MAGNETIC FIELD SIMULATION OF PINCH MODE MAGNETORHEOLOGICAL FLUID VALVE

MOHD ZUL ASRI BIN MOHD RAMLI

BACHELOR OF MECHATRONICS ENGINEERING

UNIVERSITI MALAYSIA PAHANG

MAGNETIC FIELD SIMULATION OF PINCH MODE MAGNETORHEOLOGICAL FLUID VALVE

MOHD ZUL ASRI BIN MOHD RAMLI

Report submitted in partial fulfilment of the requirements

for the award of the degree of

Bachelor of Engineering in Mechatronics Engineering

Faculty of Manufacturing Engineering

UNIVERSITI MALAYSIA PAHANG

June 2016

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name	:	MOHD ZUL ASRI BIN MOHD RAMLI
Identification Card No	:	930601-05-5121
Title	:	MAGNETIC FIELD SIMULATION OF PINCH MODE MAGNETORHEOLOGICAL FLUID VALVE
Academic Session	:	SEMESTER 2 2015/2016

I declare that this thesis is classified as:

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
☐	**OPEN ACCESS**	I agree that my thesis to be published as online open access (Full text)

I acknowledge that Universiti Malaysia Pahang reserve the right as follows:

1. The Thesis is the Property of University Malaysia Pahang.
2. The Library of University Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

____________________________ ____________________________

(Author's Signature) (Supervisor's Signature)

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering in Mechatronics.

Signature :

Name of supervisor : DR. IZWAN BIN ISMAIL

Position : SENIOR LECTURER

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotation and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :

Name : MOHD ZUL ASRI BIN MOHD RAMLI

ID Number : FB12011

Date :

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

CHAPTER 2 LITERATURE REVIEW

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

B	Magnetic Flux Density
H	Magnetic Field Intensity
τ	Shear Stress
τ_y	Field-Dependent Stress
γ	Fluid Shear Rate
η	Dynamic Viscosity
Φ	Magnetic Flux

LIST OF ABBREVIATIONS

AWG	American Wire Gauge
DC	Direct Current
ERF	Electro-rheological Fluid
FEMM	Finite Element Method Magnetics
MGP	Magnetic Gradient Pinch
MRF	Magneto-rheological Fluid

MAGNETIC FIELD SIMULATION OF PINCH MODE MAGNETORHEOLOGICAL FLUID VALVE

MOHD ZUL ASRI BIN MOHD RAMLI

Report submitted in partial fulfilment of the requirements

for the award of the degree of

Bachelor of Engineering in Mechatronics Engineering

Faculty of Manufacturing Engineering

UNIVERSITI MALAYSIA PAHANG

June 2016

ABSTRACT

This thesis presents the magnetic field simulation of magnetorheological fluid using finite element method. Magnetorheological fluid (MRF) is a smart material fluid carrying small magnetic particles. There are four operational mode of MRF that is squeeze mode, valve mode, shear mode and pinch mode. This thesis will focus on pinch mode which is named as magnetic gradient pinch mode (MGP). The objective of this thesis is to develop a design concept of a magnetic gradient pinch mode valve. It is very important to develop a concept design because it can help in finding the possible design configuration in producing a magnetic gradient pinch shape inside the valve from the reaction of the electromagnetic. From the concept design, simulation was conducted using Finite Element Method Magnetics (FEMM) software to get the magnetic flux density, B and magnetic field intensity, H produced by MGP valve. By getting the magnetic flux density from the finite element analysis, magnetic saturation was prevented in the valve. Magnetic saturation happened when the magnetic flux density at the valve gap is more than the maximum magnetic flux density of the MRF at 0.78 T. Magnetic field intensity, H, determine the generated maximum yield stress. One of the proposed design which is the third design, was exhibit highest magnetic flux density, B than other two design. Therefore, the thrird design is suitable for MGP valve due to abality to produce highest yield stress, thus, can withstand higher pressure when applied.

ABSTRAK

Tesis ini membentangkan simulasi Medan Magnet Cecair Magnetorheological menggunakan kaedah unsur terhingga. cecair Magnetorheological (MRF) adalah bahan cecair pintar membawa zarah magnet kecil. Terdapat empat mod operasi MRF iaitu mod memerah, mod injap, mod ricih dan mod secubit. Tesis ini akan memberi tumpuan kepada mod secubit yang dinamakan sebagai Mod Secubit Kecerunan Magnet (MGP). Objektif projek ini adalah untuk membangunkan satu konsep reka bentuk kecerunan magnet injap mod secubit. Ia adalah sangat penting untuk membangunkan reka bentuk konsep kerana ia boleh membantu dalam mencari konfigurasi reka bentuk yang mungkin dalam menghasilkan bentuk kecerunan secubit magnet di dalam injap dari reaksi elektromagnet. Dari reka bentuk konsep, simulasi dijalankan dengan menggunakan perisian Kaedah Unsur Terhingga Magnetics (FEMM) untuk mendapatkan ketumpatan fluks magnet, B dan keamatan medan magnet, H dihasilkan oleh injap MGP. Dengan mendapatkan ketumpatan fluks magnet daripada analisis unsur terhingga, tepu magnet dihalang dalam injap. tepu magnet berlaku apabila ketumpatan fluks magnet pada jurang injap adalah lebih daripada ketumpatan fluks magnet maksimum MRF di 0.78 T. keamatan medan magnet, H, tentukan tegasan alah maksimum yang dihasilkan. Salah satu reka bentuk yang dicadangkan yang merupakan reka bentuk yang ketiga ialah pameran ketumpatan fluks magnet tertinggi, B daripada dua reka bentuk yang lain. Oleh itu, reka bentuk thrird sesuai untuk injap MGP kerana abality untuk menghasilkan tegasan alah tertinggi, dengan itu, boleh menahan tekanan yang lebih tinggi apabila digunakan.

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Magneto-rheological fluid valve is one of the application of the magnetorheological fluid (MRF). This smart fluid is a fluid which acts as carrying fluid that carry small magnetic particles. The carrying fluid usually use mainly water based or mineral oil based which is silicone oils, polyesters, polyethers and synthetic hydrocarbons oils. The compositions of it a alter according the needs of the users. This fluid reacts or behaving as tiny magnet when magnetic filed is applied to perpendicularly (Daniel et al. 2014). To make sure that the MRF are highly magnetization saturation, the small magnetic particles are made of from carbonyl iron particles.

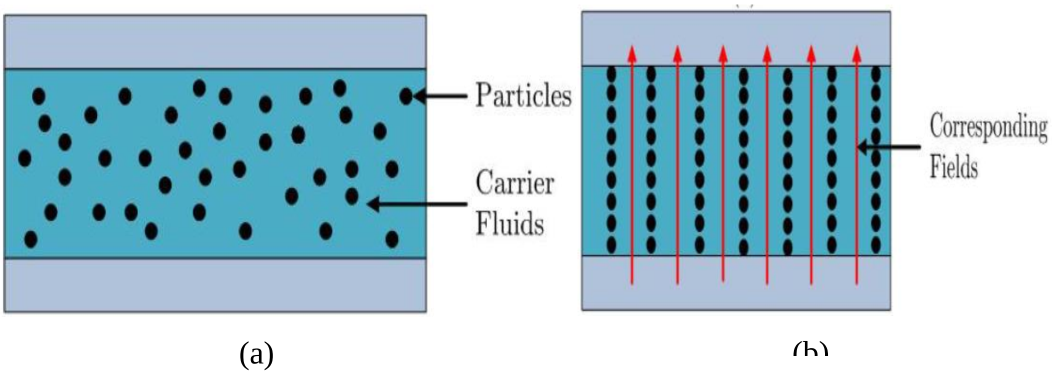

Figure 1.1: The behaviour of MRF. (a) During off-state conditions. (b) During on-state conditions.

Source: (Li 2014)

For addititional lubrication, additives are added to the MRF to prevent sedimentation and aggregation. Additives such as thixotropic agents, surfactants and polymers are added. MRF show unusual behaviour in their rheological properties because it can be continuously and reversibly changed within response time in milliseconds by applying or removing a magnetic field. The interactions between the particles give rise to chain-like structures aligned parallel to the direction of the exciting magnetic field as show in Figure 1.1

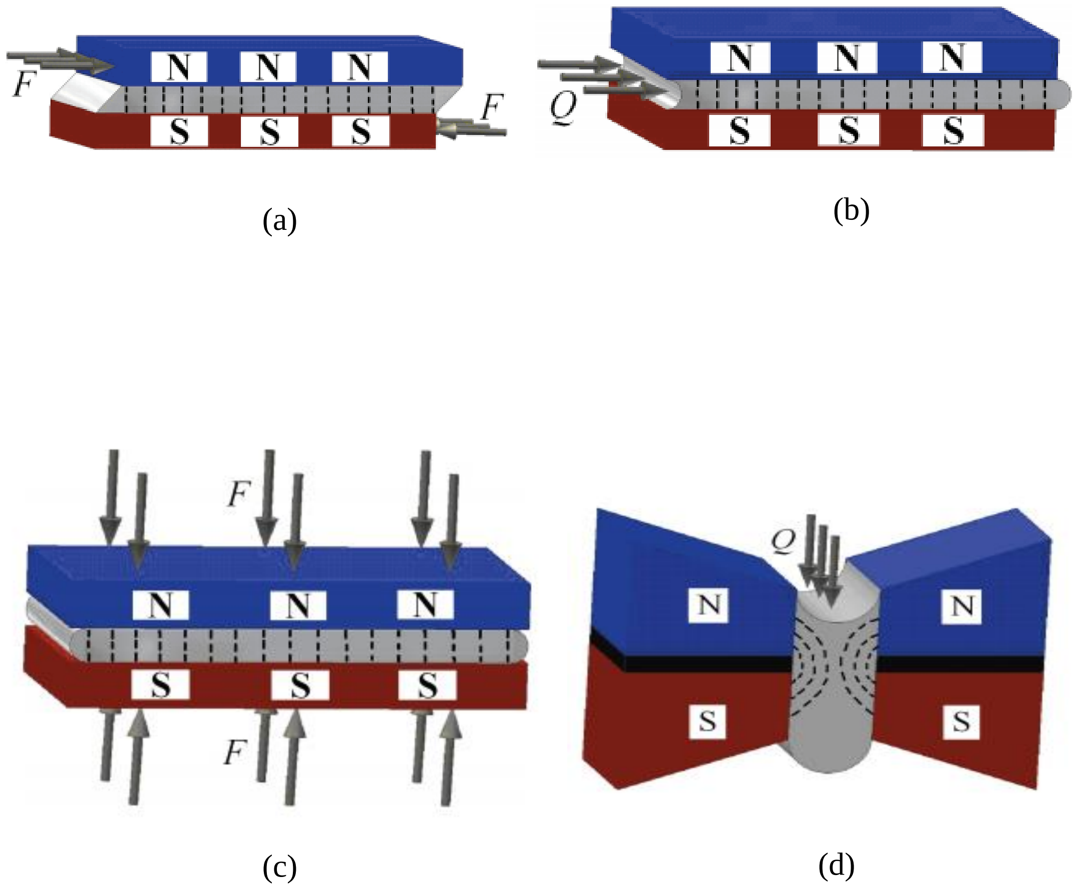

Figure 1.2: MRF operational modes. (a) Shear mode (b) Valve mode (c) Squeeze mode and (d) Pinch mode.

Source: (Goncalves & Carlson 2009)(Olabi & Grunwald 2007)

MRF are defined as non-Newtonian fluids because of its variable yield stress. It also defined as Bingham plastics model (Daniel et al. 2014). The Bingham Plastic does not exhibit any shear rate until a certain stress is achieved. For the Newtonian fluid the slope is viscosity, which only parameter needed to describe it flow but the Bingham Plastic requires two parameters, the yield stress and the plastic viscosity. The reason for this behavior is the liquid contains particles which require certain amount of stress to

REFERENCES

This thesis is prepared based on the following references;

Agrawal, A. et al., 2001. An Overview of Magneto- and Electro-Rheological Fluids and Their Applications in Fluid Power Systems. *International Journal of Fluid Power*, 2(2), pp.5–36.

Daniel, G. et al., 2014. Bingham-papanastasiou and approximate parallel models comparison for the design of magneto-rheological valves. *2014 IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, pp.168–173. Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=6878073.

Goncalves, F.D. & Carlson, J.D., 2009. An alternate operation mode for MR fluids—magnetic gradient pinch. *Journal of Physics: Conference Series*, 149, p.012050. Available at: http://stacks.iop.org/1742-6596/149/i=1/a=012050?key=crossref.f167c33f72eb1bdbf11cb7e184196bae.

Ichwan, B. et al., 2015. DESIGN AND PERFORMANCE ANALYSIS OF MAGNETORHEOLOGICAL VALVE MODULE WITH ANNULAR-RADIAL CONCEPT. , 10(17), pp.7743–7748.

Jolly, M.R. et al., Properties and Applications of Commercial Magnetorheological Fluids.

Kumbhar, B.K., Patil, S.R. & Sawant, S.M., 2015. Engineering Science and Technology , an International Journal Synthesis and characterization of magneto-rheological (MR) fl uids for MR brake application. *Engineering Science and Technology, an International Journal*, 18(3), pp.432–438.

Li, W., 2014. Design and Development of Magneto-Rheological Actuators with Application in Mobile Robotics. , (May).

Nguyen, Q. & Choi, S., 2012. Optimal Design Methodology of Magnetorheological Fluid Based Mechanisms. *Smart Actuation and Sensing Systems – Recent Advances and Future Challenges design*, pp.347–382.

Nguyen, Q.-H. et al., 2007. Geometry optimization of MR valves constrained in a specific volume using the finite element method. *Smart Materials and Structures*, 16(6), pp.2242–2252. Available at: http://stacks.iop.org/0964-1726/16/i=6/a=027?key=crossref.a7d10909c7549ee732891d35a4a17eea.

Of, F., Engineering, I. & Science, C., 2011. *Design of a Magnetorheological Fluid for* *an MR Prosthetic Knee Actuator with an Optimal Geometry*,

Olabi, A.G. & Grunwald, A., 2007. Materials & Design Design and application of magneto-rheological fluid. , 28, pp.2658–2664.

Salloom, M.Y. & Samad, Z., 2011. Finite element modeling and simulation of proposed design magneto-rheological valve. *International Journal of Advanced Manufacturing Technology*, 54(5-8), pp.421–429.

Zhang, X.Z.X., Li, W.L.W. & Zhou, Y.Z.Y., 2009. A variable stiffness MR damper for vibration suppression. *2009 IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, pp.106–111.