A practical method for friction identification in hydraulic actuators

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Abstract

Friction in hydraulic actuators can be described using nonlinear, velocity dependent models. In this paper, the friction is described by an exponential Stribeck friction model. An iterative algorithm is presented to identify the friction model parameters. The method fits two lines on the experimental data relating steady-state velocities to actuator pressure differentials. The parameters of the fitted lines are obtained using an iterative optimization technique. Based on the obtained parameters, the original nonlinear friction model parameters are completely reconstructed. The proposed method is validated by building a simulation model for a valve-controlled hydraulic system in which the friction is modeled based on the method described here. The proposed method can be used in practical situations, whereby fast and reliable identification of major parameters of the friction in hydraulic actuators is needed with easy to obtained pressure measurements.

1. Introduction

In high precision positioning systems, friction cannot be ignored during controller design [8] as it have a negative influence on control performances. Friction can generate undesired effects such as limit cycle, steady-state error or tracking lag. Modeling friction and identification of its parameters is the first step towards effective friction compensation in mechanical control systems. Hydraulic actuators are widely used in many industrial systems including off-highway machines (excavators) and underwater manipulators. In a hydraulic actuator the piston does not move until the tangential force between the piston seal and the cylinder reaches the level of static friction (phenomenon of sticking). Once the motion starts, the friction force changes with velocity. Tribological experiments have showed that in the case of lubricated contacts in the low velocity regime, the friction force decreases with velocity (Stribeck effect). During the high velocity regime, the friction force increases with velocity (viscous effect). Both static and single- and multi-state dynamic models [2,4,12,1] have been introduced to describe friction phenomenon. Dynamic friction models can also explain friction induced phenomena that occurs in the case of very small displacements, such as the presliding displacement and friction lag.

To deal with friction in hydraulic actuators various identification and compensation algorithms have been proposed. Zweiri et al. [24] described how the Coulomb and viscous friction coefficients could be identified in a hydraulically-driven excavator using Least Squares and generalized Newton methods. An on-line Coulomb friction observer, combined with velocity observer was proposed in [20]. A technique for simultaneous estimation of Coulomb friction, velocity, and acceleration for tracking control of electrohydraulic manipulators was suggested in [21]. Bonchis et al. [7] proposed an identification method for viscous and Coulomb friction parameters in hydraulic cylinders based on pressure measurement. However, in their work no systematic method was proposed as to how the values of stick friction and Stribeck velocity can be obtained. A friction identification method was introduced in [25] for a parallel hydraulically-driven robot based on a simplified form of the Stribeck model. An evolutionary algorithm was applied in [23] to identify the parameters of a hydraulic servo with flexible load.

Control algorithms that incorporate friction compensation were also developed by many researchers. In [18] a Lyapunov-based discontinuous friction compensation technique was proposed for position regulation of a hydraulic actuator. In [13] the LuGre friction model was used to compensate for the effect of friction in a hydraulic manipulator. In [22] a sliding mode controller was proposed for positioning of hydraulic actuators with significant friction. The paper by Knohl and Unbehauen [11] presented an adaptive compensation method for friction induced dead zone using neural networks. Neural networks were also employed to identify faults due to increased friction [14]. Garagic and Srinivasan [9] developed a fuzzy system based controller to deal with nonlinearities in hydraulic actuators including friction.

The aim of the current work is to provide practitioners with a simple, yet effective identification algorithm to determine the