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Torque Enhancement for a New Magnetorheological Brake

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Abstract

The conventional magnetorheological fluid (MR) brake has been used as resistant sources for specific applications. However, the limited torque prevents it to be widely commercialized. This paper presents a new MR brake that improves the brake torque by enlarging the magnetic field strength. The unique structure is formed by multiple electromagnetic poles surrounded by several coils. Various input power supplies and geometrical dimensions have been offered. The effects of brake structure and input power for torque enhancement were investigated. The design with maximized torque based on optimal input power has been found using Sequential Nonlinear Programming (SLNP) optimizer. The operation concept of the new MR brake was confirmed by the magnetic simulation results. It concluded that the brake archives high braking torque, which promises for future applications.

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Keywords: Magnetorheological Fluid; MR Brake; Torque Enhancement.

1. Introduction

Conventional MR brake has been developed for years. The brake is equipped by a single magnetic pole structure originally [1-4]. The disadvantages of this structure are limitation for active MR fluid area and the non-flexibility in enhancement of applied magnetic field. Active MR fluid is the fluid placed under applied field and its yield stress can be controlled by varying the field strength. As shown in Figure 1, the active MR fluid area of conventional designs are limited by the geometrical constrain. For disc type, the area is limited by

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the dimension C as figure 1(a). For the drum type, it is limited by the dimension A as figure 1(b). Moreover, as the dependence of field torque to magnetic field strength [5], it is difficult to enhance the field strength by increasing the turn of coil. Because the coil size is restricted by dimensions A and B for both structures.

This study proposes a new operation concept of MR brake which solves those two issues. Concept and mathematical model of the new MR brake were discussed. Torque enhancement for the new MR brake was investigated by multiple aspects such as material, geometrical dimension and input power.

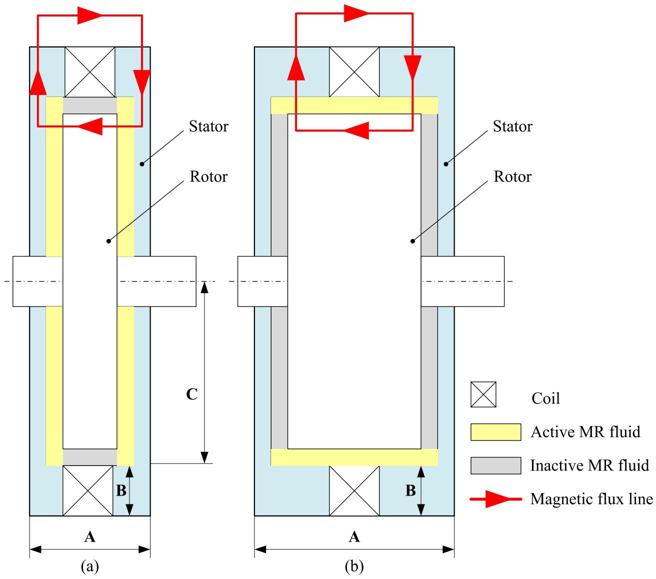

Fig. 1. Structure of conventional MR brake: (a) Disc type and (b) Drum type

2. Theory and mathematical model

The new MR brake consists of a solid and magnetically permeable stator with multiple poles. The rotor is placed outside while its poles surround the inner rotor as in figure 2. The magnetic flux travels following the path of red lines and the direction of magnetic flux in each pole is opposite to that of its two adjacent magnetic poles. By that distribution, the flux will travel in a closed loop: from one pole, through the MR fluid gap, to the rotor, back to the MR gap and into the two adjacent poles. As a result, all MR fluid in the channel between the cylindrical surface of the rotor and the stator will be orthogonally penetrated by magnetic flux. It produces yield resistance in the fluid, thus creating field torque for the brake. In this study, the performance of those two types MR brakes with 6 poles have been analyzed and verified.

To described the shield characteristic of MR fluid, Bingham-Plastic model has been used in this study [6]. According to the model, total shear stress in MR fluid under applied magnetic field is given by

$$\tau = \tau_y + \eta\dot{\gamma} \tag{1}$$

where τ is the total shear stress, τ_y is the yield stress developed in response to the applied magnetic field, η is the viscosity of the MR fluid with no applied magnetic field. The shear rate of the MR $\dot{\gamma}$ brake behaves like direct shear mode [7]: