DEVELOPMENT OF PI CONTROLLER FOR DISC SPEED

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ıstract- **This paper discuss about the development of ·oportional and Integral (PI) controller for disc speed by ʋolving the disturbance at the feedback control. The effect of e disturbance to the disc speed system is eliminated by ·oportional and Integral (PI) controller. The PI controller is ned heuristically from the MATLAB/simulink at which tegrated with the disc plant. The performance of the disc plant analyzed in real-time. Based on the analysis in real-time, this ıper shows that the performance of the PI controller with sturbance and without disturbance. The result with sturbance shows that the output response quite closes to the sult without disturbance even though the overshoot is about 8 ·rcent. By the way, the rise time and settling time of the disc eed with disturbance is reduced for the time less than 0.01 and 95 seconds each. From the results with and without sturbance, this paper concludes that the development of PI ntroller for this speed in simulation give less error about 0.02 ımpared to the real-time system.**

ɜywords: PI controller, disc speed, tuning, MATLAB/simulink, simulation, real-time

I. Introduction

Theoretically, control system having controller as one of the ɜvice to monitor and affect the operational conditions in ʼnamical system. Dynamical system is referring to the otion, forces and torques theory produced in dynamics [1]. xtension to the dynamics, this paper will discuss on the ɜvelopment of Proportional and Integral (henceforth PI) ɲtroller for disc speed.

The development of PI controller interlinked to the latest ɲtrollers in market. In market, the latest controllers are rely useful for complicated model or plant design that ɜpends on control loop [2] used as an example in vehicles ʼnamics. Moreover, the PI controller at which is well-known one of classical controller [3] satisfy robust performance for e fractional order interval plant. The PI controller as ·oposed in this paper is designed for the speed of rotational sc as shown on Fig.1 by which referring to the open and osed-loop system.

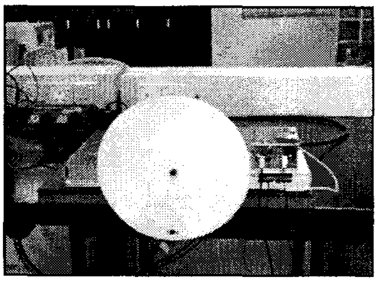


Fig.1: Rotational disc plant

Basically, the disc speed plant determined from the transfer function of the open-loop model control that based on real-time. The open-loop model control collect data from the MATLAB system identification that represented in block diagram as shown in Fig.2. MATLAB system identification defined term X1 as the speed of disc and X2 as the time of running disc in real-time.

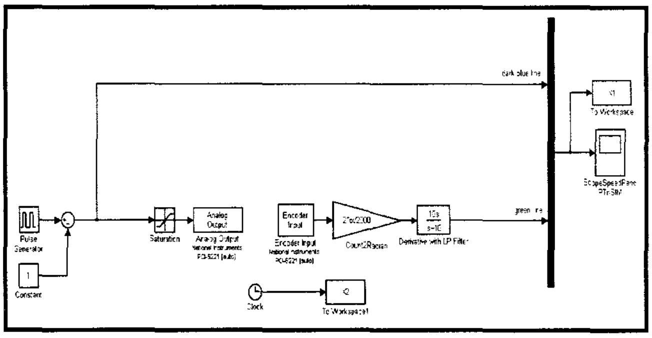


Fig.2: Model for open loop system of disc speed

Via the speed of rotational disc also, the development of the parameter estimation algorithm considered the overall stability of the closed-loop control system. The stability of the closed-loop system used the convergence of the system state and the boundedness of the error [4] to gain approximates parameter vector. This parameter vector might be helpful in improving output response of the disc speed from the MATLAB/Simulink model as illustrates in Fig.3.

Fig.3 illustrates the proposed set up of the closed-loop stem which is used to be implemented in this project. This oposed set up consist motor and robot driver that are tegrated with the MATLAB software and plant for velopment of control algorithm. From the plant, the sensors e used as a feedback to the main controller at which, the PI ntrol systems of feedback control mechanism is designed id developed for this project. The project development is scussed further in experimental design with the additional sturbance at the feedback control.

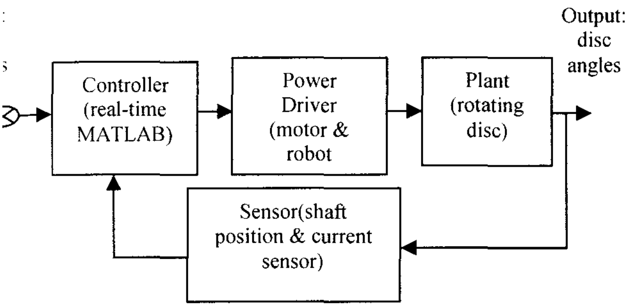


Fig.3: Proposed system of a rotating disc feedback control mechanism for control system study

II. Experimental Designs

According to Meriam and Kraige [5], when the earth otates, the acceleration of a freely falling body as measured om a position attached to the surface of the earth is slightly ss than the absolute value. The lab experimental tests might ove the acceleration of a freely falling body gives impact to e disc rotating. This impact could be improved for better ith system design. System design applied rotational disc odel development at which helpful and useful to get the best sponse of stability. This sub-section also covers the ntroller design and disturbance.

Rotational disc with the transfer function equation

By applying the rotational motion [6], the transfer function f the rotational disc is derived as following:

$$\frac{\theta_m(s)}{T_m(s)} = \frac{[s^2 J_d + sB_d + K_2 + K_1]}{\begin{array}{l}[s^2 J_m + s^2 J_d + K_2 + sB_m]K_1 \\ +[s^3 J_m + s^2 B_m + sK_1]B_d \\ +[s^2 J_m + sB_m]K_2 \\ +[s^4 J_m + s^3 B_m]J_d\end{array}} \quad (1)$$

where $\theta_m(s)$ refers to the position angle of the disc and $T_m(s)$ refers to the torque of DC servomotor.

Tab.1 describes the parameter used in the equation of the rotational disc. The variation of parameters [7] used creates a link with the PI controller at which give impacts to the dynamic performance.

Table 1: Parameters of rotational disc

Physical quantity	Symbol (SI unit)	Measurement Values
torque constant	K_1 (Nm/A)	36.4×10^{-3}
spring constant	K_2 (Nm/A)	53.25×10^{-3}
viscous-friction coefficient	B_m (Nms/rad)	5.469×10^{-3}
rotor inertia	J_m (kgm^2)	6.77×10^{-6}
load inertia	J_d (kgm^2)	2.132×10^{-3}

B. Controller Design

Generally, the controller design applied conventional control for dynamic systems which refers to Proportional-Integral-Derivative (PID) control, classical control, state-space methods, optimal control, robust control, nonlinear methods, adaptive control, stochastic control and discrete event systems [8]. The disc speed model can applied conventional control which is PID control, classical control like Bode and Nyquist methods or root-locus design, and state-space methods like state feedback. For this paper, Proportional and Integral (PI) is designed to get the better signals and comparison stability system study. This controller is built and designed by applying the root-locus technique and the PI gain is tuned heuristically.

Based on control theoretical study, PD controller cannot fulfill the compensation. In that case, the integral [9] element of the PID controller is considered at which working on the set point of the plant. The PI controller is constructed in transfer function, $G_c(s) = K_P + (K_I/s)$ [6] and derived in block diagram as shown on Fig.5. Generally, PD, PI and PID controllers differentiate by their gains.

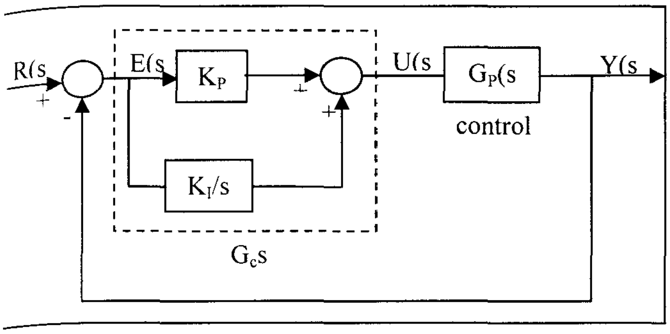
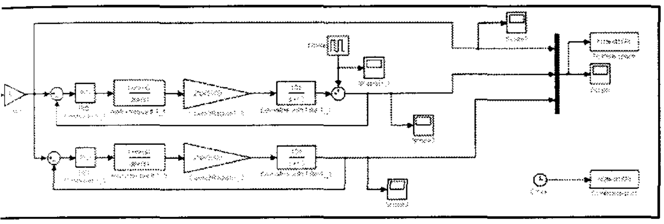


Fig.5: Control system with PI control (adapted from Golnaragi)

Disturbance

From the two previous sub-sections, this paper discuss on e transfer function derivation and controllers designation. oth matters are used in performing the simulation and real-ne system with the additional disturbance. This paper will ok for the disturbance of the pulse generator in simulation ıd real-time system as shown in Fig.6 and Fig.7.The mulation block diagram in Fig.6 combines the model with ıd without disturbance in parallel.



'ig.6: Disc speed model for simulation with and without disturbance

On the other way, for the real-time block diagram as ıown in Fig.7 no parallel combination required as a few rors relate to the sample time occur in the system. This error ın be solved by producing separate model with and without sturbance in Fig.7 (a) and Fig. 7(b) as following. Fig. 7(a) ves result of response with disturbance from pulse generator. ased on the real-time experimental, the results of the disc eed is captured at the running time begin with 9seconds.

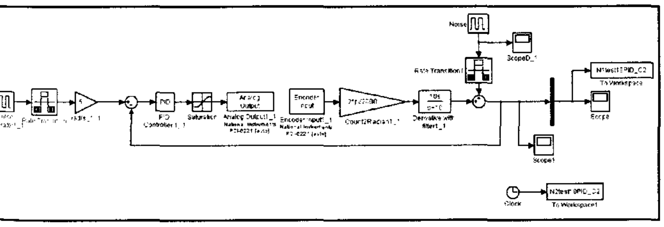


Fig.7 (a): Disc speed model for real-time with disturbance

For the disc speed model without disturbance as shown on e block diagram in Fig. 7(b), the results of the output sponse are compared. These output response are compared ⁄ overshoot, rise time, settling time and error.

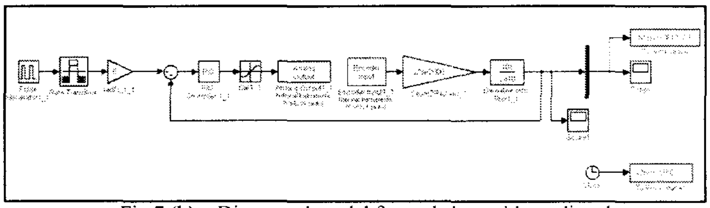


Fig.7 (b): Disc speed model for real-time without disturbance

III. Results And Discussion

System analysis of graphical response

Model and controller design in MATLAB simulink produced results to analyze graphical response. These graphical responses show the implementation of PI controller in real-time and simulation. The implementation of the PI controller in closed-loop system is because the open-loop [10,11] only operate in time basis and the output is necessary to recalibrate from time to time.

From the Fig.8, the output response of the disc speed for simulation shows less than 0.02 of the error, less than 8 percent of the overshoot, less than 0.01seconds of the rise time and less than 0.95seconds of the settling time compared to the real-time system. By using the PI controller, the disturbance that effect to the speed disc signal can be eliminated.

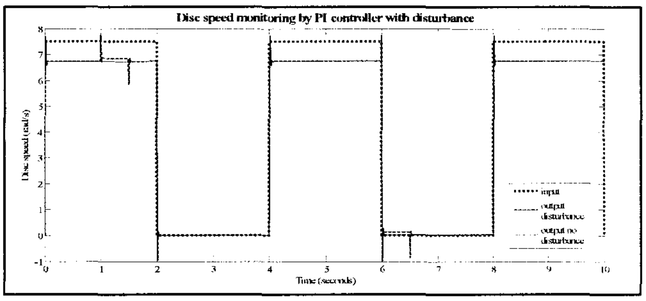


Fig.8: Disc speed outputs and input with and without disturbance by the simulation

The running simulation of the disc speed will look quite difference with the running of the real-time as shown for the output response without disturbance in Fig.9 (a). Fig. 9(a) shows the overshoot of the output response less than 8 percent with the settling time less than 0.95 seconds and the rise time more than 0.01seconds. For an additional element of the closed-loop system in this paper, the disturbance will be added before of the feedback control action.

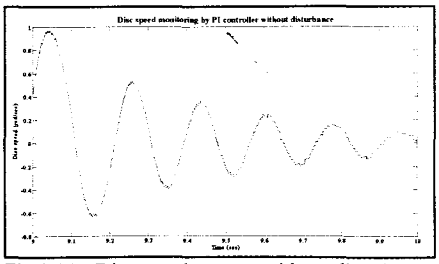


Fig.9 (a): Disc speed outputs without disturbance by the real-time

For the real-time system as shown in Fig.9 (b), the disc ɔeed with disturbance show that the settling time quite same ; without disturbance with less than 0.95seconds and the rise ne try to reach 0 seconds. By the way, the overshoot look uite high with more than 8 percent compared without sturbance. Based on experimental test done, root locus ;sign presents a small gain of integral that proved the fective [11] and acceptable [12] performance of PI ɔntroller. The performance of PI controller will also look for e overshoot appears and may improve the signal with the ıriable gain of PI [13]. By the way, the PI controller esented in this paper is not limited for one control method 4] only. Following from Selvaraj's and Rahim's [15] ɔints, PI controller have high dynamic performance under pidly changing atmospheric conditions.

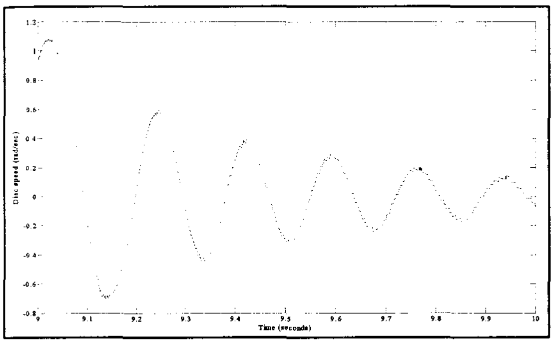


Fig.10 (b): Disc speed outputs with disturbance by the real-time

IV. Conclusion

The development of control system for this rotational disc arified one or more controller used, at which involving the ılse generator as disturbance to the feedback control. esides, this disturbance of pulse generator is recommended ɔr other disturbances like White noise, Gaussian noise and ıy available noises. The effect of the disturbance to the disc ɔeed in this paper is reduced by developing the PI controller. rom theoretical understanding, a few experimental tests have eak out the comparison stability of control system by using e PI controller. Consequently, this paper can conclude that e stability of control system depends on performance of the I controller to eliminate the disturbance from output response f the disc model.

Acknowledgement

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References

[1] *Principles of Engineering Mechanics (Dynamics-The Analysis of Motion)* vol. 2: Springer, 2006.

[2] G. Avesta, A. Samaneh, and E. Ebrahim, "Design of an Integrated AFS/ACD Control System to Enhance 4WD Vehicles Dynamics and Stability," *ASME Conference Proceedings*, vol. 2010, pp. 307-314.

[3] C. Yeroglu and N. Tan, "Classical controller design techniques for fractional order case," *ISA Transactions*, vol. 50, pp. 461-472, 2011

[4] T. Samad, *Perspectives in Control Engineering*. New York: IEEE PRESS, 2001.

[5] J. L. M. L. G. Kraige, *Engineering Mechanics Dynamics* vol. 2: John Wiley & Sons Inc, 2007.

[6] B. C. K. F. Golnaraghi, *Automatic Control Systems*, 8 ed.: John Wiley & Sons Inc, 2003.

[7] K. Dasgupta and H. Murrenhoff, "Modelling and dynamics of a servo-valve controlled hydraulic motor by bondgraph," *Mechanism and Machine Theory*, vol. 46, pp. 1016-1035, 2011.

[8] K. M. P. S. Yurkovich, *Fuzzy Control*: Addison Wesley, 1998.

[9] L. A. Thiago, F. F. M. Antonio, and L. L. C. Joao, "Optimizing Pipeline Transportation Using a Fuzzy Controller," *ASME Conference Proceedings*, vol. 2010, pp. 587-593.

[10] K. Ogata, *Modern Control Engineering*, Fourth ed. New Jersey: Prentice Hall, 2002.

[11] N. S.Nise, *Control Systems Engineering*, Fifth Edition ed.: John Wiley & Sons, Inc, 2008.

[12] S. F. G. Graham C.Goodwin, Mario E.Salgado, *Control System Design*, 2000.

[13] A. Draou, A. Miloud, and Y. Miloud, "A variable gains PI speed controller in a simplified scalar mode control induction machine drive ; Design and implementation," in *International Conference on Control Automation and Systems (ICCAS)*, 2010, pp. 2467-2471.

4] H. Moradi, A. Alasty, and F. Bakhtiari-Nejad, "Control of a Nonlinear Boiler-Turbine Unit Using Two Methods: Gain Scheduling and Feedback Linearization," *ASME Conference Proceedings,* vol. 2007, pp. 491-499, 2007.

[15] J. Selvaraj and N. A. Rahim, "Multilevel Inverter For Grid-Connected PV System Employing Digital PI Controller," *Industrial Electronics, IEEE Transactions on,* vol. 56, pp. 149-158, 2009.