Tyre Safety by Electromagnetic Field

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ABSTRACT

The automotive industry is one of the larger markets in the world. It had previously been one of the fastest growing globally. An automobile is being used in every part of our social life. It is also used in emergency situation as ambulance, VVIP movement, Defense Services & Rescue Operations. The most common problem in automobile is air leakage in tyres. As per experiences, very little nail of ferrous metal are responsible for this leakage. This paper presents an idea to safe guard the tyres with the help of electromagnetic field. The method is purely based on numerical approach. Average weight of ferrous metal nail is to be found out by the sample collected from tyre repair shop and accordingly required force can be calculated to lift the nail from the road. A high strength magnetic field is generated to lift the nails from the road. Further calculation for required electrical parameter (current, voltage, wire, core etc) is done. This will increase the tyre life and reduce the risk of delay in travel during emergency situation. It will also help the environmental by increasing the life of tyre and reducing the frequent change of tyres, which will also reduce the production demand.

Keywords: *Electromagnet, Magnetic field, Permeability, coercivity, levitation, force constant, steel nails.*

1. INTRODUCTION

An electromagnet is a type of magnet in which the magnetic field is produced by the flow of an electric current. The magnetic field disappears when the current ceases. Electromagnet uses electricity to produce magnetic force. The main advantage of an electromagnet over a permanent magnet is that the magnetic field can be rapidly manipulated over a wide range by controlling the amount of electric current. However, a continuous supply of electrical energy is required to maintain the field [1].

This magnetic field will be used just before the front wheel of an automobile to attract the nail from the road before reaching the tyre at the position (Fig.1).

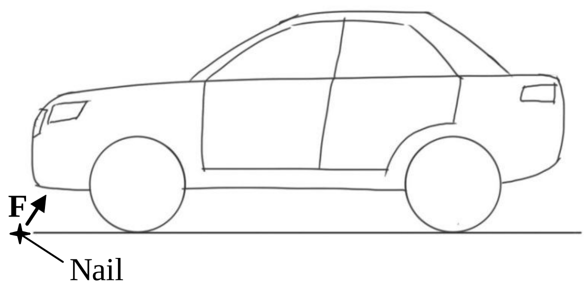

Fig.1. Schematic Diagram of Working Principle

2. LITERATURE REVIEW

The lifting power of an electromagnet is the ability of the magnet to lift a ferromagnetic material from a given distance. Different magnets have different magnetic strength [1]. If the magnetic field is confined within a high permeability material, such as certain steel alloys, the maximum force is given by [1-2]:

$$F = \frac{A * B^2}{2 * \mu_0} \quad (1)$$

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Where:

F is the force in Newton's

B is the magnetic field in Teslas

A is the area of the pole faces in square meters

ì $_0$ is the permeability of free space

In the case of free space (air), ìo = 4ð *10^{-7}Hm^{-1} (Where H is Magnetic Field Strength)

The main consideration in the design of an electromagnet is its lifting power of the magnet [1]. Cast steel was selected for this design because it has a narrow loop area which gives it a high permeability, hence making it suitable for core of electromagnet. The core of the electromagnet is first specified, the core area (shape), diameter, and the required length of the winding are then selected by estimating or calculating amount of current expected to pass through when lifting the required load.

The main nonlinear feature of ferromagnetic materials is that the B field saturates at a certain value, which is around 1.6 Teslas (T) for most high permeability core steels. The B field increases quickly with increasing current up to that value, but above that value the field levels off and becomes almost constant, regardless of how much current is sent through the windings. So the strength of the magnetic field possible from an iron core electromagnet is limited to around 1.6 to 2 T.

For given core geometry, the B field needed for a given force can be calculated from equation (1) ; if it comes out to much more than 1.6T, a larger core must be used. Once the B field needed is known, the magneto motive force the product of current and the number of turns in the winding can be calculated. The lifting power of an electromagnet is the ability of the magnet to lift a ferromagnetic material from a given distance [2]. Equation (1) is the lifting power or force for I-shape core of the electromagnet. For U-shape the force formula is divided by two, while for E-shape it's divided by three, because the U-shape has 2 poles and E-shape has 3 poles respectively which will participate in lifting of the load.

3. DESIGN & CALCULATION FOR ELECTROMAGNET

In this design a bolt that forms an I-shape which is made from steel rod with the following dimension when measured was used. A 1.5 inch diameter (38.1mm), 4 inch (101.6mm) pitch (length of the winding area or former).

The average weight of nail is calculated in Table.1 by the collected nails from tyre repairing shops. The average ground clearance is calculated in Table.2 by collecting the data for different Indian cars.

Average weight of nails responsible to puncher the tyre is 3.872 gm [Table.1] but calculation is done for 20gm to be in safer side. Average ground clearance for Indian cars is 160.40mm [Table.2] but calculation is done for 170 mm.

In this design 18 gauge Annealed copper wire of diameter 0.048 inch (1.219mm) is used for winding the core (on the basis of current density).

Table - 1

Average Ground Clearance of Indian Cars

S.N.	Entry-level Sedans	Ground Clearance
1	Fiat Linea	185 mm
2	Maruti Suzuki SX4	170 mm
3	Mahindra Verito	172 mm
4	Toyota Etios	170 mm
5	Ford Fiesta	168 mm
6	Ford Fiesta Classic	168 mm
7	Volkswagen Vento	168 mm
8	Skoda Rapid	168 mm
9	Honda City	165 mm
10	Hyundai Verna	165 mm
11	Tata Manza	165 mm
12	Nissan Sunny	165 mm

S.N.	Entry-level Sedans	Ground Clearance
13	Toyota Corolla Altis	175 mm
14	Honda Civic	170 mm
15	Renault Fluence	170 mm
16	Chevrolet Cruze	165 mm
17	Skoda Laura	164 mm
18	Volkswagen Jetta	139 mm
19	Hyundai Sonata	155 mm
20	Honda Accord	155 mm
21	Volkswagen Passat	150 mm
22	Nissan Teana	145 mm
Average Ground Clearance of Indian Car=164.40mm		
But calculation is done for 170mm		

Table - 2
Average Weight of Nails

S.N.	Weight of Nail
1	03 grams
2	1.5 grams
3	06 grams
4	05 grams
5	3.5 grams
6	10 grams
7	04 grams
8	02 grams
9	2.6 grams
10	1.8 grams
11	3.2 grams
Average weight of nail=3.872gm	
But calculation is done for 20gm	

Fig.2. Nails Collected from Tyre Repa ir Shop

When the magnet energizes, it will tend to lift the ferromagnetic material around its pole(s) [3-5]. It can only lift this load (object) w hen the magnetic force is greater than the gravitational force of the load [6]. The gravitational force is giv en by:-

$$F = mg \qquad (2)$$

Where m is the average mass of the load (nail), and g is the acceleration due to gra vity ($9.81 m/s^2$)
The average weight of nail is calculated by collecting the sample from tyre repairing workshop and it is found to be 8-12 gram. But the calcu lation is to be done for 20 gram to be in safer side.

F magnet = F gravity.

In this case the maximum mass of the object to be lifted is 20g (0.02Kg). Therefore, the gravitational force is:

$0.02kg \times 9.81m/s^2 = 0.1962N$.

The lifting force has to be gr eater than 0.1962N.

The pole area is given by $A = \frac{\pi}{4} D^2$,
Where D = pole diameter which is 38.1mm

$$A = \frac{\pi}{4} * (38.1 * 10^{-3})^2 = 1.14009 \times 10^{-3}\ m^2 \qquad (3)$$

$\mu o = 4\pi \times 10^{-7} = 1.2566 \times 10^{-6}$
m=20g,
$g = 9.81 m/s^2$

Substituting this in equation (1) we have:-

$$0.1962 = [B^2 * 1.14009 \times 10^{-3}] \div [2 * 1.2566 * 10^{-6}] \qquad (4)$$

From which B is calculated as 0.020796653 wb/m^2
This is the flux density in th e air gap and is the same as the flux density in the cor e for a very small air-gap; the total flux in the core is as equation (5);

$$\Phi = B * A \qquad (5)$$

Where A is the core area, since the magnet acts like a closed cylinder;

The area is given by :

A= 2ðrl + 2ðr^2 (6)

Where r is the half diameter of the core and l is the length of the former

Since r =19.05mm and l=101.6mm

The area is computed to be A=0.014441162 m^2

Hence the total flux from equation (5) is obtained to be

Ö =3.003278487*10^{-4} Wb.

This total flux in the core, is the same as the flux in the air-gap

The magnetizing force (H) in the air-gap is given by

H = B/ìo (7)

Therefore,

H = B/ìo

=0.020796653/1.2566x10^{-6}

= 16549.93872AT/m

For the air-gap (ground clearness of the cars) of 170mm the magneto-motive force (mmf) is given by

AT = HxL = 16549.93872*170*10^{-3}

= 2813.48958 2 AT (8)

L is the length of air-gap specified as170mm.

This magneto-motive force is the product of the current that will go round the magnet and the number of turns of the wire that make up the magnet. If one of the variable is chosen the other variable can be calculated, thus if the number of turns is chosen to be 1657, then the current in the electromagnet is given by;

I =mmf/N

Applying the values,

I= 2816.48 95/1657

I=1.70 (9)

Therefore the current is computed to be 1.70A.

Finally the lifting power or force of the magnet is computed using equation (1) as

F= (B^2 *A)/2 ìo

=2.48520 N (10)

The educed lifting force (2.48520 N) is more than the required force (0.1962 N). This will attract the iron nails from the road to safe the tyre.

The maximum operating voltage and the current are determined by the wire used to create the magnetic field.

3.1 Determination of the length of the wire needed

The wire is to be wound on the core of the electromagnet. At this point, the following parameters are known. Diameter of the former is 38.1mm, the length of the pitch or former is 101.6mm and the diameter of the wire to be wound is 1.2192mm.

The maximum number of winding in the first layer will be 101.6mm / 1.2192mm =83.49 turns,

Chosen a stacking factor of 0.9, the maximum number of turns on the first layer will then be 83.49*0.9 =75 turns.

If each layer is to have this maximum number of turns then, the total number of layers required to give the total number of turns will be;-

Total no of layers = 1657/75 =22.09=22 layers.

When rewinding the wire the perimeter of each subsequent layer will be increased by 2d, where d is the diameter of the wire i.e. (1.2192mm).

First layer perimeter (length) will be

= ðD*75

=ð *38.1mm * 75 turns

=119.69m m* 75turns

Hence the length of one turn on first layer is 119.69mm

The length of one turn on second layer is 119.69mm + 2d, =119.69 mm + 2 x (1.2192mm)

The length of one turn on third layer = second layer perimeter + 2d

The length of one turn on fourth layer = third layer perimeter + 2d

The length of one turn on fifth layer = fourth layer perimeter + 2d etc this is an arithmetic progressive (AP).

The AP formed has the followin g parameters;-
First term (a) = 119.69mm, common difference d = 2d= (2.4384mm),
Number of turns n = 22
The length of the wire can be computed using sum of AP:-

$$\text{Sum} = \frac{n}{2(2a(n-1)d)} = 3195.06\text{mm}$$

Hence the total length require d is the sum multiply by the total number of turns.

The total length is 3195.06*75=239629.5mm or **239.2695m** which is the same as 261.66 yards or 785.0048 ft.

3.2 Weight of Wire

The wire is normally sold per kilogram; from the table gage 18 has a weight of 20.92 pounds per 1000 yards. As Mentioned above, the length of the wire is 261.66yards, therefore the weight is calculated as follows;-

$$\frac{20.92\text{pounds}}{1000\text{yards}} * 261.66\text{yards} * 0.\frac{4536}{1\,\text{pounds}} = 2.4829\text{ kg.}$$

4. WORKING MODEL FABRICATION

To study the effect of above p arameter, a working model is designed. An electrom agnet (6-7) with above specification is fabricated an d installed on a toy tricycle [Fig.3] just before the front wheel. The electromagnet attract the nails towards its pole.

Fig.3. Workings Model of Electromagnet to Safe the Tyres from Nails.

4.1 Advantages

- Provides safety to vehicles from tyres damage.
- Cost effective.
- Requires less maintenance.
- Eco-friendly.
- Reduces the accidents caused by tyres burst.
- Increase tyres life significantly.
- Saves the time to repair the tyres.
- Very helpful on Indian road condition.
- Very useful in emergence services.

4.2 Disadvantages

- Increase the weight of vehicle.
- May affect the balancing of vehicle.
- Engine performance may be affected by heavy electromagnetic field.
- Performance of electromagnet may reduce at high speed.

5. CONCLUSION

The electromagnet was designed and constructed and it was found out that it can fully suspend the steel nails at different positions when the current through it was varied. The electromagnet can suspend any ferromagnetic material irrespective of its shape and size. The current through the magnetic coil limits the maximum load it cans lift. It helps to provide safety to the tyres by magnetic field and removes the problem of puncher. It also increases the tyres life and reduces the accident on Indian roads.

Still a lot of work is to be done on this concept for betterment.

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