Fractional Order Fuzzy Logic Position and Force Control of Experimental Electro- Hydraulic Servo System

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Abstract- This research demonstrates the design of Fractional Order Fuzzy Proportional Derivative Controller (FOFPDC) and Fuzzy Proportional Derivative Controller (FPDC) for force control for simulation and experimental of electro- hydraulic servo system (EHSS). The parameters of the scaling factor for FLC have been tuned by Modified Adaptive Accelerated Coefficients Particle Swarm Optimization (MAACPSO). The simulation study was created using SIMULINK/ MATLAB package based on the differential equations that describe the dynamic behavior of the industrial hydraulic servo system. The simulation and experimental results present minimum values for performance index in terms of settling time, rise time and percentage overshoot in case of using FOFPDC. Furthermore, the other criteria such as multistep response, sinusoidal response and actuator saturation test demonstrate a good result for applying FOFPDC for force control problems. As a result, the main concern goes to apply the FOFPDC controllers for force control for the studied industrial electro- hydraulic servo system.

Keywords: FOFPDC; MAACPSO; EHSS; Position and Force Control.

I. INTRODUCTION

The hydraulic systems have a wide range of applications in industries. This includes, pressing machines, material testing machines, plastic injection machines, robotics, flight simulator and aircraft landing system. The position and force control purposes will be presented in this paper. The main requirement from the designed controller is to improve the response of the system so that it can give a smaller settling time, overshoot and rise time with no steady state error. To achieve the mentioned requirements, there are two different types of control strategies. The control strategies are FPDC and FOFPDC. In addition, the MAACPS is used as optimization technique to figure out the optimal parameters for tuning the studied control strategies. All the study will be applied on a simulation model then the results will be verified with the experimental system.

The position control problem of a hydraulic servo system using Proportional Integral Derivative (PID) controllers that tuned via some evolutionary techniques such as Particle Swarm Optimization (PSO), Adaptive Weighted PSO (AWPSO) and Genetic Algorithm (GA) is discussed in [1]. A hybrid control strategy for a hydraulic control loading system of electro hydraulic system of a flight simulator is presented in [2]. An effective control strategy for force control problem for a typical electro hydraulic actuator system is demonstrated in [3]. The investigated control scheme in [3] is considered as a combination of a Feed Forward Neural Network - based PID (FNNPID) controller and a Fuzzy Grey Predictor (FGP). The development of a semi-parallel control method that is based on the inversion of identified model of a Magneto Rheological (MR) fluid damper along with a smart predictor controller for the damping system is presented in [4]. The implement of a Predictive Functional Control (PFC) algorithm for position control problem of Electro Hydraulic Actuator (EHA) is given in [5]. In Ref. [6] the modeling and simulation of position control of valve controlled electro hydraulic servo system based on fuzzy-PID controller is described. A new control algorithm for the trajectory control of an electro hydraulic actuator (EHA) based on an iterative Back stepping control scheme is introduced in [7]. In [8], a model predictive trajectory tracking control for hydraulic excavator on digging operation has been presented. In that paper [8], a method for the trajectory tracking control using model predictive control (MPC) which incorporates servo mechanism has been introduced. In [9], a method of control strategy is implemented by employing a fuzzy logic controller (FLC). In addition, its parameters such as scaling factors of the inference system have been optimized using particle swarm optimization (PSO) technique.

II. SYSTEM MODELING

The system model in this paper is implemented based on system identification as described in details in [10]. The identified force models have been built using discrete transfer function with acceptable best fit criteria for force as explained in [10]. The discrete force model is given in the following equations respectively.

$$\frac{F(z)}{U(z)} = \frac{0.188*z^{-1} - 0.28*z^{-2} + 0.014*z^{-3} + 0.263*z^{-4} - 0.184*z^{-5}}{1 - 4.93*z^{-1} + 9.7*z^{-2} - 9.55*z^{-3} + 4.7*z^{-4} - 0.926*z^{-5}} \quad (1)$$

The studied problem is displayed schematically in Fig. 1. It describes the system and presents the connection between the hydraulic components and measuring devices for the experimental EHSS.

II. EXPERIMENTAL TEST RIG

The experimental test rig is mainly containing the following components: test rig hydraulic components such as an axial piston pump, servo valve with electrical position feedback