DESCRIBING FUNCTION BASED CONTROLLER FOR STICTION MINIMIZATION

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Abstract

In industry almost all the control valves are nonlinear. There are lot of nonlinearities such as stiction, deadzone, backlash, hysteresis etc. If a pressure is applied to the control valve, there will be an oscillation in the movement of control valve stem which is unsatisfactory in process control. This is termed as static friction or stiction, present in control valve cause oscillations which will cause loose of quality and expense of raw materials. Stiction can be diagnosed and eliminated by proper valve maintainances. It can done only during plant shut down which will take place only in 3 to 6 months. This project aims at compensating stiction while the plant is running. . Early used methods for compensations are dithering and impulsive control for electromechanical systems. Applications of dithering and impulsive control in pneumatic control valve do not produce good results, like filter all the high frequency signals. The other proposed method was based on input-output linearization called knocker. This method will reduce the variability of process variable with increasing the stem position. Describing function method mainly focuses on give retuning signals to the valve to attain the steady state position.

Keywords: *stiction, deadzone, backlash, hysteresis, knocker.*

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1. INTRODUCTION

There exist hundreds or thousands of control loops in a typical modern chemical plant. These control loops are designed to maintain the processes at desired operating conditions. Performance of control loops directly affects the quality of the plant operations. Observing oscillations in the signals of a control system is typically considered as a result of unsatisfactory performance. The oscillations may have different root causes. Aggressive controller tuning, external disturbances and existence of nonlinearity in the system are some known sources of oscillations. This work focuses on nonlinearities in the control loops, more specifically static friction (stiction) in control valves. As one of the important parts of a control loop, the control valve is often a source of nonlinear behavior. Reports show that 20–30% of all oscillations occurring due to nonlinear sources are closely associated with various non linearities in control valves.

2. SYSTEM DESCRIPTION

2.1 Control Valve

One of the basic components of any control system is the final control element which comes in a variety of forms depending on the specific control application. The most common type of final control element in chemical processing is the pneumatic control valve, which regulates the flow of fluids.

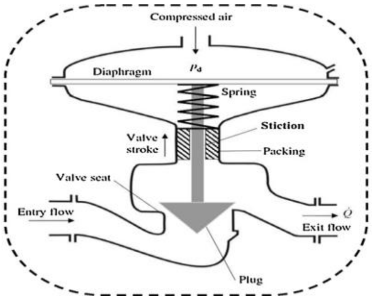


Fig-1: Process diagram

Some other types include the variable speed pump and the power controller (used in electrical heating). The control valve is essentially a variable resistance to the flow of a fluid, in which the resistance and flow can be changed by using a signal from the process controller.

2.2 Block Diagram

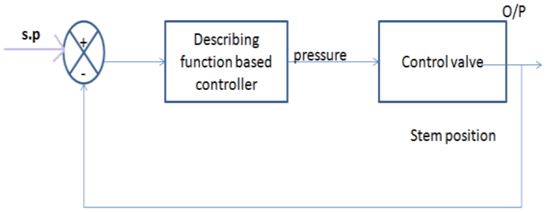


Fig- 2: Block diagram

The controller using here is PID controller, which is describing function based PID controller and the process is control valve. If stiction is present in the valve then we won't get desired output that is stem position, which is converted into voltage by using sliding m mode potentiometer that voltage is compared with set point value and reduced the error by describing function method.

3. MATHEMATICAL MODELLING

Modelling steps is based on Newton's second law. Newton's 2^{nd} law is given by

$$m\ddot{x} = \sum Forces$$

$$m\ddot{x} = F_{pressure} - F_{spring} - F_{friction}$$

Where,
m= mass of moving part
x =stem position
$P_{ressure}$ = pressure exerted
S_a=diaphragm area
P= applied pressure
S_{pring}=force applied on spring = $K_m x$
Where,
K_m=spring constant
$F_{riction}$=frictional force

$$\frac{x(s)}{P(s)} = \frac{0.060}{0.124s+1}$$

4. CONTROLLER IMPLEMENTATION

4.1 PID Controller

A proportional-integral-derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. Adjusting the process control input the controller attempts to minimize the error. The PID controller calculation algorithm involves three separate constant parameter the proportional,the integral and derivative values denoted P, I, and D. P depends on the present error, I on the past errors, and D is a prediction of future errors..[1] The sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied process. PID controller has been considered to be the best controller. By tuning the parameters the PID controller can provide control action designed for specific process requirements. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability.

4.2 Describing Function Method

Final control element used in industries is control valve. One third of poorly performing control loops are caused by nonlinearities present in the control valves, one of which is static friction, due to the effect of nonlinearities oscillations will be present in the process variables. Since industrial plants include numerous interacting loops, the oscillations will be transmitting to the entire system. Repairing the faulty valves will be the only solution to this problem, which is possible only during process shut down. But, as shutting down the process to isolate the faulty valve for maintenance purposes is not economical, this solution does not count as the primary one. So, there is a need for a method to compensate the destructive effect of the stiction phenomenon in the control valve, when maintenance is not available.

Describing function provides a linear approximation to the non linear elements, based on the assumption that input to the non linear element is sinusoid of known constant amplitude. The signals are given depending upon the controller output.

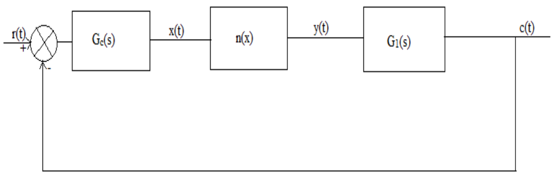


Fig-3: Block diagram of non-linearity

It is an appropriate procedure for analyzing certain non linear control problems. It is a mathematical tool for analyzing limit cycle in the closed loop controllers, this method predicts weather limit cycle oscillation will exist or not and gives numerical estimates of oscillation frequency and amplitude when limit cycle are predicted. Basically this method is an approximation extension of frequency response method to non linear system. Gc(s) and G1(s) are linear elements and n(x) is non linear element. Describing function provides a linear approximation to the non linear elements, based on the assumption that input to the non linear element is sinusoid of known constant amplitude. To find steady state value and amplitude the fundamental harmonic is compared with phase relation. This relation is used for the describing function for the nonlinear element.

5. CONTROLLER DESIGN

5.1 PID Controller Design

From the Zeigler Nichols open loop tuning

28.3% of the steady state value = t_1 = 0.283k = 1.05sec

63.2% of the steady state value = t_2 = 0.63k = 1.08sec

Time constant (τ) = ($t_2 – t_1$)× 1.5

τ = 0.045

Time delay (t_d)= $t_2 – τ$ = 1.08-0.045=1.035sec

$$k_c = \frac{1.2*T}{t_d k_p} = \frac{1.2*0.045}{1.035*0.06} = 0.8695$$

Proportional gain, k_c = 0.8695

$T_i = 2t_d$ =2×1.035=2.07sec

$$k_i = \frac{k_c}{T_i}$$

Integral gain, k_i = 0.4200sec¯1

Td=0.5τd=0.5×1.035=0.5175sec

Kd = kc×Td=0.8695×0.5175=0.4499sec¯1

5.2 Analysis

Consider G_c, G_p, m and x as the controller transfer function, process transfer function amplitude of nonlinearity and x the stem position of the control valve for a non linearity represented as NA. In describing function method the non linearity is defined as

$$G_c G_{p=}\text{-}1/NA$$

Since the nonlinear parameters are unknown consider the first case in which the amplitude is the only term which is effected by non linearity. So we are considering nnlinearity given by the expression NA=$-\frac{4M}{\pi X}$

$$GcGP=-1/\frac{-4M}{\pi X}$$

$$GcGP= \frac{\pi X}{4M}$$

$$GcGP4M=\pi X$$

$$Gc=\frac{\pi X}{4MGp}$$

This is the transfer function of the controller, but here the numerator is higher order than denominator, so we introduce a filter function like an IMC controller. Hence the new controller transfer function will be G_c= G_c/fs+1.

$$G_C=\frac{\pi X}{4MG\text{p}}$$

$$G_P=\frac{0.606}{0.124S+1}$$

$$G_C=\left[\frac{\pi X}{4M}\right]\left[\frac{0.124S+1}{0.0606}\right]$$

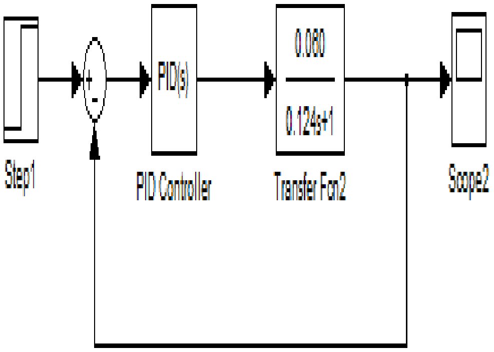
$$G_C=\frac{0.124\pi X+\pi X}{0.0606*4M}$$

$$G_C=\frac{\pi X\,(0.124S+1)}{4M*0.606}*\frac{1}{fS+1}$$

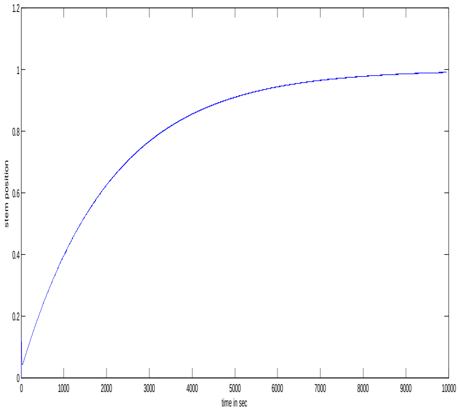
$$G_C=\frac{(0.124S+1)\pi X}{0.606\,(fs+1)}$$

6. SIMULATIONS

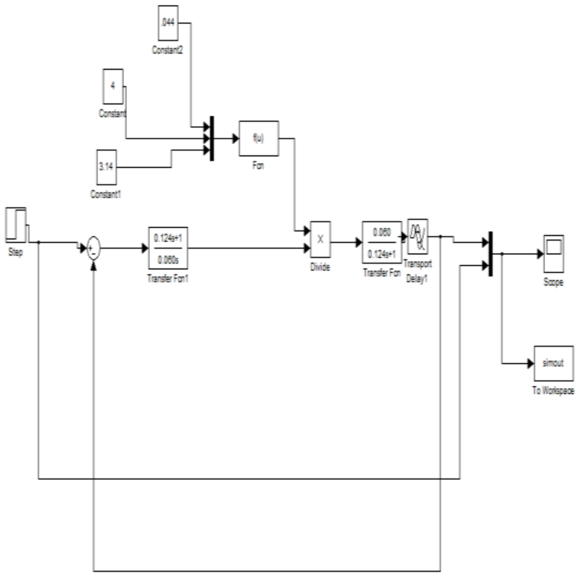
6.1 Block Diagram of PID Controller



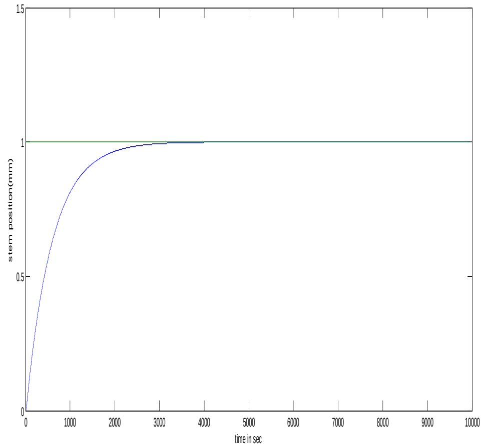
6.2 Response of PID Controller



6.3 Block Diagram of Describing Function



6.4 Response of Describing Function



7. RESULTS

Table-1: Comparison of describing function with PID controller

Controller	Rise time (sec)	Settling time(sec)	Over shoot (%)
PID	1.91	6.5	5.73
Describing function based	0.056	0.02	0

8. CONCLUSIONS

Nonlinearities in the control valve where studied in which stiction is found to be the most affecting nonlinearity for a control valve. Hence stiction reduction methods were introduced. Based on the modelling equation the transfer function of the process is calculated and controller was designed. A PID controller is designed and the values of the proportional derivative and integral are obtained. The controller based on the describing function was also determined depending on the parameters of nonlinearity. Both the controller responses were compared. Describing function based controller provides a response which is of reduced oscillations

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Lina Rose is currently working as assistant professor under Electronics and Instrumentation department in Karunya university Coimbatore. She received her M.Tech degree from same institution and B.E from Sahrdaya College of Engineering and Technology Thrissur. Her intrested area is process control. She has good hands on work experience in Test and Measurement Industry using NI Lab VIEW and MATLAB software.