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DESIGN AND FABRICATION OF ELECTROMAGNETIC BRAKING SYSTEM

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Abstract: This paper describes the design, fabrication, working and the advantages and disadvantages of Electromagnetic Braking System. This method is a better substitute for the present conventional braking systems. The concept helps in reducing or eliminating sources of heat generation, friction, noise, and wear of materials. There is no involvement of fluids as used in hydraulic braking systems. Electromagnetic brakes work on the principle of repulsion and attraction between two electromagnet field coils. The repulsion between the field coils opposes the motion of the wheel. This repulsion is initiated within the field coils by a switch or a lever that allows current to be supplied to the coils. Each coil is separately spaced evenly on both the outer and inner array of field coils. The repulsive forces are cumulative as one outer field coil passes the inner field coil, and the forces keep adding up to the deceleration of the wheel in motion. The field coils are constructed in a simple manner as of a basic electromagnet with a soft ferrous core and copper wire wound around the core. The polarity of the coils follows the right-hand thumb rule of electromagnetism. The poles of the field coil that come near to each other are always made sure to be of the same poles, either north-north or south- south, to generate the repulsive forces between the outer and inner field coils.

Index Terms – Brake, Magnetic coil, Cooling, Performance.

I. INTRODUCTION

Firstly, the wheels used are from a generic wheelchair. The rim size was found to be suitable for our project. The profile of the rim had the correct width to fit field coils made by us. Since the material of the wheel is aluminium, the cores were bolted onto the rim rather than being welded.

The cores were tap drilled to 4mm and bolted to the outer rim while the inner stationary field coils were welded onto a hub which is fixed to the frame. The shaft of the wheel goes through this hub and rests on a set of bearings which are mounted on the frame. The motor is mounted onto the frame directly and drives the wheel by chain drive with the help of sprockets. After the coils are mounted onto the wheel and the hub, the gap existing between the field coils is around 5 mm.

This helps to maximize the repulsive force while also allowing undisturbed rotation of the wheel. The repulsive force between one outer field coil and one inner stationary field coil is targeted to be one sixth of the total force required to stop or slow the rotation of the wheel. The field coils are assembled in such a manner that they align with axial coincidence while rotating. When the coils coincide axially the polarities are swapped to opposite causing attraction forces which hold the coils together for small amount of time, this adds up to more decelerating forces on the rotating wheel. The combined effect is the electromagnetic braking force desired by us. The swapping of polarities is controlled by an arduino uno microcontroller.

II. LITERATURE SURVEY

Rodrigues, O et al. [1] had performed experiments on eddy current which is an induced current generated due to changes in the magnetic field in the conductor. Initially, the magnetic field is induced in the direction of its main magnetic field; therefore, there is a repulsive force between the two poles.

Karakoc, K et al. [2] had performed experiments on Eddy current brakes (ECB).The main components of the ECB consist of magnetic field sources and inductance. Based on its structure, the ECB can be categorized into axial, radial, linear, and retarder types. In this research, a unipolar design of the ECB is developed and evaluated. The unipolar design has advantages over other ECB designs.When the coil is given a current, the permanent magnetic field will add to the strength of the magnetic field, which works to produce braking torque, because a parallel arrangement is arranged. The magnetic field is produced by an electrically wound coil. The amount of magnetic flux produced by a coil depends on the amount of flowing electric current. The amount of torque is regulated by changing the amount of flowing current. The greater the electric power given, the greater the magnetic field produced.

Kim, Y.S et al. [3] have performed experiments on the amount of magnetic flux produced by a coil. This magnetic flux depends on the amount of electric current flowing to the system. The amount of torque is regulated by changing the amount of current. Greater electric power leads to a greater magnetic field. In addition, the frequency and shape of the current signal also affect the braking performance. It was also found that the braking torque can be increased by adopting AC power.

Jian Wang. et. al. [4] studied the Limitations of permanent magnets. Permanent magnets have a fixed capacity depending on the material used to make permanent magnets, such that the strength that can be obtained can no longer be increased.

A.Baskaran&P.Koshy Mathews et.al [5] studied the performance comparison of Vapour Compression Refrigeration System Using Eco Friendly Refrigerants of Low Global Warming Potential. R600a performance have a slightly higher than coefficient(COP) R134a for the condensation temperature of 50^0C and evaporating temperatures ranging between -30^0Cand10ºC.Hence,the coefficient performance (COP) of this mixture was up to 5.7% higher.

Singh A. [6] have studied experimentally the Field of rectangular electromagnets.The braking forces acting on a thick conducting disc rotating in the field of rectangular electromagnets are examined. Finite thickness of the plate is taken into account explicitly in deriving the general expression for the braking force. This expression is shown to reduce to the conventional induction motor characteristic in the thin plate limit and a simple original expression is presented for the calculation of braking forces in the skin-effect region.

Sutopo W et. al. [7] have experimentally studied about Lithium-ion batteries.ircuits of batteries can be made parallel and in series. Performing a series of settings, obtaining the performance as needed. The EMF obtained can be altered based on the number of batteries used and the circuit type the batteries are connected in.

III. OBJECTIVES

The objectives of our project work are as follows:

i. Main objective is to stop the wheel using magnetic field generated by the field coils using Parallel & opposite (Radial) forces.
ii. To implement a braking system which can stop and start within one unit.
iii. To eliminate the concept of friction and heat generation and wear.

IV. METHODOLOGY

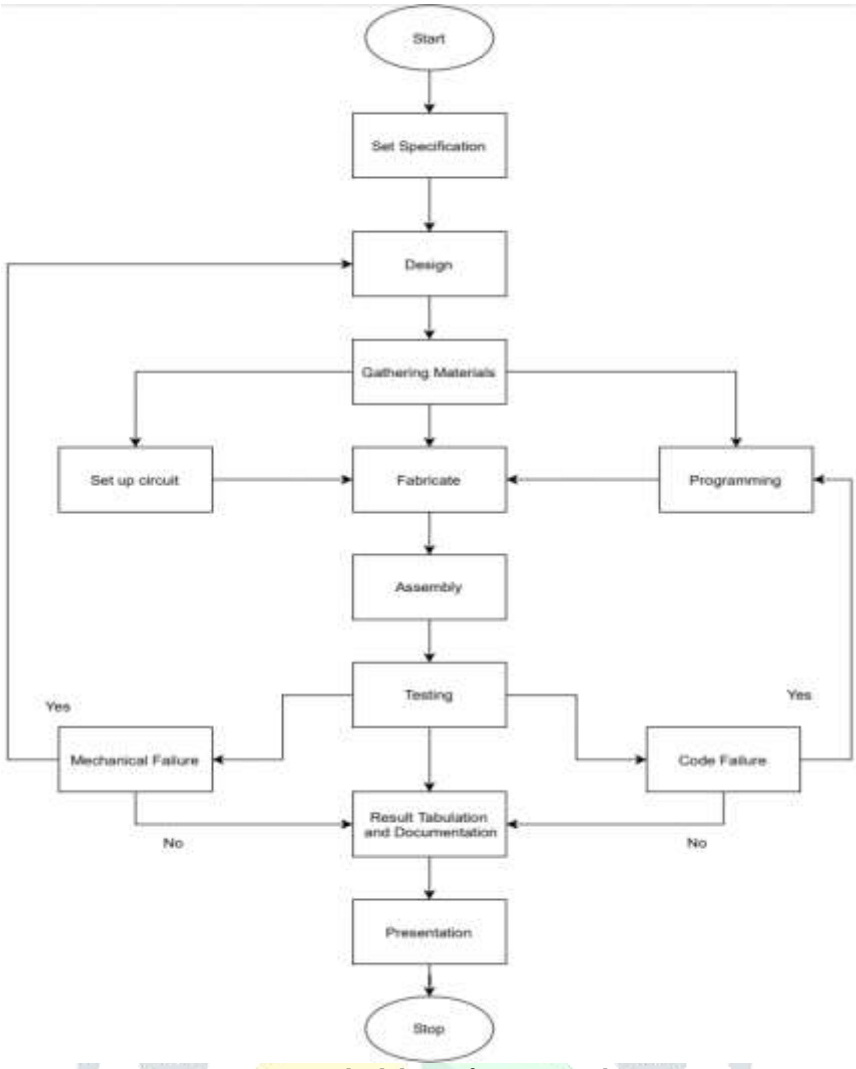

Fig.1 Methodology of Project work

Set specification: Setting the parameters of design which includes required dimensions, environmental factors, ergonomic factors, aesthetic factors, maintenance that will be needed, Mining information and data of present brakes from industry, finding potential computer software's in order to model the project etc.

Design: It is the plan for the construction of the product for the implementation of process. It involves the selection and comparing various material for the cores, Creating CAD model of the parts using SOLIDEDGE/CATIA, Selecting and deriving formulas essential for calculating unknowns, thickness of wire and battery specifications etc.

Gathering materials: Procurement of raw materials needed for the project according to design and set specification. It includes the electronic gadgets, mounting frame, mechanical tools, circuit parts, electronic components, arduino Uno microcontroller, etc.

Set-up circuit: The electrical circuit required for the project is planned and set up.According the required safe parameters and operating specifications the circuit is assembled and soldered on a PCB and Breadboard connected to the battery.

Programming: The coding needed for the electrical components are done and implemented. The Code which is typed in JAVA/PYTHON or C++ is fed into the microcontroller.

Fabricate: Implementation of the design into manufacturing the parts. It includes the fabrication of the cores according to required dimensions, Welding the frame (mount for the project)etc.

Assembly: The manufactured parts are assembled to obtain the final product. This involves mounting the wheel in the shaft, Fixing the cores around the circumference of the wheel and coupling the wheel to the motor, winding of copper coil onto the soft iron cores etc.

Testing: The assembled product is tested for its working. There is a chance of having either a mechanical failure or a mistake in the programmed code.

1) **Mechanical failure:** If there are any failures in the mechanisms such as fractures, high wear & tear, excessive deflection,

vibration, etc. The design might have to be changed.

2) **Code failure:** The failure in programming leads to improper working of the product. If this occurs, the code is to be changed in the programming sector.

Result tabulation & documentation: The tested product is then documented for its function ,working and specifications.

Presentation: The final project is then available for presenting.

Table:1 Parts of the Prototype

SL No.	Description	Material/Name
1.	Frame	Iron
2.	Motor	3 Phase AC motor
3.	Motor controller	Lunyee 90K W
4.	Non-Rotating Disk	Non ferrous Material
5.	Rotating wheel Part 1	Stainless steel
6.	Rotating Wheel Part 2	Stainless steel
7.	Shaft	Mild steel
8.	Field coils	Iron
8.	Microcontroller	Arduino Uno

1. Frame

A Frame is used for mounting our entire project on it for Working and display.

The frame used is an Iron frame. The edges have been welded using arc welding

Fig:2 Iron Frame

2. Electric Motor & 3.Motor controller

An **Electric motor** is an electrical machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of torque applied on the motor's shaft. Electric motors can be powered by direct current sources, such as from batteries, or rectifiers, or by alternating current sources, such as a power grid, inverters or electrical generators.

Fig:3- III Phase AC motor

Motor controller is a device or group of devices that can coordinate in a predetermined manner the performance of an electric motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and electrical faults.

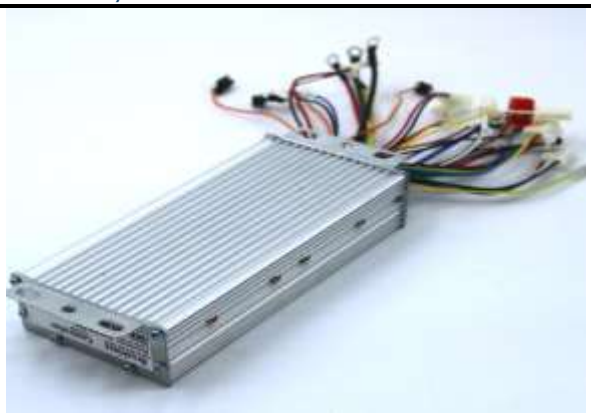

Fig:4 Motor controller Lunyee

4. Non-Rotating Disk

The non rotating disk is Made of Non Ferrous material as the magnetic properties of the material can affect the Magnetic fields produced by the field coils mounted over it.

This disk does not rotate with the wheel hence it is to be welded onto the Frame by any means .It is free of the shaft and all rotating elements of the project setup. The thickness of the disk does not matter. The only important parameter is the outer diameter.

5.. Rotating wheel part 1

The Wheel used in our Project is a Stain less Steel wheel Used in Wheelchairs .Its dimensional parameters are showing in Table 5.The Wheel has 6 Hinges mounted and welding around the circumference of the rim. The purpose of these hinges are to mount the Part 2 of the wheel onto the Part 1. The main purpose of this wheel is to rotate and act as a medium to transmit forces from the Part 2 of the wheel to the shaft.

Fig: 5 Rotating wheel Part 1

4. Rotating wheel Part 2

This part of the wheel is where the Braking takes place. The main purpose of this part is to transmit the forces induced by the field coils when they enter a magnetic field (Braking Force) .It Also consists of 6 hinges welded on the circumference of the Rim which are used to connect or Join the 2 parts of the wheel.

Fig:6 Rotating Wheel Part 2

5. Shaft/Axle

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power.

Fig: 7 Mild steel Shaft

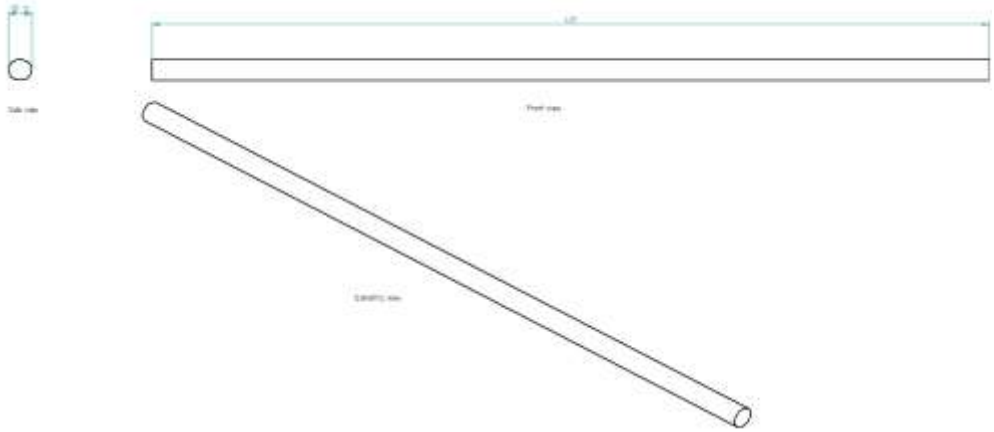

Fig:8 2D Draft of the Shaft

6. Field coils

A field coil is an electromagnet used to generate a magnetic field in an electro-magnetic machine, typically a rotating electrical machine such as a motor or generator. It consists of a coil of wire through which a current flows.

Fig:9 Soft Iron cores

The Magnetic cores used in out setup are shown in the above figure. They are Soft annealed Iron, They have been fabricated into Shape by us using conventional Lathe. They have been provided with 4mm Tapping with internal threading in order to mount it onto the Part 2 of the Wheel and onto the Drum. A Total of 12 Field coils are Used in this project.6 Cores are mounted on the Part 2 Wheel and the other 6 are mounted on the Non-rotating disk.

7. Electronic circuit and Microcontroller

An electrical network is an interconnection of electrical components (e.g., batteries, resistors, inductors, capacitors, switches, transistors) or a model of such an interconnection, consisting of electrical elements (e.g., voltage sources, current sources, resistances, inductances, capacitances).

A microcontroller (MCU for microcontroller unit) is a small computer on a single metal-oxide semiconductor (MOS) integrated circuit (IC) chip. A microcontroller contains one or more CPUs (processor cores) along with memory and programmable input/output peripherals.

The microcontroller used in our circuit is an **Arduino Uno.**

Fig:10 Arduino Uno

Stationary coil circuit :

The Battery is connected to a Potentiometer which can vary the Resistance to the flow of current. Which is connected to the User's pedal/Lever. Which in turn varying the current supplied to the microcontroller. The microcontroller then sends the current supplied from the battery to the field coils based on the angle of the wheel. During other times current is not supplied .Hence, Switching off the field coils.

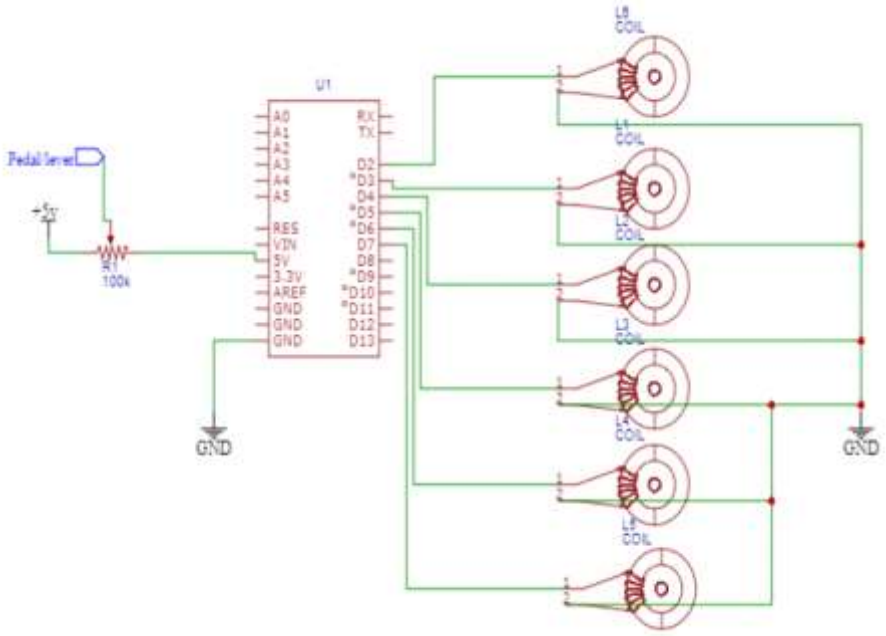

Fig:11 Circuit For Stationary Element

Rotating coil circuit :

The other circuit is for the Rotating coils . There is no Arduino or any control over this circuit it is an Active circuit (i.e. Always ON/Always OFF). In this circuit the Battery is connected directly to the Rotating field coils .Hence, Switching ON/OFF the battery means Switching ON/OFF the field coils. The circuit is shown in the figure below .

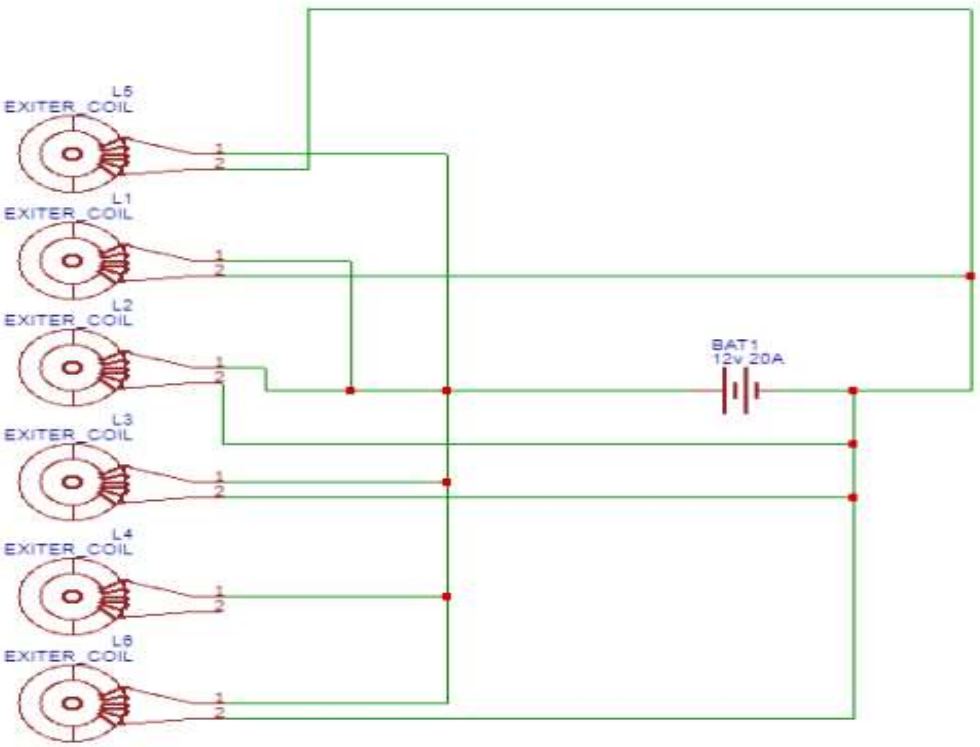

Fig: 12 Circuit For Rotating Element

V. EXPERIMENTAL WORK

Construction:

The construction of the setup Is to be done in this order for easy installation and clean setup.

The soft iron cores are tapped with 4mm threaded holes after which they are fixed onto the Part 2 of the Wheel using screws of that thread. The Part 2 of the wheel is fixed onto the Part 1 of the wheel using Nuts and Bolts and Washers. The Axle/Shaft is inserted into the Hub of the wheel and is mounted on Bearings. The remaining field coils are mounted over the Non-rotating Disk and is kept concentric to the Part 2 of the wheel. The motor with sprocket and chain is installed and coupled with the shaft. 24 gauge enameled Copper wire is wound over the Soft iron cores and is connected to the Electronic circuit Shown above and The entire setup is to be mounted on a Frame using Arc welding.

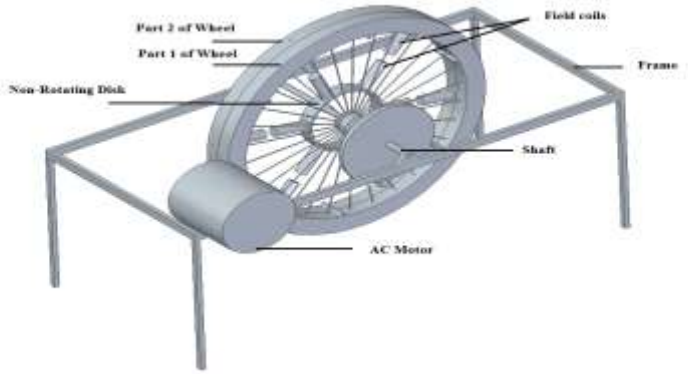

Fig: 13 Construction of the Model

VI. WORKING:

The Working principle on which this concept works on **Ampere's Law**

Taking a rectangular path about which to evaluate Ampere's Law such that the length of the side parallel to the solenoid field is **L** Gives a contribution **BL** inside the coil .The field is essentially perpendicular to the sides of the path, giving negligible contribution, If the end is taken so far from the coil that the field is negligible ,then the length inside the coil is the dominant contribution. Shows for a solenoid.

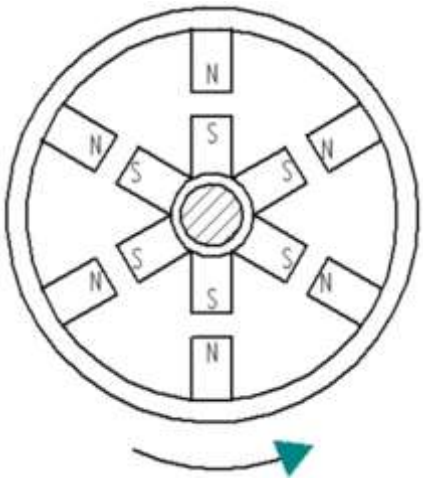

Fig:14 Poles in ON condition

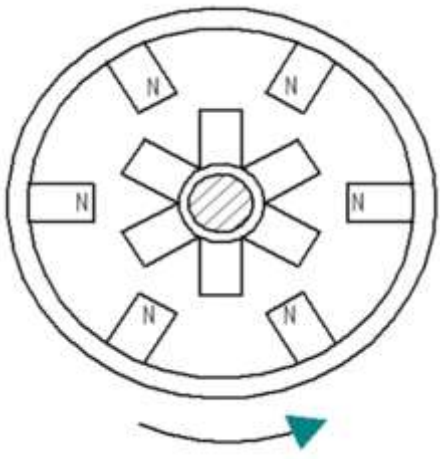

Fig:15 Poles in OFF condition

VII. CALCULATIONS

Torque:

T = 60P/2×pi×N in Nm

T= (60×900)/2×pi×1000

T= 8.6 Nm

We know that **P=2PiNT/60 W.** Hence it is known that **P=900W** and speed of the motor will be 1000 rpm as requirement. By substituting the values of P and N we can calculate Torque as **8.6Nm**.

Force:

F = T/r in N

F = 8.6/.2286

F = 37.62 N

We know that Toque= Force×radius of the wheel

Therefore Force=Torque/radius of the wheel.

Since the radius of the wheel used in this project is **228.6mm** or **.2286m**

Force is calculated to be **37.62 N** .

It is Found that 1Tesla=1Netwon/1A×1m

Therefore For 20A and a length of .07m. We can conclude that for our experiment

14Tesla=1Newton.(i.e 526.68Tesla=37.62 Newton) .

Which means we will need to produce about 526.68 Tesla units to act as an anti torque to the wheel.

Individual magnetic field:

B = F/6 in T

B = 526.68/6

B = 87.78 T

Since the above force is for the whole unit and not for individual field coil we divide the magnetic field required by the number of field coils used.(i.e 6 field coils).

Magnetic field:

B = μnI in T

B = (200×4×pi×10^-7)×n×20

87.78= (200×4×pi×10^-7)×n×20

87.78=2513.27×10-7×20×n

Therefore: **n=17463.3 Turns/m**

We know that,

μ = Permeability of the material which is equal to μ0×K in T/A m and I=20A since a 20 A battery is used.

μ0 is the Absolute permeability of free space i.e (4pi×10^-7)

i.e. μ=μ0×K=(4×pi×10^-7)×200 T/A m

by calculating it is found that **μ=2513.27×10-7 T/A m**

By substituting all the values n is found to be **17463.3 turns/m.**

Turn density:

n = N/L in Turns/m

17463.3 = N/.07

N = 17463.3 × .07 = 1222.4.

N ≈ 1222 Turns

Obtained Turn density as 17463.3 turns/m

By substituting the values of n and L which is the length of the coil i.e .07m

The results found to be **1222 turns** per field coils.

VIII. CONCLUSION

i. It is concluded that this concept of braking can be used in wide range of applications (I.e. Any rotating element).

ii. Also it is understood that this concept of braking can eliminate the concept of friction and ease out all the problems which arise due to conventional brakes. However it is a complex system.

iii. We would like to implement this system on an actual moving vehicle.

iv. Further advancement in the coding and increasing the number of field coils can fruit in even larger application as implementing a system which can brake and accelerate at the same time.

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