Study on the Effects of Different Proportional Values on Gas Pressure Control

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***Abstract*—Gas pressure system is self-regulating process that is fast and noisy. This study is carried out to determine the process characteristics, mode of control and the effects on response curve when three different proportional (P) values are implemented into a gas pressure control system. The process characteristics are determined by using reformulated tangent method while the mode of control is by using Ziegler-Nichols tuning rules. Both of these are done based on the response curve from conducting open loop test while the effects of proportional (P) values are from conducting load disturbance test. As a result, , 0.0355 1/s response rate, 1.3043 s time dead and 32.3478 s time constant are obtained. From the tuning rule, 4.9599 proportional (P) value and 4.3433 s integral (I) value are determined. Lastly, the process took 79.30 s to become stable when an increased proportional (P) value is used, 59.35 s when a decreased value is used and 63 s when there are no change in proportional (P) value. In conclusion, higher proportional (P) value took longer time for the process to stabilize.**

***Keywords*— Gas Pressure Control, Load Disturbance Test, Open Loop Test, Reformulated Tangent Method, Ziegler-Nichols Tuning Rules**

I. INTRODUCTION

Process control system is responsible to do some adjustments in variables of a process in order to ensure that the process reach its desired operation point [1]. Feedback control is the simplest strategy for an automatic process control [2]. Open loop system is when an operator is needed to do the adjustment on the control system rather than let it works automatically [3].

In a process, the process characteristics consist of the response rate (RR), dead time (T_d) and time constant (T_c) of the response curve. On the other hand, the mode of control for a process depends on the control loop variables, whether it is flow, level, pressure or temperature. The mode of control can be proportional-only (P), proportional+integral (P+I) or proportional+integral+derivative (P+I+D) [3].

In this experiment, the feedback control is analysed in an open loop system and the process involved is a self-regulating process, specifically, a gas pressure control. Pressure control possessed a noisy, fast and acceptable off-set characteristics, therefore, only P and I values are needed to be analyzed [3].

The objectives for this research project is to determine the response rate, dead time and time constant in the graphical response from the open loop test by using reformulated tangent method and determine the mode of control for gas pressure process by using Ziegler-Nichols tuning rules. Another objective is to analyze the graphical response from the load disturbance test when implementing different P values in a pressure controller.

Both open loop test and load disturbance test are done at Process Control Laboratory UiTM Shah Alam using gas pressure (AP922) plant model. Different values of P is obtained by increasing and decreasing the original P value, making there 3 sets of values for P. Each of these values is introduced into the process before conducting the load disturbance test, in other words, load disturbance test is done 3 times each with different P values.

II. METHODOLOGY

A. Reformulated Tangent Method

This method is used when conducting the open loop test [4]. Initially, the mode is set to manual and changes in manipulated variables (Δ MV) around 10 % is done. The response curve is recorded until the curve is stabilized. From the curve, a tangent line is plotted and the process characteristics which consists of response rate (RR), dead time (T_d) and time constant (T_c) are calculated. Equation (1), (2) and (3) are used for determining the process characteristics [5].

Where,
RR = response rate, 1/s
a = scaling factor for y-axis, %/mm
b = scaling factor for x-axis, s/mm
$\triangle$MV = change in the output of the controller, %

Response rate (RR):

$$RR = \frac{\tan\theta}{\Delta MV}\frac{a}{b} \quad \text{… … … … … … … … (1)}$$

Dead time (T_d):

$$T_d = T_d(length) \times b \quad \text{… … … … … … … … (2)}$$

Time constant (T_c):

$$T_c = T_c(length) \times b \quad \text{… … … … … … … … (3)}$$

B. Tuning Rules by Ziegler-Nichols

Based on the response rate (RR), dead time (T_d) and time constant (T_c) values, the PID controller parameters are determined using Ziegler-Nichols tuning rule. This tuning rule is still widely used even though it was presented in the 9140s [4]. The Table 1 below shows the tuning rules by Ziegler-Nichols [5].

Table 1: the tuning rules by Ziegler-Nichols

Mode	P	I	D
P	100 RR T_d		
PI	111.1 RR T_d	3.33 T_d	
PID	83.3RR T_d	2 T_d	0.5 T_d

Where the P value will be used to determine the gain,

$$Gain\ (K) = \frac{1}{P} \quad \text{… … … … … … … … (4)}$$

III. RESULTS AND DISCUSSION

A. Open Loop Analysis

Open loop test is done by changing the manipulated variable (MV) during manual mode. The test here used a 10% step change in MV from 55.4% to 65.4%. Since pressure is a self-regulating process, the response curve is recorded once steady state is achieved [3]. Figure 1 below shows the response curve obtained.

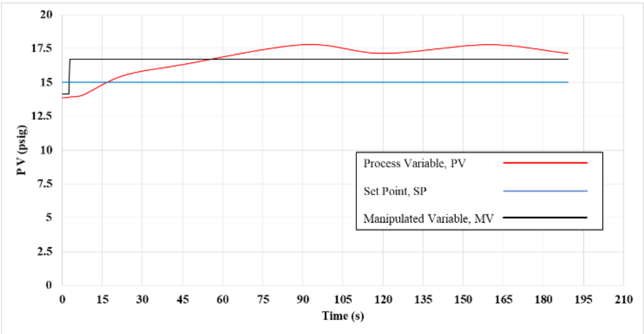

Figure 1: The response curve from open loop test

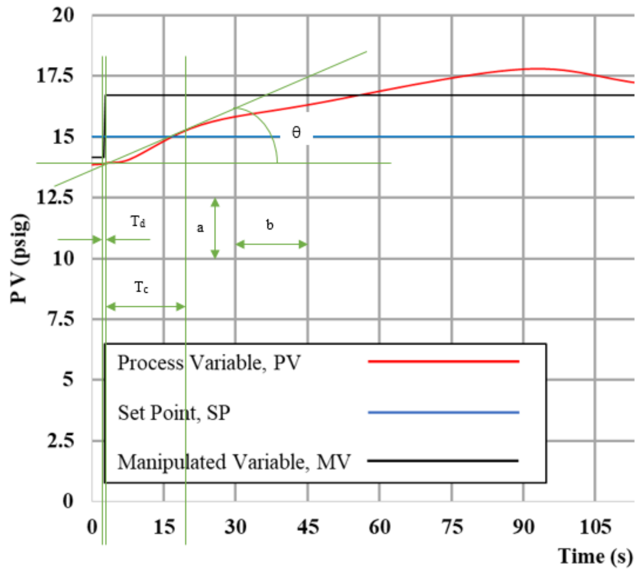

Figure 2: The response curve from open loop test for calculation

The mathematical solution on RR, T_d, T_c and P+I value determination are shown as below:

- From Figure 2;

$$\text{Scaling factor for } y-\text{axis}, a = \frac{10\ \%}{17.5\ \text{mm}} = 0.5714\ \%/\text{mm}$$

$$\text{Scaling factor for } x-\text{axis}, b = \frac{15\ \text{s}}{11.5\ \text{mm}} = 0.4348\ \text{s}/\text{mm}$$

$\theta = 38°$

$MV_i = 55.4\%$

$MV_f = 65.4\%$

T_d (length) = 1 mm

T_c (length) = 24.8 mm

- Based on equation (1), (2) and (3);

$$RR = \left(\frac{\tan\theta}{\Delta MV}\right)\left(\frac{a}{b}\right) = \left[\frac{\tan 38°}{(65.4-55.4)\%}\right]\left[\frac{\left(0.5714\frac{\%}{\text{mm}}\right)}{\left(0.4348\frac{\text{s}}{\text{mm}}\right)}\right]$$

$$= 0.0342\ \frac{1}{\text{s}}$$

$$T_d = T_d(\text{length}) \times b = 1\ \text{mm} \times 0.4348\frac{\text{s}}{\text{mm}} = 1.3043\ \text{s}$$

$$T_c = T_c(\text{length}) \times b = 24.8\text{mm} \times 0.4348\frac{\text{s}}{\text{mm}} = 32.3478\ \text{s}$$

From the calculation, the scaling factor a and b are 0.5714 %/mm and 1.3043 s/mm respectively. The value for RR, Td and Tc are 0.0355 1/s, 1.3043 s and 32.3478 s are obtained respectively.

Before the PID controller parameters are calculated, the control mode selection need to be done first. This is to determine whether need to calculate only P mode, PI or PID. Since pressure control is a fast, noisy and not accepting any offset, therefore, PI mode need to be determined. By using Ziegler-Nichols tuning rules, the P and I value are 4.9599 and 4.3433 s respectively. The calculation can be referred as below.

- Based on Ziegler-Nichols Tuning Rules on table 1;

$$P = 111.1(RR)(T_d) = 111.1\left(0.0342\frac{1}{\text{s}}\right)(1.3043\ \text{s}) = 4.9599$$

$$I = 3.33(T_d) = 3.33(1.3043\ \text{s}) = 4.3433\ \text{s}$$

B. Load Disturbance Test

1. Initial proportional (P) value.

Before conducting the load disturbance test, the previous P value is scaled down to 0.5 while the I value are scaled up to 15 s. these values are set into the process in manual mode and switched to auto mode right after. The response curve is let to stabilize.

In order to conduct load disturbance test, the mode is switched to manual. Next, the manipulated variable is decreased by 10% from 65.6% to 55.6% and the mode is switched back to auto. The response curve took 63 s before stabilized. The response curve can be referred as in the figure 2 below.

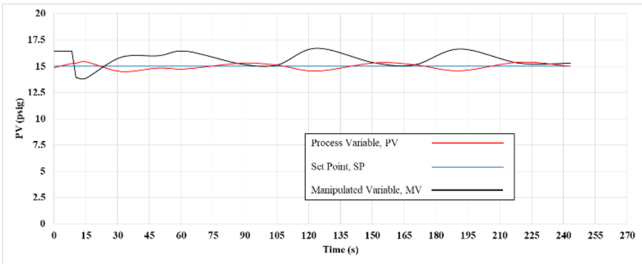

Figure 3: The response curve for initial proportional value process

2. Increased proportional (P) value

The previous I value is set as constant while the P value is increased by multiplying the value by 4, giving the new P value is 2.0. The new P value is inserted into the process and the resulting response curve is analyzed.

The 10 % decrease in manipulated variables occurs from 64% to 54% in manual mode. Here, the response curve took 79.30 seconds before reaching a stable condition. The figure 3 below shows the resulting curve.

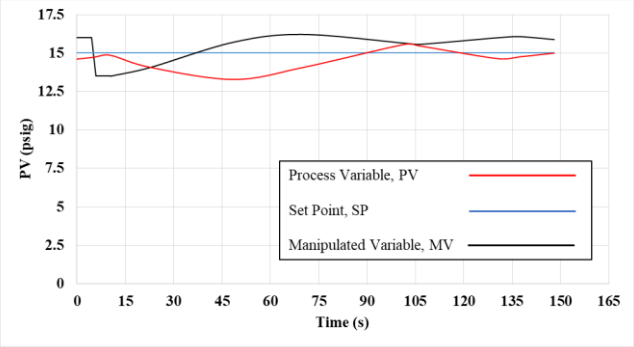

Figure 4: The response curve for increased proportional value process

3. Decreased proportional (P) value

The I value is still let to be constant here and the P from the original value is decreased by dividing the value by 2. This resulting with a new P value which is 0.25 and it is being introduce to the system.

The response curve is obtained after making a 10% decrease in the manipulated variables from 60 % to 50%. As a result, the time taken for the process to stabilize is 59.35 seconds as referred in figure 4 below.

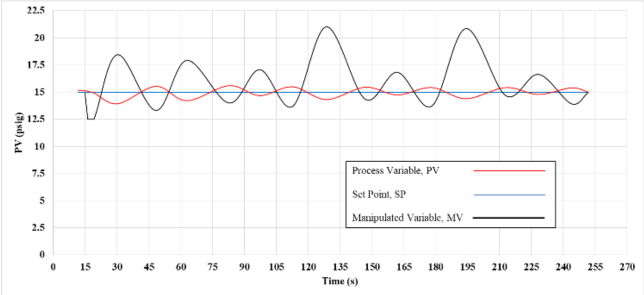

Figure 5: The response curve for decreased proportional value process

The different in the time taken for the response curve to stabilize can be relate to the PID controller algorithm. The algorithm can be referred as below.

$$MV = \frac{100}{P}\left(e + \frac{1}{I}\int e\,dt + D\frac{de}{dt}\right) \quad \ldots\ldots\ldots\ldots\ldots \text{ Equation (4)}$$

Assumptions must be made when referring to this algorithm. The assumptions are:

i- $PV \propto MV$

ii- $MV \propto 1/P$

Therefore, increasing the value of P, will make the value of MV to decrease since $MV \propto 1/P$ is assumed. Going further, the PV value will also be decreased since $PV \propto MV$ is referred. The same fundamental is applied when P value is decreased. This supports the results obtained from the load disturbance tests.

IV. Conclusion

In conclusion, the process characteristics and mode of control for gas pressure control system are determined by applying reformulated tangent method and Ziegler-Nichols tuning rules. For the results from the load disturbance tests, it can be concluded that if the proportional (P) value is high, the time taken for the process to stabilize is long.

It is recommended to further study on the effects on the response curve if I value is manipulated and P value is constant. In addition, a study when both P and I values are manipulated can also be done. The results from this findings might help to obtain the best changes that can be done in order to achieve a faster stabilized process response since the longer the time taken for the stabilized response, the higher the amount of loss in the end product [3].

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