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Position control of high performance hydrostatic actuation system using a simple adaptive control (SAC) method

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ABSTRACT

This paper deals with the issue of position tracking control of a high performance hydrostatic actuation system using simple adaptive control. For energy-efficiency and savings, a speed-controlled fixed displacement pump is utilized to drive a symmetrical linear actuator instead of a directional control servo valve. The whole control system is composed of a pair of interconnected subsystems, that is, a feedback control system and a feedforward control system to enhance the tracking performance. The experiment using the proposed control scheme has been performed and a significant reduction in position tracking error is achieved compared to a conventional PID control.

1. Introduction

Electro hydrostatic transmissions [1–3] have been the focus of much interest in the fluid power world due to issues associated with energy-efficiency and savings as well as environmental problems arising from CO_2 emission. Variable transmission of power can readily be achieved by directly connecting an input shaft speed-controlled pump to a hydraulic actuator. A directional control servo valve is not required in this scheme and thus the power loss across it can be avoided. Most hydrostatic circuits use a variable displacement pump driven at a fixed shaft speed. The movement of the hydraulic actuator is regulated by moving a swash plate on the pump that changes the magnitude and direction of flow. These circuits can be energy inefficient, as the pump continuously runs irrespective of the motion or dwell period of the actuator. Furthermore, use of variable displacement pumps can result in ripple effects that could degrade high precision motion [2]. The electro hydraulic actuator (henceforth referred to as the EHA) [3,4] examined in this paper uses a fixed displacement pump whose speed and direction is controlled by an AC motor.

Hydraulic servo systems may be required to perform under a variety of operating conditions: therefore robust control performance is important, particularly in motion control applications. When the desired position is time varying, classical feedback control alone is not sufficient to ensure good tracking behavior. Performance can be significantly improved through the use of a feedforward tracking controller [5]. However, parameter variations and/or disturbances may result in mismatches between the real plant and the model used for controller design, which may lead to significant degradation in tracking performance or even instability of the overall system. In such cases, adaptive algorithms have been demonstrated to provide accurate and stable tracking performance [5–7]. In order to effectively adjust the parameters related with an adaptive algorithm, a set of assumptions that form the basis of adaptive control theory are necessary, i.e., linearity of plant model, plant order being known, minimum phase system, and no disturbance condition. Simple adaptive control (hence forth referred to as SAC) is a control methodology based on a two-degree-of-freedom control system, ensuring stability of the overall system through output feedback, while guaranteeing a tracking capability of reference input through feedforward control methods [7,8]. The controller structure of the SAC is simpler than the conventional adaptive control method and also it is known to be excellent in terms of control performance and robustness [9,10].

At the University of Saskatchewan, a high precision position EHA systems has been developed by Habibi et al. [4]. This system employs a velocity feedback inner loop controller around the DC motor and an outer loop position controller which has resulted in positional accuracies of 150 nm. Several control strategies has been applied to achieve this accuracy such as nonlinear gain scheduling [12], and fuzzy controls [13], Studies to investigate tracking performance involved the application of a variable structure filters and sliding mode control [14] and robust discrete-time sliding mode control [15] which yielded reasonable performance. However, it was of interest to consider an adaptive type controller to

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