**MAGNETIC BRAKING**

**ABSTRACT**

In this paper the basic of magnetic braking are introduced. Firstly, a simple theory is proposed

using Faraday's law and the Lorentz force. With this theory magnetic braking on copper

rectangular sheet moving linearly through the magnet is explained. Secondly, a magnetic drag

force and a magnetic lift force on a magnetic dipole moving over a nonmagnetic conducting

plane are explained with image method based on Maxwell’s equations. At the end of the

seminar the practical uses of forces on moving magnets are shown.

**1. INTRODUCTION**

The topic of magnetic braking has dramatically increased in popularity in recent years. Since

1987, numerous articles about magnetic braking were published. These articles describe both

experiments dealing with magnetic braking, as well as the theory behind the phenomenon.

Magnetic braking works because of induced currents and Lenz’s law. If you attach a metal

plate to the end of a pendulum and let it swing, its speed will greatly decrease when it passes

between the poles of a magnet. When the plate enters the magnetic field, an electric field is

induced in metal and circulating eddy currents are generated. These currents act to oppose the

change in flux through the plate, in accordance with Lenz’s Law. The currents in turn heat the

plate, thereby reducing its kinetic energy.

The practical uses for magnetic braking are numerous and commonly found in industry today.

This phenomenon can be used to damp unwanted nutations in satellites, to eliminate

vibrations in spacecrafts, and to separate nonmagnetic metals from solid waste [1].

**2. THEORY**

The subject of magnetic braking is rarely discussed in introductory physics texts. To calculate

the magnetic drag force on a moving metal object is generally difficult and implies solving

Maxwell's equations in time-dependent situation. This may be one of the reasons why the

phenomenon of magnetic braking, although conceptually simple to understand, has not

attracted the attention of textbooks authors. A simple approximate treatment is however

possible in some special cases. In our seminar we will try to explain magnetic braking with

the understandable (simple) theory. Reports in literature have made the theory behind this

phenomenon easily accessible. First we will be interested in the braking of a rectangular sheet

moving linearly through the magnet.

**2. 1 Magnetic braking of a rectangular sheet moving linearly through the magnet**

A good source for explaining why this braking happens we find in [2]. We assume that the

speed of the sheet is sufficiently small that the magnetic field generated by the induced

current is negligible in comparison with the applied magnetic filed. Under this condition just

stated, the magnetic drag force is seen to arise from mutual coupling between the induced

current and the applied magnetic field.

When the metal plate enters the magnetic field, a Lorentz force

*F q*(*v B*)

\_ \_ \_

, (1)

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is exerted on the conduction of electrons in the metal. Here, *v*

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is the velocity vector of the

charge *q*, and *B*

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is the magnetic field vector. The force on the electrons induces a current in

the metal (eddy current). An induced current moves along a closed path as if induced by an

electromotive force. Figure 1 shows these eddy currents in relation to the metal plate which

moves perpendicular to the magnetic field.

Figure 1: Induced currents in the metal plate [2].

We use Faraday’s law, which says that the magnitude of the induced emf is equal to the time

rate of change of the magnetic flux,

*B dS v*(*B L*).

*dt*

*d*

*dt*

*d*

*Ui*

\_ \_ \_ \_ \_

\_ (2)

A horizontal magnetic force is exerted on the portion of the eddy current that is within the

magnetic field. This force is transmitted to the metal sheet, and is the retarding force

associated with the braking:

*F IL B*,

\_ \_ \_

(3)

where *I* is the current and *L* is the vertical height of the magnetic field.

Like we said when the metal sheet passes between the poles of the magnet, circulating

currents (eddy currents) are generated. As a result, a magnetic breaking force is induced on

the eddy currents which opposes the motion of the sheet. This is a simple theory of magnetic

braking, which assumes that the magnetic field generated by the induced current is negligible

in comparison with the applied magnetic filed. But we would like to have a theory, which

does not assume that the magnetic field generated by the induced current is negligible.

In next sections of our seminar equations for a magnetic drag force and a magnetic lift force

(a magnetic drag force acts together with a magnetic lift force) on a magnetic dipole moving

over a nonmagnetic conducting plane are shown. A magnet (a magnetic dipole) is moved

along the plane (in *x* direction), in which therefore the eddy currents are induced. Eddy

currents generate the magnetic field and in this magnetic field the magnet experiences the

magnetic force with two components: up (in *z* direction) and in opposite direction as the

magnet moves. As we already mentioned this are the magnetic lift force and the magnetic

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drag force. To get equations for both we will use the image method based on Maxwell’s

equations [3].

The aim of this theory is also qualitatively to describe the magnetic field generated by the

induced eddy currents. These eddy currents are induced in the plane.

**2. 2 Image method based on Maxwell’s equations (The Principle of Mirror Images)**

We approximate movement of the magnet over the conducting plane with series of sudden

jumps. Firstly, we look example when at time *t* = 0 a magnetic dipole suddenly appears over

the conducting plane (Figure 2a). The eddy currents, which are generated in the plane, protect

the place on the other side of the plane (negative side of the plane) from changing the

magnetic field. In [3] it’s discussed:

Negative side: The magnetic field of eddy currents has together with the magnetic field of the

dipole in every point value 0. The magnetic field of the eddy currents on the negative side

equals to the magnetic field of the switched magnetic dipole on the positive side (Figure 2c).

Positive side (side, on which magnet is): Symmetry of the problem implies that the magnetic

field of the eddy currents is equal on both sides of the plane. The magnetic field of the eddy

currents on the positive side equals to the magnetic field, which is generated by mirror image

of the magnetic dipole on the negative side (Figure 2b).

Figure 2: The magnetic field of the magnetic dipole (a), magnetic field of induced eddy currents on

positive side of the plane (b) and magnetic field of induced eddy currents on negative side. The

complete magnetic field is shown in Figure 3 [3].

When the magnetic dipole suddenly appears on the positive side of the plane, there is no

magnetic field on the negative side of the plane, but on the positive side of the plane the

magnetic field of eddy currents has influence on the magnetic field of the magnetic dipole, it

fakes the magnetic field of the dipole (Figure 3).

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Figure 3: The magnetic field on positive side of the plane, when the magnetic dipole appears over the

conducting plane [3].

If we are interested in the force on the magnet, we are only interested in the magnetic field on

the positive side of the plane; therefore we will focus on mirror images of the magnetic dipole

on the negative side.

When the magnetic dipole suddenly disappears, two mirror images are created: one on the

positive side and the other on the negative side, magnetic fields are in opposite direction like

in a previous case.

**2. 3 Velocity of mirror images**

In superconductor eddy currents would last for ever, but in the conductor they disappear with

time (they are less and less stronger) and heat up the plane. How quickly eddy currents

disappear depends on the conductivity, the thickness *c*, and the permeability of the

metal [3]. Theory points out that the magnetic field of the eddy currents on the positive side is

weaken by time like mirror image on the negative side would move perpendicular away from

the metal plane with a velocity

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*c*0

*w* (4)

**2. 4 Force on magnet moving over conducting plane**

**2. 4. 1 Qualitative explanation with method of discrete steps**

Imagine our movement of the magnetic dipole over conducting plane with small steps –

jumps. The magnetic dipole does not need any time for jumping on other place, on each place

the magnetic dipole waits short period of time d*t*. We are interested in the magnetic field on

the positive side of the plane, which is result of mirror images (of the magnetic dipole) on the

negative side (under the plane). When the dipole suddenly jumps on the next place, two

images are woken. One (negative) image appears under old location and other (positive)

under new location. Figure 4 shows 1. couple of images, made at last jump. At next jump the

story is the same, again couple of images is made and older couples propagate downward at

velocity *w*. The magnetic field, at point where dipole is, equals to sum of all magnetic fields

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of mirror images under the plane. If we want to know the force on a moving magnetic dipole,

we have to sum all magnetic fields of mirror images.

Figure 4: A magnet moves over conducting plane in right with the velocity *v*, under the plane there are mirror

images, which the magnet is leaving behind. Every step of the magnetic dipole (jump) takes no time and the

magnetic dipole stays on each place short period of time d*t* [4].

Figure 5: An example where the magnet moves over the conducting plane in left with the velocity *v*.

The velocity of magnet is less than the velocity of mirror images [4].

w

w > v

v

vdt

vdt

vdt

vdt

wdt

wdt

wdt

3. couple

4. couple

2. couple

vdt

z0

1. couple

7

Figure 6: An example where the magnet moves over the conducting plane in right with the velocity *v*.

The velocity of magnet is greater than the velocity of mirror images [4].

Two examples applying the image method are shown in Figure 5 and Figure 6. In the first

example (Figure 5) the velocity of the magnet is less than *w*. The positive image has moved

down the distance *w*d*t* when the negative image appears at the same location. Then, as the two

images move away head-to-tail, induced field falls to zero. In the second example (Figure 6),

the velocity is considerably greater than *w*. The positive image has moved only a small

distance when the negative image appears, and the two images nearly cancel each other

thereafter. In both figures (Figure 5 and Figure 6) slope of mirror images depends on both

velocities (

*v*

*w*

).

**2. 4. 2 Calculation of forces**

A good source for our calculation of forces is [4]. The magnetic field vector*B* \_

of the

magnetic dipole is given by

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0 4

3( )

*r*

*p r r r p*

*B m m*

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

\_ \_ \_ \_

\_ 

. (5)

Where *m p*

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is the magnetic moment: *p IS m*

\_ \_ . The magnetic dipole is perpendicular to the

plane (in *z* direction): (0,0, ) *m m p* *p* \_

. The component *y* of magnetic field is not interesting for

us ( *r* (*x*,0, *z*) \_

), therefore we write down only components *x B* and *z B* :

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( )

3

4 2

5

2 2

0

*x z*

*p xz*

*B m*

*x*

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

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( )

(2 )

4 2

5

2 2

2 2

0

*x z*

*z x p*

*B m*

*z*



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

(6)

The magnetic dipole in an externally-produced magnetic field has a potential energy *W*:

*W p B*. *m*

\_ \_ (7)

The force on the magnetic dipole is proportional to the negative gradient of energy:

w

w < v

v

8

*F* *W*.

\_

(8)

The force is acting in that direction, that energy decreases most when moving in this direction.

*F* ( *p B*). *m*

\_ \_ \_

(9)

If we use0 *m p*

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, we get the equation:

*F* ( *p* )*B*, *m*

\_ \_ \_

(10)

which gives us the force on the magnetic dipole in external magnetic field. The magnetic

field, at point where dipole is, equals to sum of all magnetic fields of mirror images under the

plane. Firstly, we look equation for the force on moving magnet in ordinary magnetic field.

The magnet with the magnetic dipole moment *p* (0,0, *p*) *m* \_

moves in our example with the

constant velocity over the conducting plane. Eddy currents in the metal plane generates above

the plane the magnetic field ( , , ) *x y z B* *B B B*

\_

. If we use the equation (10), the force equals to

( ,0, ) ( ,0, ) *D L*

*x z F F*

*z*

*B*

*p*

*z*

*B*

*F p* 

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





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. (11)

The component of the force in *x* direction is the magnetic drag force and *z* component is the

magnetic lift force. If we want to know both forces, we need *x B* and *z B* . The image method

implies that *x B* is sum of all magnetic field components in *x* direction, which are result of

images on negative side of conducting plane, similarly *z B* is sum of all magnetic field

components in *z* direction. We use equations (6) and (11) to calculate the magnetic drag force.

Distance between a magnetic dipole and the nearest mirror image is 0 2*z* , and the mirror image

generates at position where the dipole is the magnetic field with the component in *x* direction

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( (2 ) )

(2 )

4

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2 5 / 2

0

2

0 0

*x z z*

*p x z z*

*Bx* 

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



(12)

The contribution of one mirror couple *x* *B* is the difference between *B* (*x*) *x* and *B* (*x dx*) *x* .

We can also write:

*dx*

*x*

*Bx*

*B x dx B x x x* 

( ) ( ) 

*x*.

*x*

*B*

*B x*

*x* 







We need the partial derivative of *x B* (12) with respect to *x* from which we get the second

partial derivative with respect to *z* as well.

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( (2 ) )

(2 )( 4 (2 ) )

4

3

2 7 / 2

0

2

2

0

2

0 0 *x*

*x z z*

*p z z x z z*

*Bx* 











(13)

9

We get the contribution of one couple of mirror images to the complete magnetic field. The

contribution of one couple of mirror images to the complete force on the magnetic dipole is:

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3 2

0 *p*

*z*

*B*

*dF p x*

*D*

.

(4 4 )

64 4 128 27 4 ( 108 96 ) 4 (27 8 )

2 9/ 2

0

2 2

0

2 3

0

2 2 2

0

3 2 2 4

0

4 4

0 *dx*

*z x z z z*

*z x z z x z z z x z z x z z*

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



(14)

In this equation we replace *z* with *wt*, where is *w* the velocity of the images. We also know

that *x* *vt* (where *v* is the velocity of the magnetic dipole in direction of *x* coordinate) and we

equate

*c*

*x*

*z* , where *c* is the constant define

*w*

*v*

*c* . We want to get the complete force on

the magnetic dipole, so we integrate the equation (14) with respect to *x* from to 0. For the

magnetic drag force we get:

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32

3

4 2 2

0

2

0

0

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\_ 

*v w*

*w*

*z*

*p*

*v*

*w*

*F dFD D* 



(15)

The calculation for the magnetic lift force is similar to those for the magnetic drag force. The

magnetic lift force equals to:

1 .

32

3

4 2 2

0

2

0 \_

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\_

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

*v w*

*w*

*z*

*p*

*FL* 



(16)

We notice relation between both forces:

. *D L F*

*v*

*w*

*F* (17)

**2. 4. 3 Limits of drag force and lift force**

Now we can look the limits of both forces (lift and drag), when the velocity of the magnetic

dipole is either much smaller or much greater than the velocity of mirror images. First we

look example when the velocity of the magnetic dipole is much smaller than the velocity of

mirror images (*v* << *w*). We search the approximation for the magnetic drag force:

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1 ( / )

1

1 1

2 2 2 \_

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\_

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\_

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

\_

\_\_





*v v w*

*K*

*v w*

*w*

*v*

*K*

*FD* (18)

where *K* is the constant

.

32

3

4

0

2

0

*z*

*p w*

*K*





(19)

Because

*w*

*v*

is small number, we can approximate the fraction in square brackets:

10

.

2

1

1 1 2

2

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\_\_

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\_

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

*w*

*v*

*v*

*K*

*FD* (20)

Result for the drag force is

*v*

*w*

*K*

*FD* 2 2

. (21)

For this example the magnetic drag force varies linearly with the velocity. The magnetic lift

force than equals to

,

2

2

3 *v*

*w*

*K*

*FL* (22)

which means that the magnetic lift force varies with square of the velocity of magnetic dipole.

When the velocity of the magnetic dipole is much greater than the velocity of mirror images

(*v* >> *w*), the limit of the magnetic drag force approaches 0 like the function 1/*v*. The

magnetic lift force at high velocities equals to the force between two magnets, in our example

to the force between magnet and his mirror image. Other mirror images are far away from the

magnetic dipole and do not have any effect on the magnetic dipole. In limit the magnetic lift

force approaches

.

32

3

4

0

2

0

*z*

*p*

*F m*

*L* 



(23)

Velocity dependence of magnetic lift force *L F* and magnetic drag force *D F* is shown in Figure

7. We can notice what equations tell us: at low velocity, the magnetic drag force is

proportional to velocity *v* and considerably greater than the magnetic lift force, which is

proportional to *v*2 . As the velocity increases, however, the magnetic drag force reaches the

maximum (referred to as the drag peak) and then decreases as 1/*v*. The magnetic lift force, on

the other hand, which increases with *v*2 at low velocity, overtakes the magnetic drag force as

the velocity increases and approaches an asymptotic value at high velocity.

Figure 7: Velocity dependence of magnetic lift force *L F* and magnetic drag force *D F* [5].

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Understanding of forces on moving magnets is very important to design some vehicles,

especially of magnetically levitated (maglev) vehicles for high-speed ground transportation.

**3. PRACTICAL USE**

**3.1 Eddy currents brakes (magnetic brakes)**

To slow vehicles down, we can use eddy current brakes (magnetic brakes). Eddy current

brakes are a relatively new technology that are beginning to gain popularity due to their high

degree of safety. Rather than slowing a train via friction, which can often be affected by

various elements such as rain, eddy current brakes rely completely on certain magnetic

properties and resistance.

The linear eddy current brake consists of an electromagnet, which is fixed on a train (vehicle).

This electromagnet is held at a definite small distance from the rail (approximately 7

millimeters). When electric current is passed through the electromagnet and the electromagnet

is moved along the rail, eddy currents are generated in the rail. These eddy currents generate

an opposing magnetic field, providing braking force. The first train in commercial circulation

to use such a braking is the ICE 3 (Figure 8).

Figure 8: An eddy current brake of an ICE 3 [6].

The eddy current brake does not have any mechanical contact with the rail, and thus no wear

and tear of it, and creates no noise. Because the braking force is directly proportional to the

speed, the eddy current brake itself can never completely stop a train. It is then often

necessary to bring the train to a complete stop with an additional set of fin brakes (friction

brakes) or "kicker wheels" which are simple rubber tires that make contact with the train and

effectively park it.

**3.2 Maglev Vehicles**

Magnetic levitation (maglev) is a relatively new transportation technology in which

noncontacting vehicles travel safely at speeds of 250 to 300 miles-per-hour or higher while

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suspended, guided, and propelled above a guideway by magnetic fields. The guideway is the

physical structure along which maglev vehicles are levitated. Figure 9 depicts the three

primary functions basic to maglev technology: levitation or suspension, propulsion and

guidance. In most current designs, magnetic forces are used to perform all three functions.

Figure 9: Three primary functions basic to maglev technology [7].

There are two primary types of maglev technology: electromagnetic suspension (EMS) and

electrodynamic suspension (EDS) [5].

*Electromagnetic (attractive force) suspension (levitation)*

Electromagnetic suspension (EMS) system depends upon attractive forces between

electromagnets and ferromagnetic (steel) guideway. Because the force of attraction increases

with decreasing distance, such systems are unstable and the magnets currents must be

carefully controlled to maintain desired suspension height. Furthermore, the magnet-toguideway

spacing needs to be small (at approximately 15 millimeters). On the other hand, it is

possible to maintain magnetic suspension even the vehicle is standing still, which is not true

for electrodynamic (repulsive force) systems. In the system in Figure 10 (left side), a separate

set of electromagnets provides horizontal guidance force, but the levitation magnets, acted on

by a moving magnetic field from the guideway, provide the propulsion force.

Figure 10: Schematic diagram of EMS and EDS maglev system [7].

*Electrodynamic (repulsive) suspension*

Electrodynamic suspension (EDS) system employs magnets on the moving vehicle to induce

eddy currents in the guideway. In system in Figure 10 (right side), resulting repulsive force

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produces inherently stable vehicle support and guidance because the magnetic repulsion

increases as the vehicle/guideway gap decreases. However, the vehicle must be equipped with

wheels or other forms of support for "takeoff" and "landing" because the EDS will not levitate

at speeds below approximately 25 mph. EDS has progressed with advances in

superconducting magnet technology. Propulsion coils on the guideway are used to exert a

force on the magnets in the train and make the train move forward. The propulsion coils that

exert a force on the train are effectively a linear motor: An alternating current flowing through

the coils generates a continuously varying magnetic field that moves forward along the track.

**4. CONCLUSION**

In our seminar we look at the magnetic drag force and the magnetic lift force on moving

magnets. Understanding of both forces is now days very important for practical uses,

especially to design magnetically levitated (maglev) vehicles for high-speed ground

transportation.

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**ABSTRACT**

            Mechatronics is a hybrid technological field which evolved from the combination of mechanical, electronics & Software engineering. Automobiles need high degree of safety to protect the occupants and their property. Bearing this in senses we come up with a new concept of Electric pulse Magnetic Braking (E.P.M.Braking).

            When the driver applies force on the brake pedal the magnitude is sensed by the pressure transducer which in turn sends the actuating signals to microprocessor. This intelligent device sends pulsating D.C. current from the capacitor to the power pack.

            The power pack develops sufficient torque to decelerate or stop the vehicle as per the driver’s requirement. The torque produced is directly proportional to the force applied on the brake pedal, as the intensity of the actuating signal from the pressure transducer is directly proportional to the pulsating D.C. current supplied to the power pack.

            Another important aspect of this braking system is that the power pack also acts as a generator, which results in additional power generation. We have also incorporated artificial intelligence. Logic gates for backup-circuit for safety and shift current for shifting the power pack from generating mode to braking mode and vice-versa to generator power.

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**1.INTRODUCTION:**

 Automobiles need high degree of safety to protect the occupants and their property.When the driver applies force on the brake pedal the magnitude is sensed by the pressure transducer which in turn sends the actuating signals to microprocessor.We have also incorporated artificial intelligence. Logic gates for backup-circuit for safety and shift current for shifting the power pack from generating mode to braking mode and vice-versa to generator power.

The scope of E.P.M. braking system is very high due to the following reasons:

  HIGH EFFECIENCY

  ROLLING STOP

  INSTANT STOP

  ADDITIONAL POWER GENERATION

  NO WEAR AND TEAR

  HIGH DEGREE OF SAFTEY

            In our universe nothing is permanent; the only permanent aspect is technology. In our machine oriented world no particular field can strive on its own, so merging of all the major technological sciences becomes inevitable to cater needs of the Human Race. A field thus evolved is *‘****MECHATRONICS’*.**

**2.WHAT IS MECHATRONICS?**

            Mechatronics is concerned with the blending of mechanical electronics & software fields. So the mechanical system, motor heads and gigabytes go hand in hand. As the saying goes ***“Necessity is the mother of invention”***, locomotion was first on feet, animals, then by wagons powered by horses, then horses were replaced by horse power produced by the engines which went at roaring speeds, their safety was a big concern, so the stoppers namely the brakes were developed for the safety of the occupants and the vehicles.

            Brakes are one of the most important control components of the vehicle. They

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are required to stop the vehicles at the smallest distance and this is achieved by converting the kinetic energy of the wheels into heat energy, which is dissipated into the atmosphere.

To provide a cutting edge upon the conventional braking systems, we have come up with a new concept of E.P.M.Braking. This will result in high safety standard which will minimize the damage to life and property.

The main parts of E.P.M.Braking system are:

  POWER PACK

  MICROPROCESSOR

  PRESSURE TRANSDUCER

  CAPACITOR

  D.C. POWER SUPPLY

  LOGIC CIRCUITS

**2.1 POWER PACK:**

            This unit is specially designed for E.P.M.Braking. This consists of armature wiring on the dead and live axle, surrounded by permanent magnet made of samarium cobalt with desired air gap. The armature is wound round with room temperature super conducting materials like carbon fibers and its composites. The whole setup is placed inside the casing. Sensors are placed inside the casing to sense the braking action. Power pack is incorporated with shift circuit for conversion of system from braking mode to generating mode or vice versa.

**2.2 MICROPROCESSOR:**

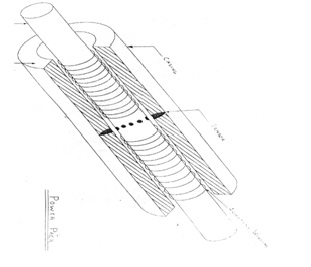
            This being the heart of the E.P.M.Braking transmits a pulsating D.C. supply to armature, which is directly proportional to the intensity of signals from the

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pressure transducer via brake pedal. This also monitors the RPM and the rotation of the wheels. Microprocessor controls the mode of operation of the power pack.

**2.3 PRESSURE TRANSDUCER:**

            This is a piezo-electric crystal. When the force is applied on the pressure transducer via brake pedal, this sends actuating signals from the pressure transducer which is directly proportional to the force applied on the brake pedal.

[](http://1.bp.blogspot.com/_CnTRDVaXo-4/TRWFeB7Z86I/AAAAAAAAAOc/VUfUlLAsxUc/s1600/1.jpg)

POWER PACK

**3.FUNCTIONAL OUTLOOK:**

            When the vehicle is moving at a desired velocity, if there is any interference in the path there arises the need for braking, while braking the wheels, should not skid as the driver looses the control of the vehicle. A good braking system should have a rolling stop, so that the driver can handle vehicle easily. When the driver applies force on the brake pedal, which is in contact with the pressure transducer or the piezo-electric crystal, it sends actuating signals to the microprocessor, which shifts the power pack from generator mode to braking mode.

            The microprocessor is programmed in such a way that the frequency of constant D.C. pulse discharged from the capacitor is directly proportional to the

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intensity of   actuating signals from the pressure transducer. This pulsating D.C. is send to the armature of the power pack, which is fitted to both the axles. This is sensed by the microprocessor through the sensors. The torque is sufficient to bring the vehicle to a rolling stop within a short distance since we apply only pulsating D.C., there is neither sliding nor skidding of the wheels.

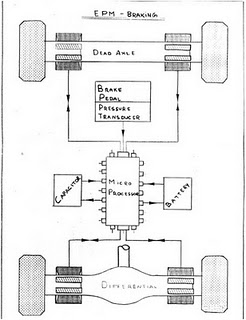
When the vehicle is operated in the reverse gear the sensors in the power pack senses the direction and communicates to the microprocessor, so that the pulsating D.C. supplied to the armature is in the reverse direction. Another important aspect of this braking system is that the power pack also acts as a generator. When there are no actuating signals from the pressure transducer the logic circuit shifts the power pack from the braking mode to the generator mode. The power produced by the generator mode is fed to D.C. power source.

**4.SHIFTING LOGIC:**

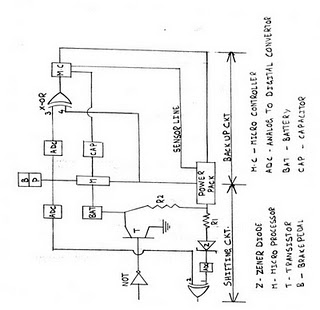
            When the power pack is operating in the generator mode power is produced. After crossing the critical speed, to prevent the over loading of the engine is in the uphill condition, we have designed a simple logic circuit, which consists of a zener diode, XOR-GATE, NOT-GATE, power transistor and current limiting resistors.

             When the velocity of the vehicle increases, power produced also increases. The power produced is fed to a zener diode through a current limiting resistor R1. when the voltage from the power pack exceeds the critical voltage of the zener diode , it overcomes the brake down voltage and the A.D.C.(Analog to Digital Converter) sends a signal to the X-OR gate to pin1. Pin2 of this gate is connected to the pressure transducer through a A.D.C. When there is no braking there is no signal

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[](http://1.bp.blogspot.com/_CnTRDVaXo-4/TRWFqf5JfJI/AAAAAAAAAOg/2EG6E2KaDXo/s1600/2.jpg)

Block Diagram

[](http://4.bp.blogspot.com/_CnTRDVaXo-4/TRWFwniE3JI/AAAAAAAAAOk/Tt_MbOXQ4H8/s1600/3.jpg)

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Logical Circuit

to pin2. As the logic of X-OR gate when the input is ‘1’ and ‘0’ the output is ‘1’, this is fed to a NOT gate which gives an output of ‘0’. The power transducer receives the signal and it is triggered to connect the power pack to the battery for charging. If the brakes are applied pin2 of the x-OR gate receives signal from pressure transducer hence the output of X-OR gate is ‘0’ and NOT gate output is ‘1’, this closes the transistor circuit and it shifts the power pack from generator mode to braking mode.

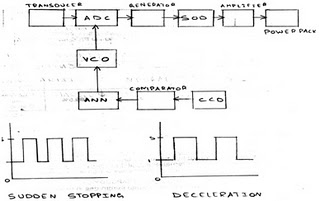
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**5.SAFETY BACKUP**:

            In the case, if the microprocessor fails, the output from the microprocessor is ‘0’, this signal ‘0’ is send to the pin3 of X-OR gate. Pin4 of the X-OR gate receives signal’1’ from the pressure transducer and the output of the X-OR gate is ‘1’, this triggers the micro controller to discharge the current from the capacitor to the power pack. This is only a constant D.C. supply not a pulsating one. This brings the vehicle to a sudden stop.

**6.INCORPORATION OF ARTIFICIAL INTELLIGENCE:**

A C.C.D.(charged couple device) camera captures the image of the surface in which the vehicle is moving. The image is in the form of pixels. A matrix of pixels is taken and the resultant brightness is found out. Similarly the resultant for all the matrix of pixels is obtained. Using a comparator circuit the resultant is matched with the resultant of template images, which are already stored in memory.

[](http://3.bp.blogspot.com/_CnTRDVaXo-4/TRWF59JSDkI/AAAAAAAAAOo/a3_QTvOw3gY/s1600/4.jpg)

Process & Graphs

Classification of the images and training of the comparator is taken care by A.N.N.(Artificial Neural Networks). With the help of V.C.O (Voltage Control Oscillator) the signals are feed into the main circuit i.e. the voltage signals are converted into

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frequency depending upon the intensity of actuating signals from the pressure transducer and also from the V.C.O. the square wave pattern is generated. If we want a vehicle to come to a sudden stop the lag time of square wave is reduced. While deceleration the lag time is increased as per the rate of deceleration.

**7.HIGHLIGHTS OF E.P.M. BRAKING SYSTEM:**

  High efficiency

  Rolling stop

  High degree of safety

  No wear and tear

  Very high response

  Additional power generation

**8.CONCLUSION:**

            The above ideas may seem to be impossible; not in mere future considering the safety of the passengers this method of braking system plays an important role. By incorporating this type of braking system there is no need of extra arrangement. The wear and tear of the brake system and the tyre is less. Apart from this advantage there is generation of additional power for the source. This also increases the efficiency of the engine.

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