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Vehicle Propulsion using Switching Magnetic(SM) Energy

Gopi Krishna. N

John Deere Technology Centre

Abstract- "Today's theories shape tomorrow's reality" and "tomorrow's standard of living will depend on the success of today's theories". These old truths, having proved themselves so many times in our history, should make us responsible for the implementation, creation, development, distribution of new scientific theories.

The idea of Switching Magnetic Energy is obtained from the principle of Electromagnetic Induction. Electromagnetic induction like in Maglev principle involves the use of electromagnets, which by changing their polarity, sets up attractive and repulsive forces on the lateral sides to propel the train forward and levitate. This magnetic push-pull principle is used in this project to propel an automobile.

This concept of mine aims at designing and fabricating a prototype model of a vehicle which runs on an alternative form of propulsion technique i.e., magnetic power. The vehicle was built, assembling of mechanical and electrical components, which perform the desired function of energy conversion from electrical to magnetic power and thus to mechanical energy of rotation. For this purpose various components were designed and were chosen accordingly to meet the requirements of the prototype vehicle and which could give satisfactory results regarding its performance parameters such as power, speed, overall efficiency, etc., which can make this concept a very feasible one.

The performance of the prototype was done by various tests conducted. These tests showed the efficiency of the prototype at the crankshaft which was between 70 to 72% sustaining 300W of input power.

I. Introduction

1.1 An Electromagnet

An electromagnet is set up with a battery (or some other source of power) and a wire. If on looks at the battery, say at a normal D cell from a flashlight, one can see that there are two ends, one marked plus (+) and the other marked minus (-). Electrons collect at the negative end of the battery, and, if you let them, they will gladly flow to the positive end. The way you "let them" flow is with a wire. If a wire is attached directly between the positive and negative terminals of a D cell, three things will happen:
Electrons will flow from the negative side of the battery to the positive side as fast as they can. The battery will drain fairly quickly (in a matter of several minutes). For that reason, it is generally not a good idea to connect the two terminals of a battery to one another directly. Normally, it can be connected to some kind of load in the middle of the wire so the electrons can do useful work. The load might be a motor, a light bulb, a radio. A small magnetic field is generated in the wire. It is this small magnetic field that is the basis of an electromagnet.

The figure below shows the shape of the magnetic field around the wire. In this figure, the cross section of the wire has magnetic field around it. The green circle in the figure is the cross-section of the wire itself. A circular magnetic field develops around the wire, as shown by the circular lines. The field weakens (so the lines are farther apart as they get farther from the wire). One can see that the field is perpendicular to the wire and that the field's direction depends on which direction the current is flowing in the wire. The compass needle aligns itself with this field (perpendicular to the wire). If the battery is flipped around and repeat the experiment, one will see that the compass needle aligns itself in the opposite direction.

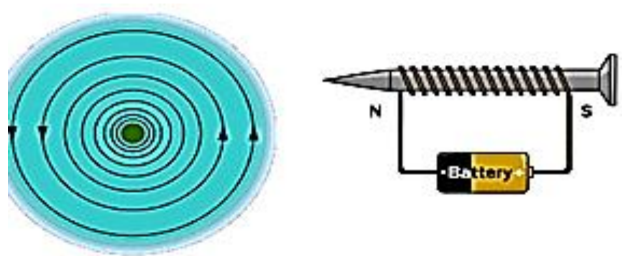

Fig.1: Electromagnet- Working phenomenon

1.2 Objective of the project

Steps have been taken to use this principle i.e. electromagnetic principle in an IC engine with modifications to run the engine and to acquire a certain speed as achieved by diesel or a petrol engine.

In this, electromagnetic coils which pulls the piston to and fro and the piston rod is connected to a crank which through effective transmission powers the rear wheel. The stand model is made with the rear wheels powered by magnetic coils and the front wheels are shown idle. Legs are provided to make the stand model. The wheels are rotating with high speed and the speed control is provided to vary the speed.

Basically this project is under innovative stage. By the application of some heavy magnetized electromagnet, desired reciprocating motion can be achieved which in turn completely revolutionizes the whole automobile industry. As we know day by day the quantity of fossil fuels is degrading in ocean and earth, steps have been taken to change the concept of movement of vehicle into concept of electromagnets, which will run as engines

1.3 Implementation of the concept in the automobile industry

Magnetic propulsion technique was never implemented in automobiles till now. Hence the project aims at adopting this technology in automobiles which could be used as an alternative way of propulsion with numerous advantages such as zero emission, reduction in noise pollution, less wear of mechanical parts and hence less maintenance which could one day revolutionize the automobile industry and thus decreasing the dependency on fossil fuels which would one day exhaust.

Upon research, it's observed that this particular technology has never found a place in automobile industry probably due to very recent invention of the maglev principle application, various other alternatives already in use such as Electric vehicles which run on electric motors, Conventional vehicles that run on petrol, diesel, etc.

1.4 Objective

Steps have been taken to use this principle i.e. electromagnetic principle in an IC engine with modifications to run the engine and to acquire a certain speed as achieved by diesel or a petrol engine. The system was designed to sustain 300W of input power.

In this, electromagnetic coils which pulls the piston to and fro and the piston rod is connected to a crank which through effective transmission powers the rear wheel. The stand model is made with the rear wheels powered by magnetic coils and the front wheels are shown idle. Legs are provided to make the stand model. The wheels are rotating with high speed and the speed control is provided to vary the speed.

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1.5 Report Organization

- Introduction
- Working principle& Methodology

This section contains information regarding the model working, its concept and principles.

- Design and Selection of Components

This section contains a detailed design of all the individual components, selection of various components based on the design calculations and verification for safe design.

- Fabrication and Assembly

This section contains fabrication of various parts which were chosen on the basis of design analysis carried out previously. It also includes the Bill of Materials which specify the materials, their price and the quantity of the various parts used. It even covers the assembly process of the vehicle which would describe the manner and the order in which the parts are assembled together.

- Performance Analysis, Testing& Experimental results

This section contains the various experimental tests conducted on the vehicle which includes recording of various performance parameters such as Power, Speed, Overall Efficiency, Power to Weight ratio, maximum payload, losses associated, etc.

Also the results of various tests conducted on the vehicle which are shown in the form of graphs are shown. These graphs indicate the variation of various performance parameters such as speed (constant and varying), load (constant and varying), overall efficiency, power output and input, etc.

- Conclusion

This section specifies whether if the set objectives are achieved based on the experimental results obtained, the future scope of the technology, benefits and its drawbacks, etc.

II. Working Principle & Methodology

2.1 Topic:

For well over a century and half, electrical current and magnetic fields/forces have known to possess a corresponding relationship that can be described and predicted through mathematical formulae. One-half of this relationship is observed when the movement of electricity, electrical current, through a wire correspondingly creates a magnetic force or field around the wire. This half of the relationship or principle is the basis for the operation of many types of electric motors, pumps, etc. Conversely, the other half of the relationship is observed when the movement of a magnetic force or field over a wire correspondingly creates electrical current in that wire. This half of the principle forms the basis for the operation of many types of electrical generators and alternators. In both halves of the relationship, the strengths and properties of two fields are proportional to one another. With this understanding, various applications have been developed using electrical/magnetic forces to create various propulsion systems and methodologies for solenoid/inducer-based power trains or power apparatuses. The basic definition of a solenoid is a cylindrical coil of wire which creates a magnetic field within itself when an electric current passes through it to draw a core of iron or steel within the coil.

The solenoid generally uses electrically conductive, non-magnetic and insulated wire of specific length that is coiled or wrapped around a tube or hollow cylinder. The core, in general terms, is a magnetic object, a portion of which moves in at least a portion of the tubes interior. The passing of an electrical current through the wire coiled around the tube generates a corresponding magnetic field or force around the tube/wire coil. This effect, commonly known as the Electro Motive Force (EMF), denotes that the polarity and strength of the electrical current passing through the wire coil will correspondingly determine the polarity and strength ofthe resulting magnetic field or force. In this manner, the manipulation of the various attributes of the electrical current (e.g.,polarity, duration and strength, etc.) respectively controls the attributes of the resulting magnetic field and the movement of the magnetic object in relation to the magnetic field. In controlling the electrical current to the solenoid or inducer, the subsequently created magnetic field draws, holds or expels the magnetic or polar object in relation to the interior of the wire wrapped tube.

For the magnetic force to be able act upon an object, the object generally is required to be magnetic: e.g., have those properties that are responsive to magnetic forces or fields. The incorporation of ferromagnetic material, such as an iron-based alloy, can also provide these magnetic/polar properties. The object can also obtain these properties through the incorporation of a wire coil set that can be energized to create an electromagnetic field or force (i.e., a solenoid inside a solenoid).

Correspondingly, the Counter EMF (CEMF) occurs when a magnetic object, by passing near an electrically conductive wire coil, generates a corresponding electrical current within that wire coil set. This CEMF occurs within a solenoid when a magnetic object moves within a non-energized wire coil set of a solenoid, creating an electrical current in the otherwise non-energized wire coil set.

Another manifestation of the Counter EMF (CEMF) starts when the electrical current is first sent through a wire coil set which has some form of built in resistance. The majority of the kinetic energy of the electrical current is stored as energy in the resulting magnetic field (the remainder of the kinetic energy is lost as heat). When the electrical current no longer passes through from the wire, the magnetic field collapses and returns its kinetic energy as electricalcurrent or avoltage spike to the otherwise de-energized wire coil set.

2.2 Scope:

Two solenoid coils have been held one after the other and a shaft is being housed between them. The basic definition of a solenoid is a cylindrical coil of wire which creates a magnetic field within itself when an electric current passes through it to draw a core of iron or steel or any ferromagnetic material within the coil. The solenoid generally uses electrically conductive, non-magnetic and insulated wire of specific length that is coiled or wrapped around a tube or hollow cylinder. The core, in general terms, is a magnetic object, a portion of which moves in at least a portion of the tube's interior. The passing of an electrical current through the wire coiled around the tube generates a corresponding magnetic field or force around the tube/wire coil. This effect, commonly known as the Electro Motive Force (EMF), denotes that the polarity and strength of the electrical current passing through the wire coil will correspondingly determine the polarity and strength of the resulting magnetic field or force. In this manner, the manipulation of the various attributes of the electrical current (e.g., polarity, duration and strength, etc.) respectively controls the attributes of the resulting magnetic field and the movement of the magnetic object in relation to the magnetic field. In controlling the electrical current to the solenoid or inducer, the subsequently created magnetic field draws, holds or expels the magnetic or polar object in relation to the interior of the wire wrapped tube.

In the first half of the cycle, the first coil is energized it will pull the shaft which in turn makes half rotation of the crank wheel.

In the second cycle, the coil is energized which in turn makes another half rotation of the crank wheel and hence completes one full rotation. The speed is controlled by the accelerator through the circuit. The timing of energizing the coil is done by control circuit, which is activated by accelerator sector which governs the speed of spindle. The spindle is coupled on the rear axle of the vehicle, which drives the axle resulting in the forward motion/movement. The chassis is made of mild steel flat and two wheels are fixed on the hub of the front axle and two wheels are fixed to the rear axle..

There is no steering mechanism in this model since it is at the initial stage of the technology. The vehicle has to be pushed for the starting momentum and for this we are using DC motor which acts like the starter when the particular momentum is reached, the motor can be disconnected, it will continue the drive by magnetic propulsion. The batteries for the DC motor is inbuilt in the vehicle and the battery used to drive the energizing of coils is external connected through the wires.

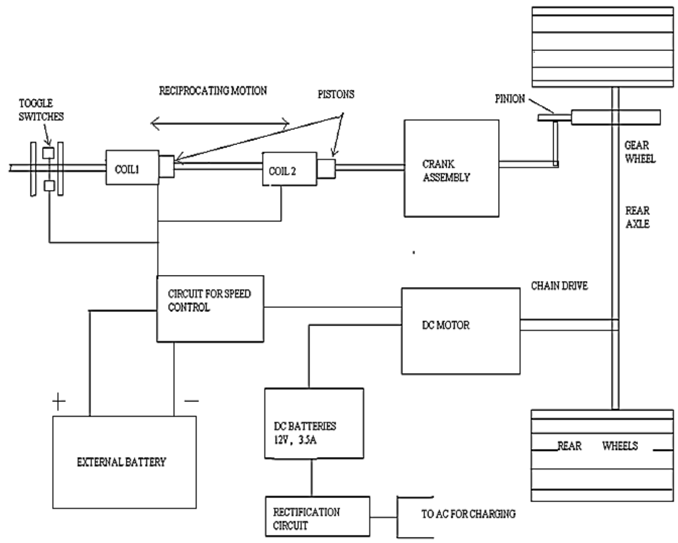

Figure2: Block Diagram of the working.

III. DESIGN & SELECTION OF COMPONENTS

For the vehicle to perform its desired functions various parts have to be designed so that we can get to know values of various physical quantities such as working stress, torque, power, force, velocity etc.

3.1 Selection of D.C. motor
3.2 Selection of solenoid coils
3.3 Spur gears
3.4 Rear axle
3.5 Rectifier circuit
3.6 Speed control circuit

3.1 Selection of the starter motor to drive the vehicle for starting torque.

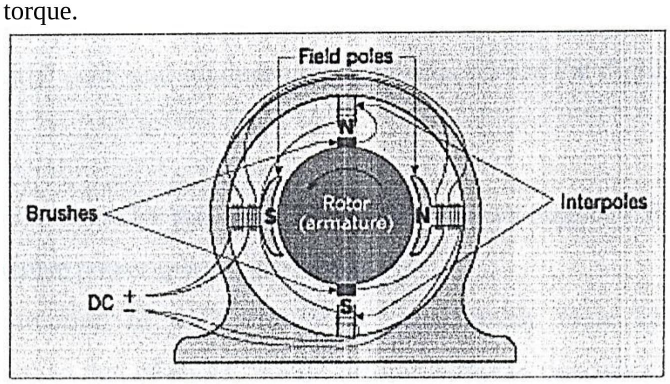

Figure3: Simple Brushed DC motor construction

DC motors consist of rotor-mounted windings (armature) and stationary windings (field poles). In all DC motors, current must be conducted to the armature windings by passing current through carbon brushes that slide over a set of copper surfaces called a commutator, which is mounted on the rotor. The commutator bars are soldered to armature coils. The brush/commutator combination makes a sliding switch that energizes particular portions of the armature, based on the position of the rotor. This process creates north and south magnetic poles on the rotor that are attracted to or repelled by north and south poles on the stator, which are formed by passing direct current through the field windings. It's this magnetic attraction and repulsion that causes the rotor to rotate.[2]

Selection of DC motor was primarily done based on the initial power requirements. The power was determined based on the initial velocity of the vehicle.

After the power requirement for the initial velocity was known, the torque needed to generate the speed was obtained. After the torque in kg-cm was known a DC motor was selected of the required capacity and RPM. DC motor speed was chosen based on the assumption that the vehicle should propel at 0.5m/s.
In order to select the DC motor for the specific application the following procedure is adopted.
Assuming the following data:
Speed at which the DC motor should run the vehicle = 1.8-2.0 Kmph
Total weight of the vehicle = 25 Kgs.
Thus we know that power required to propel the vehicle is given by,
$P = \frac{(F_t \times v)}{(3600 \times \eta_t)}$[4]
F_t= Tractive effort in Newtons.
v = Velocity of the vehicle in m/s.
η_t= Transmission efficiency.
But F_t =R =$K_t \times W$ Newtons where,
K_t=Coefficient of road resistance.
For smooth surfaces K_t=0.0059;
Assuming η_t =90% we get F_t=0.0059×250 =1.475 Newtons.

Now power required $P = \frac{(F_t \times v)}{(3600 \times \eta_t)}$
$= \frac{1.475 \times 2000}{3600 \times 0.9} = 0.91$W

The Torque transmitted is obtained from the Equation

$T = \frac{(60 \times P)}{(2\pi \times N)}$ where P= power transmitted in watts

N= speed in RPM
The circumference of the wheel (πD) = 70.5 cms

Then the linear velocity v& rpm'N 'are related by;
$$v = \frac{(\pi DN)}{60}$$

Let v = 2 kmph (Required speed of the vehicle) then the value of N obtained from the above formula = 47.28rpm;

Torque transmitted, $T = \frac{(60 \times P)}{(2\pi \times N)}$
$= \frac{(60 \times 0.91)}{(2\pi \times 47.2)}$

=0.184 N-m(approx. 2kg-cm)

But a 2 Kg-cm D.C. motor produces only N= 10-15 RPM. Hence a 6 kg-cm D.C. motor is selected which produces 35-40 RPM which can propel the vehicle with velocity of 2 kmph.
3.2 Selection of coils to generate electromagnetic force to pull the piston.

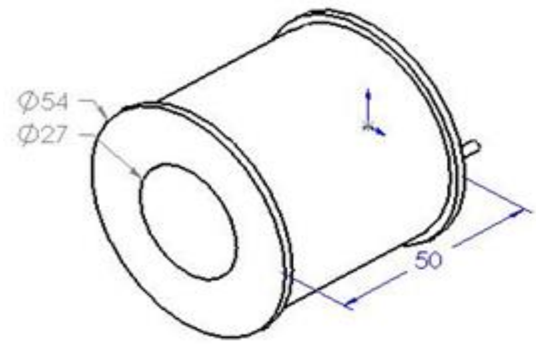

Figure 4: Solenoid coil

Coils were bought based on the strength of the magnetic field needed. Each coil of specified number of turns exhibits varying force depending on the ferromagnetic material used. Force exerted by the coils on the piston is far greater which by reduction gear gives the required speed.

Since the piston was made up of mild steel material a coil of 240 turns was chosen which could exert force at a range of 50 to 90 kN which would obviously vary due to a varying electric field as per the variations done in the speed control circuit.
Specifications of the coil:
No. of turns in the coil =230
Piston radius =14mm.
Clearance =1mm.
Thickness of the coil =10mm.
Inner diameter of the coil =30mm.
Outer diameter of the coil =40mm.
Length of the coil =50mm.
Piston material used is C30 steel.

Magnetic field generated by the solenoid:
$B = \frac{(\mu NI)}{L}$; where $\frac{N}{L}$ is the turn density $=\frac{230}{0.05}$ =4600/m.

B =Magnetic field in teslas.
μ=Permeability of the material.
I =Current in Amperes.
N = No. of turns.
L =Length of the coil.
But $\mu = K^*\mu_0$ where μ_0= Absolute permeability= $4\pi \times 10^{-7}$T/mA.
K = Relative permeability for steel = 100
Therefore $\mu = K^*\mu_0 = 100 \times 4\pi \times 10^{-7} = 4\pi \times 10^{-5}$T/mA.

Hence $B = \frac{(\mu NI)}{L}$
$= 4\pi \times 10^{-5} \times 4600 \times 25$
= 14.45Teslas.

3.3 Design of the drive gear which drives the driven gear mounted on the drive axle

Designing of gears was done after knowing the power requirements i.e after knowing the desired speed in which the vehicle should accelerate. Based on this gear of required number of teeth and module was chosen. With knowledge of Machine Design it was conclusive that the design was safe.

Gears of cast steel material was chosen for the power transmission process and the working stress was obtained knowing the pitch line velocity with which the gear should transmit power.The no. of teeth on the gear wheel was chosen on the assumption that the vehicle should propel at 2.5-3.0 m/s.

1) GEAR WHEEL:

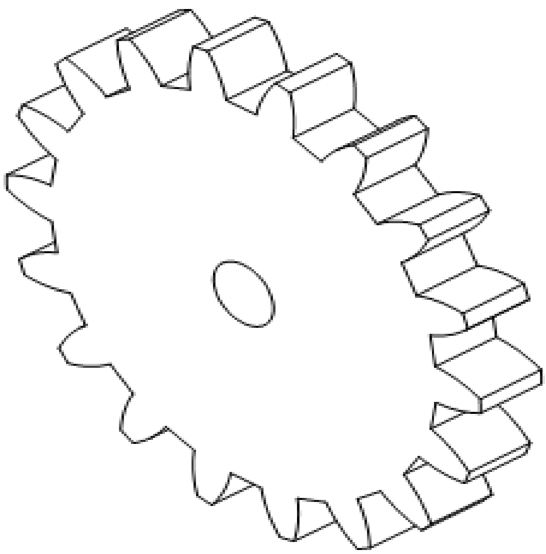

Figure 5: Gear wheel[3]

Gear wheel is designed on the basis that the rear axle should be producing a angular speed of 320 to 330 RPM, which is enough to propel the vehicle at 3.5 to 4 m/s.
The gears are of module (m) = 1.75mm and are 20^0 full depth involute.
For 20^0 full depth involute ;
Addendum = module(m) = 1.75mm(from design data hand book)[5]

Dedendum = (1.25)module = 2.1875mm.

Material of the gear = Cast Steel (0.3%C)

Addendum circumference = 288mm.

Therefore addendum diameter = 91.67mm.

Hence pitch circle diameter = 91.67- (2*1.75)
= 88.17mm.
Allowable static stress for C30 Steel =220.6 N/mm^2

Pitch line velocity (v) is given by $v = \frac{\pi DN}{60}$
Therefore $v = \frac{\pi \times 0.08817 \times 330}{60}$
=1.523m/s.

Velocity factor (C_v) is chosen on the value of Pitch line velocity, Hence for a velocity of 1.523m/s which is less than 8m/s the formula for velocity factor $C_v = \frac{3.05}{3.05+v}$
$= \frac{3.05}{3.05+1.523}$
= 0.6669
Working stress = $C_v \times \sigma_d$
= 0.6669× 220.6
=147.115 N/mm^2
Since the working stress =147.115 N/mm^2 is less than allowable static stress = 220.6 N/mm^2.
Hence the gear wheel is designed safe.
No. of teeth on the gear wheel = 49.
No. of teeth on the pinion = 22.
It is chosen such that we have speed reduction to 330 RPM from the speed of the pinion which is calculated as follows

$\frac{N_{pinion}}{N_{gear}} = \frac{T_{gear}}{T_{pinion}}$[4]

Therefore $\frac{N_{pinion}}{330} = \frac{49}{22}$

N_{pinion}= 735RPM

Beam strength of the gear wheel is given by the Lewis equation as follows:

$W_T = f_w \times b \times p_c \times y$N[5]

f_w= Working stress
b = Width of the gear face
$p_c = \pi \times m$ = Circular pitch
y = Tooth form factor (From design data hand book for a gear of 49 teeth and 20 degree full depth involute) = 0.13

$W_T = 147.115 \times 10 \times \pi \times 1.75 \times 0.13$

= 1051.44 N
Power produced by the crankshaft (P)

$$P = F \times v$$

Where F = Force acting on the reciprocating parts such as the piston, crankshaft, connecting rod etc.
V = Maximum velocity of the piston during its stroke.

Maximum velocity of the piston $v_{Pmax} = (\omega_{crankshaft} \times r)(\sin\theta + \frac{\sin 2\theta}{2n})$[4]

Where $n = \frac{L}{r}$; L = Length of the connecting rod = 62mm
r = Radius of the crank = 25mm
Therefore $n = \frac{62}{25} = 2.48$
θ = Angle of the crank at the maximum velocity of the piston = 90^0
$\omega_{crankshaft} = \omega_{pinion} = \frac{2\pi \times N}{60} = \frac{2\pi \times 735}{60}$ = 76.96 rad/sec
$v_{Pmax} = (76.96 \times 0.025)(\sin 90 + \frac{\sin 180}{2*2.48})$
= 1.924 m/s.

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But,

Force (F) = m × a_P; where

m = mass of the reciprocating parts such as the piston, crankshaft, connecting rod etc = 1800gms.

a_P= Piston acceleration = $(\omega^2_{crankshaft} \times r)(\cos\theta + \frac{\cos 2\theta}{n})$

$= (76.96^2 \times 0.025)(\cos 90 + \frac{\cos 180}{2.48})$

$= 59.7\ m/s^2$

Therefore power, $P = m \times a_P \times v_{Pmax}$

$= 1.8 \times 59.7 \times 1.924$

= 206.75 Watts

Assuming a transmission efficiency of 95% the power produced at the gear wheel

P = 80.4 × 0.95

=196.415 Watts.

Torque at the gear wheel is given by,

$$T = \frac{60 \times P}{2\pi \times N} = \frac{60 \times 76}{2\pi \times 330} = 2.22\ N\text{-}m$$

Tangential tooth load $F_t = \frac{P \times C_s}{v}$; where C_s=service factor (From design data hand book for medium shocks and for an intermittent operation) = 1.25

v = Pitch line velocity of the gear wheel,

$F_t = \frac{76 \times 1.25}{1.523}$

= 62.37 N

2) PINION:

Pinion is designed on the basis that the rear axle should be producing a angular speed of720 to 740 RPM, which is enough to propel the vehicle at 3.5 to 4 m/s.

The pinion are of module (m) = 1.75mm and are 20^0 full depth involute.

For 20^0 full depth involute ;

Addendum = module(m) = 1.75mm(from design data hand book and Kurmi /Gupta)

Dedendum = (1.25)module = 2.1875mm.

Material of the pinion = Cast Steel (0.3%C)

Addendum circumference = 136.47mm.

Therefore addendum diameter = 43.44mm.

Hence pitch circle diameter = 43.44 - (2*1.75)

= 39.94mm.

Allowable static stress for C30 Steel =220.6 N/mm^2

Pitch line velocity (v) is given by $v = \frac{\pi D N}{60}$

Therefore $v = \frac{\pi \times 0.03994 \times 735}{60}$

= 1.537 m/s.

Velocity factor (C_v) is chosen on the value of Pitch line velocity, Hence for a velocity of 1.537m/s which is less than 8m/s the formula for velocity factor $C_v = \frac{3.05}{3.05 + v}$[5]

$= \frac{3.05}{3.05 + 1.537}$

= 0.664

Working stress = $C_v \times \sigma_d$

= 0.664× 220.6

=146.68 N/mm^2

Since the working stress =146.68 N/mm^2 is less than allowable static stress = 220.6 N/mm^2.

Hence the pinion is designed safe

Beam strength of the pinion is given by the Lewis equation as follows:

$W_T = f_w \times b \times p_c \times y$ N

f_w= Working stress

b = Width of the gear face

$p_c = \pi \times m$ = Circular pitch

y = Tooth form factor (From design data hand book for a pinion of 22 teeth and 20 degree full depth involute) = 0.105

$W_T = 146.68 \times 8 \times \pi \times 1.75 \times 0.105$

= 387.07 N

The power produced at the pinion = Power at the crankshaft which is given by

$P = m \times a_P \times v_{Pmax}$

$= 1.8 \times 59.7 \times 1.924$

= 206.75Watts

Torque at the gear wheel is given by,

$$T = \frac{60 \times P}{2\pi \times N} = \frac{60 \times 80.4}{2\pi \times 735} = 1.044\ N\text{-}m$$

Tangential tooth load $F_t = \frac{P \times C_s}{v}$; where C_s=service factor (From design data hand book for medium shocks and for an intermittent operation) = 1.25

v = Pitch line velocity of the gear wheel,

$F_t = \frac{80.4 \times 1.25}{1.537}$

= 65.38 N

3.3 Design of the rear axle

After obtaining the values of torque and power the axle design was taken to consideration. It was calculated for its combined bending and torsional strengths based on max. shear stress theory.

The axle is made up of carbon annealed steel and knowing its material properties its working stress was compared with the yield strength of the material and on this basis it was pretty conclusive that the design was safe.

Shaft diameter = 20mm

Shaft material = Carbon-Steel-Annealed

Yield stress of the material(τ_y) = 131 N/mm^2

The material is ductile and the specimen is subjected to combined bending and twisting load. According to maximum shear stress theory, the maximum stress induced should be less than yield value of the shear stress.

Twisting moment (T) is given by the torsional equation as follows:

$$\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{l}$$

Where T = Torque in N-m,

J= Polar moment of inertia in Kgm^2

τ = Torsional shear stress in N/m^2

R = Radius of Curvature in m,

G = Rigidity modulus in N/m^2

θ = Angle of twist in radians,

l = Length of the shaft in m.

$$\therefore \frac{T}{J} = \frac{\tau}{R}$$

$\therefore\ \tau_{shear} = \frac{TR}{J}$[4]

Power produced at the output shaft (rear axle) P = 208 W
Torque produced at the output shaft(Rear axle) T = 2.22 N-m

Bending moment equation is given by,

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}[4]$$

where M = Bending moment in N-mm,
I = Moment of inertia in Kg-mm^2
σ = Bending stress in N/mm^2
y = distance of the outermost fibre from the neutral axis in mm,
E = Young's Modulus of the material in N/mm^2
R = The radius of curvature in mm

$\therefore$ M = $\frac{I\times\sigma_{bending}}{y}$

The vehicle produces a power of 76 W

$\therefore$ M = $\frac{P}{N}$ where P = Power in W
N = Speed of the axle in rpm.

$= \frac{76\times60}{330}$

= 37.818 N-m.

Equivalent Twisting moment = $\sqrt{M^2 + T^2}$

$= \sqrt{37.818^2 + 2.22^2}$

= 37.883 N-m

According to Maximum shear stress theory,

Maximum shear stress $f_{smax} = \frac{1}{2}\sqrt{{f_b}^2 + 4{f_s}^2}$[5]

Where f_b = Bending stress in N/m^2
f_s = Shear stress in N/m^2

$$\frac{\pi}{16}(f_{smax})d^3 = \sqrt{M^2 + T^2}$$

$$\therefore\ f_{smax} = \frac{\sqrt{M^2 + T^2}}{\frac{\pi}{16}\times d^3}$$

$$= \frac{14}{\frac{\pi}{16}\times 0.02^3}$$

= 24.117 N/mm^2

Hence, f_{smax}= 24.117 N/mm^2 is less than Yield stress of the material(τ_y) = 131 N/mm^2[4]
Hence the shaft design is safe.

3.4 Design of circuit for rectification

It will involve a suitable transformer to step down the current from the AC to charge the batteries. It will also involve a 4 bridge diode for proper rectification from AC to DC.

A transformer unit is used to step down the voltage required to charge the DC batteries which powers the DC motors for the initial torque

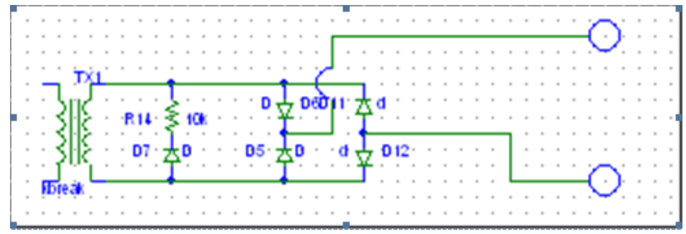

Figure 5: Transformer circuit

3.4 Design of circuit for speed control

Speed control circuit will be built using relays, transmitter, resistors and an IC. An LED is used to indicate the charging of the DC batteries and also to indicate the current flow in the circuit.

Relays are used mainly to protect the circuit and the toggle switches from any surge in voltage which could result due to the sudden switch of power to the external main batteries whenever there is a DC motor cut off. The motor is cut off with the help of a switch in the speed control circuit and the power is automatically directed to the external batteries which has a capacity about 12V and 25amps. A second Relay is used for motor cut off.

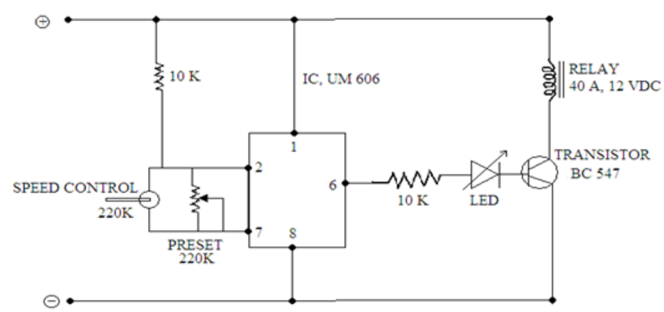

Figure 6: Speed control circuit

Use of Relay in the circuit:

The core of the electromagnetic relay, naturally, is an electromagnet, formed by winding a coil around an iron core. When the coil is energized by passing current through it, the core in turn becomes magnetized, attracting a pivoting iron armature. As the armature pivots, it operates one or more sets of contacts, thus affecting the circuit. When the magnetic charge is lost, the armature and contacts are released. Demagnetization can cause a leap of voltage across the coil, damaging other components of the device when turned off. Therefore, the electromagnetic relay usually makes use of a diode to restrict the flow of the charge, with the cathode connected at the most positive end of the coil.

Contacts on an electromagnetic relay can take three forms. Normally opened contacts connect the circuit when the device is activated and disconnect it when the device is not active, like a light switch. Normally closed contacts disconnect the circuit when the relay is magnetized, and a change-over incorporates one of each type of contact. The configuration of the contacts is dependent upon the intended application of the device.

The electromagnetic relay is capable of controlling an output of higher power than the input, and it is often used as a buffer to isolate circuits of varying energy potentials as a result. When a low current is applied to the electromagnet, throwing the switch, the device is capable of allowing a higher current to flow through it. This is advantageous in some applications, such as tripping alarms and other safety devices, because a safer low current can be used to activate an application requiring more energy.[1]

Power utilization:

The electromagnetic coils are supplied by 12VDC, may draw 25amps current.

Lead acid battery is used to give power to the DC motor and this battery can be recharged when connected directly to AC supply.

IV. FABRICATION & ASSEMBLY

The parts fabricated are:

4.1 Magnetic coil set:
4.2 Moving Shaft:
4.3Crank lever:
4.4Shaft Guides:
4.5Crank shaft:
4.6 Crank wheel:
4.7 Crank pin:
4.8 Crank housing
4.9 Crank lever
4.10 Base frame
4.11 Coil holder
4.12 Battery box
4.13 Circuit holder
4.14 Switch activating bushes
4.15 Drive Gear & Pinion

After the fabrication of the individual components upon design and their selection, they were then assembled. The order of the assembly is given below:

1) Chassis: The chassis frame was made of many different mild steel components that were welded together. This forms the skeleton of the vehicle.

2) Stand: The stand was then bolted under the chassis to support the weight of the vehicle. Two stands are provided, one below the rear axle and one below the front axle.

3) Front axles with wheels and Bearing: Front axle was welded onto the chassis frame with the bearings and the wheels.

4) Base Plate: The base plate was welded onto the chassis frame. This forms a support structure for the crank assembly.

5) Supports frames for Coils, Switches and Shaft: The support frames of various dimensions were welded/bolted on top of the chassis frame.

6) Crank Housing: Crank housing is welded onto the base plate which supports the crank assembly.

7) Crankshaft: Crankshaft was installed on the crank housing along with the bearings.

8) Piston with coils: Shaft is passed through the shaft guides and through the coils and with the help of a L-nut, the piston is fixed onto the shaft.

9) Crank Assembly: The Crank assembly consists of the connecting rod and the cam plate. This assembly was taken from a two-wheeler and installed.

10) Pinion: The pinion was boltedonto the crankshaftwhich overhangs from the cam plate and the Crank housing.

11) Rear axle assembly: The Rear axle assembly consists of Gear wheel, Sprocket, Rear wheels and bearings.

12) DC motor with Sprocket and Chain: The DC motor was mounted onto the Crank housing and then the Sprocket was bolted to the output shaft of the motor. The sprockets were then connected using the chain.

13) Battery with Transformer Circuits: DC batteries that run the DC motor are fixed onto the Battery Box which are welded onto the chassis frame. The rectifier circuits are built and soldered to the DC batteries. The batteries are connected to a transformer is bolted onto the chassis frame. Connections from the transformer is given through the wires for external charging.

14) Electronic Circuitry: The circuit components required for speed control are IC, Transistor, Resistor, Capacitor, Regulator, Preset which are soldered onto the PCB(Printed Circuit Board). Relays, LEDs, Toggle switches, etc. are also added along with wiring.

15) Switch actuators: These are a pair of mild steel strips bolted over the moving shaft at preset positions firmly. When the moving shaft reciprocates, the actuators operate the toggle switches thereby alternating the current to the coils.

V. PERFORMANCE ANALYSIS, TESTING & EXPERIMENTAL RESULTS

The various parameters involved in the performance testing of the vehicle is listed below:

1) Rotational speed of the Rear axle
2) Force exerted by the piston
3) Power generated
4) Load on the engine
5) Efficiency:
   a) Coil efficiency
   b) Piston efficiency
   c) Crank & Transmission efficiency
   d) Overall efficiency.

5.1 Rotational speed of the rear axle:

The speed of the rear axle 'N' is measured in rotations per minute (RPM) which is measured using a digital tachometer by which the power at the rear axle is measured. As per the readings by the tachometer the rear axle rotates at 330 RPM and the pinion or the crank shaft with a speed of 750 RPM. Varying speed can be obtained by the speed control circuit which varies the speed by a range of 80 RPM.

5.2 Force exerted by the piston:

The piston is subjected to magnetic force which acts tangential to the surface of the piston and the piston in turn exerts a force on the crank assembly and the other reciprocating parts. The force exerted by the piston is measured using the formula,

F = Mass * Acceleration

Where the mass of the reciprocating parts is expressed in terms of Kg

Acceleration in terms of m/s2 and is given by the formula

a_P = Piston acceleration = $(\omega^2_{crankshaft} \times r)\ (\cos\theta + \frac{\cos 2\theta}{n})$

Force in terms of Newtons (N).

5.3 Power Output:

The power generated at the rear axle was found out taking into account the transmission and the crank efficiency. The input power generated by the piston before the cranking and the transmission is given by

$$P = m \times a_P \times v_{Pmax}$$

where $v_{Pmax} = (\omega_{crankshaft} \times r)(\sin\theta + \frac{\sin 2\theta}{2n})$[4]

5.4 Load on the engine:

Various performance tests were conducted on the vehicle in varying conditions such as constant load- varying speed, constant speed-varying load. The load applied were in an interval of 2kg and parameters like speed, efficiency, power input were measured. The vehicle was tested with a minimum load of 5kgs and a maximum of 11kg.

5.5 Efficiency:

a) Coil efficiency:

Coil efficiency is defined as the amount of DC power transmitted by the coils to the power input by the batteries. This parameter was almost negligible since the losses associated with the dissipation of the power was very low and this was calculated knowing the resistance exerted by the supply wires and the wires in the coil.

b) Piston efficiency:

Piston efficiency is defined as the amount of power generated by the piston to the power input by the coils. This was calculated by knowing the power exerted by the piston on the crank assembly and the power input by the coils taking into account the dissipation factors due to the resistance exerted by the coil.

c) Crank & Transmission efficiency :

Transmission efficiency is defined as the power generated by the gear wheel to the power input by the pinion. For a standard pinion and gear assembly, the transmission efficiency is assumed to 95 %.

Crank efficiency is defined as the power generated by the crankshaft to the power input by the piston. For a standard crank assembly, the efficiency is assumed to be 96%.

d) Overall efficiency:

Overall efficiency is defined as the power generated at the output shaft to the power input by the DC batteries. This efficiency is the product of the all the efficiencies i.e., Coil efficiency, Piston efficiency, Crank and Transmission efficiency.

EXPERIMENTAL RESULTS:

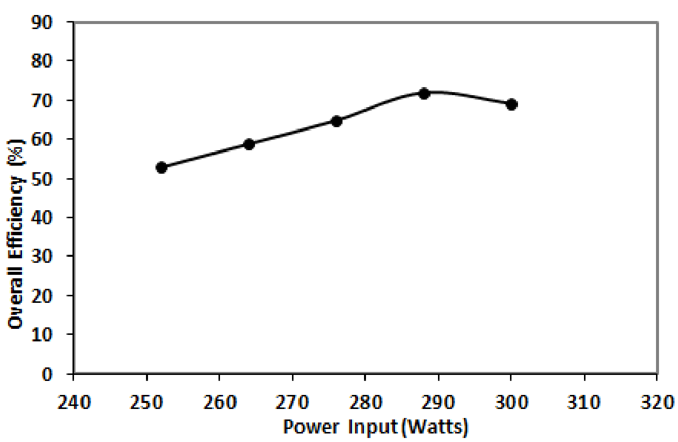

Figure 7: Overall Efficiency vs. Power input

1. This test was conducted to know the overall efficiency of the vehicle at varying power input. It can be concluded from the graph that the overall efficiency of the vehicle is low at a lesser power input due to the resistance offered by the reciprocating mass(inertia force) and this force decreases with the increasing power input. Hence the efficiency increases at a range of 285 to 290 W, with a peak efficiency of 70 to 72% percent. The decrease in efficiency after 290W was due to the increase in frictional losses & heating of coils.

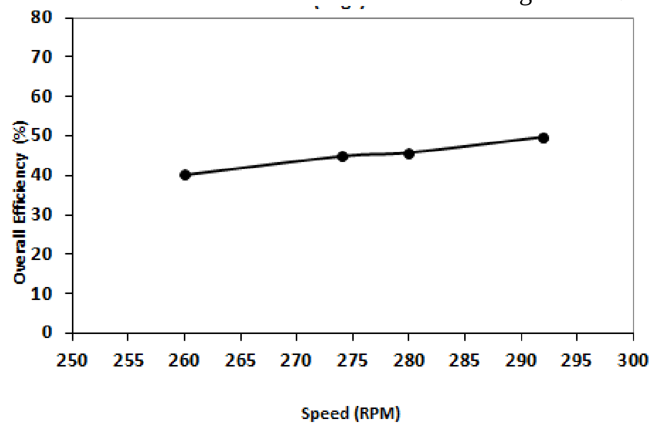

Figure 8: Overall efficiency vs. RPM

2. This test was conducted to know the overall efficiency at varying speed .The overall efficiency was found to be maximum at a speed of 290RPM due to the increase in power input and the reason for this is same as graph showing the overall efficiency Vs power input. Further test was not conducted since I had to risk overheating of coils.

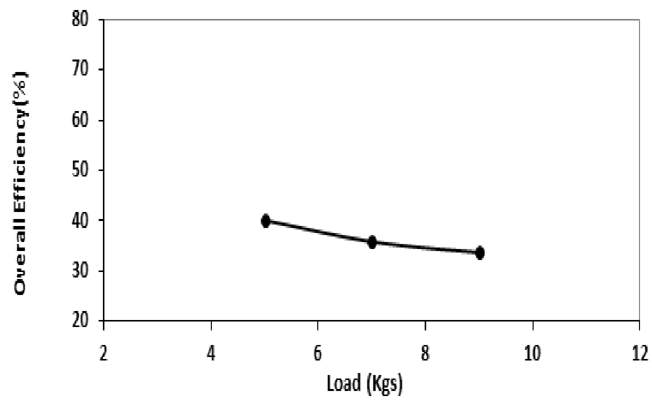

Figure 9: Overall efficiency vs. Load

3. This test was conducted to know the variation of overall efficiency with increasing load at a constant speed of 260RPM. It was found that the input power required to keep the vehicle running at 260RPM drastically increased, thus decreasing the overall efficiency. The load was increased by 2Kg for the 3 trials conducted.

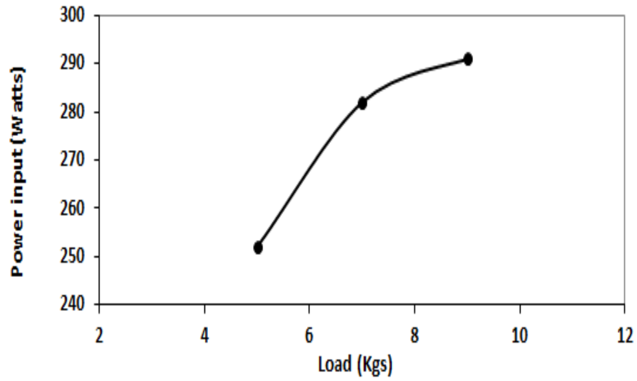

Figure 10: Power input vs. Load

4. This test was conducted to know the power input with the increasing load at a constant speed of 260RPM. As load was increased it was observed that the power input required increased drastically to keep the vehicle running at 260RPM thus decreasing the efficiency.

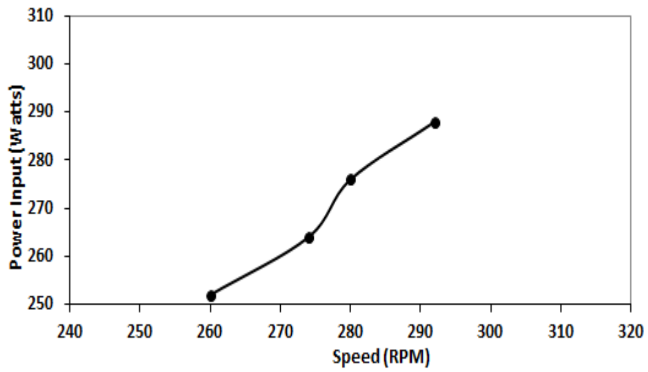

Figure 11:Power input vs. Speed

5. This test was conducted to know the variation of power input with increasing speed at constant load of 5Kg. The power input required increased with increase in speed.

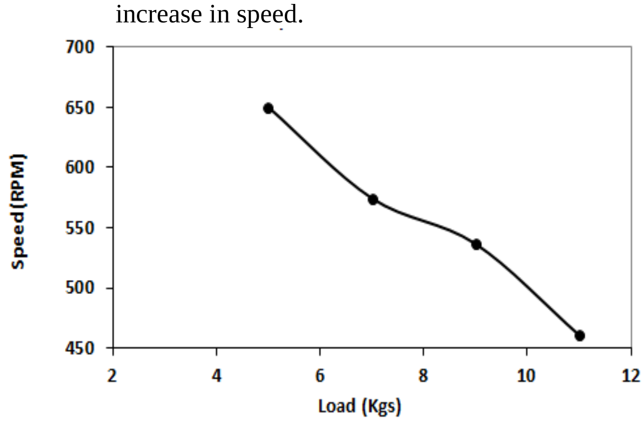

Figure 12: Speed vs. Load

6. This test was conducted to know the variation of speed with increase in load. The speed recorded in this case is the speed of the pinion which varied due to the increase in resistance offered by the rear axle due to the increase in load. The load was increased with an increment of 2kg for every trial.

ATTAINMENT OF OBJECTIVES:

- The prototype was aimed at obtaining an alternative method for propulsion technique in automobiles. With the help of this prototype model, it could be shown that it is possible to use magnetic power efficiently for transportation in automobiles. The prototype could produce an overall efficiency of 72% which could be improved with further research on this concept.
- The project was also aimed at using electrical energy to propel the vehicle which obviously results in zero emission. With the increase in Carbon emission from automobiles and due to the fast depletion of fossil fuels, this technology will find its place soon in the market.
- This technology is very efficient because it involves few number of moving parts and there is no mechanical contact and friction taking place between the piston and the coils unlike IC engines wherein the piston slide inside the cylinder. Hence there is not much of lubrication involved.

VI. SUMMARY/CONCLUSION

Scope for Improvement:

- The efficiency could be increased significantly by using bigger and more efficient design of coils, installation of flywheels, cooling systems for the coils, etc.,.
- Efficiency of the prototype could be increased further by efficient design of coils so that the magnetic flux induced by the solenoid coils could be utilized to the fullest
- By reversing polarity using polarity timer & using permanent magnets as the piston material, by inducing repulsion simultaneously in the other coil the efficiency could be further enhanced.
- By using a piston enhancer (an electromagnetic coil at the dead center) the reciprocation could be improved
- An AC generator in the crankshaft can be used to appropriately rectify & charge the batteries thus improving the efficiency.
- 2n no. of pistons & solenoid pairs can be used with n of pistons and solenoids at each end to see if better efficiency is achieved.
- Parallel connecting rods could be introduced with the similar set up thus to power a common crankshaft & try to achieve a better efficiency.

Actual Model:

CONCLUSION:

- Switching Magnetic Energy can be the technology for the future.At this forefront of new inventions and discoveries man is always in a quest for moving faster and more efficient ways of energy utilization.
- This technology is very efficient because it involves few no. of moving parts and there is no mechanical contact and friction taking place between the piston and the coils unlike IC engines wherein the piston has a sliding contact with the cylinder. Hence there is not much of lubrication involved in the prototype.
- This principle can revolutionize our modes of transport. Due to an increase in carbon emission orgreenhouse gases people in the future will be resorted in using electricity as a primary fuel for automobiles which will be the obvious result of the disadvantages faced by us due to dependency on fossil fuels.
- If this technology is implemented it will cut off the carbon emission and thereby facilitate a greener, cleaner environment which can ultimately give a cure for global warming.

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AUTHORS

Correspondence Author – Gopi Krishna N, John Deere India, Regd unit: John Deere Technology Centre India, 1W- 195, Manufacturing services, Tower No. 14, Cyber city, Magarpatta city, Hadapsar, Pune- 411013, Maharashtra, India.
E mail address: **gopikris1901@gmail.com**
Telephone number: **+91-8806198176**