ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc THESIS

İhsan ULUOCAK

MAGNETIC RETARDER WITH EXTENDED CONTROL SYSTEM

DEPARTMENT OF MECHANICAL ENGINEERING

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We certify that the thesis titled above was reviewed and approved for the award of degree of the Master of Science by the board of jury on 21/08/2014.

……………………………..….	……………………….	……………………………...
Assoc. Prof. Dr. Hakan YAVUZ	Prof. Dr. Kadir AYDIN	Asst. Prof. Dr. Hasan SERİN
SUPERVISOR	MEMBER	MEMBER

This MSc Thesis is written at the Department of Institute of Natural And Applied Sciences of Çukurova University.
Registration Number:

Prof. Dr. Mustafa GÖK
Director
Institute of Natural and Applied Sciences

ABSTRACT

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MAGNETIC RETARDER WITH EXTENDED CONTROL SYSTEM

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ÇUKUROVA UNIVERSITY
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DEPARTMENT OF MECHANICAL ENGINEERING

Supervisor : Assoc. Prof. Dr. Hakan YAVUZ
Year: 2014, Pages: 41
Jury : Prof.Dr. Kadir AYDIN
: Assoc.Prof. Dr. Alper YILMAZ

Vehicles often use mechanical braking systems. In these brake systems, the kinetic energy of the vehicle is converted into heat and are released into the medium by brake system components. Although some serious difficulties are encountered in mechanical brake system, they are very much compact and effective in most cases. In particular, increasing temperature reduces brake forces posing a serious problem for the vehicle control. In addition, the mechanical brake system's complexity, the contamination of the brake fluid with water may lead to serious technical problems. The targeted magnetic retarder system is expected to resolve some of these issues and is intended to provide an alternative braking system. In this type of magnetic retarder based brake systems, the kinetic energy of the vehicle is not converted into heat by friction. On the other hand, in the standard magnetic retarder system, there are 4 brake force levels in total. The targeted system has been designed to increase this brake force levels to 1024. Instead of conventional four positions, the new retarder force control arm is therefore could be positioned anywhere between 0 and 1024. The retarder lever arm position is used in generation of the magnetic retarders electronically controlled brake force. In this manner, a highly sensitive desired level of braking force can be achieved.

Key Words: Magnetic retarder, Magnetic breaking, Power electronics, Sensitive braking operation

ÖZ

YÜKSEK LİSANS TEZİ

GENİŞLEŞTİRİLMİŞ KONTROL ARALIKLI MANYETİK RETARDER

İhsan ULUOCAK

ÇUKUROVA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ
MAKİNE MÜHENDİSLİĞİ ANABİLİM DALI

Danışman : Doç. Dr. Hakan YAVUZ
Yıl: 2014, Sayfa: 41
Jüri : Prof. Dr. Kadir AYDIN
: Doç. Dr. Alper YILMAZ

Yapılan çalışma, manyetik retarder sistemiile mekanikfrensistemlerindeki sorunların bir kısmının çözüme kavuşturulması ve mekanikfrensistemlerineyardımcı bir fren sistemi sunulması amaçlanmaktadır. Manyetik retarder sistemlerinde aşınma, kinetik enerjinin sürtünme ile ısıya dönüştürülmesi söz konusu değildir. Diğer taraftan, standart manyetik retarder sistemlerinde de toplam 4 kademe vardır. Geliştirmiş olduğumuz bu sistemde kademe sayısı 1024’e çıkarılmıştır. Sistemin kumanda kolu 0 ile 1024 arasında bir konumda bulunabilmektedir. Retarder kolunun okunan pozisyonu manyetik retarderda elektronik kontrollü olarak fren kuvvetinin oluşmasına, sebep olur. Bu şekilde istenilen seviyede oldukça hassas fren kuvveti elde edilmesi mümkün olmaktadır.

AnahtarKelimeler: Manyetik retarder, Manyetik frenleme, Güç elektroniği, Hassas ayarlanabilir fren kuvveti

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ABBREVIATIONS

CHB	: Conventional hydrolic brake
ECB	: Eddy current brake
EHB	: Electro hydrolic brake
ABS	: Anti lock brake
NHV	: Noise, vibration and harness
SMPS	: Switch mode power supply
EMC	: Electromagnetic compability
MCU	: Microcontroller
DSP	:Digital signal processor
PIC	: Peripheral interface controller
MSB	: Most significant binary
LSB	: Least significant binary
Km	: kilometer
Kg	: kilogram
Mm	: Milimeter
Rpm	: revolution per minute
Cc	: centimeter cubic
I/O	: input, output

1. INTRODUCTION

Road vehicles rely mainly on mechanical friction brakes. These brakes are composed of two functional parts: a cast-iron rotor (disc or drum) and pads pressed against the rotor to generate the braking force by friction. The pressure is applied by a hydraulic or pneumatic circuit. Friction braking is dissipative: the vehicle's kinetic energy is dissipated as heat on the disc, which heats up to several hundred degrees Celsius. The friction coefficient between the pads and the disc, and therefore the maximum braking force obtainable depends on temperature (Limpert, 1999), increasing slightly from room temperature to a maximum, and decreasing rapidly beyond a certain point (Figure 1.1).

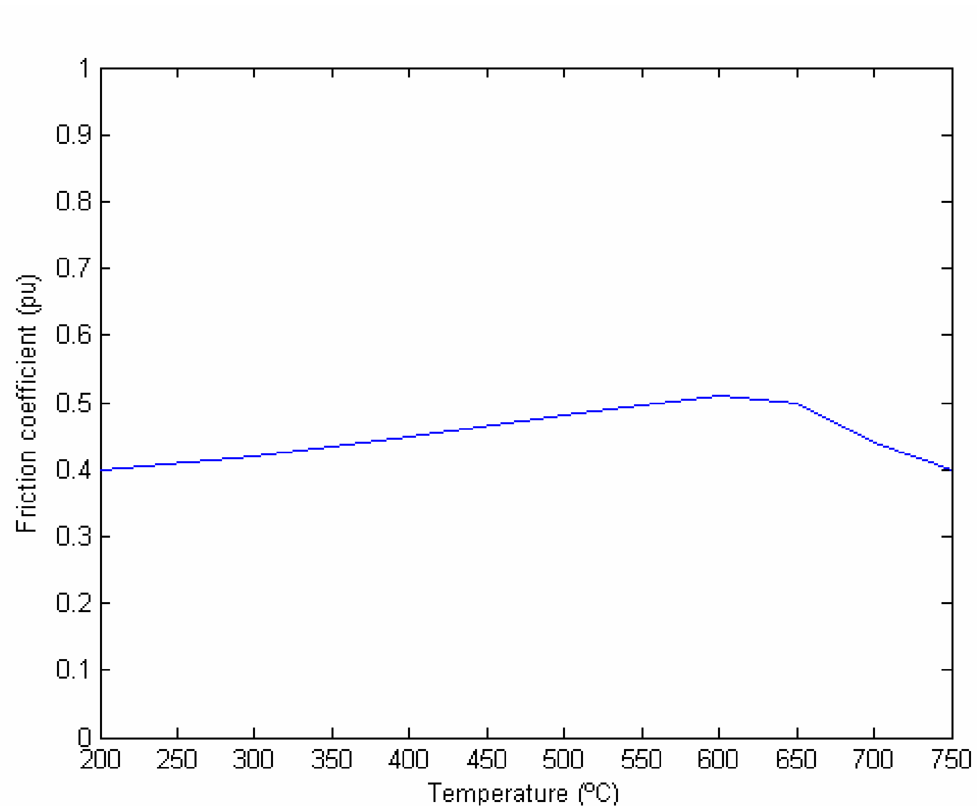

Figure 0.1. Temperature dependence of friction coefficient

Despite its tremendous advantages in compactness and effectiveness, friction braking suffers from severe limitations:

- Loss of braking force with increasing temperature;
- Warping of discs;
- Wear of pads and rotors;
- Complexity and fuel consumption of power assistance;
- Slow response time due to power assistance, especially in trucks, buses and trains;
- Complexity of controlling each wheel’s braking independently;
- Necessity of complex and costly anti-lock controls;
- Risk of hydraulic fluid leak;
- Risk of brake fluid contamination by water and subsequent loss of braking power;
- Challenging integration with anti-lock, traction, and dynamic stability controls.
- The concept of integrated contactless magnetic retarder was invented to remove to these problems. The integrated brake combines a conventional friction brake with a magnetic brake (Fig. 1.1). This concept has many advantages over friction brakes:
- Reduced wear and higher part live (Table 1.1);
- Reduced fuel consumption of power assistance;
- Faster control dynamics;
- Easier integration with anti-lock, traction, and dynamic stability controls;
- Easy individual wheel braking control;
- Electric actuation, no fluid.

However, their requirement for a large excitation current is a major disadvantage. The most significant drawback is the lack of failure safety. The excitation current may not be available for a variety of reasons, in which case the retarder is totally useless. Furthermore, the excitation current is necessarily supplied at a low voltage, which induces high ohmic losses in conductors, diminished bus voltage, and renders electronic control challenging. Additional resulting problems include heavy wiring from the battery to the retarder, heating of the coils.

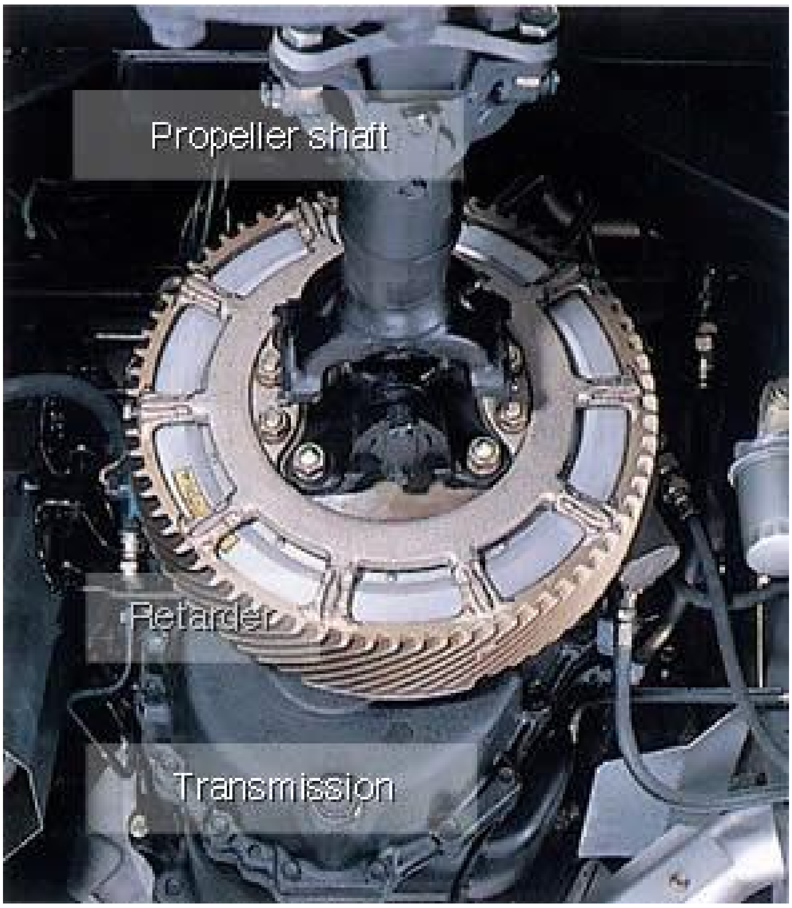

Figure 0.2. Electromagnetic Retarder

A magnetic retarder brake consists of a stationary source of magnetic flux (permanent magnet or electromagnet) in front of which a conductor (metal disc, drum or rail) is moving. Because of the motion, the conductor experiences a time-varying magnetic flux density, which by virtue of Lenz's law results in an electric field:

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \tag{1.1}$$

This electric field results in circulating currents in the conductor by virtue of Ohm's law:

$$\vec{J} = \sigma . \vec{E} \tag{1.2}$$

These currents are called eddy-currents. The interaction of eddy-currents with the flux density results in a force that opposes the motion:

$$\vec{F} = \vec{J} \times \vec{B} \tag{1.3}$$

The fundamental physics of eddy-current braking applied to a disc is illustrated in Fig. 1.3.

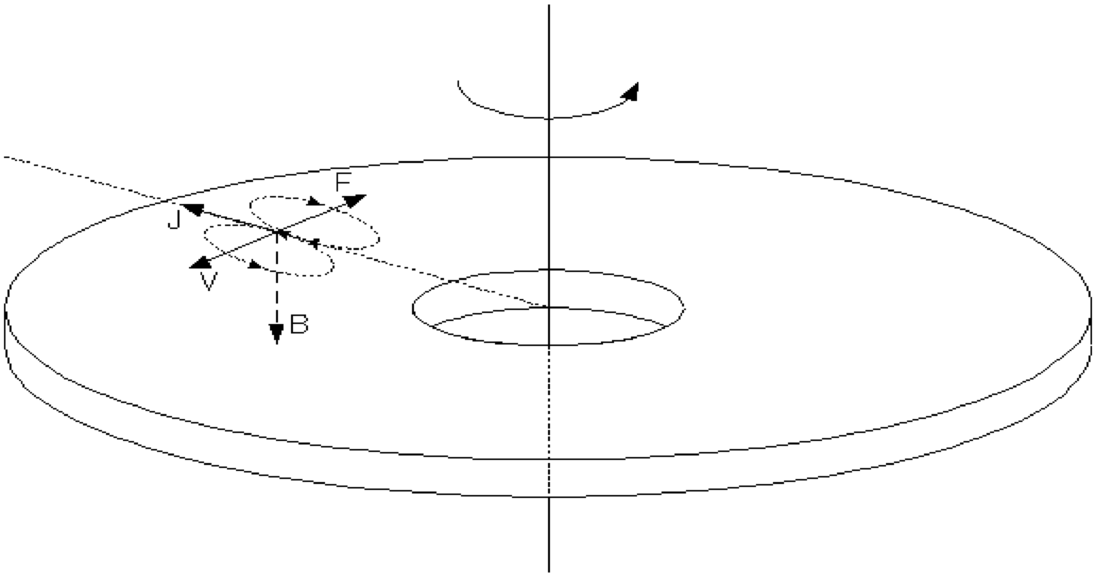

Figure 0.3. Fundamental physics of eddy-current braking

Table1.1. Comparison of Braking Systems

	With Retarder		Without Retarder	
Replaced Parts	Part Change(km)	Change number(in 600k km)	Part Change(km)	Change number(in 600k km)
Tires	200k	3	150k	4
Pads(front)	300k	2	30k	20
Pads (rear)	200k	3	20k	30
Brake drum	600k	1	150k	4
Out of service		9 days		58 days

Diesel engines are used throughout the world in a wide variety of applications. They are essential for mass transit systems, the interstate trucking industry, agricultural and industrial machinery, and electrical power generation. An important part of these efforts is the testing of these engines and its components. Diesel engines are popular in these applications because of their reliability, efficiency. The manufacturers of diesel engines continue improving their products by increasing the operating efficiency and the durability of the engine while reducing its harmful emissions.

2. PRELIMINARY WORK

Automotive industry is a dynamic and challenging field and considerable technological innovations are proposed every year. Considerable resources are invested in research and development for building safer, cheaper and better performing vehicles.

G.A.Haines et. al. (1986) presented A simple theory of magnetic braking in a thin metal strip is proposed. The predictions of the model are compared to experiment and good agreement is obtained. The experimental tests were conducted by spinning a thin aluminum disk of large radius between the pole pieces of an electromagnet. The model contains all the important physical features of this phenomenon and it is easily presented at an early level as an illustration of the importance of the Lorentz force law.

Lee Barnes et. al. (1993) described details of a computer model of an eddy-current brake for application in an exercise device. A computer analysis program called EBRAKE which calculates disk torque as a function of disk speed, for a given system geometry and coil current was used. EBRAKE utilizes a library feature for disk and core materials whereby one may enter conductivity for various disk materials and a family of points to be used in the interpolation of the core properties.

Simeu et. al. (1995) presented an application of some existing techniques for the modeling and regulation of an eddy current brake process. An approximate theoretical model is derived for the behavior of an eddy current disc brake in the low-speed zone. Input-output information is used to obtain a polynomial state-affine behavior model for such a process. Dynamic and static feedback compensator schemes are proposed for the process speed control in the presence of unknown braking resistant torque. The dragging torque value is estimated by an appropriate nonlinear observer. He divided his study to 3 sections, parametric model of the process is proposed in Section 1. In Section 2, the coefficients of the previous model are estimated, and Section 3 deals with a dynamic and static continuous time compensator design for speed control, and some experimental results.

Jang et. al. (1995) investigated two-dimensional analytical technique in his paper which deals with flux density and forces calculation for three types of mover: DC excited electromagnet, Halbach magnetized and vertical magnetized permanent magnet. All these models, the mover have a non-magnetic conducting plate. Therefore, these models were considered the nonlinear characteristic of the B-H curve of iron. And braking force was compared analytical results with experimental data about linear Eddy- Current brake model with the strongest force characteristic.

Bunker (1997) presented in this paper is the robust multivariable feedback controller design of a highly coupled, nonlinear diesel engine-dynamometer system. The performance goal was to maximize the closed loop reference tracking of pre-specified engine speed and torque curves by reducing the output variations due to system nonlinearities/uncertainty, and loop interactions through feedback control. The performance goal was realized by balancing the bandwidths of the loop transfer functions to avoid excessive loop interactions in the closed-loop system. Standard high-gain and high-bandwidth solutions cannot be used for this design since the system contains pure delays and the controller implementation has sample rate limitations. The engine dynamometer models used for controller design are developed from spectral estimation techniques and step responses where the effects of the system nonlinearities are captured in a parametric uncertain format. The controllers were designed using a sequential frequency domain approach. The controllers were implemented on an 8.3L turbocharged diesel engine and eddy current dynamometer. The controllers were evaluated based upon the ability of the closed-loop system to track step inputs and a transient test cycle.

Lee (1998) developed and its performance is investigated by using a scaled model. Braking torque analysis is performed by using an approximate theoretical model and the braking torque is experimentally compensated. Optimal torque control which can shorten the braking distance is achieved by maintaining a desired slip ratio which gives the maximum braking force coefficient. A sliding mode controller is used for the optimal torque controller. From simulation and experimental results, it is observed that the eddy current brake (ECB) provides a fast braking response because it is capable of fast anti-lock braking.

Ryoo et. al. (2000) presented a downscaled ECB magnet is designed and the braking and attraction forces of the ECB are simulated by 2-D FEM. The simulation results are experimentally verified on a downscaled prototype. A control algorithm of the ECB is proposed to generate constant braking torque using linear variation of the reference current according to speed. Key performance characteristics are experimentally verified with a high-speed railway-train simulator down scaled to 1/500. The simulator is made of two sets of converter- inverter system, four induction motors and a flywheel. The ECB is installed at the under-frame of the flywheel in the simulator.

Anwar et. al. (2004) introduced an enhanced polynomial-based parametric model of an eddy current electric machine for automotive braking. The parametric model captures the steady state torque-speed-current characteristics of the eddy current brake. A two-stage estimation process has been introduced to identify the coefficients of the retarder model from experimental data through a least square type algorithm. The model is then validated via on-vehicle test data.

Anwar (2004) presented a nonlinear sliding mode type controller for slip regulation in a braking event for a hybrid electromagnetic-electro-hydraulic brake-by-wire system. The ABS controller modifies the brake torque command generated by a supervisory controller based on driver’s command via brake pedal sensor. The brake torque command is then generated by closed loop actuator control algorithms to control the eddy current brake (ECB) and electro-hydraulic brake (EHB) systems. The proposed control algorithm shows very good slip regulation in a braking event on low friction coefficient surfaces when compared with non-ABS braking. Usage of ECB resulted in a smooth ABS stop minimizing the NVH (noise, vibration and harness) of current hydraulic ABS systems.

E. Gay et. al. (2006) analyzed the effects of design parameters on the torque-speed curve of the eddy-current brake by the means of three-dimensional (2-D)finite-element analysis. The paper follows a previous work in which analysis was performed with a 2-D analytical model. The example computed analytically in has been computed with FLUX 3D. A normal flux condition on the surface above the magnet models the infinitely permeable stator back-iron, while the “infinite box” models air beyond the brake. The disc material is copper for this simulation.

Park (2006) proposed brake system consists of rotating disks immersed in a MR fluid and enclosed in an electromagnet, which the yield stress of the fluid varies as a function of the magnetic field applied by the electromagnet. The controllable yield stress causes friction on the rotating disk surfaces, thus generating a retarding brake torque. The braking torque can be precisely controlled by changing the current applied to the electromagnet. In this paper, an optimum MRB design with two rotating disks is proposed based on a design optimization procedure using simulated annealing combined with finite element simulations involving magnetostatic, fluid flow and heat transfer analysis. A sliding mode controller was designed for an optimal wheel slip control, and the control simulation results show fast anti-lock braking.

Sodano et. al. (2010a) developed a mathematical model to predict the amount of damping induced on the structure was shown to be accurate when the magnet was far from the beam but was less accurate for the case that the gap between the magnet and beam was small. In the present study, an improved theoretical model of the previously developed system will be formulated using the image method, thus allowing the eddy current density to be more accurately computed. In addition to the development of an improved model, an improved concept of the eddy current damper configuration is developed, modeled, and tested.

Karakoc et. al. (2006) presented design considerations for building an automotive magnetorheological (MR) brake are discussed. The proposed brake consists of multiple rotating disks immersed in a MR fluid and an enclosed electromagnet. When current is applied to the electromagnet, the MR fluid solidifies as its yield stress varies as a function of the magnetic field applied. This controllable yield stress produces shear friction on the rotating disks, generating the braking torque. Then, a finite element analysis is performed to analyze the resulting magnetic circuit and heat distribution within the MR brake configuration. However, the braking torque generated is still far less than that of a conventional hydraulic brake, which indicates that a radical change in the basic brake configuration is required to build a feasible automotive MR brake.

Goslineet. al. (2005) describe the design of an eddy current brake for use as programmable viscous damper for haptic interfaces. He overviewed the governing physical relationships, and describe design optimization for inertial constraints. A prototype haptic interface is described, and experimental results are shown that illustrate the improvement in stability when simulating a stiff wall that is made possible using programmable eddy current dampers.

Tan et. al. (2010) proposed an identification and control method for a control stage with eddy current. The proposed method is that we first obtain the system parameters using an adaptive algorithm and then we design a model-based controller to achieve good performance. The detailed theoretical analysis is given. The experimental results show that the proposed method can guarantee the parameter convergence and improve the control performance.

Ma et. al. (2010) proposed mechanism implements eddy current phenomenon in developing a braking system. The potential applications of the braking system can be a decelerating system to increase the safety of an elevator or any guided rail transportation system. To provide scientific investigation for industrial application of magnetic braking, this study presents four systematic engineering design scenarios to design a braking system. The constant magnetic field is the simplest and easiest design to implement. The optimal magnetic field distribution is obtained by minimizing the deceleration effort. The piecewise-constant magnetic field distribution offers a compromise between performance and magnetic field requirements. The advantages of the section-wise guide rail are tolerable deceleration; and simple design requirement and manufacturing processes. In the study, an experimental braking system using constant magnetic field is build to demonstrate the design procedure.

Tan(2010) proposed a control method for an air bearing motion stage complemented eddy current braking. The proposed control scheme uses two control inputs to handle the nonlinear air bearing system: one is P control plus a feed forward term and one is eddy current feedback. The stability analysis is discussed involving two cases: (1) accurate model, (2) uncertain model. An air bearing system is based on a pressurized thin film of air to support an applied normal load. Moving heavy loads on air is a clean, quiet and safe method which will not damage floors.

Karakoc (2012) proposed eddy Current Brakes (ECBs) as possible substitutes for the conventional hydraulic brakes (CHBs) in automotive applications due to its unique potential for performance advantages (e.g., non-contact and fast response). As a potential solution for the limited braking torque of typical ECBs at low speeds, the application of time varying fields (i.e., AC) is proposed. A finite element model (FEM) that accounts for the effects of time varying fields on the performance of the ECB was developed, which was then validated using an existing analytical model for the DC field. It was shown that improved braking performance can be obtained when AC fields are used at both low and high velocities. Time varying fields in different waveforms (i.e., sinusoidal, square, saw tooth and triangular waves) were applied and triangular wave field application resulted in the highest braking torque. The numerical results also showed that the braking torque decreases with increasing braking torque due to induction effects when the time varying fields are applied.

Hu(2012) studied test-bed test system of automobile eddy current retarder. After introduction to sensors needed and detection principles, the process of signal collection and treatment by single chip is put forward. Besides, precision compensation and standardization of sensor is conducted, all constituent parts and function are introduced, including forward computer interface. Simple analysis and discussion is conducted on analogue principle of two operation stations of retarder. In the end, the design idea of test software is put forward and flow chart of the design is provided.

He(2013) introduces an eddy current and electro-hydraulic hybrid brake system to solve problems such as wear, thermal failure, and slow response of traditional vehicle brake system. Mathematical model was built to calculate the torque of the eddy current brake system and hydraulic brake system and analyze the braking force distribution between two types of brake systems.

3. MATERIAL AND METHOD

3.1. Material

3.1.1. Electromagnetic Retarder

Electromagnetic retarders converts direct current to magnetic field between stator and rotor with help of coils, that magnetic field leads a brake force. Rotating parts called rotors are attached to the driveshaft (Figure 3.1). Separated by a narrow air gap, the stator is connected to the vehicle chassis. When electricity flows through the stator coils, electromagnetic fields with alternate polarities are created. As the rotors pass through these fields, eddy currents are generated which slow the rotors and thus slow the driveshaft. Any heat generated during braking is self-dissipated through the rotor vanes.

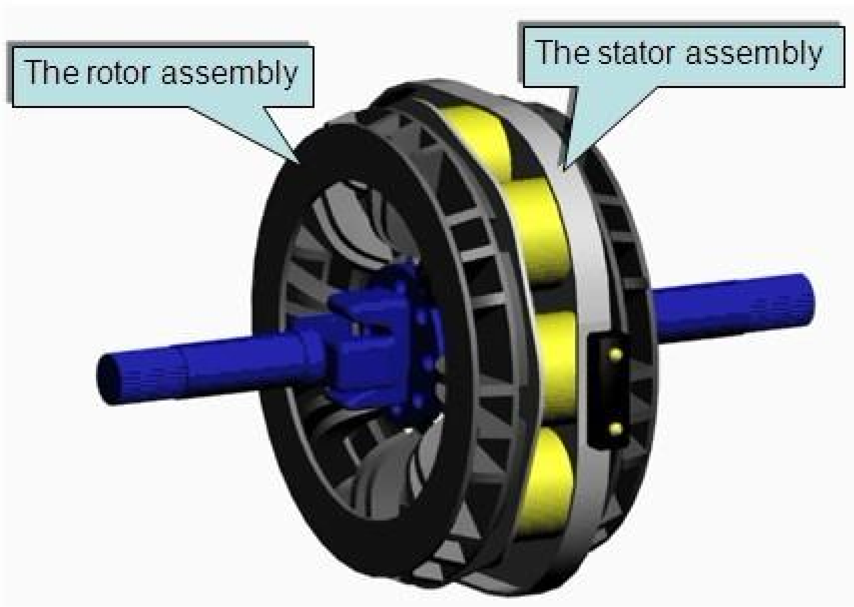

Figure 0.1. Magnetic retarder

Table 0.1. Technical specifications of the Telma FV-6130

Maximum Torque	1300 N.m
Mass	129 kg
Rotors Inertia	1.23 kg.m^2
Voltage	24 V
Resistance per Circuit	1.6 ohm
Nominal Air Gap	1.3 mm

Detailed technical drawing of the magnetic retarder and its electric wiring schematic are respectively shown in Figure 3.2 and 3.3.

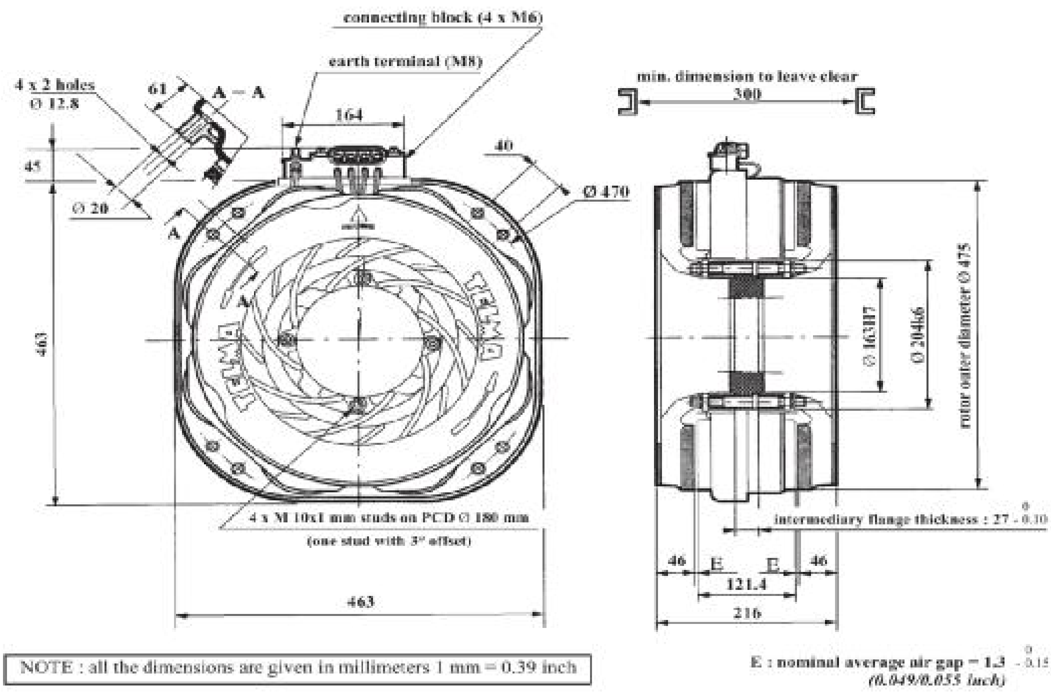

Figure 0.2. Technical drawing of retarder

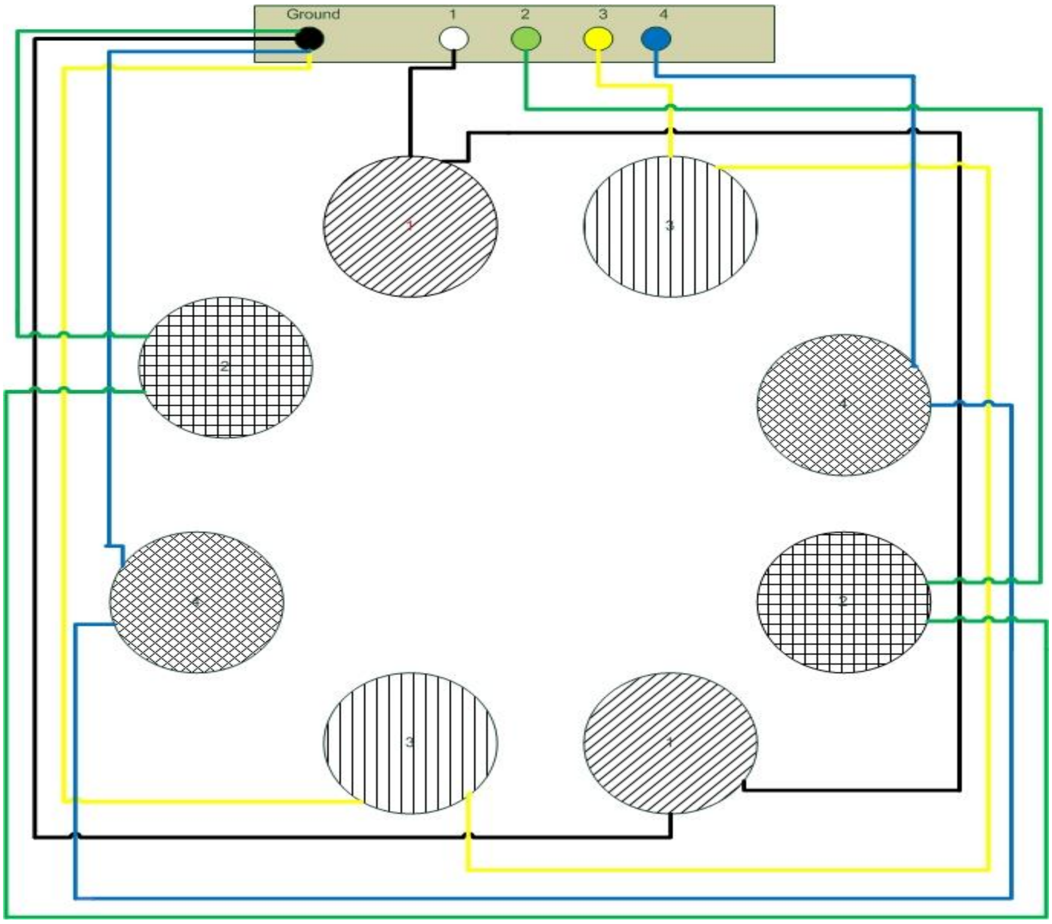

Figure 0.3. Electrical scheme of retarder

The electromagnetic technology guarantees unequalled instantaneous availability and full braking power provided by the Telma retarder, regardless of the vehicle's speed.

Telma retarders remain effective even after the engine stops, or when the gearbox is in neutral. As they dissipate the energy generated during braking directly into the atmosphere without using the engine's liquid cooling system, Telma retarders are effective in all situations, thereby ensuring that a vehicle always remains at the driver's desired speed.

With exceptional endurance, Telma retarders ensure most vehicles' braking needs. Risks associated with service braking system overheating are therefore avoided and the system remains fully operational in case of emergency.

During so-called service braking, the energy to be dissipated to slow down or stop a vehicle with a conventional braking system is so important that the components of the braking system, including the brake linings, undergo significant heating, which accelerates wear. Telma retarders ensure the vehicle's braking needs. Vehicles equipped with a Telma retarder can multiply the lifespan of their service braking system up to ten times: maintenance costs are therefore greatly reduced and operational availability is increased.

The exceptional reactivity of Telma retarders prevents excessive fuel consumption during fast switches between deceleration and acceleration phases. Telma retarders never go against the engine: they can instantly stop producing braking torque upon driver's request.

The recognized quality, reliability and durability of Telma retarders make them a profitable investment that quickly pays for itself and, by extending the vehicle's braking ability, they increase the average operational speed.

The complete lack of friction makes Telma retarders totally silent in all conditions of use. The electromagnetic technology guarantees Telma retarders' instant response to driver solicitations, thus allowing for an unprecedented driving experience. The ease of use, flexibility and progressive character of Telma retarders guarantees exceptional comfort for the driver and its passengers. Telma retarders also provide great adaptability due to the wide range of products offered, the simplicity of integration and the compatibility with all electronic braking systems available on the market With their tried and robust technology, Telma retarders require no specific maintenance.

Telma retarders comply with the European ROHS directive (2002/95/CE) restricting the use of certain hazardous substances in the construction of electrical equipment. The total lack of friction makes Telma retarders fully silent under all conditions of use and guarantees the absence of particle emissions or any other pollutant release into the environment. Telma retarders are maintenance-free and do not require any fluid change or wearing parts replacement. As they comply with the European Directive 2004/108/EC on electromagnetic compatibility (EMC), Telma retarders present no electromagnetic incompatibility with the environment. Finally, the contribution of Telma retarders to the reduction of the equipped vehicles' energy consumption actively contributes to the reduction of greenhouse gas emissions.

3.1.2. Engine

The specifications of the engine that is used in the study are as listed below;

Table 0.2. Technical specifications of the engine

Brand	MWM
Model	4D34-2A
Configuration	In line 4
Type	Direct injection diesel with glow plug
Compression Ratio	16:1
Cylinder Volume	4300 cc
Power	107 kW @ 4000 rpm
Torque	500 Nm @ 2600 rpm
Oil cooler	Water cooled
Air cleaner	Paper element type
Weight	380 kg

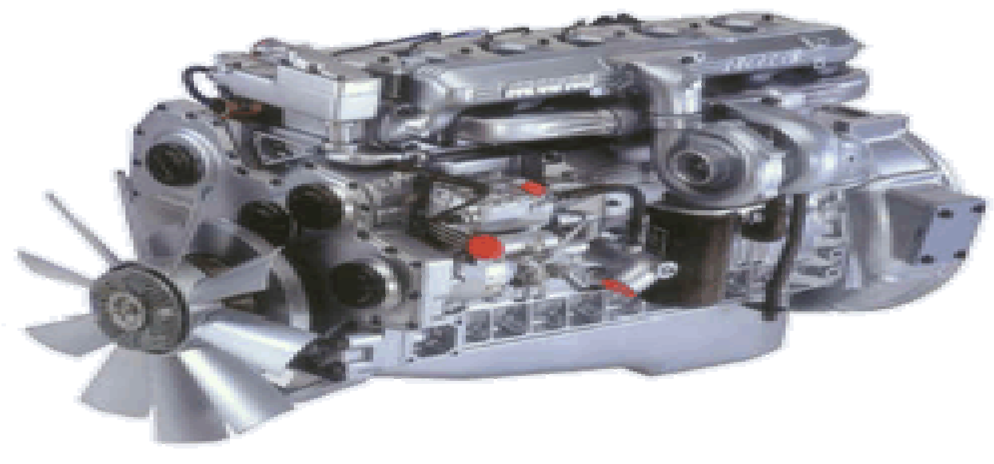

Figure 0.4. MWM TCA 4.10 Diesel Engine

3.1.3. Torque Sensor

The TORKDISC® system utilizes a unique digital data transmission technique. A radio frequency signal generated within the receiver box is inductively coupled from the pick-up antenna to the transmitting antenna and rectified to provide

DC voltages to operate the rotating TORKDISC® transmitter. The transmitter has been configured for a full-scale input of ±1.5mV/V or ±2.0mV/V. The rotating circuitry provides excitation for the strain gage bridge, amplifies, and filters its output. The resulting signal is presented to an analog to digital converter that samples it and converts it to a noise immune digital code. To provide up to a 2kHz measurement bandwidth without creating aliasing errors, the A-to-D converter samples at a rate in excess of 26,000 samples per second. Data are transmitted off the rotor in this digitally encoded form. In this manner, they are not subject to noise degradation or per-rev effects. The digital data are recovered in the receiver box where they are re-converted to an analog signal. This signal is used to generate the standard voltage and frequency system outputs.

As with any digital data acquisition system, the calibration of the TORKDISC® system is easy to accomplish and is extremely stable over time. Although routine calibration checks are not generally required, the product is equipped with a remotely activated shunt calibration feature that can be controlled from the front panel of the receiver box. This allows the user to check calibration at any time during system operation. When the shunt calibration feature is invoked, a precision resistor is switched across one leg of the Wheatstone Bridge, producing a positive shift in the receiver’s output.

Figure 0.5. Transmitter Part of Torque Sensor

The outputs of the torque sensor arc provided on the hack of the receiver via the connector labeled “I/O" on figure 3.6.

Figure 0.6. I/O Connector and backpanel

3.1.3. Controller

Controller part basically consists of 2 devices. These are microcontroller and digital potentiometer.

3.1.3.1. Microcontroller

A microcontroller (sometimes abbreviated MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.

Some microcontrollers may use four-bit words and operate at clock rate frequencies as low as4 kHz, for low power consumption (single-digit miliwatts or microwatts). They will generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping (CPU clock and most peripherals off) may be just nanowatts, making many of them well suited for long lasting battery applications. Other microcontrollers may serve performance-critical roles, where they may need to act more like a digital signal processor(DSP), with higher clock speeds and power consumption.

Figure 0.7. PIC 16F877 Microcontroller

PICis a family of modified Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1650originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to "Peripheral Interface Controller"' now it is "PIC"' only. PICs are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability.

PIC16F877 is one of the most advanced microcontroller from Microchip. This controller is widely used for experimental and modern applications because of its low price, wide range of applications, high quality, and ease of availability. It is ideal for applications such as machine control applications, measurement devices, study purpose, and so on. The PIC 16F877 features all the components which modern microcontrollers normally have. The figure of a PIC16F877 chip is shown below.

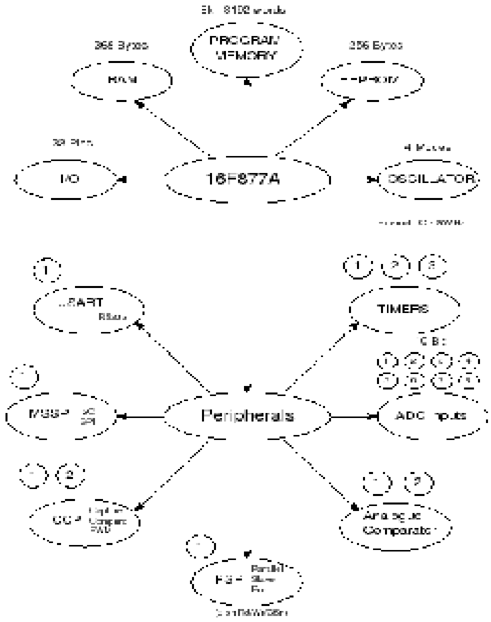

Figure 0.8. Schematic illustration of PIC16F877A microcontroller properties.

3.1.3.2. Digital Potentiometer

A digital potentiometer (also known as digital resistor) has the same function as a normal potentiometer but instead of mechanical action it uses digital signals and switches. This is done by making use of a 'resistor ladder', a string of small resistors in series. At every step of the ladder, an electronic switch is present. Only one switch is closed at the same time and in this way the closed switch determines the 'wiper' position and the resistance ratio. The amount of steps in the ladder determines the resolution of the digital pot. Digital resistors can be controlled by using simple up/down signals or by serial protocols as seen in Figure 3.10.

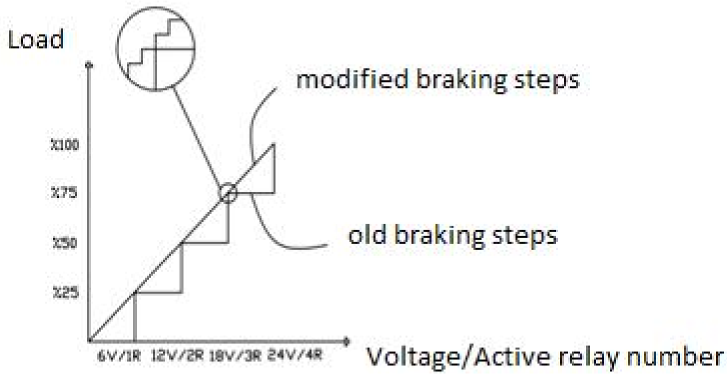

Figure 0.9. Comparison of new and old control system

The DS1868 Dual Digital Potentiometer Chip consists of two digitally controlled solid-state potentiometers. Each potentiometer is composed of 256 resistive sections. Between each resistive section and both ends of the potentiometer are tap points which are accessible to the wiper. The position of the 2 of 14 wiper on the resistor array is set by an 8-bit value that controls which tap point is connected to the wiper output.

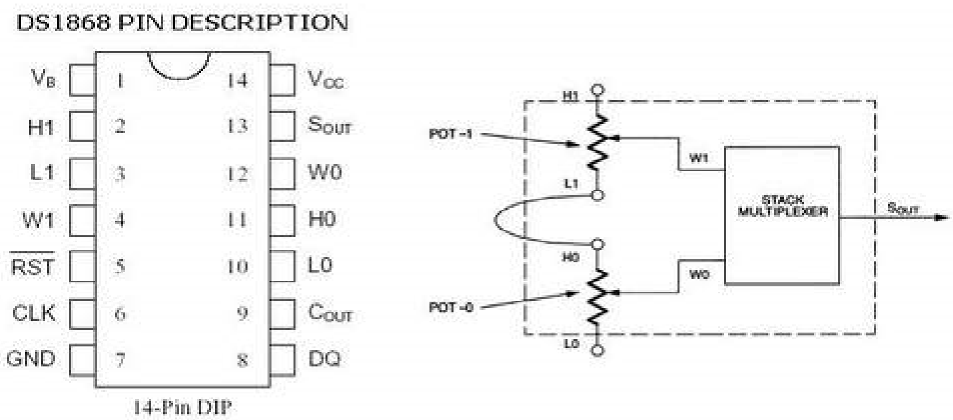

Figure 0.10. DS1868 pin description

Communication and control of the device is accomplished via a 3-wire serial port interface. This interface allows the device wiper position to be read or written. Both potentiometers can be connected in series (or stacked) for an increased total resistance with the same resolution. For multiple-device, single-processor environments, the DS1868 can be cascaded or daisy chained. This feature provides for control of multiple devices over a single 3-wire bus. The DS1868 is offered in three standard resistance values which include 10, 50 and 100 kOhm versions. The part is available in 16-pin SOIC (300-mil), 14-pin DIP, and 20-pin (173-mil) TSSOP packages. The DS1868 contains two 256-position potentiometers whose wiper positions are set by an 8-bit value. These two 8-bit values are written to a 17-bit I/O shift register which is used to store the two wiper positions and the stack select bit when the device is powered.

Communication and control of the DS1868 is accomplished through a 3-wire serial port interface that drives an internal control logic unit. The 3-wire serial interface consists of the three input signals: RST , CLK, and DQ. The RST control signal is used to enable the 3-wire serial port operation of the device. The RST signal is an active high input and is required to begin any communication to the DS1868. The CLK signal input is used to provide timing synchronization for data input and output. The DQ signal line is used to transmit potentiometer wiper settings and the stack select bit configuration to the 17-bit I/O shift register of the DS1868. The 3-wire port is inactive when the RST signal input is low. Communication with the DS1868 requires the transition of the RST input from a low state to a high state. Once the 3-wire port has been activated, data is entered into the part on the low to high transition of the CLK signal inputs. Data written to the DS1868 over the 3-wire serial interface is stored in the 17-bit I/O shift register. The 17-bit I/O shift register contains both 8-bit potentiometer wiper position values and the stack select bit. Bit 0 of the I/O shift register contains the stack select bit. This bit will be discussed in the section entitled Stacked Configuration. Bits 1 through 8 of the I/O shift register contain the potentiometer-1 wiper position value. Bit 1 will contain the MSB of the wiper setting for potentiometer-1 and bit 8 the LSB for the wiper setting. Bits 9 through 16 of the I/O shift register contain the value of the potentiometer-0 wiper position with the MSB for the wiper position occupying bit 9 and the LSB bit 16.

3.1.5. Proton PIC Programmer Software

Proton IDE is a professional and powerful visual Integrated Development Environment (IDE) designed specifically for the Proton Plus compiler. Proton IDE is designed to accelerate product development in a comfortable user development environment without compromising performance, flexibility or control.

The code explorer, compiler results, programmer integration, integrated bootloader, real time simulation support, serial communicator are the features of Proton IDE.

Code Explorer is possibly the most advanced code explorer for PIC based development on the market quickly navigate your program code and device Special Function Registers (SFRs).

Compiler Results provides information about the device used, the amount of code and data used, the version number of the project and also date and time. One can also use the results window to jump to compilation errors.

Programmer Integration enables to start preferred programming software from within the development environment.

Real Time Simulation Support and Proteus Virtual System Modeling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete microcontroller based designs. It is also possible to develop and test such designs before a physical prototype is constructed.

Serial Communicator is a simple way to use utility which enables you to transmit and receive data via a serial cable connected to PC and development board. The easy to use configuration window allows you to select port number, baudrate, parity, byte size and number of stop bits. Alternatively, Serial Communicator can be used favorites to quickly load pre-configured connection settings.

3.1.6. Proteus

Proteus is a single application with many service modules offering different functionality (schematic capture, PCB layout, etc.). The wrapper that enables all of the various tools to communicate with each other consists of three main parts.

Proteus consists of a single application. This is the framework or container which hosts all of the functionality of Proteus. ISIS, ARES, 3DV all open as tabbed windows within this framework and therefore all have access to the common database.

The common database contains information about parts used in the project. A part can contain both a schematic component and a PCB footprint as well both user and system properties. Shared access to this database by all application modules makes possible a huge number of new features, many of which will evolve over the course of the Version 8 lifecycle.

Together with the common database the maintenance of a live net-list allows all open modules to automatically reflect changes. The most obvious example of this is wiring in ISIS producing connections in ARES but it goes much further than that. The new Bill of Materials module contains a live viewer and the 3D Viewer and Design Explorer are also linked into the live net-list.

This document covers the Proteus 8 application framework and other functionality related to the software suite as a whole. The various application modules (e.g. ISIS, ARES) each have their own reference manuals and tutorial documentation.

Proteus VSM supports both the simulation and the debugging of microcontroller based designs. In order to properly debug firmware the simulation needs to be aware of high level source lines, address information, local variables and various other information that is not contained in the raw HEX file used to program a physical device.

3.1.7. Power Supply

A power supply is a device that supplies electric power to an electrical load. In this project, electric power is taken from the power supply system sent to magnetic retarder with adjustable voltage. Power supply system is directly controlled by a microcontroller circuit.


Figure 0.11. Power supply circuit unit

Power supply system is driven by an integrated chip. The KA3525A is a monolithic integrated circuit that included all of the control circuit necessary for a pulse width modulating regulator. There are a voltage reference, an error amplifier, a pulse width modulator, an oscillator, under-voltage lockout, soft start circuit, and output drivers in the chip.KA3525 chip is shown in Figure 3.10.

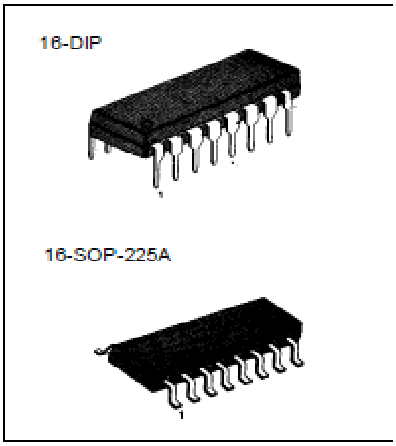

Figure 0.12. KA3525 SMPS Controller

It has features such as 5V reference oscillator, sync terminal, internal soft start, dead-time control, under-voltage lockout.

Table 0.3. Technical specifications of the KA3525 SMPS Controller

Supply Voltage	40 V
Collector Supply Voltage	40 V
Output Current, Sink or Source	500 mA
Reference Output Current	50 mA
Operating Temperature	0-70 C
Torque Arm Length	350 mm

3.2. Method

Current control system of retarders on buses and trucks are relatively simple. It consists of only 4 relays which are used to trigger each coil circuit as shown in the figure. These coils circuits are charged by a constant voltage of 24 Volts. Consequently, this system can be only driven by a load of 25, 50, 75, 100 percentages. This system is not practical enough and also not capable of sensitive braking as shown in Figure 3.13

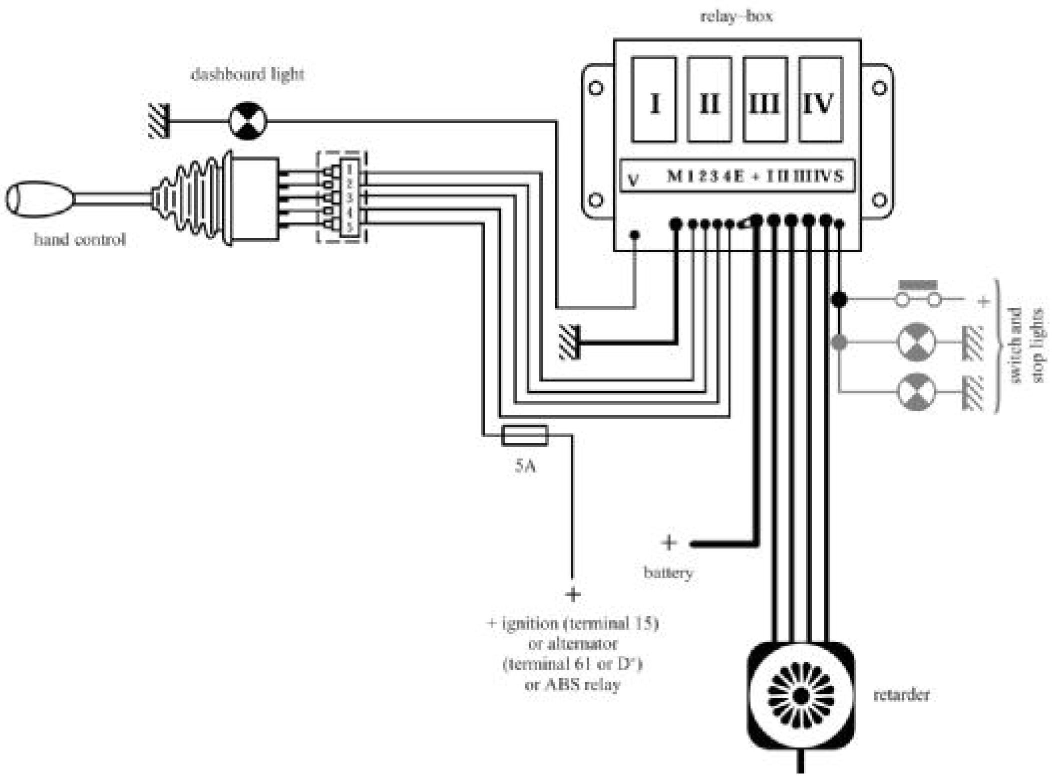

Figure 0.13. Schematic of old control system of magnetic retarder

In this thesis, a control system which consists of a power circuit and a microcontroller circuit is tried to achieve as it can be seen in Figure 3.14.So that, braking level of the retarder is increased to 4 from1023. The braking level is controlled by driver with a potentiometer which is shown in Figure 3.14.

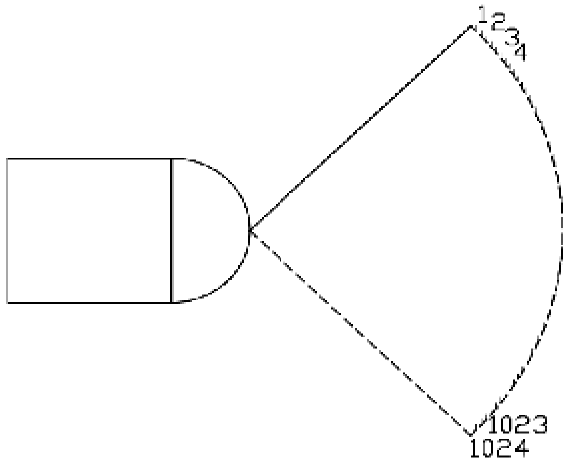

Figure 0.14. Demonstration of braking level potentiometer

In order to build such system, a methodology is used. Method of the study is divided by 2 stages.

3.2.1. Mechanical Installation

The mechanical system that is planned to use for study was assembled two years ago. However, the system was not able to use because of the mechanical problems. The first aim is to figure out design and assembly mistakes, balancing, and vibration problems of magnetic retarder

The first design of the chassis had fatal mistakes. In addition, the magnetic retarder was damaged. In order to solve these problems, at first place, a new magnetic retarder is donated from TEMSA company. The other problem was welding defects during assembling operation. Most of the chassis parts are disassembled and some parts are modified with the aid of the CATIA software program. Then the improved chassis is analyzed with ANSYS software program in order to observe possible difficulties in service conditions. The new chassis drawing and simulation results are labeled in Figure 3.15.

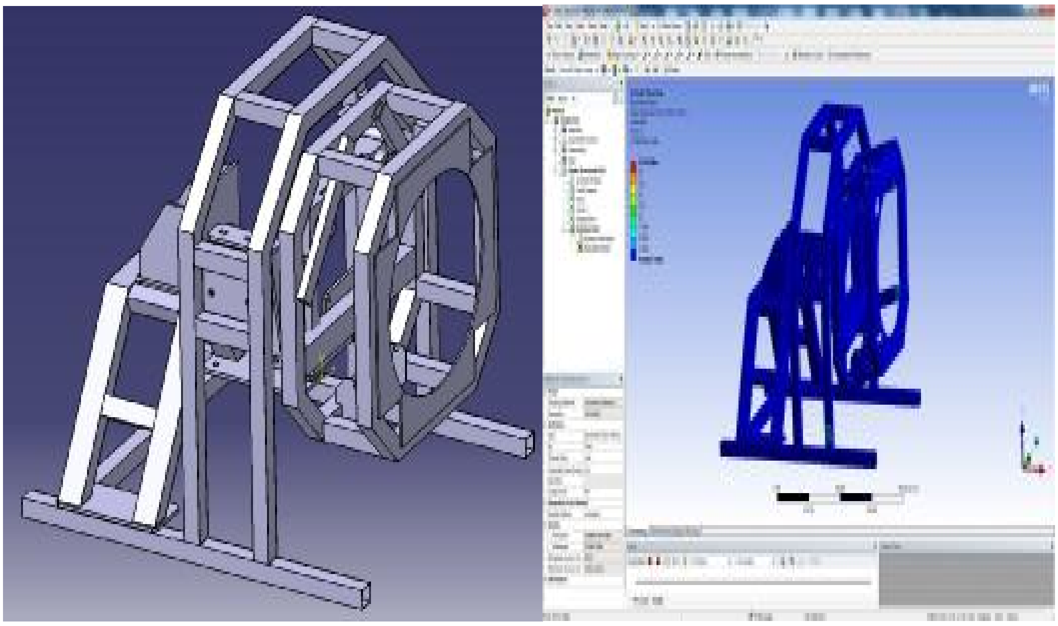

Figure 0.15. Drawing of Chassis and Simulation Results

The shaft of the system was also buckled. The shaft is repaired on a turning machine. An additional support flange for retarder is also added on shaft. The reassembled operation is done by with help of technicians as seen in Figure 3.16.

Figure 0.16. Reassembling operation

3.2.2. Designing of Electrical Control Unit:

In order to design the electronic control unit, there are some basic steps must be followed. The first step is choosing which microcontroller is used. In order to run system, Analog-to-digital converter and SPI serial communication abilities must be included. So, PIC16F877A microcontroller is chosen for our test rig because PIC microcontrollers are one of the most reliable microcontroller and also cheaper, on market.

Secondly, the digital potentiometer chip which applies braking level change commands and connects microcontroller to rest of the system. DS1868 digital potentiometer integrated chip is selected because of its reliability and reliability.

The next step is writing of source code of microcontroller. Source code can be described as collection of microcontroller instructions written using some human-readable computer language, usually as text and designed to facilitate the work of microcontroller programmers. In order to write a source the source code, the working flowchart of the system has to be made. Flowcharts are used to show diagrammatic representation illustrates a solution model to a given problem with the steps as boxes of various kinds, and their order by connecting them with arrows as seen in Figure 3.17.

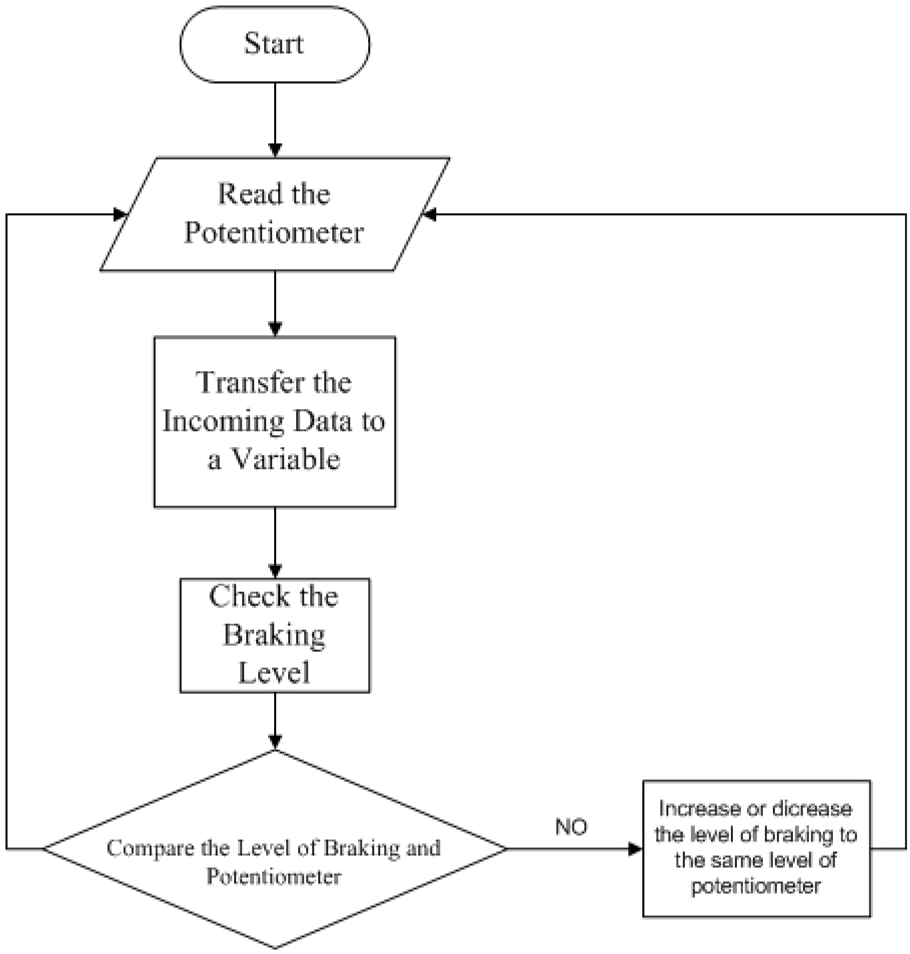

Figure 0.17. Flowchart of Microcontroller

The next step is to simulate the design in software. The model of the system is developed achieved on computer and it is seen that microcontroller circuit works perfectly as seen in Figure 3.18. Trial version of Proteus is used for this operation for that purpose.

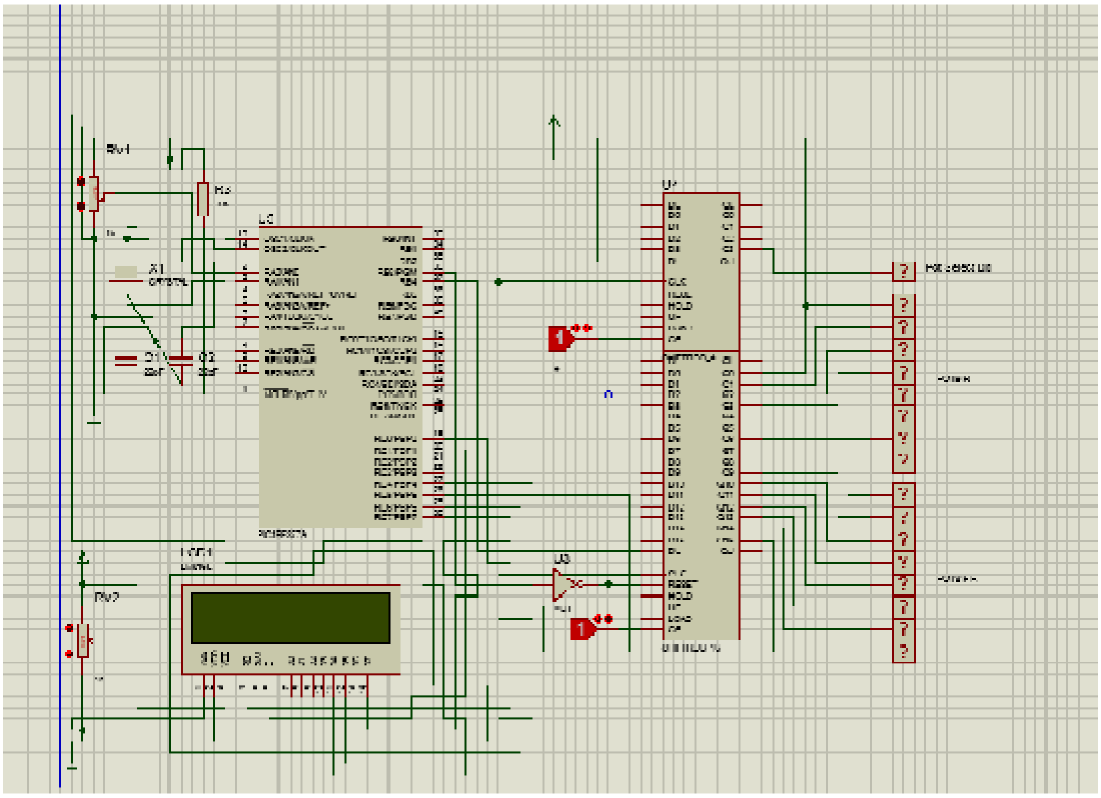

Figure 0.18. Software design, analysis and Modeling of Microcontroller Circuit

The microcontroller circuit is built on a breadboard. These boards are used a construction base for prototyping purpose of electronics. It basically consists of block of plastic with numerous number of tin plated alloys. The microcontroller photo is shown in the figure.

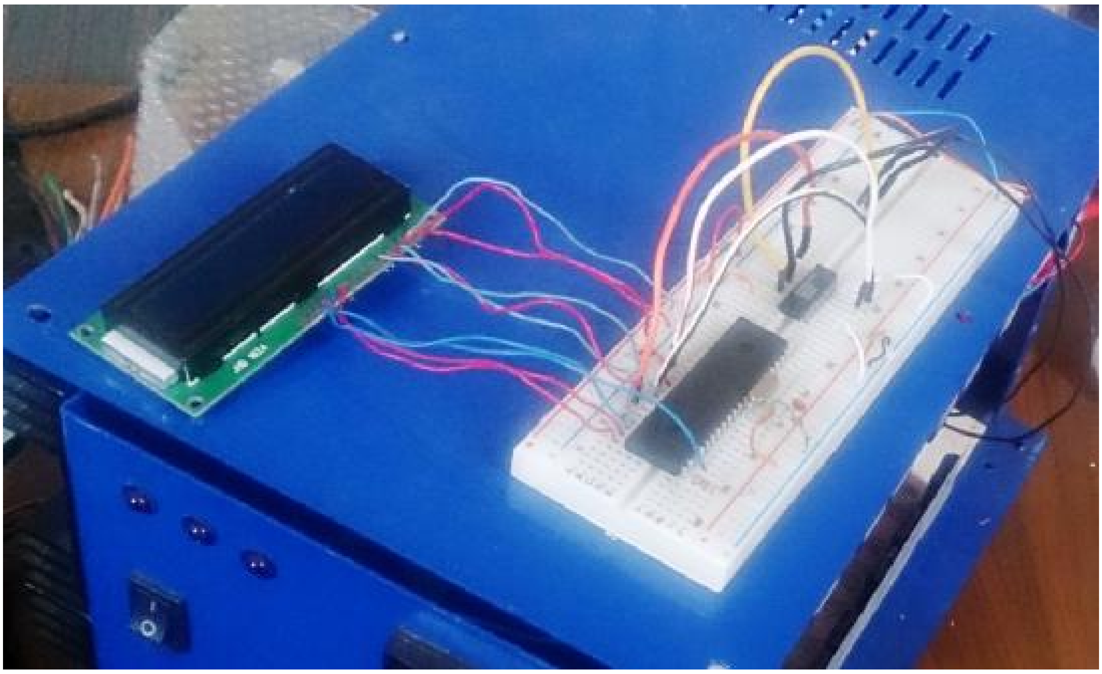

Figure 0.19. Photo of Microcontroller Circuit and Power Supply Unit

4. RESULTS AND DISCUSSION

The experiment was performed on our test rig (Figure 4.1.) which takes place in Petroleum Research Laboratories of the Department of Automotive Engineering in Çukurova University.

Figure 0.1. A photo of the magnetic retarder test rig

Test results were gathered and then sent to Curve Expert software. The CurveExpert software is a cross-platform solution for curve fitting and data analysis. The data can be modeled using a toolbox of linear regression models, nonlinear regression models, smoothing methods, or various kinds of splines. Over 90 models are built-in, but custom regression models may also be defined by the user. Full-featured publication-quality graphing capability allows thorough examination of the curve fit. The process of finding the best fit can be automated by letting CurveExpert compare your data to each model to choose the best curve.

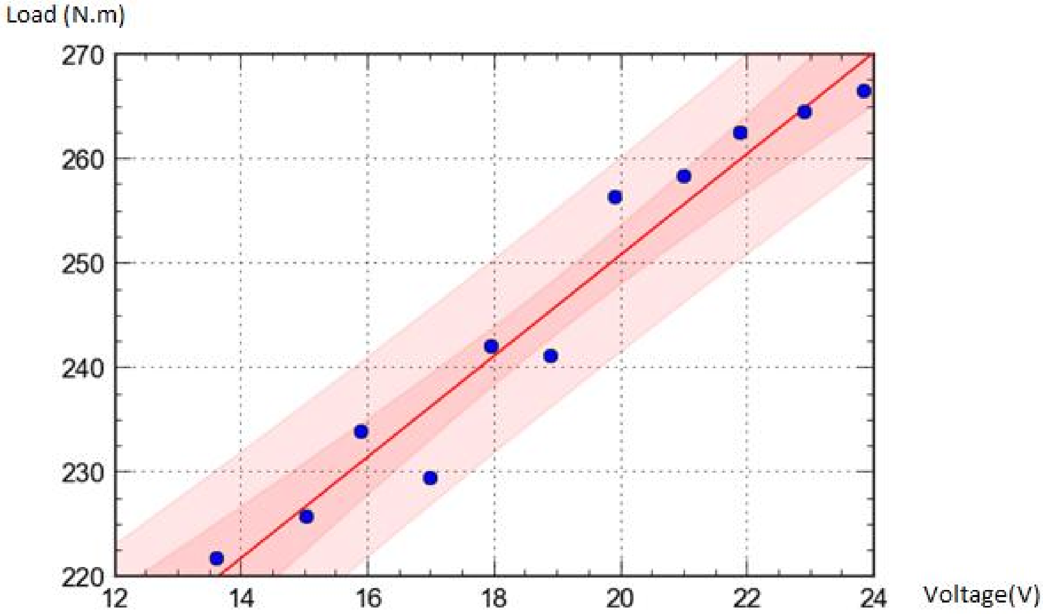

Figure 0.2. Graph of experimental results

The braking torque versus voltage is shown in figure 4.2. The demonstration gives considerable information about braking performance. The results show that braking performance is acceptable between minimum and maximum control voltages.

5. CONCLUSION

The aim of the study is to achieve more precise and efficient braking system for trucks and buses. Magnetic retarders extend the period of use of braking system parts as well as improving the comfort of the passengers.

Consequently, the developed system uses input voltage to control the system that has 1023 braking levels in comparison to 4 stage original system. This system provides a huge impact on the performance and effectiveness of the retarders. Also, curve fitting operations show that retarder coils works efficiently between minimum and maximum control voltages.

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CURRICULUM VITAE

İhsan ULUOCAK was born in İstanbul on June 16, 1988. He graduated from Zekai Gümüşdiş İlköğretim Okulu in 2002 and from Fatih Lisesi in 2005. Then, he started his BSc. degree in 2005 at Gaziantep University, Mechanical Engineering Department. He started his MSc study in the same department of Çukurova University in 2011. He has been working as a Research Assistant since 2011.