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PROSTHESIS AND ORTHOSIS REALIZED WITH SMART FLUID DEVICES

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Abstract
The applications of smart fluids, with controllable rheological properties can be extended in the field of the medical engineering. In the paper, there are exemplified some possibilities of applications in prosthetics and orthotics, in order to realize some new types of prosthesis and orthosis [1]. Among the advantages of utilizing the smart fluid devices can be mentioned: an easy and accurate control; an improving of mobility, making the climbing up and down stairs and inclining much easier, an increasing of gait balance, stability and energy efficiency; a fraction of the cost of other motor-controlled, active damper systems.
Keywords: prosthesis, orthosis, smart fluid.

1. Magnetorheological Fluid Devices

Magnetorheological fluids (MRF) belong to the class of controllable fluids. The essential characteristic of MRF is their ability to reversibly change from free-flowing, linear viscous liquids to semi-solids having controllable yield strength in milliseconds when exposed to a magnetic field. This feature provides simple, quiet, rapid response interfaces between electronic controls and mechanical systems.

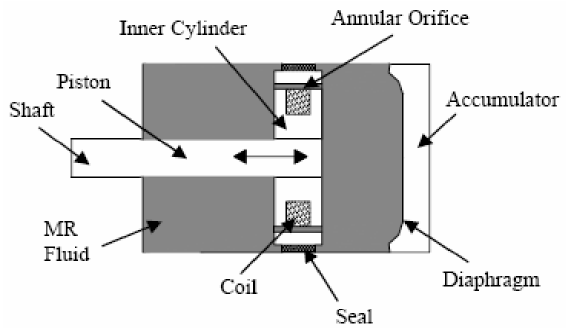


Fig. 1 Schematic of RD-1500 [2]

The most utilized model of semi-active MRF damper is RD-1005-03, produced by LORD RHEONETIC (figure 1). It is a compact magneto-rheological fluid damper unsurpassed in its combination of controllability, responsiveness and energy density. As a magnetic field is applied to LORD MR fluid inside the monotube housing, the damping characteristics of the damper can be controlled with very high precision and the response time is order of 10-millisecond. Featuring straightforward controls, simple design, and quiet operation, the MR damper was designed for seat suspensions, but can be adapted to a wide variety of applications [2].

Another device, frequently used to orthosis and prostheses, is presented in figure 3.

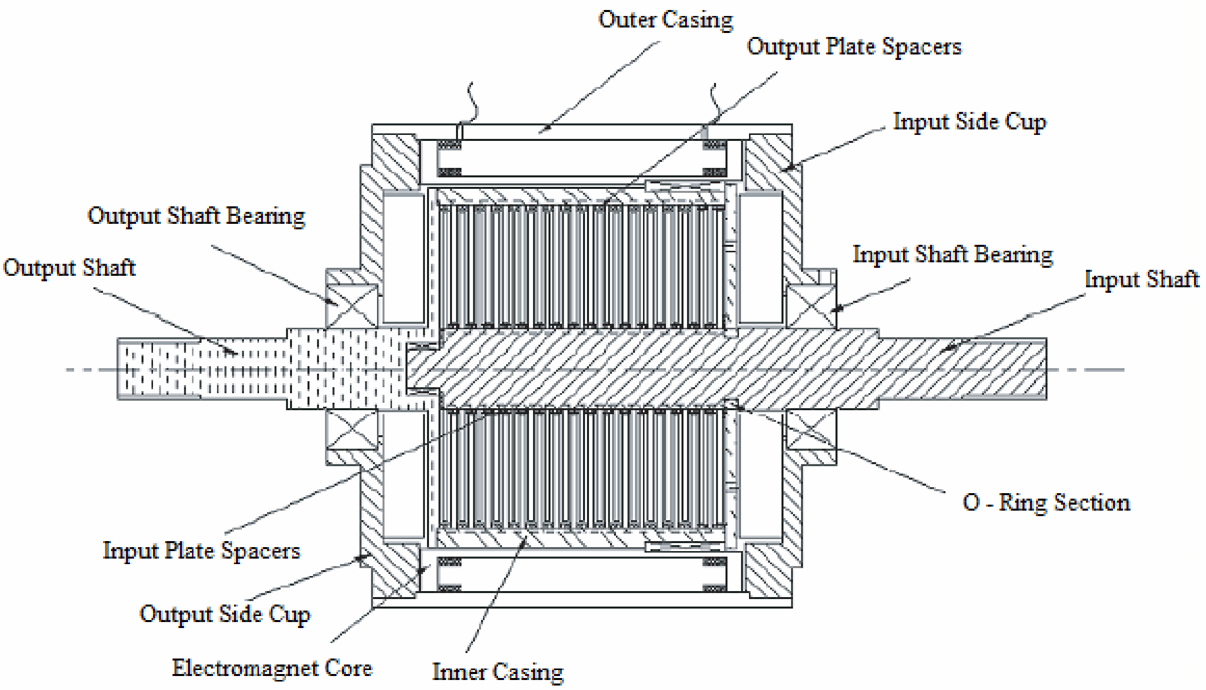


Fig. 2. Cross-sectional view of multi-plate MR fluid LSD clutch.

2 Electrorheological Fluid Devices

Electrorheological fluid (ERF) based dampers have smart capabilities because ERF undergo large changes in yield stress as electric field is applied [3].

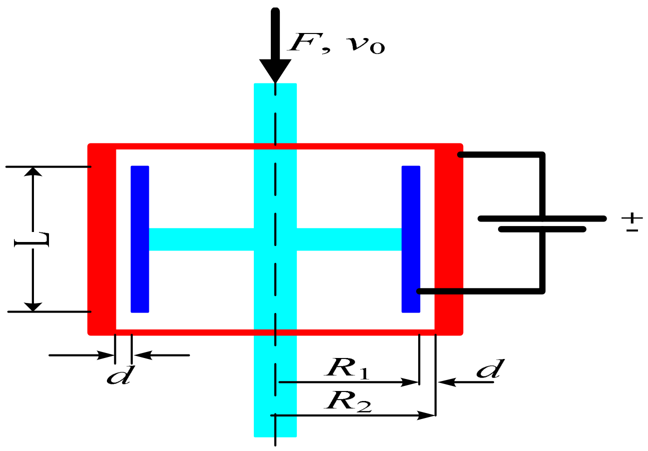


Fig. 3. Flow mode ERF damper.

The inner and outer electrodes are stationary, and the piston head travels relative to the electrodes

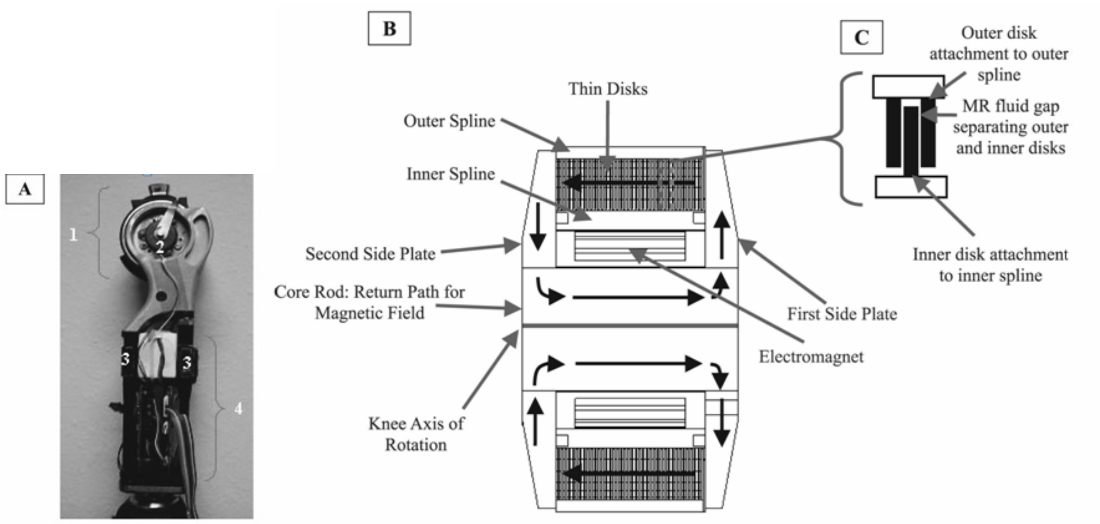
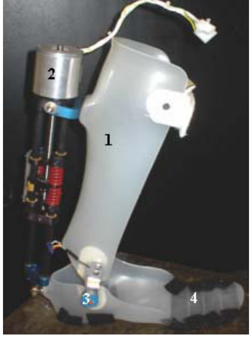


Fig. 4 [4]

The prosthesis comprises MR brake (1), potentiometer angle sensor (2), force strain gage sensors (3), and battery and electronic board (4). Current passing through an electromagnet generates a magnetic field that passes through a magnetic core rod, radially outwards through a first side plate, laterally through an interspersed set of thin metal disks, and then radially inwards through a second side plate. The thin disks comprise inner and outer disks where each inner disk is positioned between two outer disk pairs. When the knee rotates, each inner disk moves relative to each outer disk pair. As is shown in Figure 4.C. between each inner and outer disk is a thin film of MR fluid (fluid gap - 20 microns). As the magnetic field strength increases, micron-sized iron particles within the MR fluid (30% iron loading) form torque-producing chains connecting adjacent disk surfaces. Thus, by controlling electromagnet current, knee damping is controlled.

3. Prosthesis and Orthoses with MRF and ERF



This device is designed to treat drop-foot, a gait pathology resulting from stroke, cerebral palsy, multiple sclerosis, or trauma. Using the actuator, the stiffness of the ankle joint is modulated from step to step to control the movement of the foot during controlled plantarflexion. The ankle-foot orthoses (1) comprises a series-elastic actuator (2), potentiometer angle sensor (3), and capacitive force sensors (4) [5].

Fig. 5. An actuated ankle-foot orthoses.

Fig. 6. Rheo knee and Ceterus foot

The Rheo knee and ceterus foot represents the most success full prosthesis for the inferior member, realized with smart fluid.

By using the technology of advanced magnetorheological (MR) initiator and a dynamic study algorithm, the Rheo knee automatically teaches the motions of user and rapidly adjusts the oscillation resistance and the press on the ground, for a cadence and optimally stable response, during the walking. The MR initiator assures an important diminishing of resistance in order to permit the initiation without effort of the flexion of knee and to normalize the pelvis position during the pre-oscillation phase.

3. Conclusions

ERF and MRF based technology represent a major progress in the motion control for different types of prosthesis and orthoses.

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