Modeling of a single rod double acting pneumatic actuator system

Syamiza Jamian[1,*], Syed Najib Syed Salim[1,4], Muhammad Nizam Kamarudin[1,3], L.Abdullah[2,4], M. A.M.Hanafiah[2,4]

[1)]Center for Robotics and Industrial Automation (CeRIA),
[2)]Advance Manufacturing Centre (AMC)
[3)]Fakulti Kejuruteraan Elektrik,
[4)]Fakulti Teknologi Kejuruteraan Elektrik dan Elektronik,
Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[*]Corresponding e-mail: syamizajamian@gmail.com

Keywords: *pneumatic system*, *system identification, system model*

ABSTRACT – This study presents the modeling of a single rod double acting pneumatic actuator system. System identification approach is used to obtain mathematical model by estimating model using System Identification Toolbox in MATLAB. To acquire the input and output data of the system, the experiment is done then the data is utilized to estimate the model by selecting general transfer function model as a model structure of the system. In this study, the best fit graph of the estimated model is indicated as 86.64%.The comparison with the other linear parametric model such as ARX, ARMAX, and state space structure are performed and evaluated.

1. INTRODUCTION

Pneumatics is an aspect of physics and engineering that use gas or pressurized air to make something move or work. The rapid development of actuators imposes the pneumatic system into a more significant element to be widely used in the robotics and automation industry. A pneumatic actuator proposes a better alternative than electrical and hydraulic actuators in any application because of its low implementation cost. It also provides the benefits of a clean, safer and easier-to-work environment [1].

The mathematical model of the system is obtaining by using system identification. System identification is defined as selection of a model for a process using a limited number of measurements of the input and outputs, which may be disturbed by noise, and a priori system knowledge [2].Based on previous study, there are various structure that can be chosen in the estimation either State Space or linear parametric models such as ARX, ARMAX, BJ and OE. Auto-Regressive Exogeneous (ARX) model is selecting as a model structure of pneumatic actuator system with control valve as previous study [3]. Rahmat et al. [4] used an Auto-Regressive Moving Average with Exogenous (ARMAX) for industrial pneumatic actuator. Next, Syed Najib et al. [5] implemented State Space model in system identification to obtain the transfer function of the pneumatic drive system. In this study, it focused on using general transfer function model to find the transfer function of the plant. This study decides to use third order system because based on previous study, most of researchers used third or fourth order.

2. METHODOLOGY

The pneumatic actuator system that is used in this study is composed of an ENFIELD double acting pneumatic cylinder (model ACTB-200-S01200) driven by a 5/3 direct acting proportional control valve (LS-V15s). Position sensor with output 0-10Vdc and the pressure range is between 0 to 150 PSIG. The interface to connect MATLAB's programs in PC with pneumatic actuator test bed used National Instrument PCI-6221 37-pin card. Figure 1 shows the apparatus set up used in this study.

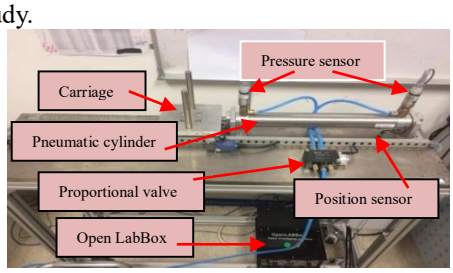

Figure 1 Pneumatic actuator system.

2.1 System model

Model of the system is obtaining by using system identification since the model and parameters of the pneumatic actuator are undefined. The experiment starts with set up the multi sine input into the pneumatic actuator system through SIMULINK to seize the position of the load. The input and output data collected will be stored in a MATLAB workspace. Model estimation and validation part will use that data. 8000 number of data are collected with sampling time 0.01 sec.

2.2 Model estimation

Input signal with multi amplitude and frequency sine wave as shown in equation (1) and illustrated in figure 2.This input is injected to the system then the output recorded.

$$V_{in} = 0.04\cos(2\pi(0.6)t) + 0.5\cos(2\pi(0.08)t) + 0.9\cos(2\pi(0.6)t \quad (1)$$

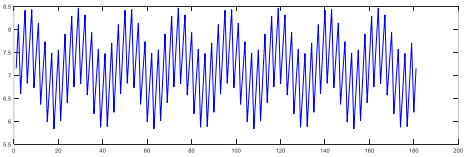

Figure 2 Input signal with multi amplitude and frequencies.

As mentioned in he introduction, this study chooses

general transfer function model as the model structure of the system.The transfer function created represented as follow:

$$Y(s) = G(s)U(s) + E(s) \qquad (2)$$

Where,

$$G(s) = \frac{NUM(s)}{DEN(s)} \qquad (3)$$

G(s) is the desired transfer function relating the input u(t) to the output y(t). Transfer function of this system comes in 3 poles and 2 zeroes with 15ms input-output delay.This study used third order system because based on previous study, most of the researchers used third or fourth order system in their study so it will make the system is easy to cooperate with complex system. The comparison performed with the other model such as ARX, ARMAX, and state space to confirm the validity of the model and it performed in the same plant.

3. RESULT AND DISCUSSION

Figure 3 shows the result of measured and simulation output. General transfer function required selected 2 cycles of the data to get the accurate result. Figure 4 shows the validation data with best-fit graph, which is 86.64%. It means that the estimate model almost track the real output data.

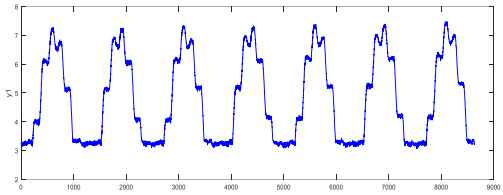

Figure 3 The output data of pneumatic actuator system.

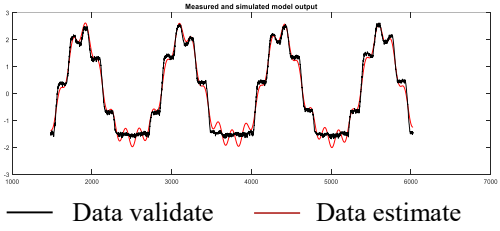

Figure 4 The best-fit graph of the estimated model.

Estimation of the model used system identification Toolbox in MATLAB and the data divided into two parts, which is for model estimation and model validation. General transfer function method selected as a model structure of the system.Table 1 tabulated the result of the parameter obtains from the parameter estimation used in this study based on general transfer function model and the other model. To show the details of the comparison, it showed in Figure 5. Based on the comparison, proposed model give the best result, as the percentage is the highest among others.

Table 1: The comparison percentage of best-fit graph

Model	Percentage (%)
ARX	77.90
ARMAX	75.43
State Space	77.59
General Transfer Function	86.64

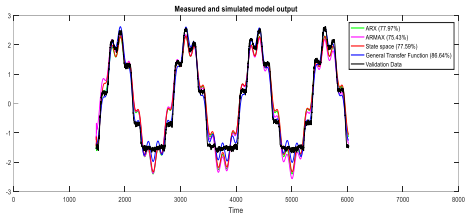

Figure 5 The graph of comparison between others models

Equation (4) indicates the continuous transfer function of the plant in this study.

$$G(s) = \exp(-15 * s) * \frac{0.01284s^2 - 0.000123s + 1.91e^{-6}}{s^3 + 0.002305s^2 + 0.0001027s + 2.297e^{-7}} \qquad (4)$$

4. CONCLUSION

General transfer function model is chose as a model structure to find the transfer function of pneumatic actuator system in this study. The technique successfully applied to the system by using System Identification toolbox in MATLAB software. The comparison with the other methods structure namely state space, ARX and ARMAX performed in this study. The best fit of the general transfer function structure is 86.64%. This indicates that it is better than other structure.

ACKNOWLEDGEMENT

Authors are grateful to the Universiti Teknikal Malaysia Melaka for the financial support through PJP/2017/FTK/HI11/S01535.

REFERENCES

[1] Noor, S. B. M., Ali, H. I., &Marhaban, M. H. (2011).Design of combined robust controller for a pneumatic servo actuator system with uncertainty. *Scientific Research and Essays*, *6*(4), 949-965.

[2] D. E. Rivera, S. Identification, and D. E. Rivera,(2004).Introduction to System Identification, *Time*, no. July, pp. 1–16.

[3] Lai, W. K., Rahmat, M. F., &Wahab, N. A. (2012).Modeling And Controller Design Of Pneumatic Actuator System With Control Valve. *International Journal on Smart Sensing & Intelligent Systems*, *5*(3)..

[4] Rahmat, M. F., Salim, S. N. S., Sunar, N. H., Faudzi, A. M., Ismail, Z. H., & Huda, K. (2012). Identification and non-linear control strategy for industrial pneumatic actuator. *International Journal of Physical Sciences*, *7*(17), 2565-2579..

[5] Salim, S. N. S., Rahmat, M. F., Faudzi, A. A. M., Ismail, Z. H., Sunar, N. H., &Samsudin, S. A. (2014). Robust Control Strategy for Pneumatic Drive System via Enhanced Nonlinear PID Controller. *International Journal of Electrical and Computer Engineering (IJECE)*, *4*(5), 658-667.