Magnetorheological Fluids or Electrorheological Fluids: Applications to Occupational and/or Rehabilitation Exoskeletons

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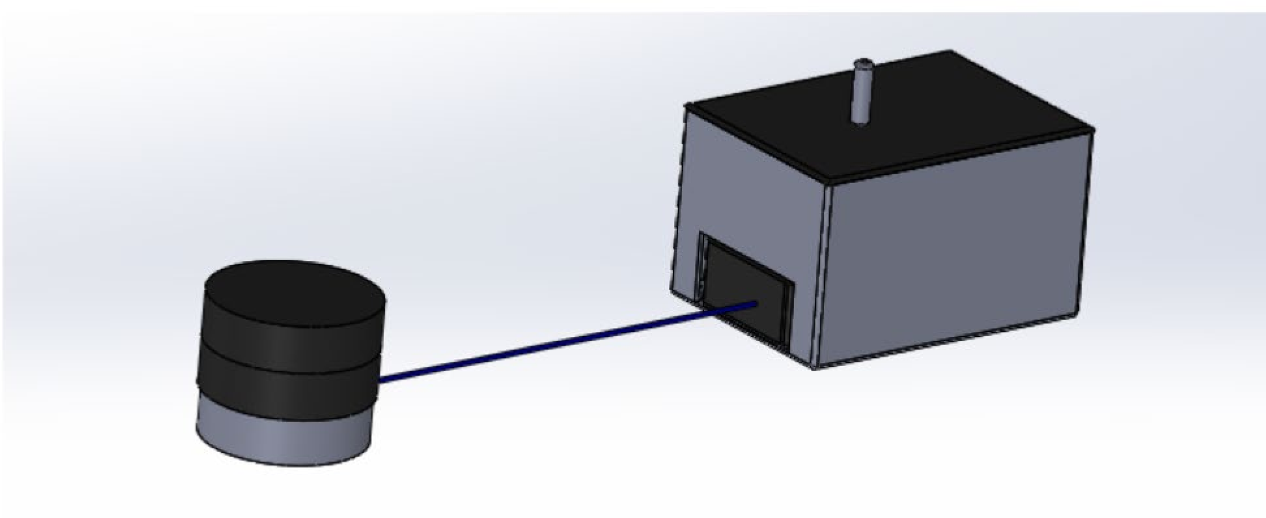
Abstract

The leading cause of injury in the manual labor force is overexhaustion and the use of exoskeletons has been an effective solution to this problem. Wearable exoskeleton technology has increased rapidly in technology and with that comes an increase in potential uses and popularity. One area that has been lacking in this technology is the ability to have an easily adjustable exoskeleton joint. Exoskeletons are also looked at as a replacement to weights for rehabilitation for stroke victims who lose function to most of their body. The application of a rheological fluid and its ability to change viscosity with a change in voltage is used as an effective solution especially for rehabilitation where very fine adjustments to resistance are needed. Rheological fluids have been used in an increasing amount over recent years. With no commercially available rotational MR fluid dampers on the market, development of a joint was necessary.

Introduction

Injuries often occur to employees who spend a lot of time doing physical activities such as lifting, pulling, pushing, holding, and carrying. Over time, these activities being performed repeatedly lead to stress on muscles and joints which can cause overexertion injuries. Wearable exoskeleton technology can be improved and optimized for these purposes by implementing dampers in the joints using magnetorheological (MR) or electrorheological (ER) fluids. These fluids are unique because applying a magnetic or electric field changes their apparent viscosity. These fluids can be finely adjusted based on the power of the electromagnet being used to activate the fluid.



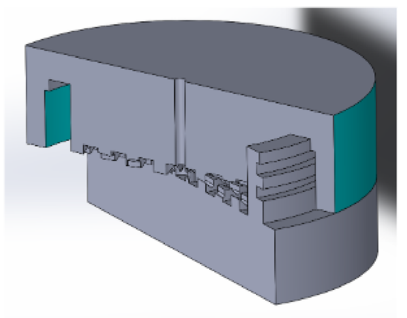
Methods and Materials

MECHANICAL HOUSING

Fluid:

The use of Magnetorheological Fluid within the joint is to control the amount of rotational resistance that can be applied by the fluid. The fluid contains three main components: oil, metallic particles and a binding agent (used to keep the combination of oil and metallic particles as an evenly mixed fluid). The fluid changes viscosity based on the strength of the magnetic field applied. The change in viscosity happens because the metallic particles within the fluid follow the magnetic field lines when the magnetic field is applied.

Housing:



The housing addresses the challenge of damping rotational motion. To do so, it was designed in the shape of a large hockey puck - as to easily be attached to an exoskeleton at the elbow or knee joints. This design is revolutionary as the predecessors of this damper have been designed as piston-cylinders

VARIABLE POWER SUPPLY

Electromagnet:

The magnet used to apply the required magnetic field to the MR fluid is a 24 VDC round solenoid electromagnet. This magnet was chosen because its magnetic field is strong enough when rated voltage is applied and the size and shape allow it to easily be placed directly into the center of the joint. When the fluid is placed in the magnetic field at 24 VDC, the viscosity is changed to its maximum. When the supplied power to the electromagnet is decreased, the field strength decreases proportionally. When the field is applied to the fluid and the field is varied, the viscosity of the fluid also varies proportionally with the strength of the field and the power supplied to the magnet.

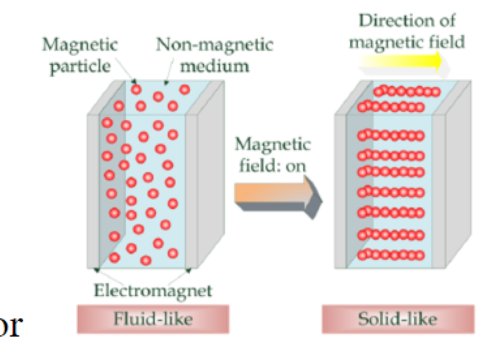
Potentiometer & Power Supply:

The power supply will supply a constant 24 VDC output. Using the potentiometer in series with the electromagnet allows for variation of the supplied current to the electromagnet between 0.63 and 1.33 amps. This range allows for maximum variation of the viscosity of the fluid.

The battery will not be integrated directly into the joint system but will be wired to the joint and mounted separately in a box along with the on/off switch and the dial for user resistance control.

Discussion/Results

By applying a rated voltage to the electromagnet, a field is produced prompting the magnetic particles to align with one another. With the use of the potentiometer, the strength of the alignment (viscosity) is controlled - allowing the perceived resistance of the joint to also be controlled. The change in fluid viscosity is proportional to the force required to move the surface along the fluid layer. Having a fluid with an adjustable viscosity allows for a constant surface area at the fluid level. Thus the changing viscosity alone will change the drag force caused by the fluid.



Conclusions

The MR fluid exoskeleton joint utilizes magnetorheological fluid in a previously underexplored way. The MR fluid will be used to provide variable resistance to an exo joint, providing assistance in occupation lifting and resistance for rehabilitation purposes. The joint housing the MR fluid is 3D-printed and designed to maximize the fluid's variable-viscosity properties to provide the best increase in resistance possible. The user will have complete control over the resistance of the joint given a simple switch and control dial which allows them to turn the resistance off at any time or vary it however they want from no added resistance to maximum.

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