year	month	day
2011	08	25

Mechanical and Structural Systems Engineering	ID	089102	Advisor	Hideki Yanada Naoki Uchiyama
Name	Tran Xuan Bo			

Abstract

Title	Dynamic Friction Behaviors of Fluid Power Actuators and Their Mathematical Model

(800 words)

Friction plays an important role in many mechanical systems, including fluid power actuator systems. Friction may lead to tracking errors, limit cycles, undesired stick-slip motion and poor performance. In order to predict the behaviors of a fluid power actuator system or to improve its control performance, it is necessary to have a full understanding of the behaviors of friction of the fluid power actuator and to find an its suitable mathematical friction model. These tasks are by no means simple ones since no universal friction model exists, and on other hand, the practical measurement of friction of fluid power actuators is not straightforward. The aim of this research is to investigate experimentally the dynamic friction behaviors of fluid power actuator and to develop a new dynamic friction model suitable for fluid power actuators.

Three experimental test setups are proposed in this research to investigate the dynamic behaviors of friction of fluid power actuators. The first test setup is for investigating the dynamic friction behaviors of a hydraulic cylinder under the effects of viscosity and type of oil. Five different types of oil are used. The effect of type of oil is examined by using four different types of oil at the same viscosity of 35mPa·s, which is realized by adjusting temperature, and the effect of viscosity is examined by changing temperature of one type of oil and by using three types of oil which have different viscosity grades at the same temperature of 34°C. The second test setup is for investigating the effects of the pressures in the cylinder chambers and the properties of the packing material on the dynamic friction behaviors of hydraulic cylinders. Four hydraulic cylinders with different packing materials and sizes are used. The effects of the pressures are examined using the four hydraulic cylinders by changing the load mass and the effect of the packing material is examined by using the three hydraulic cylinders with the same model but different packing materials. The third test setup is for investigating the dynamic friction behaviors of pneumatic cylinders under various operating conditions of velocity and pressure variations. In this test setup, the test cylinder is driven by a hydraulic cylinder system in order to control accurately the velocity of the test cylinder. Pressures in the cylinder chambers are controlled by using two proportional pressure control valves. Three pneumatic cylinders with different operating characteristics of velocity and pressures are used for the test. In all the test setups, the friction force of the hydraulic or pneumatic cylinders is measured based on the equation of motion of their pistons using measured values of the pressures in the cylinder chambers, the acceleration of the piston, the weight of the load mass and the applied force.

A new mathematical model of friction for fluid power actuators is developed based on the modified LuGre

model by taking the dynamics of fluid friction into account, which can be expressed by replacing the usual fluid friction term with a first-order lead dynamics. The effects of viscosity of oil and external load (pressures in cylinder chambers) are also taken into account in the new friction model. In addition, an identification method for the parameters of the new friction model is proposed.

The experimental results have shown that: i) the hysteresis behavior of the friction force-velocity curve of hydraulic cylinders is affected to some degree by the type of oil and is hardly affected by the viscosity; ii) the hysteresis behavior of the friction force-velocity curve of hydraulic cylinders is affected by the packing material; iii) the size of the hysteresis loop of the friction force-velocity curve of hydraulic cylinders is increased with increasing external load (or at large values of p_1 and/or at large pressure differences between the two chambers); iv) the size of the hysteresis loop of the friction force-velocity curve of hydraulic/pneumatic cylinders is increased with increasing the frequency of velocity variation; v) the size of the hysteresis loop of the friction force-velocity curve of pneumatic cylinders is increased with the driving pressure and is decreased with the resistance pressure.

The new dynamic friction model has been validated based on the friction characteristics obtained experimentally for different types of fluid power actuators and under various operating conditions of velocity, pressures, viscosity of oil and external load. It has been demonstrated that the model can accurately simulate almost all the friction behaviors obtained experimentally for fluid power actuators. It is believed that the new dynamic friction model can be predicted the friction behaviors observed in many types of contact surfaces and can be applied to improve the simulation accuracy of the motions of fluid power actuators and to develop control strategies of these systems.