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Research

Linear Regression Analysis on Fluid Flow Rate in Tank Level Control

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ABSTRACT*: This research was conducted to study the effect of pump speed on changes in fluid levels in the tank and linear regression analysis of fluid flow. The variation used is a 4 mm solenoid and a variable pump speed range of 30-50%. The results of increasing the level at a pump speed of 32% obtained a level of 82 mm and a pump speed of 50% obtained a level of 149.9 mm, with fluid flow rotation occurring in the first minute. In addition, the determination calculation uses actual fluid level data at time 0 seconds (n=1), time 60.27 seconds (n=30), and time 180 seconds (n=61), with a fluid level value of 1 mm, 118 mm, and 141 mm. So the determination evaluation (R^2) obtained is 0.863, which indicates that the model is included in the high tolerance category. So this indicates that the PID controller in this series of piping system equipment is still suitable for use because in the recording of the fluid flow data obtained no significant gaps were found. Apart from that, it can also be seen that the pump speed affects the fluid flow rate due to the change in mechanical energy into kinetic energy which pushes the fluid towards the tank. Process time also influences changes in fluid levels in the tank as a result.*

Keywords: *Fuid flow; Linear regression; Flow rate; Level control; Tank.*

1. INTRODUCTION

Industry is a production activity that processes raw materials, semi-finished materials, and/or finished goods into goods that have added value and are useful [1]. The production process in industry is closely related to the control system, one of which is level control [2][3][4]. The control process usually uses an automatic control system such as a Proportional-Integral-Derivative (PID) Controller. As is widely known, the PID Controller is one of the types of controllers most widely used in automatic control systems. The function of implementing a PID Controller is to control the system so that the output reaches the desired value, by reducing the error level between the system output and the setpoint (desired value). The components of the PID Controller include: Proportional (P), which is part of producing a response that is proportional to the size of the current error. The bigger the error, the bigger the output given. However, the use of proportional control alone is usually not enough to achieve optimal stability. Integral (I) which is an integral part in overcoming errors that accumulate over process time. When there is a persistent error, this integral component will add corrections to eliminate the error continuously/sustainably. Typically used to eliminate offsets or fixed errors. Next, Derivative (D) plays a role in paying attention to the rate of change in errors. This provides corrective actions that depend on how quickly the error changes, helping to reduce oscillations and increase system stability. In implementing a piping system, PID has the ability to stabilize the system by controlling process variables, such as fluid flow rate or valve opening and closing [3]. The fluid flow rate can be adjusted by

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setting the pump speed so that the fluid can flow continuously and stably. In a consistent fluid flow, it can be influenced by the initial velocity so that it has an impact on the pressure in the pipe or tank [4]. Apart from that, fluid flow can also be influenced by pipe diameter which also has an impact on the head loss value [5].

In controlling fluid levels, it is important to regulate the flow rate. Where the fluid flow rate can be adjusted by setting the pump speed so that the fluid can flow continuously and stably. In a consistent fluid flow, it can be influenced by the initial velocity so that it has an impact on the pressure in the pipe or tank [6]. Furthermore, fluid flow can also be influenced by pipe diameter which also has an impact on the head loss value [7][8].

The control process usually uses an automatic control system such as a Portorional-Integral-Derivative (PID) Controller. PID has the ability to stabilize the system by controlling process variables, such as fluid flow rate or valve opening and closing [9][10]. Rahmani et al. [11], stated that the use of a PID controller has no overshoot, settling time, has a fast rise time, and small steady-state error. Apart from that, the research was carried out using a single-level tank and then the results of the research were analyzed using the equation for conservation of mass in the tank and discharge velocity. Puspitarini et al. [12], carried out tests on fluid level control in couple tanks in series using the predictive control model method. C. Chen et al. [13], conducted fluid flow experiments with level settings using CFD analysis. Ashok S.G et al. [14] conducting multi-tank level control experiments with the integration of intelligent fuzzy logic techniques.

This research was carried out using a type of multilevel tank or arranged in parallel as in Figure 1. The results of the research were carried out by regression analysis to determine the determination value (R2) linearly and exponentially. This determination value will indicate the accuracy of the PID used in the series of equipment. The results of this research are used to develop learning materials in the fields of fluid flow, fluid mechanics, and instrumentation and process control.

2. RESEARCH METHODS

The research method used is experimental. In this experiment, fluid will flow from tank 1 (chamber) to tank 2 with the help of a pump. In tank 2, a fixed variable is provided, namely a solenoid valve (4 mm) to control the flow if excess pressure from the fluid occurs. In addition, this experiment uses pump speed variations (range 30 to 50%) to determine the increase in fluid level in tank 2.

The equipment used in this research is a PCT50 Level Control unit which consists of a series of parallel tiered tanks. The unit is equipped with a Portorional-Integral-Derivative (PID) Controller, solenoid valve and pump. The ingredients used are distilled water.

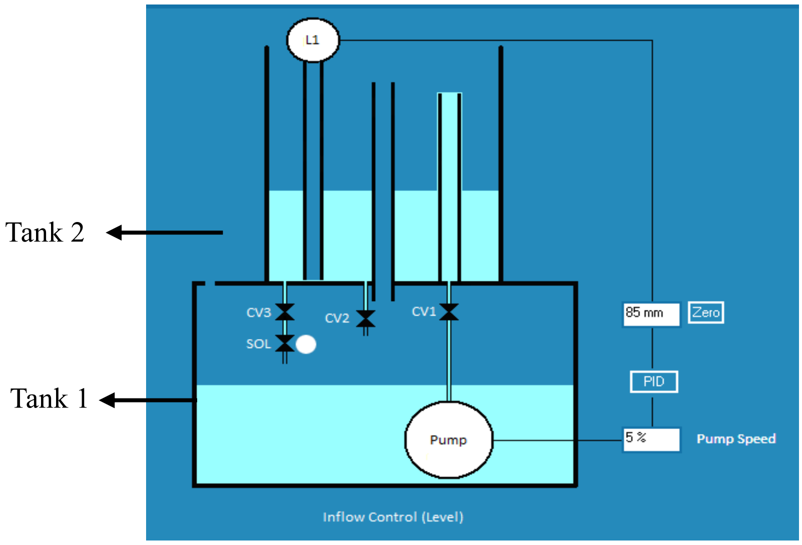


Figure 1. PCT 50 multilevel tank

The experimental data obtained were in the form of fluid flow rate values, process time and fluid level in tank 2. These results were calculated using a linear regression model, namely :

$$y = a + bx \qquad (1)$$

Where;
y : dependent (bound) variable
x : independent variable (free)
a : constant
b : regression coefficient

Next, the regression parameters are calculated by :
Regression coefficient (b), namely:

$$b = \frac{n\sum(xy) - \sum x \sum y}{n\sum(x)^2 - (\sum x)^2} \qquad (2)$$

Constant (a), namely :

$$a = \frac{\sum y - b\sum x}{n} \qquad (3)$$

Where;
n : number of data
Σ : addition operation

Evaluate the model using determination (R^2), namely :

$$R^2 = 1 - \frac{\sum(y_i - \hat{y}_i)^2}{\sum(y_i - \bar{y}_i)^2} \qquad (4)$$

Where;
y_i : actual value
$\hat{y}_i$: predicted value
$\bar{y}_i$: average of actual values
An R^2 value close to 1 indicates a good model.

3. RESULTS AND DISCUSSIONS

3.1 Level Changes to Pump Speed

In the science of fluid mechanics or piping systems, it will always be related to pumps, where the pump has the function of pushing fluid to move from the piping to the tank. In this research, an experiment was carried out using variable pump speed (32% to 50%) to determine changes in the fluid level in the tank. Changes in fluid level can illustrate the accuracy of the PID Controller function in reading the addition of fluid in the tank. From this experiment, results were obtained as shown in Figure 2. In Figure 2, the changes in fluid level in the tank are shown along with the length of time the pump has been running. The pump works to produce a force which will cause fluid to flow from tank 1 to tank 2 at a certain speed. In this study, the pump work was regulated at speeds ranging from 32% to 50%. So, we know how long it takes to reach the peak of the fluid in the tank.

The experiment was carried out using process time as a fixed variable, namely 3 minutes, and pump speed as the independent variable. Pump speed variations are made from 30% to 50%. It's just that from the experiments carried out, when setting the pump speed at 30% there was no fluid movement in the piping system. It can be concluded that the motion energy is converted into kinetic energy and the pressure is not strong enough to push the fluid towards the tank. In his observations, the fluid began to move up towards the tank when the pump speed was increased to 32%, this speed was the beginning for the fluid to rise towards the tank.

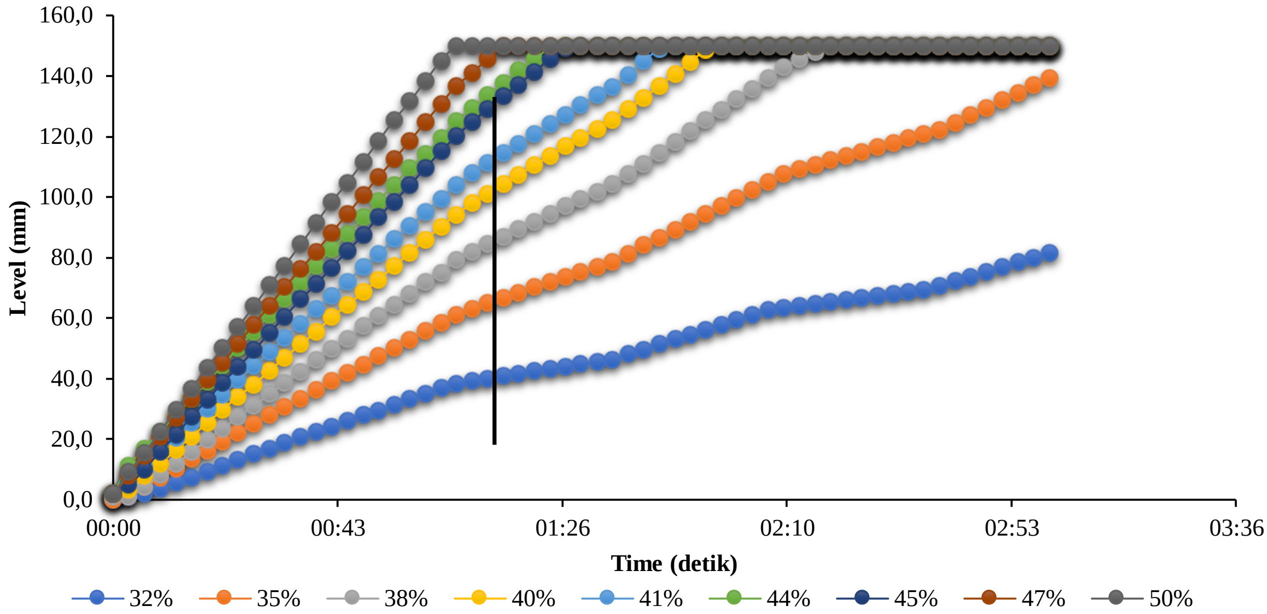
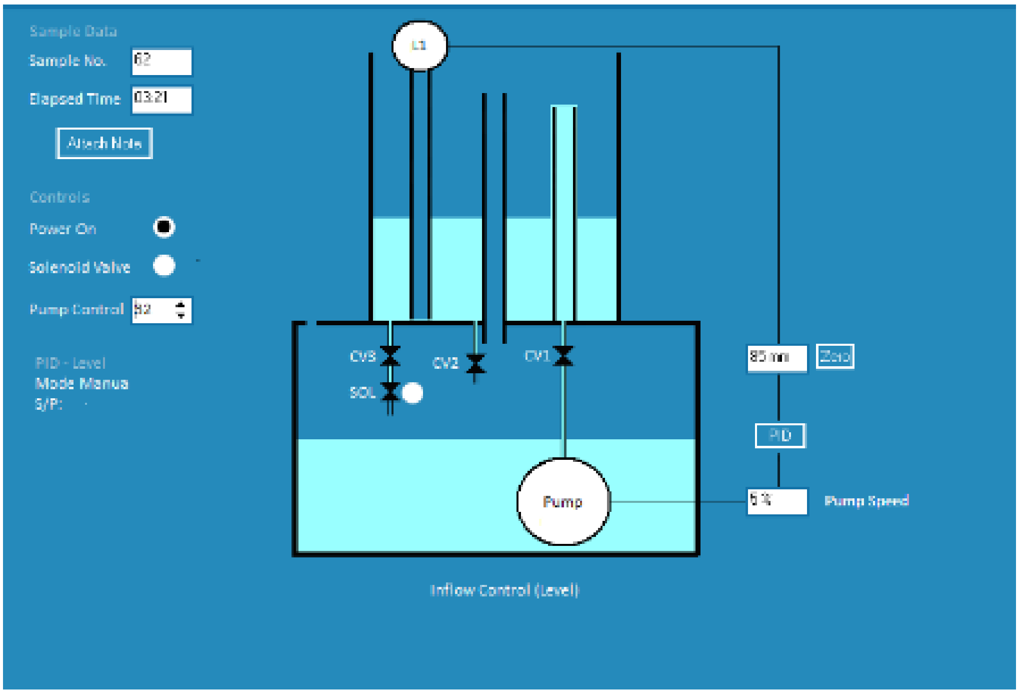
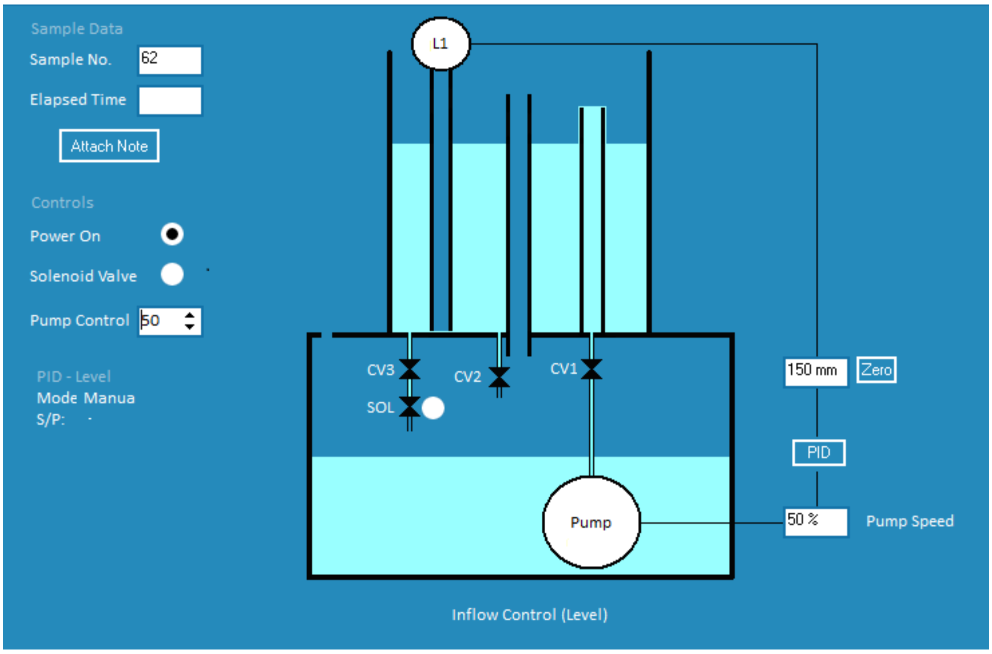


Figure 2. Changes in level with pump speed

In Figure 2, it can be seen that the fluid level in the tank driven at a pump speed of 32% is at the bottom line, with an average level value of 82 mm in the 3rd minute. Meanwhile, at a pump speed of 50%, the average level value is 149,9 mm starting in the first minute. These differences can be seen in Figure 3.



(a)



(b)

Figure 3. Line-up of the tank filling process with various speed pumps; (a) 32% and (b) 50%

Apart from that, from the results obtained, it can be seen that the fluid level in the tank continues to increase significantly from the 0th second to the 60th second or the first minute. It is known that after the 60th second, no more fluid flows into the tank than the fluid that flows at the 0th second. This is influenced by changes in energy that affect the fluid's thrust at the first moment [15] [16]. Apart from that, the change in energy is also influenced by the increase in pump speed provided, This affects the fluid flow rate in the pipe to the tank [17]. So it is known that the maximum fluid level achieved in this study was 149.9 mm or close to 150 mm in 1 minute with a pump speed of 50%. This shows that the pump speed given at the beginning of the process is able to increase the fluid flow rate thereby influencing the increase in level that occurs in the tank. Apart from that, changes in energy also affect the amount of compressive energy provided by the pump to the fluid

From this observation it is known that the pump speed given at the beginning of the process is able to increase the fluid flow rate thereby influencing the increase in level that occurs in the tank. Apart from that, changes in energy also affect the amount of compressive energy provided by the pump to the fluid.

3.2 Linear Regression Analysis of Flow Rate Against Process Time

The data is in the form of changes in fluid level over time for each pump speed variation, then a simple analytical calculation is carried out using the linear regression method. From each pump speed variation, an average calculation is carried out which is then plotted as shown in, as presented in Figure 4.

From the results of the data plot, equation (5) is obtained with values of $a = 29{,}579$ and $b = 2{,}2673x$.

$$y = 29{,}579 + 2{,}2673x \quad (5)$$

Then, to calculate the determination using equation (4), actual fluid level data is needed, so data is used at time 0 seconds (n=1), time 60.27 seconds (n=30), and time 180 seconds (n=61), namely of 1 mm, 118 mm, and 141 mm. Apart from that, the average of the actual value is 87 mm, with a predicted value of 121.03 mm. So calculated using equation (4), the value obtained is,

$$R^2 = 1 - \frac{(141 - 121{,}03)^2}{(141 - 87)^2}$$
$$R^2 = 1 - 0{,}1367$$
$$R^2 = 0{,}863$$

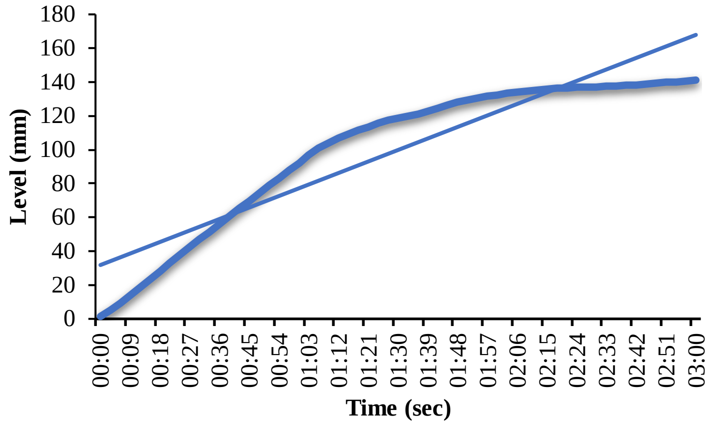


Figure 4. Changes in level with processing time

The determination evaluation (R^2) was obtained at 0.863. These results indicate that the model is included in the high tolerance category. So it was concluded that the length of the process time influenced the change in level height in the tank. This result also reflects that the PID controller provides data recording that matches predictions so that no significant gaps are found in the actual data and calculations..

Asaad et al. [18], in his research stated that the development of an automatic fluid level control system is the best way to detect the fluid level in the tank. Anika [19], states that the use of the Automatic Air Level Control System is efficient and effective in maintaining optimal fluid levels.

Correlation in fluid level control with a PID controller can also be implemented in a series of stirred tanks for industrial production needs. This breadth of coverage means that the scientific fields of chemical engineering and instrumentation engineering can be aligned to meet process needs in industry. Vardaan dkk [20], conducting research to control water level automatically based on Arduino. The ultrasonic sensor used is the "echo" principle which can calculate fluid flow time. In the experiment, the pump was automatically set to ON when the fluid level was detected to be low. This can increase the effectiveness of fluid use in a production process [21][22][23]. This fluid level control arrangement was also developed by analyzing the performance of three control schemes, the Proportional Integral (PI), Ziegler Nichols (ZN) and Ciancone Correlation (CC) methods [24]. Apart from that, level control can also be simulated using Model Predictive Control (MPC) which is able to improve control performance [25].

4. CONCLUSION

This research resulted in the conclusion that changes in pump speed can affect the increase in fluid level in the tank. The increase in level occurs very significantly at the beginning of the process due to the change in mechanical energy into kinetic energy and quite large pressure. Apart from that, the results of calculations using the equation obtained a determination evaluation value (R2) of 0.863. These results show a high level of tolerance, thus indicating that the PID controller in this series of piping system equipment is still suitable for use. As a suggestion for the progress of this research, a test can be carried out to control the fluid level in the tank using fuzzy logic or adaptive control. Where fuzzy logic has the advantage of being able to handle decision making with variables that cannot be defined, while adaptive control is able to adjust control parameters based on changes in system dynamics or environmental conditions.

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