern smart positioners have special features to detect these anomalies.

V. STICTION

Static Friction also called stiction is the condition in which a valve stops moving at a particular position requiring additional forces to overcome it. This may be caused by hardened gland packing or viscous flow in trim. After this additional forces is enough to move it away from the stiction point the valve moves to an overshoot position. This overshoot causes the process variable to overshoot its set point. Stiction is can be observed by monitoring the relationship between the controller output and process variable. In order to avoid stiction the valve actuator must be properly sized and the torque acting on the gland pacing should be within the specified range.

VI. HARDWARE DEFECTS

Valve hunting may also be caused due to internal wear in trims. This prevents the valve from being completely shut off. A damaged trim will also cause the control valve to lose its controllability at higher operating ranges. Gland packing in a control valve is used to ensure that the process medium is contained within the valve body. If it gets damaged there will leakage through the bonnet which is hazardous to the working environment. Another factor contributing to valve hunting is leakage in actuator of the valve. The positioner initially sets the position of the stem, but due to leakage the stem is allowed to move continuously which make the positioner to re adjust its output resulting in an endless hunting of stem position. This is one of the most common reasons for control valves hunting with steady state control signals.

VII. DIAGNOSIS

Valve diagnostics refers to troubleshooting the problems leading to abnormal behavior of the control valve. Diagnosis is made by referring various parameters like stem travel, histograms, air pressure, input set point, valve position, actuator input pressure etc. A force balance test is done to determine whether the process pressure and spring tension are properly balanced. A stiction diagnosis is done to determine the static friction in a valve. An air circuit diagnosis is done to detect water accumulation in the positioner using a specific algorithm. Excessive usage of air can be due to mechanical damage inside positioner, air tubing or air regulators. Deviation in stem travel is caused by low volume of air supply and improper calibration. Table 1 shows some of the common symptoms and causes in a control valve.

Table 1. Symptoms and Cause in Control Valve

Sl.No	Symptoms	Possible causes
1.	Stem not moving from initial position	(i) Air leakage (ii) Supply pressure low (iii) Cam position reversed (iv) Air tubing reversed
2.	Calibration issues in Positioner	(i) Feedback alignment (ii) Internal air leak (iii) Positioner in bypass (iv) Blocked air vent (v) Damaged cam
3.	Control valve hunting	(i) Fluctuating supply pressure (ii) Damage in positioner spool valve (iii) High gain in positioner (iv) Flow direction is reversed (v) Valve trim damaged (vi) Valve sizing too large or too low (vii) Feedback link to positioner is loose
4.	Sluggish response	(i) Actuator supply too low (ii) Friction in gland packing (iii) Damaged actuator diaphragm or seals (iv) Leakage in air path
5.	Fluctuating supply pressure	(i) Malfunction of air pressure regulator (ii) Controller problem

VIII. BACKGROUNG REVIEW

For stiction modeling there are a number of methods like curve fitting method, cross correlation method, relay fitting method, Hilbert method etc. Oscillations or hunting can be caused due to loop problems or external factors. To identify the problem, place the controller in manual mode and observe if the hunting stops.

If it stops then the problem lies within the loop and can be resolved by proper tuning. Oscillations generated internally can be caused by faulty equipment or by tuning. If the valve is still hunting in manual mode then problem can be due to damage components in the valve or process parameter fluctuations. The common reasons for control valve hunting are stiction and positioner overshoot. The output response of a valve with stiction is shown in figure1.

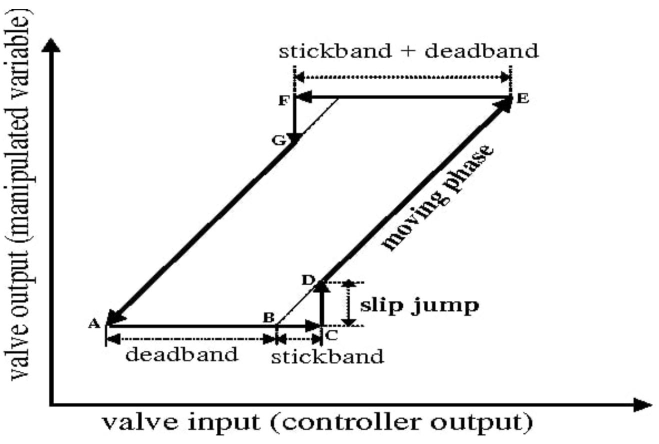

Figure 1. Stem movement vs Valve input showing stiction in a control valve

Karthiga D and Kalaivani S [1] proposed a compensation method by introducing an additional pulse signal to the controller to compensate for the stiction in control valves. The pulse was generated by taking into consideration the weak stiction and strong stiction differences. M.A Cuadros [2] proposed a four movement compensation method by applying it in an open loop to maintain the valve at a steady position and further modifying it to provide two movements to smoothen the valve movement. This method has the advantage that no knowledge about the plant is required. On the flip side it is still prone to sudden disturbances and requires the same process dynamic. Puneet Mishra [3] and Pardeep Rohilla [4]proposed a nonlinear PI Controller (NPIC) for efficient control of a flow process having a sticky control valve. The effectiveness of the proposed technique was evaluated by comparing its performance with a classical PI controller in closed loop. NPIC demonstrated superior performance as compared to PI controller. Shoukat Choudary [5] presented a simple method to detect stiction by varying the controller gain online without putting the loop in manual mode. This method also identifies the external disturbances created from other loops. The above mentioned approaches has some disadvantages, like in knocker method the valve movement is too fast and additional input is required to compensate the stiction. Also some of the approaches requires good knowledge about the process. Zabiri [6] implemented a hybrid control method by combining a PID controller with a fuzzy integral controller to overcome the above disadvantages. The compensating signal generated is when the controller output is not constant. It does not take into consideration whether the problem is with the controller. If that is the case the compensating signal generated may be erratic. Also in hybrid controller based compensation there is no proper way to segregate the problem. The proposed method in this article helps to identify the root cause of hunting and then take a suitable action to eliminate it.

IX. HUNTING ANALYSIS AND DIAGNOSIS

To determine whether the control valve is hunting due to controller tuning or mechanical problems in control valve it is proposed to output a constant pressure to the control valve actuator by bypassing the output from the controller for a very brief time and check the output response. The movement of the valve stem is measured using a linear potentiometer and the output pressure to the positioner is measured using a pressure sensor. The valve stem travel versus the controller output is generated by connecting the sensors to a data acquisition card and plotting it using labview. The input from the pressure sensor and set point to the controller is taken as input to the microcontroller. The deviation of the pressure with respect to its equivalent set point is noted. If this continues for more than five times then that condition is considered as hunting. In that case the output from the controller is isolated and the pressure corresponding to the set point is automatically generated using a current to pressure converter and given as input to the control valve positioner. After a delay of a few seconds the deviation is again monitored. If the deviation is reduced then it is safe to assume that there is no problem with the control valve and its accessories. Hence the controller needs to be specifically tuned for the loop.

However if the valve is still hunting then the problem may be due to trim damage or stiction due to gland packing. With the help of the graph obtained it is easy to identify the stiction region where there is dead band. In case of continuous hunting a noticeable dead band does not exist. Hence the possibility of hunting is predominantly due to trim damage. This method also allows checking whether the hunting is present only in frequently operated region or in all control ranges. However this is not covered in this article. In addition to this it is further proposed to extend the research by adding sensors to detect the normal operation of spool valve inside the positioner and integrating with in IoT platform to create an IoT enabled smart positioner for control valves.

X. RESULTS AND CONCLUSIONS

The proposed work has been implemented in a half inch globe valve as shown in figure 4 with equal percentage characteristics. The process parameter controlled using the valve is water at a pressure of 3 kg/cm2. The positioner used is a pneumatic positioner. The valve movement is obtained from a linear potentiometer as shown in figure 5 in 0 - 5 Volts corresponding to 0 - 100% valve travel. The output from the controller is obtained using a pressure sensor in the range of 0.5 to 5 Volts.

The graph for valve movement versus output pressure was plotted using National Instruments myDAQ and Labview as shown in figure 2 for visualizing the valve characteristics. Table 1 shows the operating range of the control valve and its process output.

Table 1.Valve Travel in % versus the water pressure in kg/cm^2

1.	Valve Travel (%)	0	25	50	75	100
2.	Pressure (kg/cm^2)	0	0.8	2.1	2.8	2.9

The valve operates almost true to its nature and follows equal percentage characteristics. We have set the value of water pressure to 0.7 kg/cm^2 in the controller, which is obtained at vale travel of 23%. Once the set point is provided to the controller in auto mode the controller takes corresponding action to reduce the water pressure. This response is viewed from the graph plotted against time and valve travel as shown in figure 3. It is clear that the valve tries to maintain the position at around 20% to 25% to maintain the required pressure for a long period of time. But the controller is not able to maintain the output pressure at 0.7 kg/cm^2 and the position of the control valve hunts around 10% to 30% as shown in figure 3. The program is written to identify the deviation between set point and the actual pressure. If this deviation continues for a delayed time period the equivalent pneumatic signal required to maintain the control valve at 23% is provided after isolating the actual signal from the controller by actuating a solenoid valve. The program then monitors the deviation between set value and actual pressure value for another delayed time period. If the deviation is still present then it is diagnosed that the problem does not rest with the controller or its tuning. The problem of control valve hunting is due to damage in valve trim.

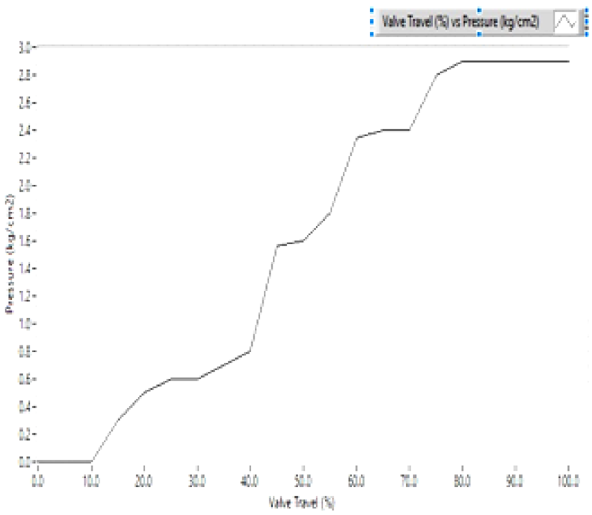

Fig 2. Valve Travel (%) vs Pressure (kg/cm^2)

To perform the diagnosis we used an arduino microcontroller with the following inputs and outputs: (i) valve travel position, (ii) pressure signal, (iii) set point and (iv) solenoid valves 1 &2. The single loop programmable controller output was converted into pneumatic signal using a current to pressure converter. The controller valve used has a slight damage in the plug. The hunting was observed in the range of 15 to 25% of valve travel. Significant amount of stiction was also observed in the range of 0 to 10 % as shown in figure 2 where the output pressure is changed only after the air pressure equivalent to operate the valve at 10% is reached. It was clear that stiction exists only during the initial phase of valve travel but the hunting occurs in the frequently operated range of 25%. This method has clearly shown to segregate hunting due to stiction and trim damage. The program has been written to display the cause of hunting to the user after putting the loop in manual and observing the response. This reduces the need for manual intervention of the engineers to put the controller mode in manual and observe it. We further plan to improve its accuracy by adding sensors to identify the possibility of hunting due to other factors. Since the loop has been put into manual without the intervention of humans and most importantly only for a few seconds it does not affect the process conditions without any risks.

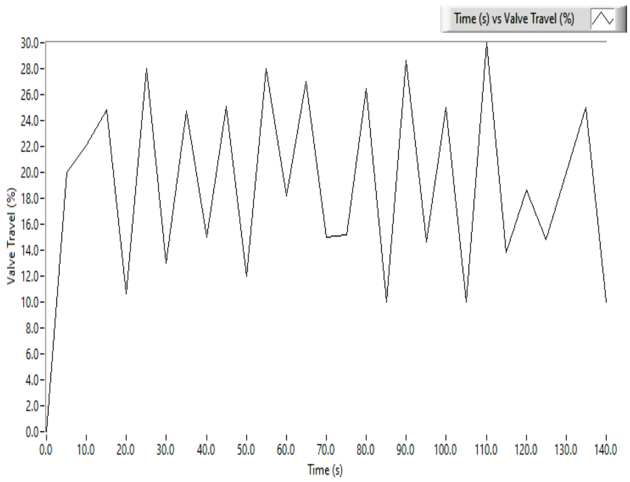

Fig 3. Time (s) vs Valve Travel

Fig 4. Control valve with pneumatic positioner

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Fig 5. Linear potentiometer for measuring stem travel

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