VIBRATION SUPPRESSION OF ROTATING DISC USING EDDY CURRENT METHOD

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ABSTRACT

This paper presents about the vibration behaviour on rotating aluminum disc using eddy current method. By increasing the induce current with different initial speed and different air-gap it make a different vibration behavior. The changing magnetic flux induces eddy currents in the conductor. These currents dissipate energy in the conductor and generate drag force. One such method is eddy current damping. Magnetic damping scheme functions through the eddy currents that are generated in a nonmagnetic conductive material when it is subjected to a time changing magnetic field. The result of this study show that the increasing of induce current, initial speed and air-gap give a significant effect to vibration behaviour effected from magnetic flux density and damping force.

ABSTRAK

Kertas kerja ini membentangkan mengenai kelakuan getaran pada cakera aluminium yang berputar menggunakan kaedah arus pusar. Dengan meningkatkan arus pendorong dengan kelajuan awal yang berbeza dan berbeza-jurang udara menghasilkan getaran tingkah laku yang berbeza. Fluks magnet yang berubah-ubah mendorong arus pusar dalam konduktor. Arus ini melesapkan tenaga dalam konduktor dan menjana daya seretan. Satu kaedah itu adalah arus pusar redaman. Skim redaman magnetic berfungsi melalui arus pusar yang dihasilkan dalam bahan konduktif nonmagnetic apabila ia tertakluk kepada masa berubah medan magnet. Hasil kajian ini menunjukkan bahawa semakin meningkat arus pendorong, kelajuan awal semasa dan jurang udara memberi kesan yang besar kepada tingkah laku getaran kesan daripada ketumpatan fluks magnet dan daya redaman.

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LIST OF SYMBOLS

r	Radius
n	Number of electromagnet
d	Diameter
A	Ampere (unit for current)
mm	Millimeter

LIST OF ABBREVIATIONS

DC	Direct current
RPM	Radius per minit
FFT	Fast fourier transform
Emf	Electromotive force

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Excessive disk vibration degrades the signal from the read/write head in a hard disk drive, and may destroy the disk drive by a head crash. In the wood-cutting industry, the undesirable vibration of the circular saw blade results in unacceptable waste of raw material. For instance, in turbine operation, the unstable vibration of the turbine wheel can cause turbine failure due to wheel-to-case impact. The excessive vibrations are not good to many mechanical appliances. It gave bad impact to the mechanical properties in time and it also affect other thing and not just on the metal but giving discomfortness on us [1]. Nevertheless there are exist solution to the problem that we may faces about the excess vibration that we called the vibration suppression. However, very few can function without ever coming into contact with the structure. One such method is eddy current damping. This magnetic damping scheme functions through the eddy currents that are generated in a nonmagnetic conductive material when it is subjected to a time changing magnetic field. The magnitude of the magnet field on the conductor can be varying through movement of the conductor in a stationary magnetic field, by movement of a constant intensity magnetic source or changing the magnitude of the magnetic source with respect to a fixed conductor. Once the eddy currents are generated, they circulate in such a way that they induce their own magnetic field with opposite polarity of the applied field causing a resistive force. However, due to the electrical resistance of the conducting material, the induced currents will dissipated into heat at the rate and the force will disappear [2]. In the case of a dynamic system the conductive metal is continuously moving in the magnetic field and experiences a continuous change in flux that induces an electromotive force (emf), allowing the induced currents to regenerate. The process of the eddy currents being generated causes a repulsive force to be produced that is proportional to the velocity of the conductive metal. Since the currents are dissipated, energy is being removing from the system, thus allowing the magnet and conductor to function like a viscous damper. One of the most useful properties of an eddy current damper is that it forms a means of removing energy from the system without ever contacting the structure. This means that unlike other methods of damping such as constrained layer damping, the dynamic response and material properties are unaffected by its addition into the system. Furthermore, many applications require a damping system that will not degrade in performance over time. This is not the case for other viscous dampers, for instance many dampers require a viscous liquid which may leak over time. These two points are just a few of the many advantages offered by eddy current damping systems [3].

However, effective methods of utilizing the eddy current effect to suppress the transverse vibrations experienced by many structures have not yet been developed. Therefore, this dissertation will develop several eddy current damping systems that can be efficiently used to suppress structural vibrations.

In general, large amplitude of transverse vibration is undesirable as it can degrade the performance of the devices, and in some cases destroy the machines. These vibration problems are aggravated as industry applications tend to push the rotation speed of the circular disk even higher. Suppressing the unwanted vibration in a spinning disk has become an increasing challenge for mechanical engineers and researchers. One of the most intuitive approaches in preventing excessive vibration in a spinning disk is to apply space restraints or vibration absorbers on the disk surface. This approach has been widely adopted in circular saw industry and the effect of the space restraints on the disk vibration has been studied extensively. In these analyses, it was found that damping in the space restraints can suppress the disk vibration when the rotation speed is lower than the critical speed of the disk [3].

However, these passive control approaches fail completely in the super-critical speed range. In implementing active control to suppress the spinning disk vibration, some developed a proportional-derivative controller aimed at increasing the transverse stiffness and damping of a circular saw with an electromagnetic actuator. One eddy current sensor close to the actuator is used to measure the displacement. They reported that unstable vibration occurs at high control gain because of complex actuator dynamics which is difficult to accommodate in the controller design. They used the on-line FFT analysis of the disk displacement to identify the dominant mode of the disk vibration. The wave amplitude controller modulates control forces on four electromagnetic actuators to oppose the displacements and velocities predicted by a minicomputer. While this system indeed suppressed the vibration of the controlled mode, it excited the uncontrolled mode at higher gain due to observation and control spillovers. In order to eliminate the observation and control spillovers, some employed the method of independent modal space. A magnetic drag force is produced to slow down the motion when a conducting material is moving through a stationary magnet or a magnet is moving through a stationary conducting material [4]. The changing magnetic flux induces eddy currents in the conductor. These currents dissipate energy in the conductor and generate drag force. This phenomenon is also called eddy current braking. The advantage of the eddy current braking is that they are non-contacting components which can eliminate the shortcomings of conventional braking systems such as heating, wearing, vibrations, and contaminations due to contact friction. Therefore, this method has been proposed to enhance notational stability of the dual-spin satellite system and to suppress vibrations in space crafts. Eddy current braking concept is also applied in dynamometers. The benefits of magnetic drag force are employed to develop various damping elements for operating without needs of electronic devices and external power supplies. Analysis of magnetic field and calculation of magnetic drag force are essential for the design of braking devices by using permanent magnet. However, the entire process is complex and difficult; it needs to solve Maxwell's equations in a time-dependent situation. Besides, many variables involve in this issue and have to be taken into account [5]. The major parameters including geometry of permanent magnet, materials of magnet, air gap, conducting materials and distribution of magnetic flux density.

1.2 PROBLEM STATEMENT

Eddy current generated when a non-magnetic conductive metal is placed in a magnetic field. The use of Eddy Current had been explored as a damper and controls the vibration of the dynamic systems. Eddy current will act like a viscous damper and control the vibration of the structure. The problem is to see how the vibration behavior when the electromagnetic take place on aluminium.

1.3 OBJECTIVES

The objectives of this project is:

i. to reduce vibration at rotating disc using Eddy Current Method
ii. to analyzed vibration on aluminum rotating disc using Eddy Current Method

1.4 SCOPES OF PROJECT

This project is about vibration suppression of rotating disc using Eddy Current Method. In order to achieve the study objective stated above, the scopes of study have been defined. DASYLAB software used for the measurement purposes in this project. Before started the experiment are important to understanding the eddy current method and study on vibration suppression on rotating disc. Lastly, must to know how to setup test rig for the experimental.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explain about the damping, theory of eddy current, eddy current on rotating disc, eddy current braking system which taken from the journals, reference books, and other related resources. This study aims to reduce and analyzed vibration on aluminum rotating disc. This study also to see the vibration behaviour in different initial angular speed (rpm), by increasing the induce current from 0A to 3A and in the different air-gap.

2.2 Damping

Vibrating systems can encounter damping in various ways like intermolecular friction, sliding friction and fluid resistance [3]. Damping estimation of any systems is the most difficult in any vibration analysis. Generally damping are complex and for mechanical systems it is small to compute but even it is small for us to compute damping is very important for an accurate prediction of vibration response of the system [3]. Damping is assumed to have neither mass nor elasticity. It is only exists only if there is relative velocity between two ends of the damper.

2.3 Eddy Current

When a conductive body moving in a magnetic field experiences eddy current. Similar to eddy current effects due to time-varying fluxes, the skin depth is defined as the thickness of the skin in which majority of the induced currents appear. As they are excited by an exterior field, they mainly occur at the sides of the body that are submitted to the magnetic field. High magnetic flux densities occurs at elevated speed when the eddy currents are pushed towards the surface of the conductor [5]. High flux densities are, however, prevented if soft magnetic material is applied. A part of the flux is pushed towards the interior of the moving body or appears as leakage flux around the body. Hence, the behavior of a moving body is largely dependent on the saturation of the soft magnetic material [6]. Moreover, the flow path of induced currents is restricted to the actual geometry of the device.

Eddy Currents are closed loops of induced current circulating in planes perpendicular to the magnetic flux [5]. They normally travel parallel to the coil's winding and the flow is limited to the area of the inducing magnetic field. Eddy Currents concentrate near to the surface adjacent to an excitation coil and their strength decreases with distance from the coil i.e. Eddy Current density decreases exponentially with depth [7]. This phenomenon is known as the skin effect. Skin effect arises when the Eddy Currents flowing in the test object at any depth produce magnetic fields which oppose the primary field, thus reducing the net magnetic flux and causing a decrease in current flow as the depth increases. Alternatively, Eddy Currents near the surface can be viewed as shielding the coil's magnetic field, thereby weakening the magnetic field at greater depths and reducing induced currents.

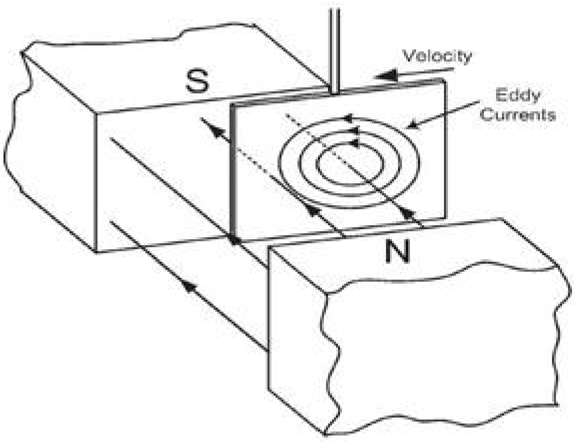

Figure 2.1: schematic of conductive material passing through a magnetic field and the generation of Eddy Current [3]

An Eddy Current is induced around the pole area when magnetic flux goes through a rotating conductive disc [2]. It produced a retarding braking force which come from the interaction occurred between the Eddy Current and magnetic flux. The motion has slow down by the magnetic drag force that has been produced while a conducting material is moving through a stationery magnet, otherwise. The changing magnetic field will induce Eddy Current in the conductor. These currents will dissipate energy in the conductor and generate drag force [7].

2.4 Uses of Eddy Current

These induced Eddy Currents generate their own magnetic field. After all, this is an actual electrical current and any current flowing in a conductor produces a magnetic field. The detection and measurements of the strength of the magnetic fields produced by the Eddy Currents makes it possible for us to learn things about conductive materials without even contacting them. For example, the electrical conductivity of a material can be determined by the strength of the eddy currents that form [8]. Since cracks and other breaks in the surface of a material will prevent Eddy Currents from forming in that region of the surface, Eddy Currents can be used to detect cracks in materials. This is referred to as Eddy Current testing in the field of nondestructive testing (NDT). NDT technicians and engineers use Eddy Current testing to find cracks and other flaws in part of airplanes and other systems where bad things can happen if the part breaks [9].

2.5 Eddy Current Method

The Eddy Current method is based on the principle of electromagnetic induction, generating circular electrical currents in a material under test, this is achieved by the use of a driving alternating magnetic (primary) field [3]. The current flow induced within the inspected material, will itself produce a magnetic (secondary) field in opposition to the primary field. The magnetic field strength and direction are varying in response to the changing current.

If the electrical currents find an obstruction (defect damage) they have to change their flow direction preferring higher conductivity regions which influences the secondary induced field. This change of the resultant fields produces a change of electrical impedance measured across a bridge circuit connected to the primary field, this bridge imbalance can be accurately measured [2]. The amplitude of the induced current reflects the volume of material loss and the depth of defect. By this principle the detection of materials integrity can be assessed.

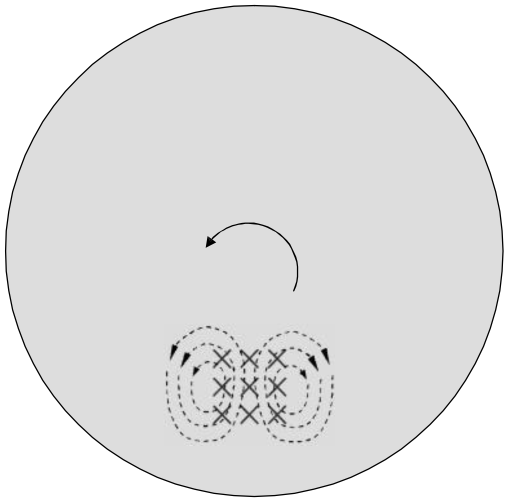

Figure 2.2 : A sketch of the eddy currents in a rotating disc [5].

The crosses represent a steady magnetic field perpendicular to the plane of the disc. According to Faraday's law, eddy currents appear in those points of the disc where the magnetic field increases or decreases [5].

Induced currents appear when electrical conductors undergo conditions of variable magnetic flux. In particular, we talk about eddy currents when bulk conductor pieces instead of wires are involved. There are two basic procedures to achieve such conditions:

- exerting a time-varying magnetic field on a static piece;
- exerting a steady magnetic field on a moving one.

An example of the latter class will be investigated. It consists of a rotating metallic disc, which is subjected to the magnetic field present at the gap of an electromagnet. Eddy currents appear inside the disc and brake its rotation. This is the foundation of the electromagnetic braking systems used by heavy vehicles such as trains, buses or lorries [10].

2.6 FACTORS AFFECT OF EDDY CURRENT

A number of factors, apart from flaws, will affect the Eddy Current response from a probe. Successful assessment of flaws or any of these factors relies on holding the others constant, or somehow eliminating their effect on the results. It is this elimination of undesired response that forms the basis of much of the technology of eddy current inspection. The main factors are material conductivity, permeability and rotating disc.

2.6.1 Material conductivity

The conductivity of a material has a very direct effect on the Eddy Current flow: the greater the conductivity of a material, the greater the flow of eddy currents on the surface. Conductivity is often measured by an Eddy Current technique, and inferences can then be drawn about the different factors affecting conductivity, such as material composition, heat treatment, work hardening etc.

2.6.2 Permeability

This may be described as the ease with which a material can be magnetised. For non-ferrous metals such as copper, brass, aluminium, and for austenitic stainless steels the permeability is the same as that of ‘free space’, ie the relative permeability (μ) is one. For ferrous metals however the value of μ may be several hundred, and this has a very significant influence on the eddy current response, in addition it is not uncommon for the permeability to vary greatly within a metal part due to localised stresses, heating effects etc.

2.7 Rotating disc

Rotating discs are the key element in many mechanical applications, such as grinding wheels, circular saws, gas turbine, and computer disc drive [6]. Generally, highly number of amplitude of a transverse vibration in rotating disc is undesirable as it can lowered the performance of the devices, and in some cases it can destroy the machines [2]. For instance, excessive disk vibration lowered the signal from the read or write head in a hard disc drive, and may destroy the disc drive by a head crash. In the wood-cutting industry, the undesirable vibration of the circular saw blade results in unacceptable waste of raw material. In turbine operation, the unstable vibration of the turbine wheel can cause turbine failure due to wheel-to-case impact. These vibration problems are aggravated as industry applications tend to push the rotation speed of the circular disk even higher. Suppressing the unwanted vibration in a spinning disk has become an increasing challenge for mechanical engineers and researchers. One of the most intuitive approaches in preventing excessive vibration in a spinning disk is to apply space-.xed restraints or vibration absorbers on the disk surface. This approach has been widely adopted in circular saw industry, and the effect of the space-.xed restraints on the disk vibration has been studied extensively. In some analyses, it was found that damping in the space-.xed restraints can suppress the disk vibration when the rotation speed is lower than the critical speed of the disk. However, these passive control approaches fail completely in the super-critical speed range [6].

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The methodology had been done right after the motivation and objective of the project were identified. This methodology functioned as guidance in order to complete the project given. The complete structure of methodology had been illustrated and planned as guideline to achieve the objective of the project.

3.2 FLOW CHART

In order to achieve the aim and the objective of the project, a methodology was constructed to have a proper guidance for a successful experimentation. A terminology of works and planning of the experiments conduct was shown in a flow chart to describe the detail of the project process. The flow chart is the best way to stay agile with the work in order to keep track of the works. Project flow chart shows in Figure 3.1

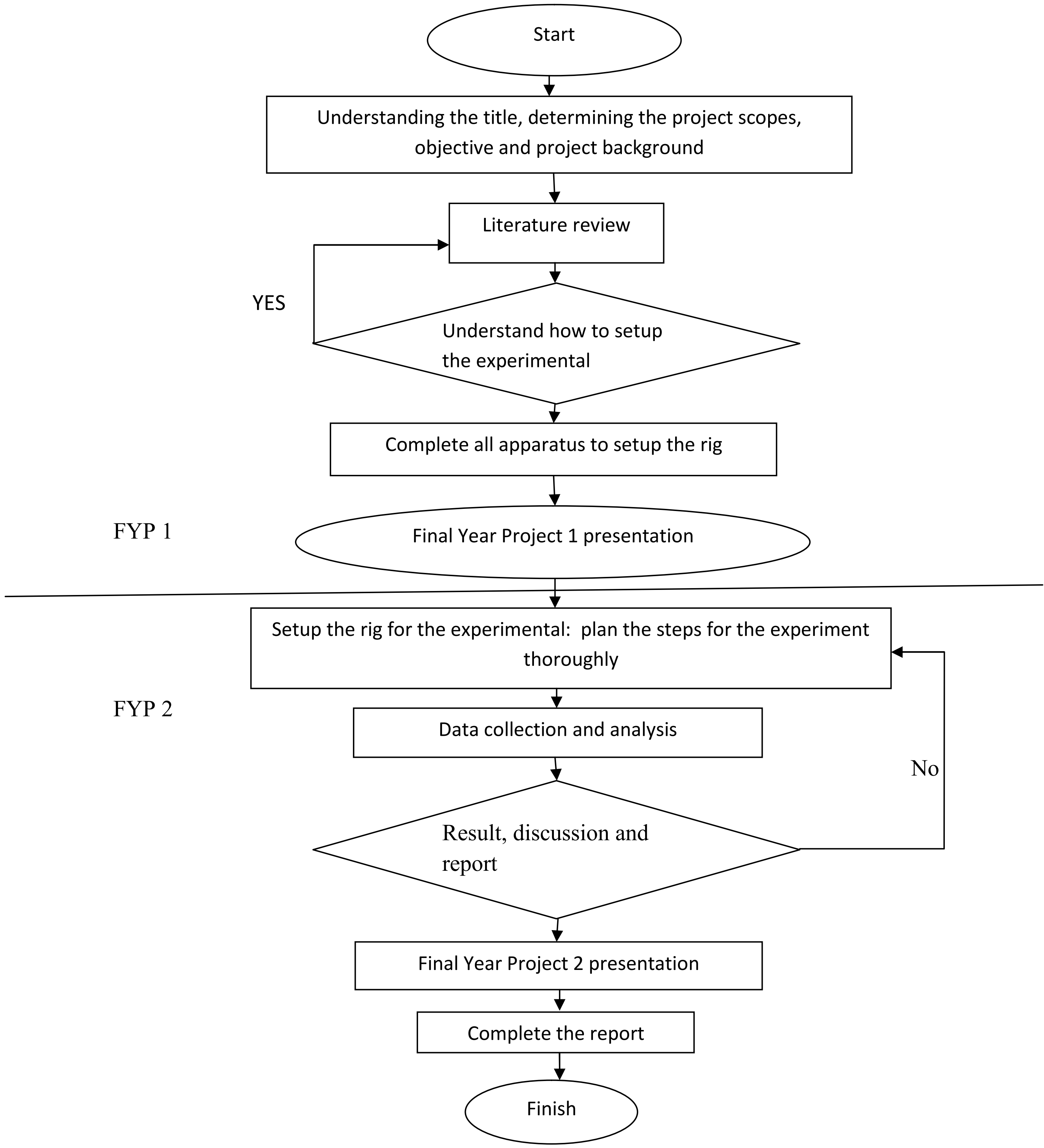

Figure 3.1: Project flow chart

3.3 APPARATUS

3.3.1 MOTOR

Figure 3.2 : Electric motor

Figure 3.2 shows the picture of electric motor is used in this experiment. The motor model is Siemens D-91056 DC motor which is capable to rotate as high as 1370 rpm unload. The function of this motor is to rotate the disc with the rpm values that has been set.

3.3.2 ACCELEROMETER

Figure 3.3 : Accelerometer

Figure 3.3 show the picture of accelerometer is used in this experiment to measure the acceleration and to monitor vibration occurred during the braking. The accelerometer model has been use is Model 4506B with sensitivity 100 mV/g.

3.3.3 TACHOMETER

Figure 3.4 : Tachometer

Figure 3.4 shows the picture of tachometer is used in this experiment. The function of tachometer is as an instrument measuring the rotation speed of a shaft or disk, as in a motor. For this experiment it has been use to measure the rotational of disc.

3.3.4 DC POWER SUPPLY

Figure 3.5 : DC power supply