Electronic Braking System

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Abstract

Generally the brakes are either hydraulically or pneumatically actuated systems. A dc motor can be used in certain system for controlling the brake application. From the study of various system of braking, which uses microcontroller, a new idea of braking for small scale application directly involving the working of a relays and a dc motor was evolved. The present project work seeks to create a pattern and design of electronic braking system using a dc motor. The project is categorized to two parts. The first parts deals with the general study of various braking system and its components. The second part deals with the various designs in accordance with the requirements. The basic precondition for developing electronic braking system is avoiding the hydraulic and pneumatic controlling and by designing a controller able to control automotive brake systems. So in this improved design we are trying to minimise the effort required for braking. In this system we are using a dc motor to actuate the fluid pressure in the brake calliper for braking.

Keywords: Angle sensor, proximity sensor, lead screw, DC and AC motor

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I. INTRODUCTION

Brakes are devices whose function is to slow down and stop automobile. They are mandatory for the safe operation of vehicles. When a car is in motion it has kinetic energy or energy derived from motion. In order for the car to slow down, this energy must be decreased. This accomplished by transforming it into another form. In the case of brakes, this form is heat. In short brakes transform the kinetic energy of the car into heat energy, thus slowing its speed and if enough energy is transferred the automobile is stopped.

Brakes have been refined and improved ever since their invention. The increases in travelling speed as well as the growing weights of cars have made these improvements essential. If the car is heavier and the faster it moves then harder it is to stop. An effective braking system is needed to accomplish the work. Nowadays cars often use a combination of disc brakes and drum brakes. Disc brakes are usually located on the front two wheels and drum brakes on the back two wheels. Disc brakes are also used in all the four wheels. Nowadays Electric Buggy Car at airport is popular around the world. It's used for carrying the passenger baggage as well as the passengers inside the airport. The brake system is probably the most important system for vehicle. Most buggy cars have disc brakes. There are two design of brake disc that is solid disc and ventilated disc. Brake disc are made from cast iron, with a ground surface on each side against which the pads are applied.

To design a suitable breaking system factors such as speed of the vehicle, maximum weight of baggage also weight of driver and passengers must be accounted. It is suitable to use motorcycle RXZ/TZM braking systems or Go Kart braking system in the Buggy Car. It is simple and efficient for the Electric Buggy Car and has easy maintenance and is not a complicated system.

II. DESCRIPTION OF EQUIPMENTS

A. AC Motor:

An induction motor (IM) is a type of alternating current motor where power is supplied to the rotating device by means of electromagnetic induction. It is also called asynchronous motor.

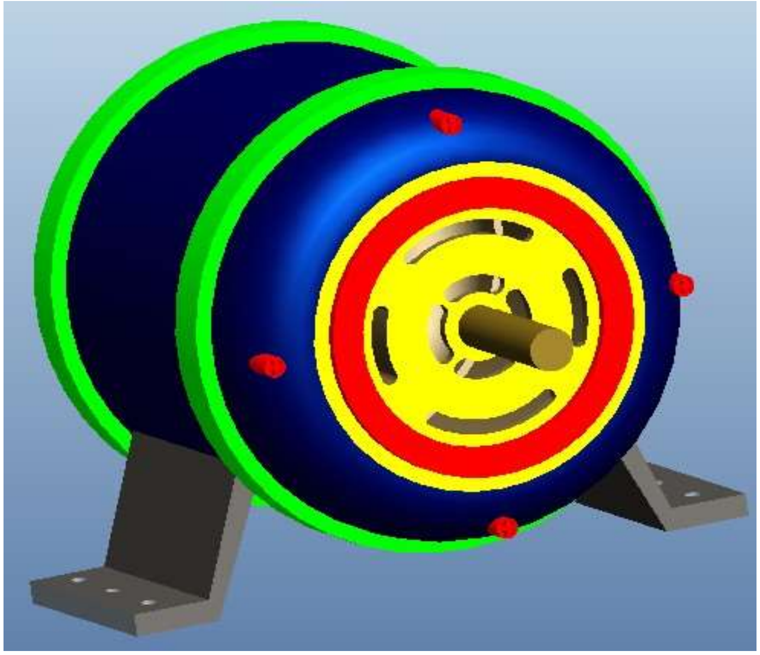


Fig. 1: AC Motor

An electric motor converts electrical power to mechanical power in its rotor (rotating part). In a DC motor this power is supplied to the armature directly from a DC source, while in an induction motor this power is induced in the rotating device. An induction motor is sometimes called a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. Induction motors are widely used, especially polyphase induction motors, which are frequently used in industrial drives.

Induction motors are now the preferred choice for industrial motors due to their rugged construction, absence of brushes (which are required in most DC motors) and — thanks to modern power electronics — the ability to control the speed of the motor.

1) Construction:

The stator consists of wound 'poles' that carry the supply current to induce a magnetic field that penetrates the rotor. In a very simple motor, there would be a single projecting piece of the stator (a salient pole) for each pole, with windings around it; in fact, to optimize the distribution of the magnetic field, the windings are distributed in many slots located around the stator, but the magnetic field still has the same number of north-south alternations. The number of 'poles' can vary between motor types but the poles are always in pairs (i.e. 2, 4, 6, etc.).

Induction motors are most commonly built to run on single-phase or three-phase power, but two-phase motors also exist. In theory, two-phase and more than three phase induction motors are possible; many single-phase motors having two windings and requiring a capacitor can actually be viewed as two-phase motors, since the capacitor generates a second power phase 90 degrees from the single-phase supply and feeds it to a separate motor winding.

Single-phase power is more widely available in residential buildings, but cannot produce a rotating field in the motor (the field merely oscillates back and forth), so single-phase induction motors must incorporate some kind of starting mechanism to produce a rotating field. They would, using the simplified analogy of salient poles, have one salient pole per pole number; a four-pole motor would have four salient poles. Three-phase motors have three salient poles per pole number, so a four-pole motor would have twelve salient poles. This allows the motor to produce a rotating field, allowing the motor to start with no extra equipment and run more efficiently than a similar single-phase motor.

B. DC Motor:

All D.C machines have five principal components viz (i) Field system (II) armature core (iii) armature winding (iv) Commutator (v) brushes

1) Field system:

The function of the field system is to produce Uniform field within which the armature rotates.it consists of a number of salient poles(of course, even number) bolted to the inside of circular frame (generally called yoke).the yoke is usually made of solid cast steel whereas the pole piece are composed of stacked laminations. Field coils are mounted on the poles and carry the d.c exciting current. The field coils are connected in such a way that adjacent poles have opposite polarity.The m.m.f. developed by the coils produces a magnetic flux that passes through the pole pieces, the air gap, the armature and the frame. Practical d.c machines have air gaps ranging from 0.5mm to 1.5mm.since armature and field systems are composed of materials that have permeability, most of the m.m.f.of field coils is required to set up flux in the air gap. By reducing the length of air gap, we can reduce the size of field coils (number of turns).

2) *Armature core:*

The armature core is keyed to the machine shaft and rotates between the field poles. It consists of slotted soft-iron laminations (about 0.4 to 0.6mm thick) that are stacked to form a cylindrical core. The laminations are individually coated with a thin insulating film so that they do not come in electrical contact with each other. The purpose of laminating the core is to reduce the eddy current loss. The laminations are slotted to accommodate and provide mechanical security to the armature winding and to give shorter air gap for the flux to cross between the pole face and the armature "teeth".

3) *Armature winding:*

The slots of the armature core hold conductors that are connected in a suitable manner.this are known as armature winding. This is the winding in which "working"e.m.f. is induced.

The armature conductors are connected inseries-parallel: the conductors being connected in series so as to increase the voltage and in parallel paths so as to increase the current.the armature winding of a d.c.machine is a closed –circuit winding. The conductors being connected in a symmetrical manner forming a closed loop or series of closed loops.

4) *Commutator:*

A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes.the commutator is made of copper segments insulated from each other by mica sheets and mounted on the shaft of the machine. The armature conductors are soldered to the commutator segments in a suitable manner to give rise to the armature winding.depending upon the manner in which the armature conductors are connected to the commutator segments, there are tow types of armature winding in a.d.c. machine viz(a) lap winding (b) wave winding.

Great care is taken in building the commutator because any eccentricity will cause the brushes to bounce, producing unacceptable sparking .the sparks may burn the brushes and overheat and carbonize the commutator.

5) *Brushes:*

The purpose of brushes is to ensure electrical connections between the rotating commutator and stationary external load circuit. The brushes are made of carbon and rest on the commutator,the brush pressure is adjusted by means of adjustable springs. If the brush pressure is very large, the friction produces heating of the commutator and the brushes.on the other hand, if it is too weak, the imperfect contact with the commutator may produce sparking.

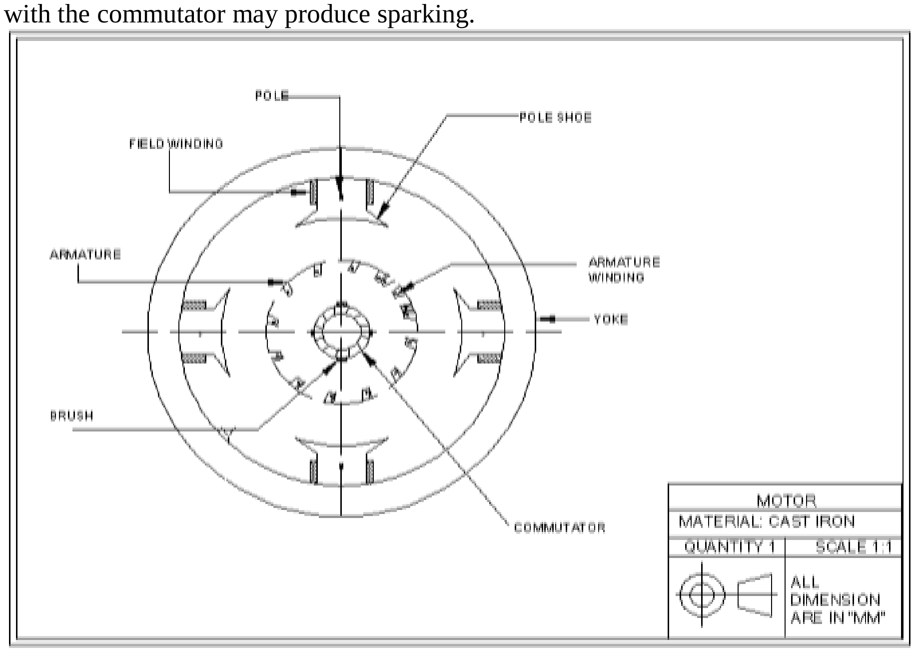


Fig. 2: DC motor

1) *STATOR:*

The stator is the stationary part of an electric generator or electric motor. The non-stationary part on an electric motor is the rotor.Depending on the configuration of a spinning electromotive device the stator may act as the field magnet, interacting with the armature to create motion, or it may act as the armature, receiving its influence from moving field coils on the rotor.

2) *ROTOR:*

The rotor is the non-stationary part of a rotary electric motor or alternator, which rotates because the wires and magnetic field of the motor are arranged so that a torque is developed about the rotor's axis. In some designs, the rotor can act to serve as the motor's armature, across which the input voltage is supplied.

3) *D.C MOTOR PRINCIPLE:*

A machine that converts direct current power into mechanical power is known as D.C Motor. Its generation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The direction if this force is given by Fleming's left hand rule.

4) *WORKING OF A DC MOTOR:*

Consider a part of a multipolar dc motor as shown in fig 1. When the terminals of the motor are connected to an external source of dc supply;

1) The field magnets are excited developing alternate N and S poles.
2) The armature conductors carry currents. All conductors under N-pole carry currents in one direction while all the conductors under S-pole carry currents in the opposite direction.

Suppose the conductors under N-pole carry currents into the plane of paper and those under S-pole carry current out of the plane of paper as shown in fig. Since each armature conductor is carrying current and is placed in the magnetic field, mechanical force acts on it. Applying Fleming's left hand rule, it is clear that force on each conductor is tending to rotate the armature in anticlockwise direction. All these forces add together to produce a driving torque which sets the armature rotating. When the conductor moves from one side of the brush to the other, current in the conductor is received and at the same time it comes under the influence of next pole which is of opposite polarity. Consequently the direction of force on the conductor remains same.

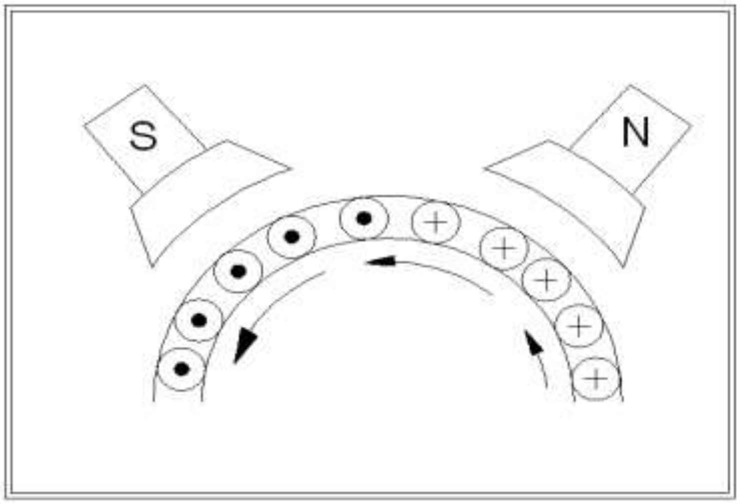


Fig. 3: Polarity in A DC Motor

C. *Proximity sensor:*

A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive or photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target.The maximum distance that this sensor can detect is defined "nominal range". Some sensors have adjustments of the nominal range or means to report a graduated detection distance.

Fig. 4: Proximity Sensor

Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object.

Proximity sensors are commonly used on smartphones to detect (and skip) accidental touchscreen taps when held to the ear during a call. They are also used in machine vibration monitoring to measure the variation in distance between a shaft and its support bearing. This is common in large steam turbines, compressors, and motors that use sleeve-type bearings.

D. *Angle Sensor:*

An angular position sensor (also referred to as a rotary sensor) measures the relation by which any position with respect to any other position is established. It calculates the orientation of an object with respect to a specified reference position as expressed by the amount of rotation necessary to change from one orientation to the other about a specified axis.

There are many different kinds of angular position sensors. The most common values for supply voltage are 4.5 to 5.5 V. We also carry angular position sensors with supply voltage up to 36 V. Supply current can have a range between 100 µA and 13.5 A, with the most common chips having a supply current of 13.5 mA.

Fig. 5: Angle Sensor

E. *U Slot Sensor:*

Slot sensors, sometimes called optical fork sensors because of their "forked" shape, detect objects that pass between the two arms—one with the emitter, the other with the receiver. The fixed slot width provides reliable opposed-mode sensing of objects as small as 0.30 mm.

Offering reliable performance in an innovative package, these sensors are the first ones to use in error-proofing, process monitoring, and general automation tasks in a number of environments. With the broadest selection of sizes, shapes, and light sources available

F. *Lead Screw:*

A lead screw (or lead screw), also known as a power screw or translation screw,is a screw used as a linkage in a machine, to translate turning motion into linear motion. Because of the large area of sliding contact between their male and female members, screw threads have larger frictional energy losses compared to other linkages. They are not typically used to carry high power, but more for intermittent use in low power actuator and positioner mechanisms. Common applications are linear actuators, machine slides (such as in machine), vises, presses, and jacks.

Lead screws are manufactured in the same way as other thread forms (they may be rolled, cut, or ground). A lead screw is sometimes used with a split nut which allows the nut to be disengaged from the threads and moved axially, independently of the screw's rotation, when needed (such as in single-point threading on a manual lathe

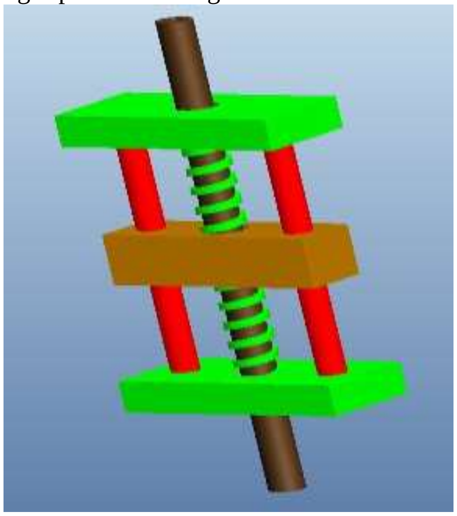


Fig. 6: Lead Screw

Power screws are classified by the geometry of their thread. V-threads are less suitable for lead screws than others such as Acme because they have more friction between the threads. Their threads are designed to induce this friction to keep the fastener from loosening. Leadscrews, on the other hand, are designed to minimize friction.[4] Therefore, in most commercial and industrial use, V-threads are avoided for leadscrew use. Nevertheless, V-threads are sometimes successfully used as lead screws, for example on micro lathes and micro mill. The advantages of a leadscrew are:

- Large load carrying capability
- Compact
- Simple to design
- Easy to manufacture; no specialized machinery is required
- Large mechanical advantage
- Precise and accurate linear motion
- Smooth, quiet, and low maintenance
- Minimal number of parts
- Most self-locking

The disadvantages are that most are not very efficient. Due to the low efficiency they cannot be used in continuous power transmission applications. They also have a high degree of friction on the threads, which can wear the threads out quickly. For square threads, the nut must be replaced; for trapezoidal threads, a split nut may be used to compensate for the wear.

III. DESIGN OF EQUIPMENT AND DRAWING

A. *Machine Components:*

The fabrication of electric braking consists of the following components to full fill the requirements of complete operation of the machine.

1) AC MOTOR
2) BELT DRIVE
3) DC MOTOR
4) ANGLE SENSOR
5) LEAD SCREW
6) PROXIMITY SENSOR
7) U SLOT SENSOR

B. *Block Diagram:*

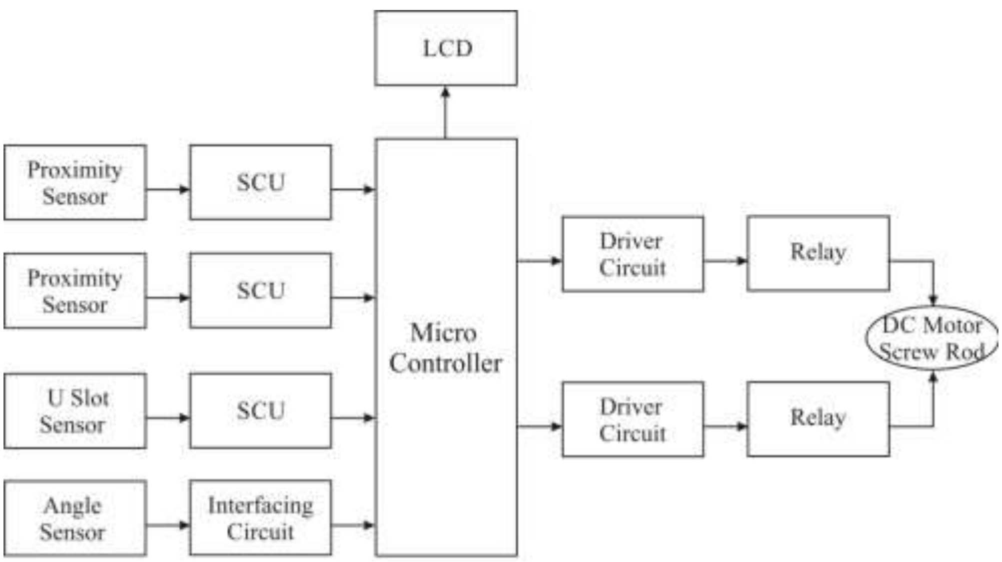
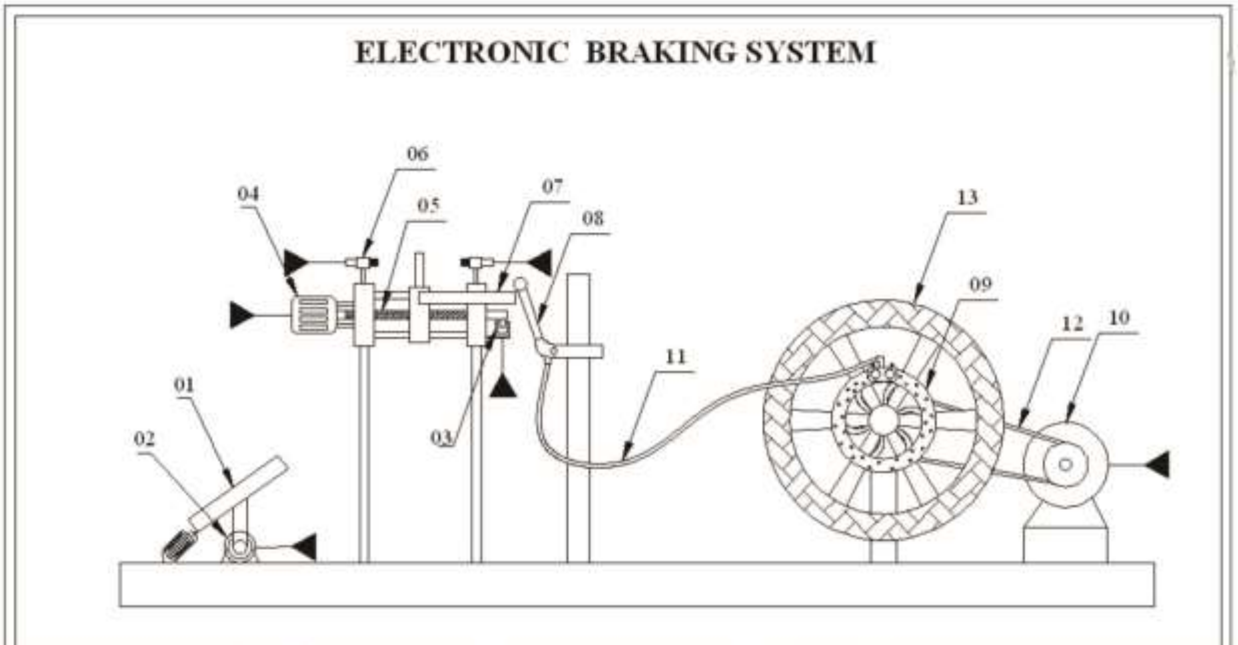


Fig. 7: Block Diagram



S.NO	PART NAME	S.NO	PART NAME	S.NO	PART NAME	S.NO	PART NAME	S.NO	PART NAME
01	BRAKE PEDAL	04	DC MOTOR	07	BRAKING ROD	10	AC MOTOR	13	WHEEL
02	ANGLE SENSOR	05	SCREW ROD	08	HANDLE FOR BRAKE	11	BRAKE CABLE	▶	TO CONTROL UNIT
03	U-SLOT SENSOR	06	PROXIMITY SENSOR	09	DISC BRAKE SETUP	12	BELT DRIVE		

Fig. 8: Electronic Braking System

All parameter values what we used in this calculation are approximate only. This is the sample design calculation for components used in this project

C. *DC Motor Calculation:*

1) *Specification:*

Speed N = 30 RPM
Voltage V = 12 Volt
Loading Current I = 300 mA
No Load Current I = 60 mA
Power P =V x I=12x0.3 = 3.6 WATT = 0.0048 HP (1)
Motor Efficiency E = 36%
Motor shaft diameter = 6 mm
The formula for calculating torque will be

$$T = (I * V * E * 60) / (N * 2\pi) \quad (2)$$

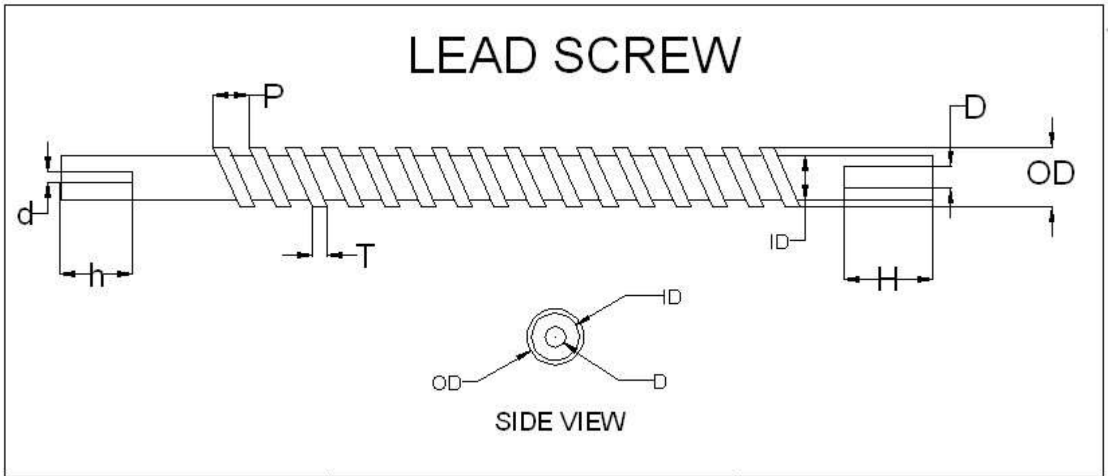
Speed N = 30 RPM
Voltage V = 12 Volt
Loading Current I = 300 mA

$$= (0.3x12x0.36x60)/30x2\pi$$

Torque = 0.412 Nm

2) *Lead Screw:*

Pitch of the lead screw P = 12.3 mm
Speed of Lead Screw, N = 30 rpm
Outer diameter = 19 mm
Inner diameter = 15 mm
Thickness = 4.7 mm



P- PITCH= 12.3 mm	OD- OUTER DIAMETER = 19 mm	h-DEPTH = 24.5mm
T- THICKNESS= 4.7 mm	ID- INNER DIAMETER=15 mm	H-DEPTH = 30 mm
d - THREAD DIAMETER DIAMETER=4 mm	D- THREAD DIAMETER = 7 mm	

Fig. 9: Lead Screw Specifications

The linear velocity of the lead screw = N x p (3)
= 30 x12.3
= 369 mm/min = 6.15 mm/s
The angular velocity of the lead screw = $2\pi N/60 = 2\pi\ (30)/60$ (4)
= 3.14 radian/s
Power of the lead screw, P = 3.6 W
Torque of the lead screw = P x $60/2\pi N$ = 3.6 x $60/2\pi N$ (5)
= 0.57 Nm
Maximum withstanding capacity = torque/radius of lead screw (6)
= $0.57 / 9.5 \times 10^{-3}$
Maximum withstanding capacity = 60 N

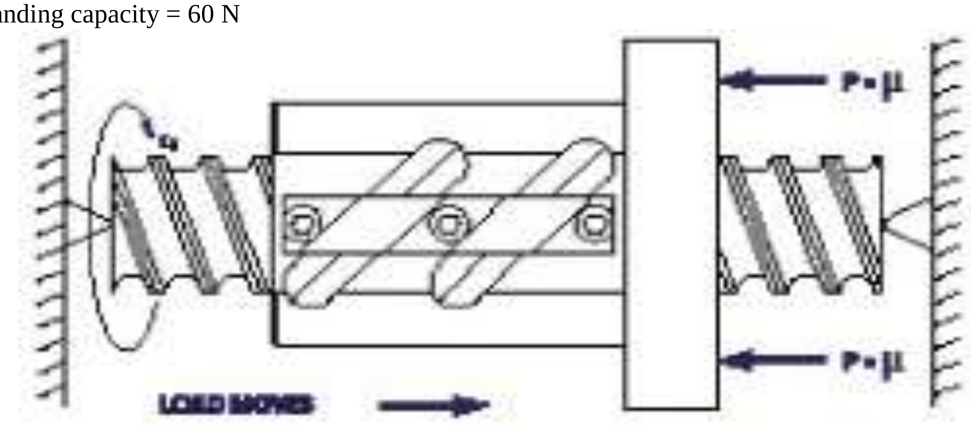


Fig. 10: Forces acting on Lead Screw

The torque required driving load W using lead screw with pitch (p) and efficiency (e) has the following components:

$$T_{Total} = T_{Friction} + T_{Acceleration} \quad (7)$$

Calculation for Frictional Torque

Friction torque can also be an assist in engineering. Bolts and nuts, or screws are often designed to be fastened with a given amount of torque, where the friction is adequate during use or operation for the bolt, nut or screw to remain safely fastened.

Frictional force [F]:

$$F=\mu_s W \quad (8)$$

Where

μ_s =coefficient of static friction, 0.15

Let us assume the torque required to accelerate the sliding parts as 200 pounds

1 pounds = 0.453 kg
200 pounds = (0.453 x 200) = 90.6 kg
1kg = 9.81 newtons
90.6 kg = (9.81 x 90.6) = 888.76 N
W is the weight of the load.
This friction component is often called “breakaway”.
Frictional force F = 0.15 x 888.76 = 133.314 N
Frictional Torque

$$T_{friction} = (F \times p) / (2 \times \pi \times e) \quad (9)$$

Where:
F = frictional force in newton
p = pitch in rev/ mm = 1/12
e = lead screw efficiency, 65%
= (133.34 x 12.3) / (2 x 3.14 x 0.65)
= 32.96 N-mm
Acceleration torque:
When the ball screw is driven with the accelerated velocity against the axial load, the maximum load is required at this time can be obtained from the following formulae

$$T_{Acceleration} = 1/g\,(J_{Load} + J_{Lead\ screw} + J_{Motor}) \quad (10)$$

The linear velocity of the lead screw = N x p
= 30 x12.3
= 369 mm/min = 6.15 mm/s
Angular velocity, radians/sec
The angular velocity of the lead screw = $2\pi N/60 = 2\pi\,(30)/60$ (11)
= 3.14 radian/s
Rotational inertia of load

$$J_{load} = w \times (p/2\pi)^2 / e \quad (12)$$
$$= [888.76 \times (12.3 / (2 \times 3.14))^2] / 0.65$$
$$= 5245.07 \text{ N-mm}^2$$

Rotational inertia of lead screw

$$J_{lead\ screw} = (\pi \times L \times \rho \times R^4) / 4 \quad (13)$$
$$= (3.14 \times 200 \times (3.47 \times 10^{-3}) \times 9.5^4) / 2$$
$$= 8875 \text{ N-mm}^2$$

Rotational inertia of Motor

$$J_{lead\ screw} = (\pi \times L \times \rho \times D^4) / 32 \quad (14)$$
$$= (3.14 \times 200 \times (3.47 \times 10^{-3}) \times 10^4) / 32$$
$$= 680.98 \text{ N-mm}^2$$

Where:
T = torque, N-mm
ω = angular velocity, radians/sec
v = linear velocity, mm/sec
L = length, 200mm (approximately)
R = radius, 9.5 mm
r = density (3.47×10^{-5} kg/mm^3, approximately)
g = gravity constant, 9804.4 mm/sec2

D. Acceleration torque:

$$T_{Acceleration} = 1/g\,(J_{Load} + J_{Lead\ screw} + J_{Motor}) \quad (15)$$
$$= 1 / 9804.4\,(5245.07 + 8875 + 680.98) \times 3.14$$
$$= 4.74 \text{ N-mm}$$

Total Torque :
The torque required driving load W using lead screw with pitch (p) and efficiency (e) has the following components:

$$T_{Total} = T_{Friction} + T_{Acceleration}$$
$$= 32.96 + 4.74$$
$$= 37.7 \text{ N-mm}$$

E. Induction AC Motor Calculation:

1) Specification:

Speed N = 1420 RPM

Voltage V = 230 Volt
Current I = 1.8 A (loading condition)
Power P =V x I=230x1.8 = 414 WATT
P=0.55HP
Motor Efficiency = 80%

2) *Formulae*

Electrical power of the motor is defined by the following formula:

$$P_{in} = I * V \tag{16}$$

Where,
P_{in} – input power, measured in watts (W)
I – current, measured in amperes (A)
V – applied voltage, measured in volts (V)

The motor speed and torque – the turning force of the motor, define how powerful the motor is. Output mechanical power of the motor could be calculated by using the following formula

$$P_{out} = T * \omega \tag{17}$$

Where,
P_{out} – output power, measured in watts (W)
τ – torque, measured in Newton meters (Nm)
ω – angular speed, measured in radians per second (rad/s).

Calculate angular speed if you know rotational speed of the motor in rpm:

$$\omega = N * 2\pi / 60 \tag{18}$$

Where,
ω – Angular speed, measured in radians per second (rad/s);
rpm – rotational speed in revolutions per minute;
π – Mathematical constant pi (3.14).
60 – Number of seconds in a minute.

Efficiency of the motor is calculated as mechanical output power divided by electrical input power:

$$E = P_{out} / P_{in} \tag{19}$$

Therefore

$$P_{out} = P_{in} * E \tag{20}$$

After substitution we get

$$T * \omega = I * V * E \tag{21}$$

$$T * N * 2\pi / 60 = I * V * E$$

Connect the motor to the load. Measure current, voltage and rpm. Now calculate the torque for this load at this speed assuming that the efficiency of the motor is known.

Motor torque changes with the speed. At no load it is having maximum speed and zero torque. Load adds mechanical resistance. The motor starts to consume more current to overcome this resistance and the speed decreases. If the load is increased at some point motor stops (this is called stall). When it occurs the torque is at maximum and it is called stall torque. While it is hard to measure stall torque without special tools it is possible to find this value by plotting speed-torque graph. It is required to take at least two measurements with different loads to find the stall torque.

F. *Torque of the Motor:*

And the formula for calculating torque will be

$$T = (I * V * E * 60) / (N * 2\pi) \tag{22}$$

$$= (1.8x230x0.8x60)/1420x2\pi$$

$$\text{Torque} = 2.23 \text{ Nm}$$

IV. WORKING PRINCIPLE

The main components involved in this project consist of foot pedal, proximity sensor, angle sensor, DC motor, lead screw setup and AC motor with belt drive, wheel, and Disc brake.

Angle sensor is placed below the foot pedal. When we press the pedal the angle sensor turns into some angle. The angle range is from 30 to 270 that is sensed by the angle sensor. The signal from the angle sensor is sent to external ADC and from there to the microcontroller chip. The microcontroller gives the signal to DC motor to rotate; Lead screw setup is engaged with Dc motor. . The purpose of lead screw is to convert rotary to linear motion. Proximity sensor is fitted at the right and left side of the Lead screw for slider in the lead screw is press the bottom end proximity sensor it gives signal to motor to stop the rotation and rotate reverse direction If motor runs slider in lead screw moves front to press brake. There are two proximity sensors one is fixed and the other is connected to the top of lead screw. The lead screw must not come into contact as they get damage when they come into contact.

U slot sensor is provided near the lead screw to find lead screw rotational speed. The U slot sensor consist of infrared rays and a metal piece the rotational speed is known by the number of times where the metal piece cut the infrared rays. AC motor is provided at the other side to rotate the wheel by using belt drive arrangement. Braking operation is done by disc brake.

V. Conclusion

The project has been designed to perform the required task taking minimum time and braking effort. The main objective of our project is to design a pattern and its method for an effective braking system which could be more effective than the braking systems existing nowadays. This project gave an ample opportunity to study and understand the various aspects of braking system and its functioning. After completing the study we were able to make a proper experimental investigation and its calculations for braking system. The implementation of the braking system is quite feasible. The main advantages possessed by the developed braking system are:

1) Electronic brake systems will reduce maintenance cost
2) The practical location of the retarder within the vehicle prevents the direct impingement of air on the retarder caused by the motion of the vehicle.
3) The retarders help to extend the life span of the regular brakes and keep the regular brakes cool for emergency situation
4) There is no need to change brake oils regularly.
5) Reduces oil leakage.
6) Easy to diagonise problem
7) Optimized brake wear
8) Constant force of brake can be applied

The disadvantage of the developed braking system is the dependence of battery power to energize the brake system which drains down the battery much faster Future scope of the project aims at the minimization of direct dependence of the system on the battery.

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