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Modeling and adaptive control of magneto-rheological buffer system for aircraft landing gear

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ABSTRACT

The main advantages of magneto-rheological buffer system for aircraft landing gear are adjustable damping force, simple structure and independent of external energy. A kind of magneto-rheological damper structure for aircraft landing gear was presented in this paper. The state equation was established and the landing buffer system control strategy was designed based on self-made magneto-rheological landing impact platform. Integrating with model predictive control, a semi-active control method was studied and used it in realizing the adaptive magneto-rheological buffer system landing process. It has been proved in practice that the proposed control method fully considered the boundless of output damping force. The problem of balancing between landing and taxiing, which is caused by un-adjustable passive damping force in the working process of oleo-pneumatic buffer system, is solved.

1. Introduction

The passive oleo-pneumatic buffer has been mainly used in airplane landing gear buffer system at present. It has advantages such as simple structure, high reliability, and so on. But some important parameters like damping force cannot be adjusted in the process of landing and taxiing, which would lead to passive response to the ground impact. Because that the design of Oleo-pneumatic Orifice for the impact process of aircraft landing will arise "too hard" phenomenon during taxiing, and on the contrary, the design of Oleo-pneumatic Orifice for the shock process of aircraft taxing will be "too soft" during landing, the passive landing buffer system is difficult to balance the impact force between landing and taxiing. However, the active control landing gear needs an external larger power source. In recent years, the newly magneto-rheological fluid (MRF) has been developed, which can control the damping force with the change of coil current adjusted by the magnetic field intensity. This provides a new solution for the impact load buffering device.

MRF is a kind of functional materials, invented and developed by Rabinow [1] who worked in National Bureau of Standards of the United States. Magneto-rheological fluid is mainly composed of the non-conductor magnetic fluid and the tiny particles dispersed uniformly with low hysteresis and high permeability. Under the effect of magnetic field, MRF can be rapidly and reversibly changed from the Newtonian fluidity liquid to Bingham plastic solid in milliseconds, which is high viscosity and low fluidity [1,2].

Magneto-rheological Impact absorption of the helicopter undercarriage can be seen as a typical application in the anti-impact load. Werely [3] uses the composite material made of rubber and magnetic-rheological fluid as the damping medium

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of helicopter undercarriage. The results show that the damper under magnetic field can provide continuous and controllable damping force. Meanwhile, it can overcome the damping amplitude loss which is caused by single frequency excitation.

Batterbee et al. proposed a novel solution to this problem, that is to implement semi-active damping using MRF. They enabled the geometry of a flow mode magneto-rheological valve to be optimized with the constraints of an existing passive landing gear [4].

Choi and Wereley theoretically evaluated the electrorheological and magnetorheological fluid based landing gear system during touchdown of the aircraft. The feasibility and effectiveness of the response on attenuating dynamic load and vibration due to the landing impact were demonstrated [5].

Andrzej and Mikolaj presented investigation results of a semi-active industrial shock absorber with MRF, which is capable of controlling the stopping process of moving objects. The proposed solution makes it possible to adjust the braking force according to the kinetic energy of moving object [6].

Magneto-rheological damper was applied in soft recoil gun by Ahmadian et al. also the shooting range test was carried out and satisfactory results were obtained [7–9]. Studies have been a useful reference in the application of impact buffer control.

Magneto-rheological intelligent buffer damper based on semi-active control technology can make up for the shortcomings of passive buffer damper effectively. It greatly improves the dynamic performance of traditional oleo-pneumatic buffer and provides high reliability. Compared to the active control, semi-active control buffer has advantages like low cost, simple structure, no need of large power source. But at present, the research around buffer technology is mainly at the stage of theoretical research. In this paper, according to the characteristics of impact load, we propose a control strategy and control algorithm, it could adaptively track ideal buffer force and velocity of impact load with magneto-rheological intelligent buffer damper in the self-made impact test platform.

2. Structure and mechanical model

2.1. Magneto-rheological buffer

The variable-structure oil holes of traditional oleo-pneumatic buffer were designed as constant geometries shown in Fig. 1. The damping force of the flowing oleo is controlled by the intensity of applied magnetic field, which is controlled by the impressed current. The gas chamber filled with nitrogen, which is mainly used to provide the need of transformable displacement when impact condition. The filling amount and the initial pressure are determined by the change of displacement and the initial position of piston rod.

2.2. Characteristics and parameter identification

Accurate damper model is the foundation for designing control strategy and obtaining good control effect. Because that it is extremely complex and difficult to analyze the damping characteristics based on rheological theory for magneto-rheological

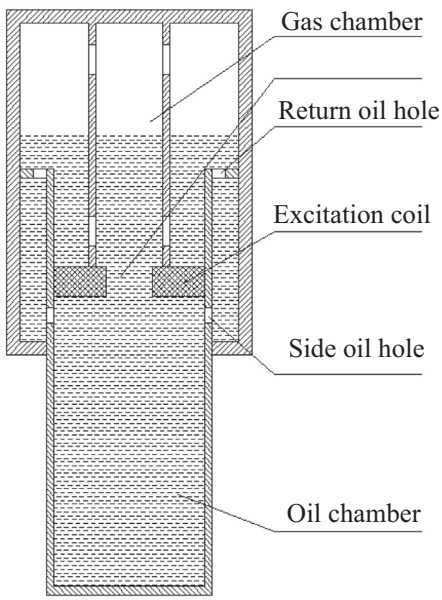

Fig. 1. Magneto-rheological intelligent buffer structure for impact.