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## Development of 2-DOF haptic devices working with magnetorheological fluids

Bin Liu  
*University of Wollongong*

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# **Development of 2-DOF Haptic Devices Working with Magnetorheological Fluids**

A thesis submitted in fulfilment of the requirements  
for the award of the degree of

**Master of Engineering – Research**

by

**Bin Liu**

**B.Eng., Harbin Engineering University, China, 2003**

from

**Faculty of Engineering, University of Wollongong**

**February 2006**

Wollongong, New South Wales, Australia

## **CERTIFICATION**

I, Bin Liu, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Master of Engineering – research, in the School of Mechanical, Materials and Mechatronic, Faculty of Engineering, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Bin Liu

5<sup>th</sup> March 2006

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*To my parents and all the people I love*

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## LIST OF SYMBOLS

$\tau$	shear stress of the MR fluids
$\tau_y$	yield stress of the MR fluids
B	magnetic induction intensity
H	intensity of magnetic field
$\dot{\gamma}$	shear strain rate
$\eta_0$	field-independent plastic viscosity of MR fluids
$\eta_{app}$	apparent viscosity of MR fluids
K	consistency index in apparent viscosity model of MR fluids
F	shear force in the shear mode
$F\eta$	shear force without applied magnetic field in the shear mode
$F\tau$	shear force related to applied magnetic field in the shear mode
A	area of the working surface
L	length of the working surface
W	width of the working surface
g	gap between the two working surfaces
$\Delta P$	pressure drop in the flow mode
$\Delta P_\eta$	pressure drop without applied magnetic field in the flow mode
$\Delta P_\tau$	pressure drop related to applied magnetic field in the flow mode
Q	volumetric flow rate in the flow mode
c	function of the flow velocity
$\omega$	angular velocity of the rotary disc
h	MR fluid gap in the disc-shaped actuator

$r$	position on the rotary disc surface
$r_{inner}$	inner radius of the rotary disc
$r_{outer}$	outer radius of the rotary disc
$T$	resistant torque
$N$	number of the turns of the coil
$I$	current in the coil
$H_f$	magnetic intensity in the MR fluid gap
$H_s$	magnetic intensity in the steel
$L_g$	width of the MR fluid gap
$L_s$	length of the steel path
$\mu_o$	permeability of free space
$\mu_r$	relative permeability of MR fluids
$\Phi$	value of magnetic flux
$Da$	radius of MR actuator
$Dc$	thickness of the casing
$Dd$	thickness of the disc
$Df$	thickness of MR fluids gap
$Dp$	thickness of the plate
$T_0$	initial resistant torque in the sub-hysteresis model
$I_s$	constant electric current difference in the sub-hysteresis model
$S_1, S_2$	two constant slopes of $T$ in the sub-hysteresis model
$I_t, I_b$	two vertexes of sub-hysteresis loop
$\theta$	degree of the longitude of the spherical coordinates
$\phi$	degree of the latitude of the spherical coordinates



$\alpha_x, \alpha_y$	rotation degree of the two MR actuators
$M_\varphi$	resistant torque along latitude direction of the spherical coordinates
$M_\theta$	resistant torque along longitude direction of the spherical coordinates
$M_x$	resistant torque along X direction of the rectangular coordinates
$M_y$	resistant torque along Y direction of the rectangular coordinates
R	value of the resistance
C	value of the capacitance
$f_c$	cut-off frequency of the filter
$U_i$	input voltage
$U_o$	output voltage
T1, T2, T3, T4	transistors

## ABSTRACT

The thesis presents the design and development of a 2-DOF (degree of freedom) magnetorheological (MR) fluid based haptic joystick and studies its applications in virtual reality. MR fluids are controllable fluids that can generate adaptable resistance forces when subjected to a magnetic field. This feature is capable of realizing novel haptic devices.

The developed system consists of three main parts: MR joystick, control and display hardware, and software. The MR joystick is constructed of two disc-shaped MR actuators positioned perpendicularly with a gimbal structure, which transfers the movement of the joystick handle into two actuator rotary movements. Therefore, operators can feel the resisting force generated by the two actuators. The dimensions of the actuators have been optimized using finite element analysis, and the steady-state performance of the actuators has been measured and analyzed. The kinetics of the joystick in terms of working space and resistance will be discussed. In the thesis, a subhysteresis model and a torque converting method will be employed to enhance the accuracy of the force control.

The applications of the MR joystick in virtual reality will be demonstrated by using six typical interface examples designed in LabVIEW. These demonstrations show that the MR haptic devices have a huge application potential in entertainment, medical, and general industry fields.