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TARX Model for Pneumatic Cylinder and Identification

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***Abstract* - Pneumatic cylinder is nonlinear system with some uncertain parameters. Owing that fact we introduce next assumptions**

a) ***the nonlinear model of the pneumatic cylinder can be approximated with time-varying ARX model (TARX model)***

b) ***owing the influence of the combination of heat coefficient, unknown discharge coefficient and change of temperature, we suppose that parameters of the pneumatic cylinder are random (stochastic parameters)***

c) ***observations have a Gaussian distribution***

Due to the abovementioned reasons, it is assumed that the pneumatic cylinder model is a linear stochastic model with variable parameters. We will use a recursive algorithm with forgetting factor. Such algorithms overcome shortcoming which is inherent to Kalman filter approach. That is a priori knowledge of stochastic disturbance variance and covariance matrix of the parameters noise.

***Key words:* System identification, pneumatic cylinder, stochastic model, time-variant parameters, Gaussian distribution**

I. INTRODUCTION

Since pneumatically driven systems have a lot of distinct characteristics of energy-saving, cleanliness, simple structure and operation, high efficiency and they are suitable for working in a harsh environment, they have been extensively used for many years in robot driven systems and industrial automation [1].

However, the problem with complex nonlinear models, such as the pneumatic servo cylinder, is that it is difficult to choose the large number of physical parameters involved in the model. Although a lot of parameter values are known a priori with reasonable accuracy, a large number of parameters are only known within a certain range, and some are even completely unknown. This may be due to manufacturing tolerances, or due to the fact that manufacturers do not provide parameter values because they consider them as proprietary information.

Furthermore, it is extremely difficult to accurately acquire some system parameters (such as component dimensions, internal leakage coefficients, static and dynamic friction forces, etc.) because the mentioned parameters cannot be directly measured or calculated. This causes a great difficulty in system modelling and control.

The consequence of these problems is that the theoretical model is often not useful for quantitative analysis of the pneumatic servo-system behaviour.

The purpose of this paper is to use the theory and findings of system identification to obtain a mathematical model, so that the controller can be designed on the basis of the model.

Östring et al. [2] identified the behaviour of an industrial robot in order to model its mechanical flexibilities, while Johansson et al. [3] used a state-space model to identify the robot manipulator dynamics. Assuming most parameters in pneumatic servo system do not change during operation, Shih and Tseng [4] performed the identification offline and adjusted servo-control before the operation accordingly. Furthermore, they investigated the impact of different parameters (sampling time, order model, different supply pressures, etc.) in the identification process.

The mentioned references consider the linear models of the pneumatic cylinder which are ad hoc adopted, without considering justification of such an approach. It is necessary to notice the following details:

- The pneumatic cylinder is a nonlinear system (presence of friction force)
- There is a significant influence of the combination of the heat coefficient, unknown discharge coefficient and change of temperature on the behaviour of the pneumatic cylinder [5]. The mentioned influences cannot be easily included in the cylinder model and have random character.

On the other hand, recent research has shown that the nonlinear model of the system can be approximated by a linear system with time-variant parameters [6]. In this paper it is assumed that the nonlinear model of the pneumatic cylinder can be approximated with time-varying ARX model (TARX model). We will use a recursive algorithm with forgetting factor. Such algorithms overcome shortcoming which is inherent to Kalman filter approach. That is a priori knowledge of stochastic disturbance variance and covariance matrix of the parameters noise.

II. MODELLING OF A PNEUMATIC CYLINDER

The system under consideration consists of an electro-pneumatic position control servo drive and a pneumatic cylinder as shown in Fig. 1.

Applying Newton's second law to the forces on the piston, the resulting force equation is