"I admit that I have read this report and found that it is suffice from aspect of scope and quality to pass the
Bachelor of Mechanical Engineering (Automotive)"

Signature :.....

Supervisor Name : DR. K. Hudha

Date : 12/05/2008

MODELING AND EXPERIMENTAL IDENTIFICATION OF MAGNETIC CLUTCH

ABDUL MUTALIB BIN ABDUL HAMED

This report is submitted
in partial fulfillment of the requirement for the
Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

MAY 2008

DECLARATION

"I admit this report is done all by myself except statement that I have already stated on each on of them"

Signature:.....
Author:.....ABDUL MUTALIB B. ABDUL HAMED
Date:.....12/5/08.....

ACKNOWLEDGEMENT

First of all, I would like to give my appreciation to the gratefulness, Allah S.W.T in order to complete my final report. This text could not have been written and produced without the help of many lecture and friend. Appreciation is expressed to those who have viewed and made contributions so much in order to completion of the project, especially for Dr. Khisbullah Hudha from Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka for his ideas, commitmen, support, advise, time shared and guidance given. His helps contribute a lot in order to complete this project.

Thanks to co supervisor, Encik Ubaiddillah, for his help will doing this project. Also thank to Meister Technology (M) Sdn Bhd especially to their owner, Mr. Mustafa and some of their technician for give the great work in the fabrication process.

I would also like to press greatest thankful to my parent, Mr Abdul Hamed B Misdan, Mrs Miskiah Binti Ponidin and Mrs Norsarifah for their support to ensure completion of this project, encourage from them be the morale for me to do the best. Thank also to all my housemate, and all my beloved family for being my inspirations.

Special thank to the special person Miss Fauziana Ahmad that give me inspiration and encourage me while I have a problem to do this project. Thank to all the people who directly or indirectly have been great help and full of support through the project period.

Thanks

ABSTRACT

Magnetic clutch is a clutch that uses Magneto-rheological fluid or commonly knows as MR fluid clutch. The application of this device is focus on the automotive sector such as automobile and heavy vehicle. The purpose of developing the magnetic clutch is to overcome the mechanical friction that happens to the conventional clutch. This thesis wills overview the MR fluid clutch through the discussions of MR Fluid technologies that adapt to the development of the MR fluid clutch. Then this thesis will introduce the MR fluid clutch, overview of MR fluid, the problem statement, and the approaches that been make for this thesis. The literature review of this thesis wills discuss the study and information collected for the MR fluid clutch. In this section it will include discussion of clutch types, the technology of MR fluid, MR cell experiment and MR fluid clutch design also the example equation from other journal. The methodology will review about the flow to develop a MR fluid clutch and process to fabricate the clutch and also the experiment setup for the MR fluid clutch study. Matlab software will be used to derive the equation of the motion for theoretical data that been discuss inside the design and analysis section. Finally, the modification to previous prototype MR fluid clutch was present in 3D model using Solidwork2007. In conclusion, recommendations are made for solving the design miss alignment.

ABSTRAK

Kluc magnet adalah kluc yang menggunakan cecair "Magneto-rheological" atau dikenali sebagai kluc cecair MR. Kegunaan alat ini lebih mengfokuskan kepada sektor permotoran seperti untuk kenderaan berat dan kereta penumpang. Kluc magnet ini dibangunkan supaya dapat mengatasi masalah geseran secara mekanikal yang terjadi kepada kluc konvensional. Tesis ini akan memberikan gambaran keseluruhan tentang kluc cecair MR berdasarkan perbincangan ke atas teknologi cecair MR yang digunakan dalam membangunkan kluc cecair MR. Selepas itu, tesis ini akan memperkenalkan tentang kluc cecair MR, gambaran keseluruhan untuk cecair MR, kenyataan masalah dan pendekatan yang telah diambil untuk tesis ini. Ulasan karya tesis ini akan membincangkan tentang kajian dan maklumat yang dikumpul untuk kajian kluc cecair MR. Bahagian ini turut disertakan perbincangan jenis-jenis kluc, teknologi cecair MR, ujikaji sel MR dan rekabentuk kluc cecair MR serta contoh persamaan yang terdapat pada jurnal lain. Bahagian kaedah akan menerangkan tentang aliran membangunkan kluc cecair MR dan proses memfabrikasi kluc serta persediaan ujikaji untuk kajian kluc cecair MR. Perisian Matlab digunakan untuk mendapatkan persamaan gerakan untuk mendapatkan data teori yang dibincankan dalam bahagian rekabentuk dan analisis. Akhir sekali, modifikasi ke atas prototaip kluc MR yang lalu dipersembahkan menggunakan lukisan 3D menggunakan perisian Solidwork2007. Kesimpulannya, cadangan diberikan untuk menyelesaikan masalah terlepas penjajaran pada rekabentuk kluc.

TABLE OF CONTENT

CHAPTER	SUBJECT		PAGE
	DECLARATION		**ii**
	ACKNOWLEDGEMENT		**iii**
	ABSRACT		**iv**
	TABLE OF CONTENT		**vi**
	TABLE LIST		**x**
	FIGURE LIST		**xi**
	SYMBOL LIST		**xiii**
	APPENDIX LIST		**xiv**
1	**INTRODUCTION**		
	1.1	Background	1
	1.2	Overview MR Fluid and MRF Clutch	2
	1.3	Objective	3
	1.4	Scope of Project	3
	1.5	Problem Statement	4
	1.6	Approach	5
	1.7	Outline	5
2	**LITERATURE REVIEW**		
	2.1	Clutch System	7
	2.2	Dry Clutch	9
	2.3	MR Fluids	12
	2.4	The Advantages of MR Fluids	15
	2.5	The Magneto-rheological Cell Experiment	17

CHAPTER	SUBJECT	PAGE
2.6	MR Fluid Clutch	19
2.7	**Previous Design** of MR fluid Clutch	20
2.8	Improvement to Second Prototype	22
2.9	Literature Review	23
2.10	Thesis Study	25
	METHODOLOGY	
3.1	Literature Search and Request	27
3.2	The Sketcher Workbench	29
3.3	Part Design Workbench	30
	3.3.1 Detail Design	30
3.4	Stage of Material Selection	31
	3.4.1 Initial Screening	31
	3.4.2 Comparing Alternative Solutions	31
	3.4.3 Selection of Optimum Solution	31
3.5	Assembly Workbench	32
3.6	Analysis Workbench	32
3.7	Drafting Workbench	33
3.8	Manufacture evaluation	33
3.9	Manufacture prototype	34
	3.9.1 Cutting process	34
	3.9.2 Lathe Process	35
	3.9.3 Milling Process	35
	3.9.4 Drilling Process	36
	3.9.5 Welding Process	37
	3.9.6 Finishing Process	37
	Prototype Validation	38

CHAPTER	SUBJECT	PAGE
	3.10.1 Result Variable	38
	3.10.2 Experiment Setup	39
	3.10.2.1 Objective	39
	3.10.2.2 Background	39
	3.10.2.3 Hypothesis	40
	3.10.2.4 Experiment Equipment	41
	3.10.2.5 Experiment Procedure	43
DESIGN AND ANALYSIS		
4.1	Electromagnet Core	44
4.2	Casing	45
4.3	Input Shaft	46
4.4	Output Shaft	47
4.5	MR Housing Cover	47
4.6	Side Cap	48
4.7	MR fluid Cluch Bracket	49
4.8	Bearing Bracket	50
4.9	MR Fluid Clutch Assemble	50
4.10	MR Fluid Clutch Exploded	51
4.11	Electromagnetic Maxwell ANSOFT Analysis	52
4.12	Mathematical Modeling Analysis	53
4.13	Experiment Result and Discussion	58
	4.13.1 Result	58
	4.13.2 Discussion	

CHAPTER	SUBJECT	PAGE
5	**CONCLUSION AND RECOMMENDATION**	
	5.1 Conclusion	61
	5.2 Recommendation	62
	REFERENCES	64
	APPENDIX	66

TABLE LIST

TABLE NO	TITLE	PAGE
1	The comparison properties between ER fluid and MR fluid [Adapt from 10]	15
2	MR fluid clutch working dimension	30
3	Experiment equipment data	41
4	Magnetic Flux and mass data (Experiment data)	58
5	Magnetic Flux and mass data (Experiment Data)	59

FIGURE LIST

FIGURE NO	TITLE	PAGE
1	The MR fluid shear stress diagram [adapt from 1]	2
2	Clutch position inside car [adapt from 2]	7
3	Diaphragm clutch when the clutch pedal is pressed [adapt from 3]	8
4	The half figure of diaphragm clutch [adapt from 10]	10
5	The diaphragm spring clutch [adapt from 10]	10
6	Shear strain rates versus shear stresses in the post-yield regime for various values of the magnetic field intensity.[adapt from 5]	12
	(a) no magnetic field (b) applied magnetic field (c) applied strain [Adapt from 4]	13
8	a) Newtonian Fluid b) Bingham Fluid [adapt from 7]	14
9	The advantages of MR fluid diagram [adapt from 10]	16
10	Schematic cross-section of magneto-rheological test cell [Adapt from 10]	17
11	Cross section of developed MR fluid Clutch	19
12	Double plate MR fluid Clutch Design [Adapt from 8]	20
13	Cross section of second prototype of MR fluid Clutch	22
14	Graf input speed Vs output torque and Current Vs Output Torque [Adapt from 6]	23
15	Band Saw Machine	34
16	Lathe Machine	35
17	Milling Process	35
18	Drilling Machine	36
19	Welding process	37
20	Current Vs Output Torque Diagram [Adapt from 6]	38

FIGURE NO	TITLE	PAGE
21	Block diagram of manual experiment set up	39
22	Experiment setup of the MR fluid Clutch	40
23	Block diagram of MR fluid clutch	41
24	Magnetic Core with force test	44
25	Casing with force test	45
26	Input shaft with force test	46
27	Output shaft with force test	47
28	MR housing cover with force test	47
29	Double side cap with force analysis	48
30	MR fluid clutch bracket	49
31	Bearing bracket	50
32	MR fluid clutch assemble model	50
33	MR fluid clutch exploded model	51
34	Magnetic flux at 1.0A current	52
35	Magnetic flux at 1.5A current	52
36	Simulink Diagram	55
37	Graph of torque transfer at 0 Ampere	56
38	Graph of torque transfer at 2.5 Ampere	57
39	The Torque Vs Magnetic Flux Graph	59
40	New recommended design	63

SYMBOL LIST

SYMBOL	DEFINATION
τ_y	Yield Stress
$\tau_{y(H)}$	High yield Stress
η	Plastic viscosity
γ	Fluid shear rate
G	Material modulus
H	Magnetic field
L	Length
F	Force
g	Gap
w	Width
Q	Volumetric flow rate
A	Area
V	Volume
F_η	Viscosity force
	Sum of a viscous component
	Sum yield stress component
λ	Control ratio
T_c	Clutch torque
τ	Fluid stresses
h_0	initial gap
d	displacement

APPENDIX LIST

APPENDIX NO	TITLE	PAGE
A	The flow chart of the PSM Project	65
B	Gantt chart PSM 1 and PSM 2	67
C	Picture	69
D	Detail Drawing	70

CHAPTER 1

INTRODUCTION

1.1 Background

In this chapter, a discussion about the objective of the project, scope of the project and problem statement will based on the project title is to model and experimental identification of magnetic clutch. The magneto-rheological (MR) fluid clutch is one of the new technologies of clutch that been use in the automotive industries. This technology of clutch will provide more efficiency high torque transformation between engines to driveline because the properties of the magneto-rheological fluid have been discussed in the next chapter. For overall in this project, a modification have been made to one model of high torque magneto-rheological fluid clutch are designed to make an experiment setup. Then experiment that has been held come out with result of relationship of current and torque transfer. The knowledge and information about the properties of fluid and the mechanism of the clutch are important to make the modification of the design and the experiment result in this project will be discuss in the next chapter.

1.2 Overview MR Fluid and MR Fluid Clutch

MR fluids are materials that change their rheological behavior in the presence of an applied magnetic field. MR fluid is oils that are filled with iron particles. Often, surfactants surround the particles to protect them and help keep them suspended within the fluid. When exposed to a magnetic field, the particles line up, thickening the fluid dramatically. The term magneto-rheological come from this effect. Rheological is a branch of mechanics that focuses on the relationship between force and the way a material shape change. The force magnetism can change both shape and the viscosity. Devices using MR fluids have an ability to provide high torque, low inertia, be a safe device and have a simple interface.

The MR fluid clutch been developed consists of an input shaft and output shaft and an MR fluid between the two component. The MR fluid clutch can either cylindrical or disc shaped. An electromagnetic coil housed inside the clutch is used to generate the necessary magnetic field in the active region containing the MR fluid change there by varying the bonding strength between the input and the output component. This is realized as a controllable change in the torque capacity of the clutch. The number of surfaces may be increased to increase the torque capacity of the clutch for a given size.

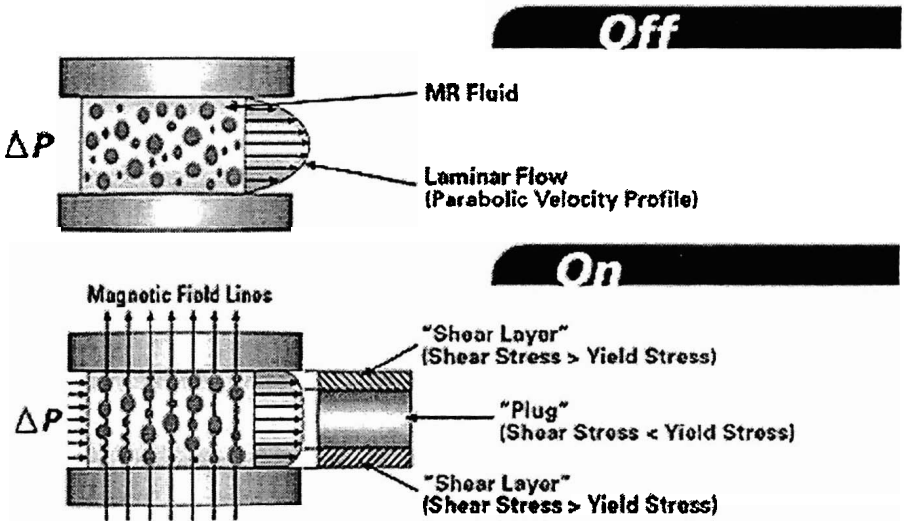


Figure 1: The MR fluid shear stress diagram. [Adapt from 1]

1.3 Objective

The objectives of this project are:

- To obtain the behavior of magneto-rheological fluid clutch experimentally.
- To find the relationship between current and torque transfer of the MR fluid clutch.
- To modify the existing MR fluid clutch.

1.4 Scope of project

The scopes of this project are to design 3D model for modification of the magneto-rheological fluid clutch prototype using the CAD software such Solid Work and Catia. Firstly, examinant the MR fluid clutch prototype design, if any failure happen to the design, modification must be made for the MR fluid clutch to ensure the model can be used. This is important to validate the prototype that been made and set-up the operation of the magneto-rheological fluid clutch. Investigation been made to the magneto-rheological fluid clutch using experiment to find the relationship between current and torque transfer. This is to know the efficiency of torque transfer that been transfer from the driver shaft to the driven shaft by using the magneto-rheological clutch and identified the most suitable value of current that give the optimum torque transfer and happen in the fewest time response. Fabricate the modification design and experiment the set-up that been made for the magneto-rheological fluid clutch prototype. Investigation on the relationship of the current that been supply to the magnetic coil also must be operated to know the characteristic of MR fluid inside the MR fluid clutch. Finally by using the experiment system, the relationship between torque transfer and current obtained.

1.5 Problem Statement

The most common problem with conventional clutch is mechanical friction. The friction material on a clutch disc is very similar to the friction material on the pads of a disc brake, or the shoes of a drum brake after a while, it wears away. When most or all of the friction material is gone, the clutch will start to slip, and eventually it would not transmit any power from the engine to the wheels.

The clutch only wears while the clutch disc and the flywheel are spinning at different speeds. When they are locked together, the friction material is held tightly against the flywheel, and the spin in synchronize. It is only when the clutch disk is slipping against the flywheel that wearing occurs. So if the driver slips the clutch a lot, they will wear out the clutch a lot faster. Another problem sometimes associated with clutches is a worn throw out bearing. This problem is often characterized by a rumbling noise whenever the clutch engages.

Mechanical friction will occurred during the conventional clutch is used and will damaging the pads of the clutch disc. By using the MR fluid clutch this problem thus not occurred because the flywheel that connected to the engine shaft been change to the input shaft in the MR fluid clutch. The input and the output shaft will be connected inside the MR fluid clutch. The connection happen when the MR fluid been in the magnetic field and change to solid and connect both of the shaft. The clutch will not get the problem to slips because there MR fluids will always fill the area and will changing into solid when the magnetic field are created. The clutch also can prevent the rumbling noise that appear when the conventional clutch bearing are broken because the MR fluid clutch does not have the bearing and effectively connected the both shaft, so by using the MR fluid clutch all the problem statement will be solve and give the car user more comfortable.

1.6 Approach

Propose for this section is to describe the approach that been made to complete this research. The approach was a study the different design of MR fluid clutch before decide to modify the previous MR fluid Clutch. The several design of the MR fluid clutch that has been found during the study is double plate O-rings shaft [8], MR Actuator housing [11] and Electro-Rheological (ER) clutch [12]. By searching equation from other journal, equation for the MR clutch can be obtained and by using the Matlab simulation software simulink diagram been made. Then the 3D modeling using Solidwork used to perform the design of the new modification of the Magneto-Rheological Fluid Clutch.

1.7 Outlines

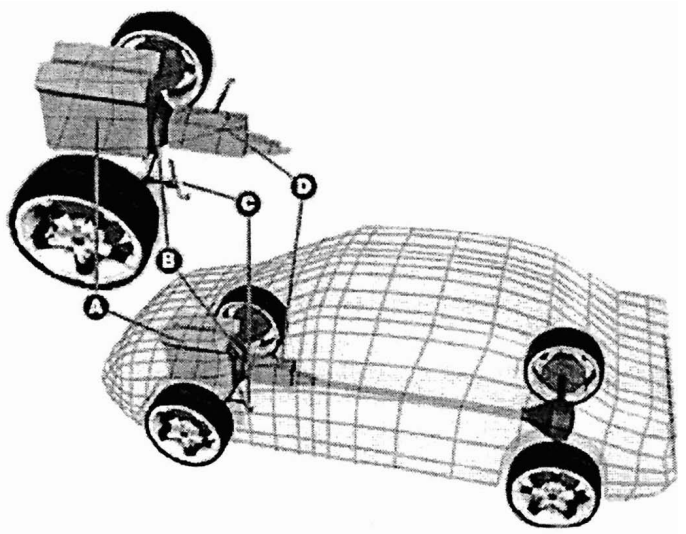
Chapter 2 presents the literature review of the MR fluid clutch. It also provides an introduction to the design, construction and performance of a magneto-rheological clutch. Chapter 3 describe in detail, the test structure used to evaluate the torque transfer for the MR fluid clutch. This chapter also presents the experimental setup of the test rig for the MR fluid clutch. This chapter also discussed about the experimental equipment. Chapter 4 discussed the results of the entire laboratory testing involving the MR fluid clutch apparatus. Finally, Chapter 5 summarizes the results of this study and the recommendation for future work.

BAB 2

LITERATURE REVIEW

The purpose of this chapter is to introduce the theoretical and practical applications of MR fluid for MR fluid clutch. First the concept and application of clutch system will be stated, after that the theory for the MR fluid will be introduce. This chapter also presents a review of the technical relating to the issues in developing a set up model magneto-rheological fluid clutch. This chapter also will be review about the magneto-rheological fluid behavior, the application, the state of the fluid and the advantages. All of this information is useful in state to know the characteristic before it can be applied to other applications. In this chapter also, it state about the previous design of MR fluid clutch with the advantage and disadvantage state. Clutch is useful to the vehicle as the part to connect the two rotation component between the engine and driveline. This will made the vehicle move out easily on the road. However using the conventional clutch it has several problems that need to solve with develop the new technology of clutch using the MR fluid clutch.

2.1 Clutch System



A - Engine **B** - Clutch **C** - Clutch Pedal **D** - Manual Transmission

Figure 2: Clutch position inside car [Adapt from 2]

Clutches are useful in devices with two rotating shafts. In these devices, one of the shafts is typically driven by a motor or pulley, and the other shaft is driving another device. For example, in a drill, for instance, one shaft is driven by a motor and the other is drilling a drill chuck. The clutch connects the two shafts so they can either be locked together and spin at the same speed, or be decoupled and spin at different speeds [2].

In a car, it needs a clutch because the engine spins all the time and the car wheels not. In order for a car to stop without shutoff the engine, the wheels need to be disconnected from the engine rotations somehow. The clutch allows us to smoothly engage a spinning engine to a non-spinning transmission by controlling the slippage between them. This is how clutch work in an automobile clutch, the flywheel is connected to the engine, and the clutch plate is connected to the transmission. When your foot is off the pedal, the springs push the pressure plate against the clutch disc, which in turn presses against the flywheel. This locks the engine to the transmission input shaft, making them spin at the same speed [2].

The amount of force the clutch can hold depends on the friction between the clutch plate and the flywheel, and how much force the spring puts on the pressure plate [2].

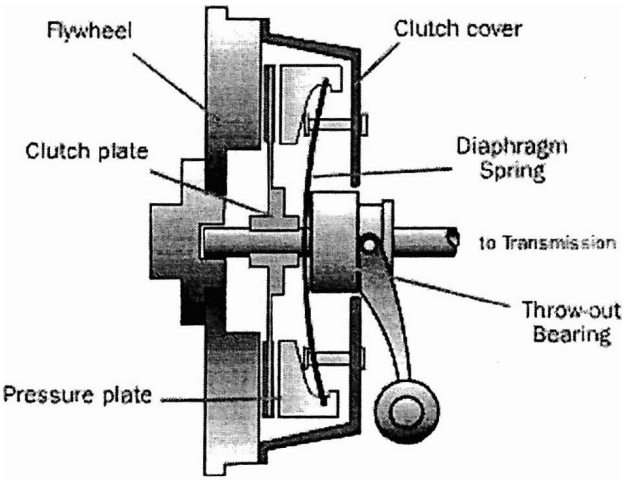


Figure 3: Diaphragm clutch when the clutch pedal is pressed. [Adapt from 3]

When the clutch pedal is pressed, a cable or hydraulic piston pushes on the release fork, which presses the throw-out bearing against the middle of the diaphragm spring. As the middle of the diaphragm spring is pushed in, a series of pins near the outside of the spring because the spring to pull the pressure plate away from the clutch disc. This releases the clutch from the spinning engine [3].

They are many other applications of clutches used in the car [10]:

- An automatic transmission contains several clutches. These are used to engage and disengage several sets of planetary gears.
- An air conditioning compressor in a car has a magnetic clutch. This allows the compressor to shut off even while the engine is running. When current flows through a magnetic coil in the clutch, the clutch engage. As soon as the current stops, such as when you turn off your air conditioning, the clutch will disengage.

Most cars that have an engine-driven cooling fan have a thermostatically controlled viscous clutch. This clutch is positioned at the hub of the fan, in the air flow coming through the radiator. This type of clutch is a special viscous clutch, much like the viscous coupling sometimes found in all-wheel drive cars. The fluid in the clutch gets thicker as it heats up, causing the fan to spin faster to catch up with the engine rotation. When the car is cold, the fluid in the clutch remains cold and the fan spins slowly, allowing the engine to quickly warm up to its proper operating temperature.

Many cars have limited slip differentials or viscous couplings, both of which use clutches to help increase traction.

- A gas powered chain saw has centrifugal clutches, so that the chains or strings can stop spinning without you having to turn off the engine.

2.2 Dry Clutch

The clutch is housed between the engine and transmission where it provides a mechanical coupling between the engine's flywheel and the transmission input shaft. The clutch is operated by a linkage that extends from the passenger compartment to the clutch housing. The purpose of the clutch is to disconnect the engine from the driven wheels when a vehicle is changing gears or being started from rest [10].

Disengaging the clutch separates the flywheel, the clutch plate and the pressure plate from each other. The flywheel is bolted to the end of the crankshaft and rotates with it. The clutch plate is splinted to the gearbox in order for both to rotate together and the pressure plate clamps the clutch plate to the flywheel. When the pressure is released by depressing the clutch pedal, the crankshaft and gearbox input shaft rotate independently. When the foot is taken off they rotate as one. The two primary types of pressure plate assemblies are coil spring assembly and one with a diaphragm spring. [Figure 4]