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Magnetic Braking System Using Electromagnetic Force

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Abstract. A vehicle is a transportation that is widely used by humans as transportation for daily activities. Vehicles generally use mechanical brakes to do braking, these mechanical brakes have a system that requires friction forces to produce a slowdown in the vehicle. The frictional forces carried out will make erosion of the mechanical brake pads and the need to periodically replace the bearings. In this study discussed the design and manufacture of braking systems using electric brakes to support the performance of mechanical brakes. Electric brakes that have advantages in the media used compared to mechanical brakes, namely electric brakes do not require friction media to slow down, but electric brakes use four aluminum plates as magnetic force media, while coils or windings with the inner core will produce electromagnetic force as an actuator braking. The braking system that is carried out will maintain the speed according to the setpoint value of 5100 rpm. This electromagnetic braking results in a maximum braking of 500 rpm and takes between 9 and 15 seconds to reach the steady state position.

1. Introduction

Each vehicle has a different braking system, including vehicles that use front and rear drum braking. Braking using drum is a system that utilizes the two-way friction force on the friction plane which is often called drum. the friction force generated depends on the composition of composites[1], then it replaced by a disk brake braking system that has a similar system, but with a different friction method. Both of these braking systems have disadvantages where friction will occur which causes erosion of the friction plane and bearing, it something that raises concerns because drum brakes and disk brakes must make regular replacement of throttle bearings. In addition, mechanical brakes that use fluid as a driver of the piston will be very dangerous when facing the downhill road It because the friction generated by the brake pads pushed by the piston will have a slowing effect on the vehicle, but the friction force also causes heat on the surface of the disc. The heat will make the brake fluid on the caliper become hot and brake fluid will changes in the structure of the particles. if this happens then the braking status can't be braking or often referred to as failure to brakes and to overcome this problem. the electric brakes are used as additional brakes which function to reduce speed when driving.

Electric brakes that use electromagnetic force have many advantages compared to mechanical brakes, which electromagnetic brakes do not use friction force but use magnetic force as braking effort. The magnetic field does not require regular replacement as happens with mechanical brakes which need to change bearings regularly. so that the electric brakes are perfect for use and combined with mechanical brakes to complement and improve the braking working system on the vehicle. A electromagnetic braking

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system that uses will be more environmentally friendly because the electric brakes do not produce pollutions and the electric brakes also doesn't require a lot of power to do braking. Electro magnetic force is much easier to use in its application as a hybrid brake on a vehicle because electromagnetic brakes can have a slowing effect on vehicles with relatively small power, besides that the electromagnetic force generated has no side effects on the performance of mechanical brakes so electromagnetic brakes are right combined with mechanical brakes so that it becomes hybrid braking.

2. Concept of Magnetic Braking System

The conventional friction brake can absorb and convert enormous energy values, but only on the condition that the temperature of the friction contact materials is controlled. Electromagnetic brakes work in a relatively cool condition and satisfy all the energy requirements of braking at high speeds. Electromagnetic brakes can be applied separately completely without the use of friction brakes. Due to their specific method of installation, electromagnetic brakes can avoid problems that friction brakes face as we mentioned before. Typically, electromagnetic brakes have been mounted in the transmission line of vehicles [3]. The propeller shaft is divided and fitted with a sliding universal joint and is connected to the coupling flange on the brake. The brake is fitted into the chassis of the vehicle by means of anti-vibration mounting.

The working principle of the electric retarder is based on the creation of eddy currents within a metal disc rotating between two electromagnets, which activate a force opposing the rotation of the disc. If the electromagnet is not energized, the rotation of the disc is unaffected by the retarder and accelerates under the action of the weight to which its shaft is connected. When the electromagnet is energized, the rotation of the disc is retarded and the energy absorbed is converted into heating of the disc. A typical retarder consists of a stator and a rotor. The stator holds induction coils, energized separately in groups (e.g. four coils in a group). The stator assembly is supported through anti-vibration mountings on the chassis frame of the vehicle. The rotor is made up of two discs, which provide the braking force when subject to the electromagnetic influence when the coils are excited

3. Theoritical Fundamentation

The electromagnetic brake is a relatively primitive mechanism, yet it employs complex electromagnetic and thermal phenomena. As a result, the calculation theory is mainly empirical. There are three theori proposed in this section

3.1 Faraday's Law

Faraday's Law of Induction describes how an electric current produces a magnetic field and, conversely, how a changing magnetic field generates an electric current in a conductor. English physicist Michael Faraday gets the credit for discovering magnetic induction in 1830. Faraday's experiments showed that the emf induced by a change in magnetic flux depends on only a few factors. First, emf is directly proportional to the change in flux ($\Delta\Phi$). Second, EMF (Electro Magnetic Flux) is greatest when the change in time(Δt) is smallest—that is, emf is inversely proportional to (Δt). Finally, if a coil has N turns, an emf will be produced that is N times greater than for a single coil, so that emf is directly proportional to N . The equation for the emf induced by a change in magnetic flux is :

$$EM\Phi = -N\, \Delta\Phi/\Delta\tau$$

This relationship is known as Faraday's law of induction. The units for emf are volts, as is usual.The minus sign in Faraday's law of induction is very important. The minus means that the emf creates a current I and magnetic field B that oppose the change in flux$\Delta\Phi$ —this is known as Lenz's law.

3.2 Lenz's Law

Lenz's Law found thatWhen an emf is generated by a change in magnetic flux according to Faraday's Law, the polarity of the induced emf is such that it produces a current whose magnetic field opposes the change which produces it. The induced magnetic field inside any loop of wire always acts to keep the magnetic flux in the loop constant. In the examples below, if the B field is increasing, the induced field acts in opposition to it. If it is decreasing, the induced field acts in the direction of the applied field to try to keep it constant.

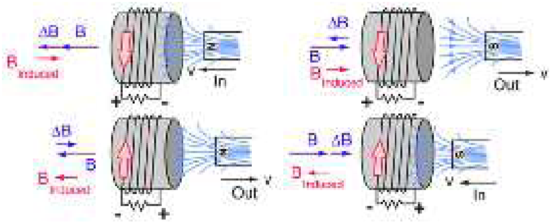

Figure 1. EMF Fields

3.3 Eddy's Current

Eddy Current are loops of electrical current induced within conductors by a changing magnetic field in the conductor due to Faraday's law of induction. Eddy currents flow in closed loops within conductors, in planes perpendicular to the magnetic field. They can be induced within nearby stationary conductors by a time-varying magnetic field created by an AC electromagnet or transformer, for example, or by relative motion between a magnet and a nearby conductor. The magnitude of the current in a given loop is proportional to the strength of the magnetic field, the area of the loop, and the rate of change of flux, and inversely proportional to the resistivity of the material.. This swirl circulation has inductance and magnetic field. This field can cause repulsion, attraction and encouragement. Eddy currents are formed because there is a change in the location of the conductor in the magnetic field. A conductor that moves in a fixed magnetic field or a magnet that starts which changes the stationary conductor, which causes eddy currents to form in the conductor

4. Materials and Methods

4.1 Diagram System

The block diagram describes the overall flow of the system. The workflow of the electric brake system starts from detection signal sensor that will give an input signal to the microcontroller. Then the microcontroller will give an output signal to the actuator and also the display. In Figure 2 is a block diagram of the braking system.

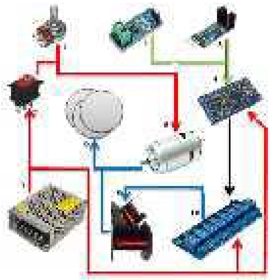

Figure 2. Diagram block system of the braking system

4.2 System Pricipal

Some components that will be used in this research include :DC Motor, Aluminium Plate,12 Selenoid Winding,Indicator Lamp,Rotary encoder ,Control Panel,Liquid crystal display (LCD),Potensiometer,Driver relay ,Stepdown ,Push button ,Arduino promini ,Current Sensor,USB to TTL. This electric brake system has several additional features to support system performance as follows :

- Auto cut off , This feature will function automatically if there is an overflow or a problem determines the value of the given parameter
- Fuse, function as a voltage breaker in total against windings, this will be done when overcurrent or windings are at the maximum point of selenoid ability
- Option mode, is a feature that is used to change the values of proportional, derivative or integral constants.

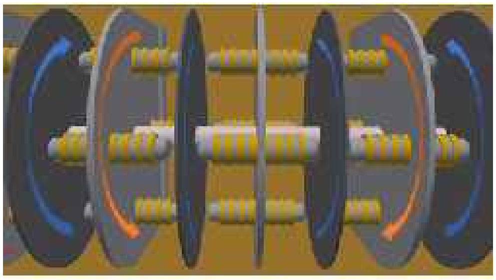

Figure 3. Direction of rotation and electromagnetic force

Magnetic forces against aluminum plates can inhibit the movement of rotation. The opposite direction between the rotation of the aluminum plate and the direction of this magnetic field will cause eddy currents. The emergence of this eddy current will provide rotation resistance on the aluminum plate. This resistance will only be formed as long as the direction of rotation is opposite, but when the rotation is in the same direction, the eddy force generated will disappear. Electromagnetic attraction combined with a very efficient eddy force is applied to reduce the rotation speed without having to make direct contact with the aluminum plate. Braking that occurs will be even stronger if more magnetic fields are produced. The more magnetic field arises, the more eddy force that is formed against the aluminum plate, with this the braking of the motor rotation will be maximal

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5. Results

Figure 4. Real Plant

Testing the increased selenoid coil is by testing the braking ability by adding an active number of coil winding, for example when using three active loops can cause braking of 200 rpm, the active coil will be added so that the resulting braking is proportional to braking. This treatment will continue until all the turns are active and the researcher gets the maximum braking value produced by twelve turns that are active together. The results of this trial will be used as data that determines the maximum braking force that can be performed on the aluminum disc rotation. In Tables 1 and Table 2 are the results of the windings trial increased from 1 to 12 active joint turns.

[redacted]FIRST TESTING OF SOLENOID

Testing Number	*Variation value for each twist (x10rpm)*					
	1	*1 2*	*1 2 3*	*1 2 3 4*	*1 2 3 4 5*	*1 2 3 4 5 6*
1	5.4	21.6	37.8	37.8	53.6	59.4
2	5.4	21.6	37.8	32.6	53.6	59.4
3	5.4	21.6	37.8	37.8	54.0	53.6
4	5.4	18.4	37.8	32.6	54.0	59.4
5	5.4	21.6	37.8	37.8	53.6	59.4
6	9.2	21.6	37.8	37.8	54.0	59.4
7	9.2	18.4	37.8	37.8	53.6	59.4
8	5.4	18.4	37.8	32.6	53.6	53.6
9	5.4	21.6	37.8	32.6	54.0	53.6
10	9.2	21.6	37.8	37.8	53.6	59.4

[redacted]SECOND TESTING OF SELENOID

Testing Number	*Variation value for each twist (x10rpm)*					
	1 2 3 4 5 6 7	*1 2 3 4 5 6 7 8*	*1 2 3 4 5 6 7 8 9*	*1 2 3 4 5 6 7 8 9 10*	*1 2 3 4 5 6 7 8 9 10 11*	*1 2 3 4 5 6 7 8 9 10 11 12*
1	64.8	64.8	75.6	86.4	97.2	113.4
2	64.8	64.8	81.0	86.4	10.26	112.6
3	59.4	70.2	81.0	86.4	10.26	112.6

4	59.4	70.2	81.0	91.8	10.26	113.4
5	64.8	70.2	81.0	91.8	97.2	112.6
6	64.8	64.8	81.0	86.4	10.26	113.4
7	64.8	64.8	75.6	86.4	10.26	113.4
8	53.6	64.8	75.6	86.4	10.26	112.6
9	64.8	70.2	81.0	86.4	97.2	113.4
10	64.8	64.8	81.0	86.4	10.26	112.6

The results of the tests as an increase on the number of winding showed : when 6 coil active, braking occured about 579 RPM, while all coil active braking occured about 1126 RPM. This testing was doing to get the DC motor time for rotation when the voltage is turned off, which is used as information to determine the time needed for the DC motor to stop completely. This test is carried out in two method :

1. *Time for Stop without Breaking*

Testing motor time rotation was done without using a braking system, when the rotating motor reaches maximum speed, the power supply will be turned off, so the driving motor rotates with the remaining force until the drive motor stops rotating.

[redacted] TIME STOP TESTING WITHOUT BREAKING

Testing Number	Time	State
1	00.11.97	Non-brake
2	00.12.06	Non-brake
3	00.11.92	Non-brake
4	00.12.15	Non-brake
5	00.11.89	Non-brake

Testing without braking on a DC motor has an average time about 11 seconds. It is the time required for the DC motor to be fully stationary/stop.

2. *Time for Stop using Breaking*

The second trial is testing with braking. The driving motor that rotates reaches the maximum speed, the power supply will be turned off, at the end the motor will stop spinning. In Table 4 is the result of trials conducted by braking.

[redacted] TIME STOP TESTING WITH BREAKING

Testing Number	Time	State
1	00.05.80	*Brake*
2	00.06.70	*Brake*
3	00.06.37	*Brake*
4	00.05.92	*Brake*
5	00.05.31	*Brake*

Tests carried out 5 times to get the time needed by the DC motor to stop by doing braking on a DC motor takes an average about 5 seconds.

6. Conclusion

The maximum braking that the system can do is 1100 rpm derived from the results of system testing and optimal braking of 500 rpm for a set point value of 5100 rpm ,braking on a DC motor takes an average about 5 seconds. to get maxiumum braking value can be achived with using stronger and more extensive electromagnetics.

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