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Design of Process Control System in Water Cooling Processing Interaction Tank using Integral Control and Robust Control in The Tire Industry

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Abstract. This laboratory based research build a process control system as water level scanner in interaction tank used for water cooling. The control valve parameter based on water level between tanks are interacted. The control method of tank valve ratio choosed in this reasearch is integral control and robust control. The desired control specification for maximum overshoot is 10%, peak time is 1 second, and error steady state is 0. The design process executed in physic system modelling step and system design criteria. Experiment executed using Matlab Script and Matlab Simulink. The simulation result will be compared to see an effective performance for processing of water cooling interaction tank control method. The design result for integral control can tracking reference accord to system design criteria and robust control can tracking reference without different experience either the system without disturbance or the system with disturbance. Keyword: water cooling tank interaction, process control, integral control, robust control.

1. Introduction

The tire industry has an important role in improving the economic process in Indonesia. This is due to the need for higher tires to support economic processes such as supporting export and import activities. Tires as part of automotive components to deliver the export and import goods. One of the processes in the tire industry, namely the curing process in accordance with the specifications [1]. In the process requires a system to cool the process, which is using water cooling processing. In the water cooling process, it takes a container as a means to prepare or commonly called water cooling process tank. The existing tanks usually only form into one separate tank. In order to maintain water availability in the tank, a control system such as PID Controller [2], [3] is required. The linear control system in this study is intended for the output can track the reference [4]. An integral and robust controller as has been done to solve tracking problems [5], [6]. In this study trials were conducted to control the interacting or paired tanks, it has also been done before using the sliding mode control [7], using a linear Model Predictive Control (MPC) [8] and currently researchers use integral and robust control tracking system.

2. Design of Control System

2.1. Physical System Modeling on Interaction Tank

In this research, Matlab simulation was conducted to control the tank connecting valves between the tank and the last tank output valve with the intermediate tank fluid level parameters between the interaction tanks commonly used in the tire industry. The height level of the fluid is translated as tank capacity. In the early stages in design of control system by physical system modeling. The following physical form of the system will be mathematically modeled to be able to determine the transfer function of system [9].

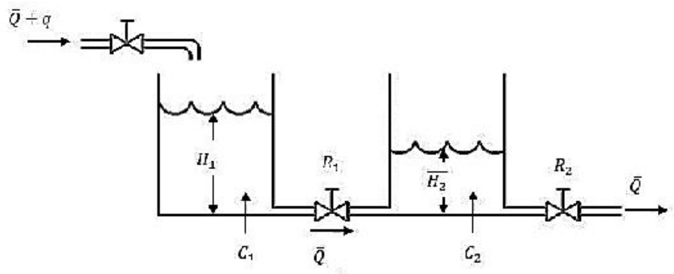

Figure 1. Physical form of fluid capacity system in interaction tank.

where

$\bar{Q}$	: steady state flow rate
$\overline{H_1}$	: steady state of fluid height in tank 1
$\overline{H_2}$	: steady state of fluid height in tank 2
R	: resistance of the fluid capacity system (valve)
C	: capacitancy of the fluid capacity system (capacity of tanks)

This tank system uses two tanks which interact with each other. The two tanks are connected and the flow rate is controlled through the ratio of valve. The system will perform the accumulated value of the comparison between the last tank output and the earliest tank input.

Based on the working principle of the above system, it can be made the block diagram system as follows.

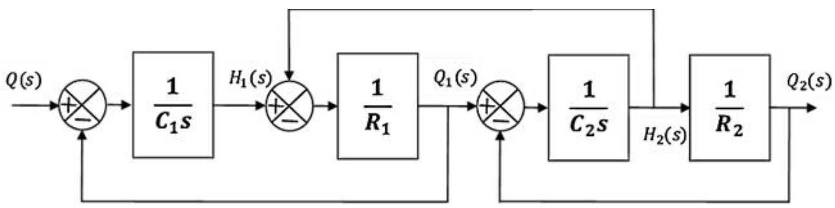

Figure 2. The block diagram of fluid capacity system in interaction tank.

To be able to determine the value of the equation for its transfer function, its component values are assumed as $R_1 = 0.5, C_1 = 3, R_2 = 0.7,$ and $C_2 = 3$. So we get the transfer function system as follows

$$\frac{Q_2(s)}{Q(s)} = \frac{1}{3{,}1\ s^2 + 5{,}7s + 1} \tag{1}$$

2.2. Criteria of System Control Design

Open loop or non-feedback system response is intended to be able to see system performance without feedback by observing performance characteristics such as maximum overshoot, settling time, and error steady state (E_{ss}) [9]. The test results states that the system has a very long time to reach steady state for 30 seconds, and without overshoot so that its performance will be improved by adding controllers. A system to be controlled and observed also needs to be tested by knowing the matrix of controllability and observability [10]. Based on the test of controllability and observability, there is no linear combination so the system can be controlled and observed.

Determination of design system criteria is intended to obtain the system with the desired performance. The system is desired as a reference in determining the reinforcement for the initial system to fit the desired system. In this research, the desired system design criteria as follows maximum Overshoot (M_P) = 10%, Peak Time (T_P) = 1 sec, Tracking reference = 1 and Error Steady State (E_{SS}) = 0.

Based on the design criteria, we can get dumping constants (ζ) is 0.59 and natural frequency constant (ω_n) is 3.89. Based on the characteristic equation, we can get.

$$\alpha_c(s) = s^2 + 4.59s + 15.1321 \tag{2}$$

2.3. Tracking design with Integral Control

To be able get results without steady-state error when the system gets parametric changes, it needs an integral controller [5], [10]. The state space provided from equation (1), the system is represented as.

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -0{,}317 & -1{,}81 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0{,}317 \end{bmatrix} u, y = \begin{bmatrix} 1 & 0 \end{bmatrix} x \tag{3}$$

Based on the system equations for integral control [10], we can get.

$$|s \quad - F + G \quad | = s^3 + (1{,}81 + 0{,}317K_0)s^2 + (0{,}317 + 0{,}317K_1)s + 0{,}317K_i \tag{4}$$

Based on the system equation on integral control, it is necessary to the 3rd order. The order is obtained from 10x ($-\zeta\omega_n$) to obtain the desired pole-pole [-2.2951 + 3.1408i -2.2951-3.1408i -22.9510] and the desired characteristic equation becomes the following.

$$\alpha_c(s) = s^3 + 27{,}5412s^2 + 120{,}4818s + 347{,}2968 \tag{5}$$

So we get the parameter of reinforcement value K = [379.068 81.171] and integral strengthening K_i = 1.095,57. The following block diagram of the system used in Matlab Simulink.

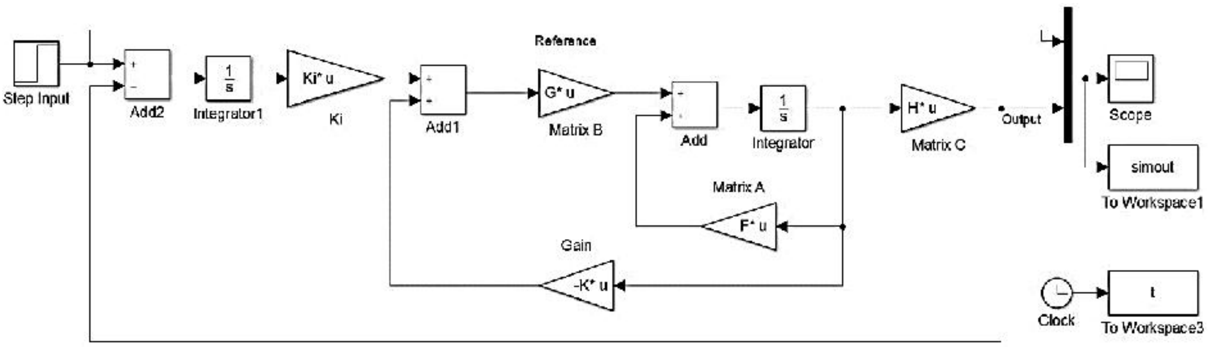

Figure 3. Matlab simulink block diagram system using integral control

2.4. Tracking design with Robust Control

In the robust controller method, it will keep the system tracking the reference and hold it against uninterrupted interference or steady state error equal to zero [6], [10], [11]. If the reference is given a step function with the equation $\frac{1}{s}$, then based on the equation of the reference characteristic and the new system equations in the error space [10] , we can get.

$$|s \quad - F + G \quad | = s^4 + (2{,}81 + 0{,}317K_0)s^3 + (2{,}127 + 0{,}317K_1 + 0{,}317K_0)s^2 + (0{,}317K_{e0} + 0{,}317 + 0{,}317K_1)s + 0{,}317K_{e1} \tag{6}$$

Based on the system equation on the Robust control [10], then the 3rd and 4th order is [-2.2951 + 3.1408i -2.2951 - 3.1408i -22.9510 -21.9510] and the desired characteristic equation becomes the following.

$$\alpha_c(s) = s^4 + 49{,}5s^3 + 725s^2 + 2992s + 7623{,}5 \tag{7}$$

By equating the desired characteristic equation, we can get the parameter of reinforcement value $K = [2.133{,}069 \quad 147{,}287]$, robust strenghtening $K_{e0} = 7.304{,}42$, and $K_{e1} = 24.048{,}89$. The following block diagram of the system used in Matlab Simulink.

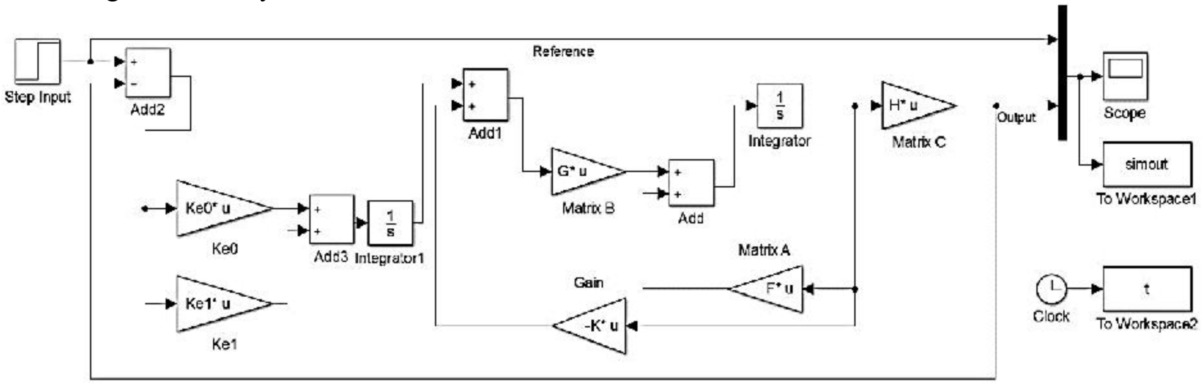

Figure 4. Matlab simulink block diagram system using robust control

3. Results and discussion

3.1. Tracking test of the fluid capacity system in interaction tank with integral control

In testing the fluid capacity system in this interaction tank is made using Matlab software. Researchers use a combination of Matlab Script and Matlab Simulink to find the results. The results obtained from testing the integral control system as follows.

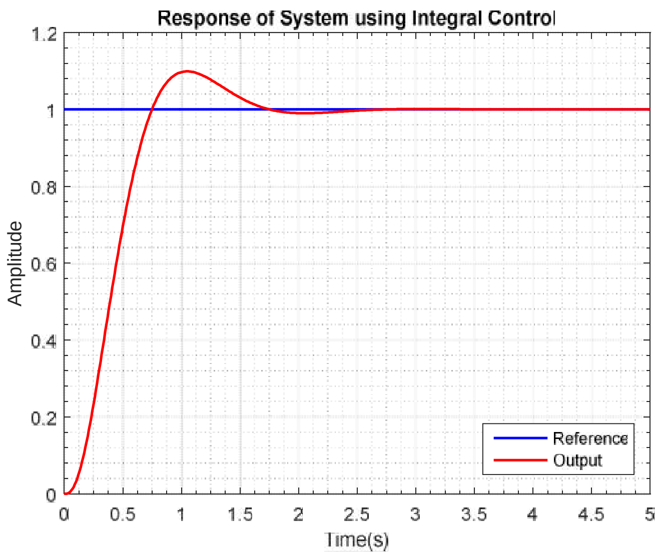

Figure 5. Testing result of the fluid capacity system in interaction tank using integral control.

Based on the above response graph, it can be seen that the output of the system successfully track the reference or steady state error is 0 with Tracking Reference is 1 in accordance with the design criteria of the desired system it can be said that the output system can track the reference well.

3.2. Tracking test of the fluid capacity system in interaction tank with robust control

In testing the system using combination of Matlab Script and Matlab Simulink to find the results. The results obtained from testing the robust control system as seen in Figure 6. Based on the system response in the Figure 6, with step unit input can be seen that the output can track reference input with Tracking Reference is 1 according to the design criteria of the desired system.

To prove that the robust system against interference will be added another reinforcement as a nuisance. Random noise reinforcement with value K_{d0} is 5 and K_{d1} is 8 is given to system. Based on the Figure 7, the system is still robust or sturdy in maintaining the circumstances to keep track of reference input.

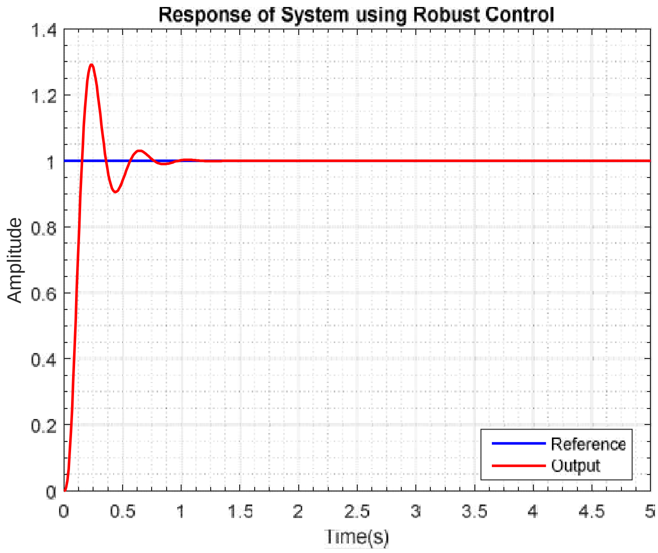

Figure 6. Testing result of the fluid capacity system in interaction tank using robust control.

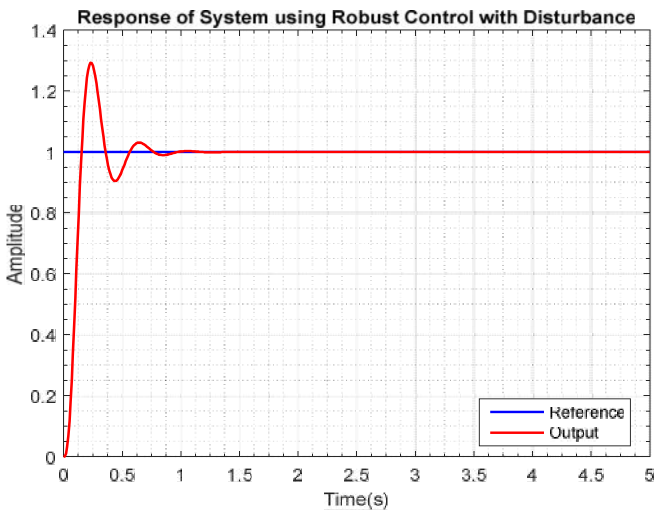

Figure 7. Testing result of the fluid capacity system in interaction tank using robust control with disturbance.

Robustness in maintaining the state of distraction is an advantage in robust control. It is based on the idea of a firm control of bringing the system from the state space to the error space so that the form of fault dynamics can be determined by placing the poles in order to remain stable. Thus, the result of applying robust control to the interaction tank system gets better performance in the form of faster settling time than integral control. The performance of the integral control is in line with its effort in controlling the system by feeding the integral error. However, there is a lack of use of robust control in the form of a little oscillation before steady state but does not affect robust control performance.

4. Conclusion

The simulation test of fluid capacity system in interaction tank in tire industry has been done so that the result of applying integral control has good performance according to the desired system design criteria in the form of maximum 10% overshoot and peak time is 1 second. While the result of robust control implementation has better performance in the form of faster settling time than integral control although having a little oscillation due to higher order of integral control system.

Acknowledgment

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