VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JnanaSangama, Belagavi – 590018

A Project Report
On

"Design and Analysis of Foot-Controlled Steering System" Submitted

in partial fulfillment of the requirements as a part of the curriculum,

Bachelors of Engineering in Mechanical Engineering

Submitted by

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2019-20

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CERTIFICATE

Certified that the Project Report entitled **"Design and Analysis of Foot-Controlled Steering System"** is presented by **Mr. Sachin Nair, Mr. Tameem Ashraf, Mr. Vaarron Raath** bonafide students of **CMR Institute of Technology** in partial fulfillment of the requirements as a part of the curriculum, **Bachelors of Engineering in Mechanical Engineering,** of **Visvesvaraya Technological University, Belagavi** during the year **2019-20**. It is certified that all correction/suggestion indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The technical seminar report has been approved as it satisfies the academic requirements in respect of the Technical Seminar prescribed for the bachelor of engineering degree.

(Mr. Shashank Dubey) **(Dr. Vijayanand Kaup)**

Signature of the Guide **Signature of the HOD**

Examiners

Name of the examiners **Signature with date**

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ACKNOWLEDGEMENT

The satisfaction and excitement that comes with the successful completion of any task would be incomplete without the mention of people who made it possible for their encouragement and steadfast guidance.

I would like to extend my gratitude to all, whose guidance and encouragement served as beacon of light and crowned our effort with success.

I would like to thank **Dr. Sanjay Jain**, Principal, CMRIT, Bangalore, for providing an excellent academic environment in the college and for his never-ending support for the B.E program.

I would also like to thank **Dr. Vijayananda Kaup**, HOD**,** Department of Mechanical Engineering, CMRIT, Bengaluru, who shared his opinions and experiences which helped build the foundation for the project.

I consider it a privilege and honour to express my sincere gratitude to my internal guide **Mr. Shashank Dubey**, Assistant Professor, Department of Mechanical Engineering, for his valuable guidance throughout the course of this project work.

I would also like to thank all the faculty members who have always been very co-operative and generous. Conclusively, I also thank the non-teaching staff and all others for their immense help, be it directly or indirectly, during the completion of my project.

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TERMINOLOGY

No	Item	Symbol	Formula
1.	Module	m_n	
2.	Pressure angle	α	
3.	Number of teeth	n	
4.	Height of Pitch Line	H	
5.	Addendum	H_a	$h_a = 0.8m_n$
6.	Pitch Diameter	D_p	$D_p = n_p \times m_n$
7.	Diametric Pitch	P_d	$P_d = n_p / D_p$
8.	Tooth Thickness	t	$t = 1.5708/P_d$
9.	whole Depth	H_t	$h_t = 1.8m_n$
10.	Clearance	C	$C = 0.2m$
11.	Outside Diameter	D_0	$D_0 = D_p + 2h_a$
12.	Dedendum	H_d	$h_d = 1m_n$
13.	Root Diameter	D_R	$D_R = D_p - 2h_d$
14.	Center Distance	a	$a = D_p /2 + H$

CONTENTS

ABSTRACT

Transportation has become an integral part of people's day to day life. At certain times, in large countries like India, people are forced to travel long distance from their work place to their place of residence. People with upper limb amputation and hands have difficulties in travelling and cannot travel these long distances. They use devices such as wheel chair, crutches and artificial limbs for mobility. These however cannot be used for long distance outdoor transportation Therefore, the aim of this project is to design and fabricate 'Foot operated system' for armless people.

The Foot Operated Steering mechanism is a mechanism controlled by foot or both the feet in order to steer the vehicle in the desired direction. This system consists of a steering which can control brake along with steering. The main objective of the project is to design a foot operated system for handicapped people.

This type vehicle can be manufactured with the some modifications and some future consideration. The product has the following advantages:

- Provides employment for the people who having no hands.
- Quickly tasks can be completed as operator's hands are free to perform working with quick movement from one place to another.

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Chapter 1

INTRODUCTION

Now-a-days transportation has become great difficulty to an individual to reach the destination on time. Everyone has their own vehicle and people with all body parts are fortunate. But it is unfortunate for partially disable people with hands. Disability is the repercussion of an impairment which can be mental, physical, emotional, vision, sensory. Disabilities can occur in upper extremities as well as in lower extremities. These people become more dependents and lose their confidence. Due to this effect, they stand a great disadvantage in using public as well as private transportation facilities.

Foot Operated Steering was something new to come up with and we had an interest to make something innovative. The system will be using "Rack And Pinion" arrangement, which converts rotary motion into linear motion. The system consists of wheels, internal threaded cylinder, lead screw, linkages, rotating pinion and rack. The main objective of the project is to design a foot operated system for handicapped people and will be useful in military purpose. This system will be cost effective and easy to operate.

A national level survey conducted in India by the Central Government of India once in ten years revealed that, around 27 million people which are about 2.21% of the Indians are differently able. Among them, around 14.98 million were men while 11.84 million were women. Thus, the percentage of disabled people in rural area was higher than those in urban areas. A total of 5.43 million people were identified with disabilities in movement which was the highest among other categories such as hearing, seeing etc. in terms of numbers of people affected.

Types of Disability	Males	Females	Persons
Mental retardation	8,70,708	6,34,916	15,05,624
In hearing	4,15,732	3,07,094	7,22,826
In seeing	26,77,544	23,93,463	50,71,007
In speech	26,38,516	23,93,947	50,32,463
In movement	11,22,896	8,75,639	19,98,535
Any other	33,70,374	20,66,230	54,36,604
Multiple disability	27,27,828	21,99,183	49,27,011
Multiple disability	11,62,604	9,53,883	21,16,487
Total	1,49,86,202	1,18,24,355	2,68,10,557

Table 1.1: Population of people with disabilities by type of disability

Residence	Males	Females	Persons
Urban	45,78,034	36,00,602	81,78,636
Rural	1,04,08,168	82,23,753	1,86,31,921
Total	1,49,86,202	1,18,24,355	2,68,10,557

Table 1.2: Disabled population by sex and residence

Chapter 2

LITERATURE SURVEY

- **Pranchal Srivastava, Raj Kumar Pal "A Low Cost Mobility Solution for Physically Challenged People"., International Journal of Mechanical Engineering and Technology (IJMET) Volume 6, Issue 12, Dec 2015**: The most common approach used in most powered wheelchairs is having two motors for traction each driving a wheel on either side of the machine. the motion is achieved by keeping the speeds of the motors identical in one direction and the other direction for reverse motion. Turns are executed by making the speeds of the motors different. The radius of turn depends on the speed difference. [1]

- **Challenged People Using Arm Processor". International Journal of Mechanical Engineering and Technology (IJMET) ,Volume 6, Issue 12, Dec 2015:** The aim of the technology is to help those handicapped who don't have healthy hands to run a vehicle by giving the voice commands. In this the driver need not use the steering instead his head. This vehicle is only for those handicapped those who can nod head well. Four switches are interfaced over the neck of the driver, and the vehicle can be controlled by the head movement. Corresponding tactile switches are activated according to the movement of the head, and towards the conclusion the practical difficulties are described and the possible solutions are discussed. [2]

- **Jose M.del Castillo** (2001) in their research obtained the analytical expression for the efficiency of any planetary gear train using Cramer's rule. They find the gear tooth ratio employing a speed and torque equations and gearing power and speed ratio. [3]

- **D.Mundo (2006) Designed a planetary gear trains** to generate a variable angular velocity ratio using non-circular gears by using CAD software, PTC-pro engineer. He reduced the typical torque fluctuations of a low speed way of pedaling in order to maximize the output.

- **Rince Wins, DhaneshChatta and Anish Nair et al., "Design of Pneumatic Collapsible Steering"** in this paper, he studied that, as we know, the fact is very correct that accidents are increasing day by day. On considering the injury potential of steering wheel this project gives a new and more safer design for the steering wheel. [4]

- **Utkarsh. M. Desai and Dhaval A. Patel et al.,"Static and Dynamic Analysis of Composite Material for Spur Gear"** , in this paper he studied that, The weight of GF 30 PEEK Composite Material is reduced as compared to the existing Material (Alloy steel) which in turn results in improved power transmission which overall improves the efficiency of the system. Besides, from the cost aspects, initially, composite material GF30 PEEK is costly than alloy steel material. [5]

- **Dipal kumar Koladia et al. studied that Mathematical Model to Design Rack And Pinion Ackerman Steering Geometry‟,** in journal he studied By applying and solving three equations of mathematical model for any vehicle, rack and pinion Ackerman steering geometry for any vehicle can be designed. Steering geometry can be optimized by using mathematical model for Ackerman condition for different inner wheel angles and select geometry for which percentage Ackermann as well steering effort is optimum. [7]

- **Clinical Survey Of Upper Extremity Amputees In India:**
  Brig. I.C. Narang, MS, FICS
  Lt. Col. B.P. Mathur, MS, M.Phil. (UK)
  Lt. Col. Pal Singh, MS
  Mrs. V.S. Jape, MA, MA(SW)

A survey of upper limb amputees has been carried out at the Defence Services Artificial Limb Centre, Poona, India. The aim of the survey was primarily to gather information directly from the patients about the utility of upper limb prostheses which are being provided at present. [6]

Age group	0-10	11-20	21-30	31-40	41-50	51-60	Above 60	Total
Males	2	3	38	45	21	11	4	124
Female	-	3	1	2	-	-	-	6
Total	2	6	39	47	21	11	4	130

Table 2.1: Age and gender determination

Chapter 3

OBJECTIVE

- To make a steering arrangement system for handicapped people with no arms.
- To design and manufacture a vehicle which can be operated by disable people.
- This arrangement will be installed in a E-kart to showcase the working of the steering system arrangement.
- Driver’s safety and comfort are some of the important factors. So it will not be compromised at any cost.
- Portability: It will be ease to handle for everyone. It will have a convenient size so that it can carry one person and easily be parked.
- Reliability: It is going to provide a stable ride, confident feel and similar performance to a conventional vehicle. It will be easy to maintain and reliable.
- To manufacture a car for city limit transportation.
- To reduce the dependency on others to perform daily duties.
- To develop a system at affordable cost.
- The foot operated steering mechanism is a mechanism which is controlled by foot.
- It will serve the purpose for the handicapped people and the war heroes who have lost their arms in a war or an accident.

Chapter 4

SCOPE OF PRESENT WORK

Nowadays electric vehicles are replacing conventional vehicles because of their environment friendly operation and less maintenance. Most of the electric vehicles use three phase induction motors. In this project BLDC motor drive is proposed as it exhibit high torque, high efficiency, easy speed control, reduced noise and longer life time. Retrofitting conventional vehicles to electric vehicles by replacing a brushless dc motor will have a great scope in future as it is economical.

Designing and fabrication of vehicle: The designing of the vehicle had been done and fabrication of vehicle will be achieved with respect to designing procedure.

- Selection of propulsion mechanism: a motor with battery arrangement, it was decided by our team to go with electric motor for propulsion mechanism for the vehicle and which is eco-friendly.

- Fabrication of the foot operating steering: The calculation and design of the foot operating steering system was done. Then it was fabricated and initial tests were done.

- Integration of steering to the E-kart: The foot operating steering system was installed in the E-kart. It was connected to the tires with the help of suitable joints.

- Testing of vehicle: Virtually, analysis on chassis was done to ensure driver safety. After fabrication, tests were performed on vehicle to check its stability, velocity and acceleration and deceleration capabilities by the team.

Chapter 5

COMPONENTS AND DESCRIPTION

The major components of E-Kart are:

- Battery
- BLDC Motor
- Throttle Control
- Ball Bearings
- Chain And Sprocket
- Frame Work

5.1 BATTERY:

Introduction:

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Batteries seem to be the only technically and economically available storage devices.

It is important that the overall system is optimized to the availability of energy and to the demand patterns. Batteries are considered to be good when they fulfil the requirements like:

(1) Low cost

(2) Long life

(3) High reliability

(4) High overall efficiency

(5) Minimum maintenance

(A) Ampere hour efficiency

(B) Watt hour efficiency

We use lead acid battery for storing the electrical energy from the solar panel for lighting the street and so about the lead acid cells are explained below.

Lead-Acid Wet Cell:

Where high values of load current are required, the lead-acid cell is used most widely. The electrolyte is a dilute solution of sulphuric acid (H_2SO_4).

In the application of battery power to start the engine in an auto mobile, for example, the load current to the starter motor is typically 200 to 400A. One cell has a nominal output of 2.1V, but lead-acid cells are often used in a series combination of three for a 6-V battery and six for a 12-V battery.

The lead acid cell type is a secondary cell or storage cell, which can be recharged. The charge and discharge cycle can be repeated many times to restore the output voltage, as long as the cell is in good physical condition. However, heat with excessive charge and discharge currents cut shots the useful life to about 3 to 5 years for an automobile battery. As compared to some other types of secondary cells, the lead-acid type battery has the highest output voltage, which allows fewer cells for a specified battery output voltage.

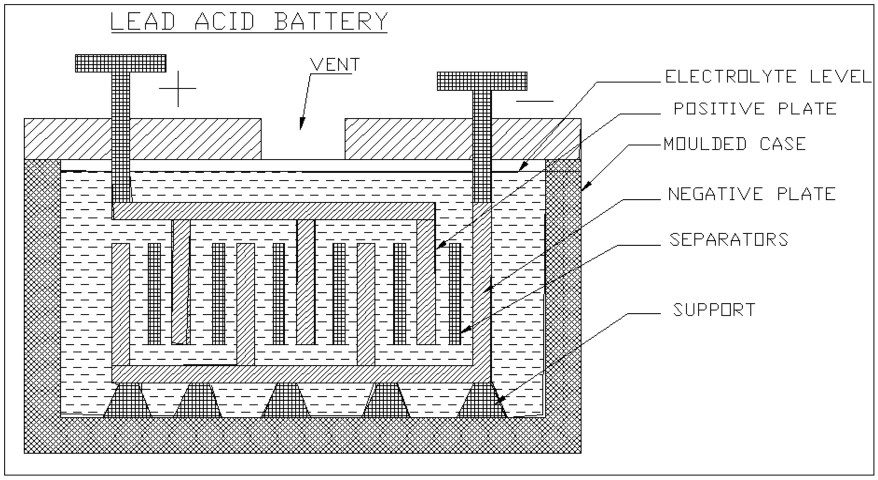


Fig. 5.1 Lead Acid Battery

Construction:

Inside a lead-acid battery, the positive and negative electrodes consist of a group of plates welded to a connecting strap. The plates are immersed in the electrolyte, consisting of 8 parts of water to 3 parts of concentrated sulphuric acid. Each plate is a grid or framework, made of a lead-antimony alloy. This construction enables the active material, which is lead oxide, to be pasted into the grid. Forming charge produces the positive and negative electrodes. In the forming process, the active material in the positive plate is changed to lead peroxide (Pbo_2). The negative electrode is spongy lead (Pb)

Automobile batteries are usually shipped dry from the manufacturer. The electrolyte is put in at the time of installation, and then the battery is charged to from the plates. With maintenance-free batteries, little or no water need be added in normal service. Some types are sealed, except for a pressure vent, without provision for adding water.

Charging:

The lead-acid battery can be charged using plug-in power and also renewable energy sources like solar energy, wind energy etc. In foreign countries they have charging points for charging the electric vehicles. By 2030 we can also expect a large variety of electric vehicles and also charging stations.

Fig. 5.2 Charging of Lead Acid Battery

5.2 Electric Motor, Controller & Throttle:

<u>Electric Motor</u>:

We have chosen electric motor instead of IC engine in our project. Motor which we are using here is reduction electric DC motor which provides required torque. The reason behind choosing a electric motor was to make it a ecofriendly and emission less vehicle. Only disadvantage with this motor is that it increases the number of batteries and decreases RPM. This reduction motor comes with controller and throttle for handling. Specifications of the electric motor are provided below:

Parameters	Specifications
Type	DC Motor
Voltage	48
RPM	3400
Rated Wattage	1000w
Rated Current	28A
Torque	45 Nm

Table 5.1: Motor Specifications

Fig. 5.3: Electric Motor

Various types of Electric Motors used in Electric Vehicles:

- DC Series Motor
- Brushless DC Motor
- Permanent Magnet Synchronous Motor (PMSM)
- Three Phase AC Induction Motors
- Switched Reluctance Motors (SRM)

DC Series Motor:

High starting torque capability of the DC Series motor makes it a suitable option for traction application. It was the most widely used motor for traction application in the early 1900s. The advantages of this motor are easy speed control and it can also withstand a sudden increase in load. All these characteristics make it an ideal traction motor. The main drawback of DC series motor is high maintenance due to brushes and commutators. These motors are used in Indian railways. This motor comes under the category of DC brushed motors.

Brushless DC Motors:

It is similar to DC motors with Permanent Magnets. It is called brushless because it does not have the commutator and brush arrangement. The commutation is done electronically in this motor because of this BLDC motors are maintenance free. BLDC motors have traction characteristics like high starting torque, high efficiency around 95-98%, etc. BLDC motors are suitable for high power density design approach. The BLDC motors are the most preferred motors for the electric vehicle application due to its traction characteristics.

Permanent Magnet Synchronous Motor (PMSM):

This motor is also **similar to BLDC motor which has permanent magnets on the rotor**. Similar to BLDC motors these motors also have traction characteristics like high power density and high efficiency. The difference is that PMSM has sinusoidal back EMF whereas BLDC has trapezoidal back EMF. Permanent Magnet Synchronous motors are available for higher power ratings. PMSM is the best choice for high performance applications like cars, buses. Despite the high cost, PMSM is providing stiff competition to induction motors due to increased efficiency than the latter. PMSM is also costlier than BLDC motors. **Most of the automotive manufacturers use PMSM motors for their hybrid and electric vehicles**. For example, Toyota Prius, Chevrolet Bolt EV, Ford Focus Electric, zero motorcycles S/SR, Nissan Leaf, Honda Accord, BMW i3, etc use PMSM motor for propulsion.

Three Phase AC Induction Motors:

The **induction motors do not have a high starting toque like DC series motors** under fixed voltage and fixed frequency operation. But this characteristic can be altered by using various control techniques like FOC or v/f methods. By using these control methods, the maximum torque is made available at the starting of the motor which is suitable for traction application. Squirrel cage induction motors have a long life due to less maintenance. Induction motors can be designed up to an efficiency of 92-95%. The **drawback of an induction motor is that it requires complex inverter circuit and control of the motor is difficult.**

Switched Reluctance Motors (SRM):

Switched Reluctance Motors is a category of variable reluctance motor with double saliency. Switched Reluctance motors are simple in construction and robust. The rotor of the SRM is a piece of laminated steel with no windings or permanent magnets on it. This makes the inertia of the rotor less which helps in high acceleration. The robust nature of SRM makes it suitable for the high speed application. SRM also offers high power densities which are some required characteristics of Electric Vehicles. Since the heat generated is mostly confined to the stator, it is easier to cool the motor. The biggest drawback of the SRM is the complexity in control and increase in the switching circuit. It also has some noise issues. Once SRM enters the commercial market, it can replace the PMSM and Induction motors in the future.

5.3 CONTROLLER:

Controller is a device that serves to govern the performance of an electric motor. This may have automatic or manual means of starting and stopping the motor, selecting forward and reverse rotation, selecting and regulating or limiting the torque and protecting against overloads and faults. The given controller is of manual starting or stopping Direct on Line (DOL) type which is controlled by using throttle. This is pre-loaded with software to work for the given electric motor. This works for all functions given above.

Fig 5.4: Controller for 1000W Electric Motor

Block Diagram of the Control System:

The block diagram of BLDC drive system is shown in Figure 1. It consists of a three phase inverter, position sensors, signal conditioner and a digital controller. The inverter along with the position sensor arrangement is functionally analogous to the commutator of a dc motor.

The commutation of a BLDC motor is controlled electronically. The stator windings should be energized in a sequence in order to rotate the motor. Rotor position should be known in order to switch the winding in sequence. A permanent magnet brushless dc motor incorporates some means of detecting the rotor position.

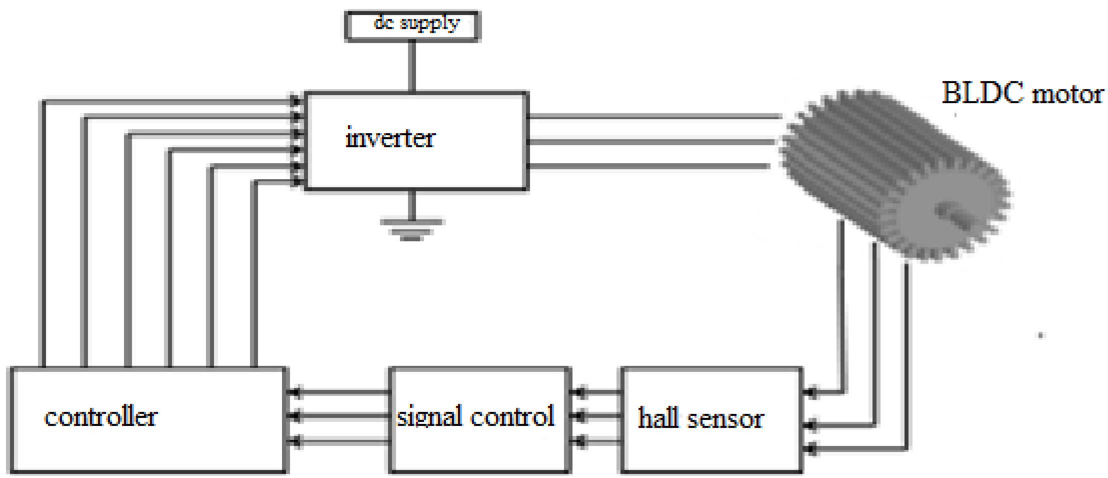


Fig 5.5 BLDC Motor

The BDLC motor detects the position of the rotor using Hall sensors. Three sensors are required for position information. With three sensors, six possible commutation sequences could be obtained. In the Hall sensor technique, three Hall sensors are placed inside the motor, spaced 120 degrees apart. Each Hall sensor provides either a High or Low output based on the polarity of magnetic pole close to it. Rotor position is determined by analyzing the outputs of all three Hall sensors. Based on the output from hall sensors, the voltages to the motor's three phases are switched.

The advantage of Hall sensor-based commutation is that the control algorithm is simple and easy to understand. Hall sensor-based commutation can also be used to run the motor at very low speeds.

BLDC motor control is to have only one current at a time. Because of which current sensor is not advised to be placed on each phase of the motor; one sensor placed in the line inverter input is sufficient to control the current of each phase. Insulated systems are not required when sensor is on the ground line.

The torque and speed of motors is managed by microcontroller. A sufficient amount of processing power is required to solve the algorithms needed to generate Pulse Width Modulated (PWM) outputs for motor.

By simply varying the voltage across the motor, one can control the speed of the motor. When using PWM outputs to control the six switches of the three-phase bridge, variation of the motor voltage can be achieved easily by changing the duty cycle of the PWM signal. The three-phase BLDC speed control is done by using both open loop and closed loop configurations. Open-loop control is used to control the speed of the motor by directly controlling the duty cycle of the PWM signal that directs the motor-drive circuitry. The duty cycle of the PWM signal controls the ON time of the power switches in the half bridges of the motor-drive circuit and this in turn controls the average voltage supplied across the motor windings. Closed loop control regulates the speed of the motor by directly controlling the duty cycle of the PWM signals that direct the motor-drive circuitry. The major difference between the two control systems is that the open-loop control considers only the speed control input to update the PWM duty cycle, whereas, the closed-loop control considers both speed-input control and actual motor speed (feedback to controller) for updating the PWM duty cycle and, in turn, the motor speed. A PID controller is a closed-loop control implementation that is widely used and is most commonly used as a feedback controller.

The actual motor speed is calculated by tracking the time period between successive Hall events, which represents a part of the mechanical cycle of the motor. In a 3-phase BLDC motor control, one electrical cycle has six Hall states and, depending on the number of poles pairs in the motor, the electrical angle measured between successive Hall state changes can be translated to a respective mechanical angle.

Principal of Operation of DC Motor:

- When a current carrying conductor is placed in a magnetic field. It experiences a force.
- In case of DC motor, the magnetic field is developed by the field current i.e. the current flowing in field winding.

- The armature winding is connected to an external dc source; hence it plays the role of the current carrying conductor placed in the magnetic field.

- Due to force exerted on it when placed in the magnetic field, it starts rotating and the armature starts rotating.

- The direction of rotation depends on the direction of the magnetic field produced by the field winding as well as the direction of magnetic field produced by the armature.

Effect of Increase in Load:

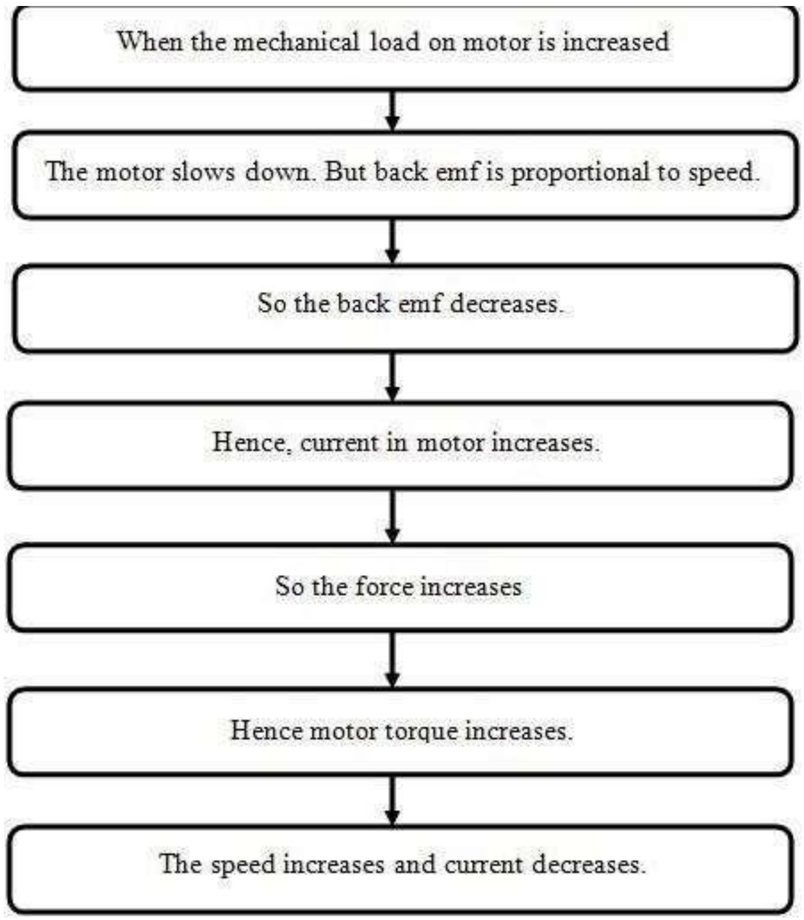


Fig 5.6: Effects of load on motor.

Characteristics of DC Motor:

Torque Armature Current characteristics:

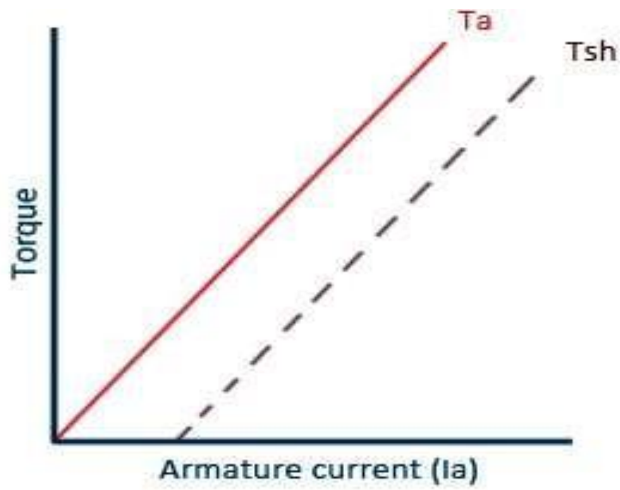


Fig 5.7: Torque Armature Current characteristics

- The torque armature current characteristics of DC shunt motor shows that the starting torque (at the time of starting the motor) is not very high.
- To generate higher starting, we have to increase armature current, to a very large value because torque is directly proportional to armature current. This may damage the motor.
- So shunt motors should be used in those applications which demand a moderate starting torque. Speed Armature current characteristics:
- As the load on the motor is increased, the torque demands increases. To generate higher the torque, motor draws more armature current.
- As armature current increases, voltage also increases.
- As the value of resistance is small, the drop in voltage is small. Hence the reduction in speed is not significantly large.
- So the characteristic is slightly dropping as shown in figure, as we increase the load from no load to full load.
- However, the reduction in speed is so negligible, that the DC shunt motors are considered as constant speed motors.

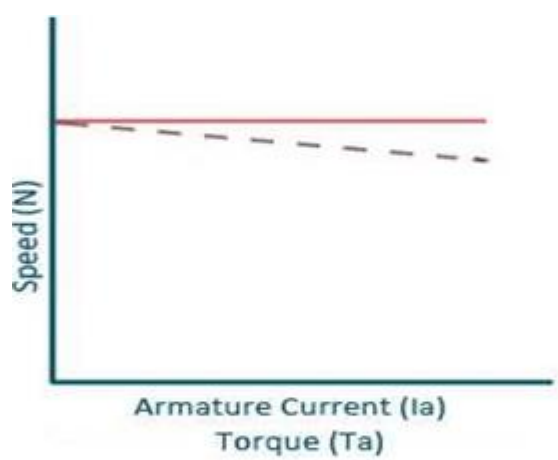


Fig 5.8: Speed Armature current characteristics

Speed Torque Characteristics:

Fig 5.9: Speed Torque characteristics

- At no load, torque produced by motor is less and rotates at constant speed.
- As the load is increased, the torque requirement also increases. To generate the required amount of torque, the motor has to draw more armature current and more armature current can be drawn if a speed decrease is more.
- Therefore, as load increases, torque will also increase and the speed decreases.

Throttle:

Electronic Throttle control (ETC) is an automobile technology which electronically connects the accelerator pedal to the throttle, replacing mechanical linkages. ETC consists of accelerator pedal module, ETB and ECM. There are throttle positions sensor embedded in ETB which helps in determining the required throttle. The given ETB works on potentiometer.

Fig 5.10: Electronic Throttle Body

5.4 BEARING:

Introduction:

Ball and roller bearings are used widely in instruments and machines in order to minimize friction and power loss. While the concept of the ball bearing dates back at least to Leonardo da-Vinci, their design and manufacture has become remarkably sophisticated.

This technology was brought to its present state of perfection only after a long period of research and development. The benefits of such specialized research can be obtained when it is possible to use a standardized bearing of the proper size and type. However, such bearings **cannot be used indiscriminately without a careful study of the loads and operating conditions**. In addition, the bearing must be provided with adequate mounting, lubrication and sealing. Design engineers have usually two possible sources for obtaining information which they can use to select a bearing for their particular application:

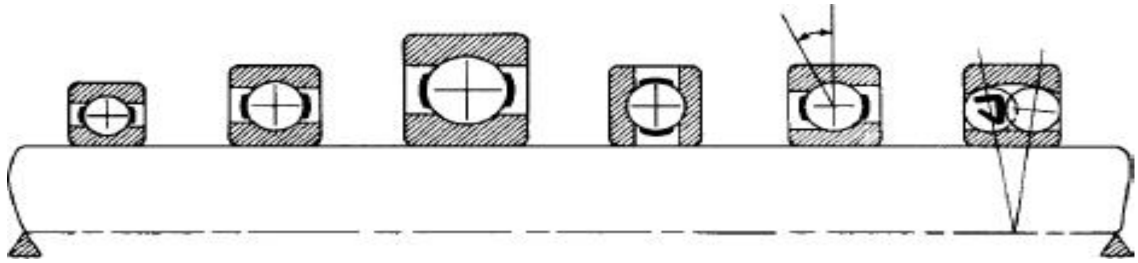
a) Textbooks

b) Manufacturers

Construction and Types of Ball Bearings:

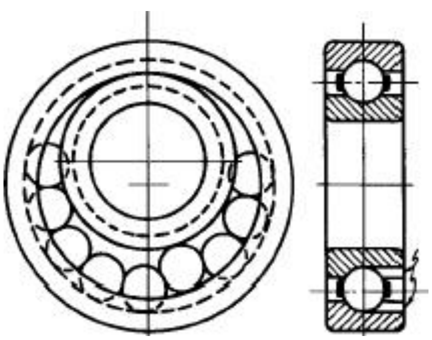
A ball bearing usually consists of four parts: an inner ring, an outer ring, the balls and the cage or separator.

To increase the contact area and permit larger loads to be carried, the balls run in curvilinear grooves in the rings. The radius of the groove is slightly larger than the radius of the ball, and a very slight amount of radial play must be provided. The bearing is thus permitted to adjust itself to small amounts of angular misalignment between the assembled shaft and mounting. The separator keeps the balls evenly spaced and prevents them from touching each other on the sides where their relative velocities are the greatest. Ball bearings are made in a wide variety of types and sizes.



100 Series 200 Series 300 Series Axial Thrust Angular Contact Self-Aligning Bearing

Fig 5.11 Types of Ball Bearings



The heavy series of bearings is designated by 400. Most, but not all, manufacturers use a numbering system so devised that if the last two digits are multiplied by 5, the result will be the bore in millimeters. The digit in the third place from the right indicates the series number. Thus, bearing 307 signifies a medium-series bearing of 35-mm bore. For additional digits, which may be present in the catalog number of a bearing, refer to manufacturer's details. Some makers list deep groove bearings and bearings with two rows of balls. For bearing designations of Quality Bearings & Components (QBC), see special pages devoted to this purpose. The radial bearing is able to carry a considerable amount of axial thrust. However, when the load is directed entirely along the axis, the thrust type of bearing should be used. The angular contact bearing will take care of both radial and axial loads. The self-aligning ball bearing will take care of large amounts of angular misalignment. An increase in radial capacity may be secured by using rings with deep grooves, or by employing a double-row radial bearing. Radial bearings are divided into two general classes, depending on the method of assembly. These are the Conrad, or non-filling-notch type, and the maximum or filling-notch type. In the maximum-type bearing, the balls are (a) 100 Series Extra Light (b)200 Series Light (c)300 Series (d)Medium Axial Thrust (e)Bearing Angular Contact Bearing (f)Self-aligning Bearing Fig. 5-11. Methods of Assembly for Ball Bearings (a) Conrad or non-filling notch type (b) Maximum or filling notch type.

5.5 **Sprocket And Chain Drive**

Drive:

Chain drive is a way of transmitting mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle using a chain. Since there is a reduction gear mounted in electric motor, that's why we do not need different gear ratios and because of this we are using direct chain drive. Moreover, gearbox in vehicle will increase in weight; we are avoiding the use of gearbox. Motor sprocket has attached to motor and with its specification we have design our shaft ratio. Since there was already reduction setup in motor we were trying to achieve 1:1 ratio from motor output to shaft. Pinion details are as follows.

Parameters	Specifications
Type	Direct chain drive using clutch
Pinion	9 Teeth
Module	2.75 mm
Pitch	9.2364
Gear Ratio	1.4
Center distance	200mm

Table 5.2 Chain Drive Specifications

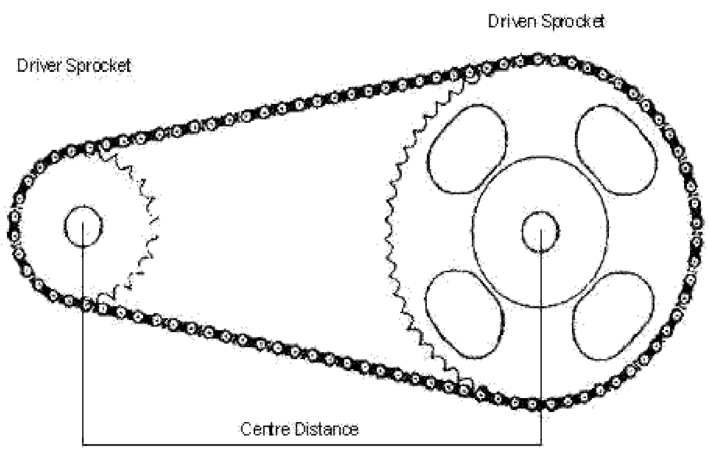


Fig 5.12: Chain Drive

This is a cycle chain sprocket. The chain sprocket is coupled with another generator shaft. The chain converts rotational power to pulling power, or pulling power to rotational power, by engaging with the sprocket. The sprocket looks like a gear but differs in three important ways:

1. Sprockets have many engaging teeth; gears usually have only one or two.

2. The teeth of a gear touch and slip against each other; there is basically no slippage in a sprocket.

3. The shape of the teeth is different in gears and sprockets.

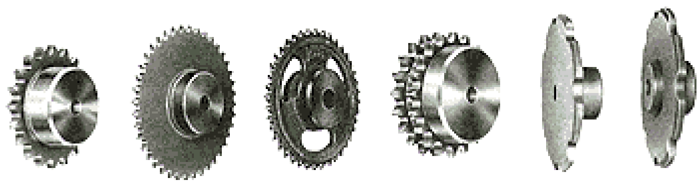


Fig 5.13: Types of Sprockets

Engagement with Sprockets:

Although chains are sometimes pushed and pulled at either end by cylinders, chains are usually driven by wrapping them on sprockets. In the following section, we explain the relation between sprockets and chains when power is transmitted by sprockets.

- Back tension

First, let us explain the relationship between flat belts and pulleys. Figure 2.5 shows a rendition of a flat belt drive. The circle at the top is a pulley, and the belt hangs down from each side. When the pulley is fixed and the left side of the belt is loaded with tension (T0), the force needed to pull the belt down to the right side will be:

T1 = T0 3 eμu

For example, T0 = 100 N: the coefficient of friction between the belt and pulley, μ = 0.3; the wrap angle u = ¼ (180).

T1 = T0 3 2.566 = 256.6 N

In brief, when you use a flat belt in this situation, you can get 256.6 N of drive power only when there is 100 N of back tension.

For elements without teeth such as flat belts or ropes, the way to get more drive power is to increase the coefficient of friction or wrapping angle. If a substance, like grease or oil, which decreases the coefficient of friction, gets onto the contact surface, the belt cannot deliver the required tension.

In the chain's case, sprocket teeth hold the chain roller. If the sprocket tooth configuration is square, as in Figure 2.6, the direction of the tooth's reactive force is opposite the chain's tension, and only one tooth will receive all the chain's tension. Therefore, the chain will work without back tension.

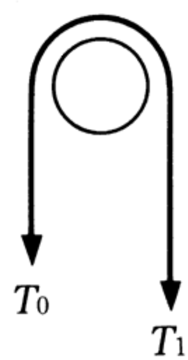


Fig 5.14: Flat Belt Drive

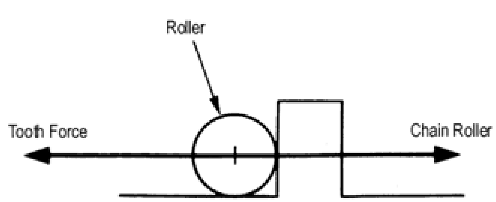


Fig 5.15: Simplified Roller/Tooth Forces

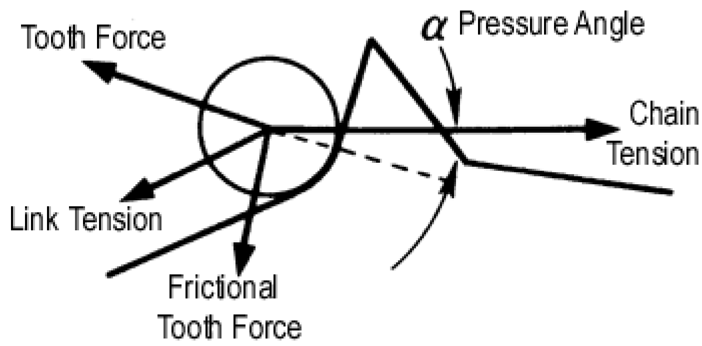


Fig 5.16 Balance of Forces Around the Roller

But actually, sprocket teeth need some inclination so that the teeth can engage and slip off of the roller. The balances of forces that exist around the roller are shown in Figure 2.7, and it is easy to calculate the required back tension.

For example, assume a coefficient of friction μ = 0, and you can calculate the back tension (Tk) that is needed at sprocket tooth number k with this formula:

Tk = T0 3 sin ø k-1 sin(ø + 2b) Where:

Tk= back tension at tooth k

T0 = chain tension

ø = sprocket minimum pressure angle 17 64/N(š)

N = number of teeth

2b = sprocket tooth angle (360/N)

k = the number of engaged teeth (angle of wrap 3 N/360); round down to the nearest whole number to be safe

By this formula, if the chain is wrapped halfway around the sprocket, the back tension at sprocket tooth number six is only 0.96 N. This is 1 percent of the amount of a flat belt. Using chains and sprockets, the required back tension is much lower than a flat belt. Now let's compare chains and sprockets with a toothed-belt back tension. Although in toothed belts the allowable tension can differ with the number of pulley teeth and the revolutions per minute (rpm), the general recommendation is to use 1/3.5 of the allowable tension as the back tension (F). This is shown in below Figure 2.8. Therefore, our 257 N force will require 257/3.5 = 73 N of back tension.

Both toothed belts and chains engage by means of teeth, but chain's back tension is only 1/75 that of toothed belts.

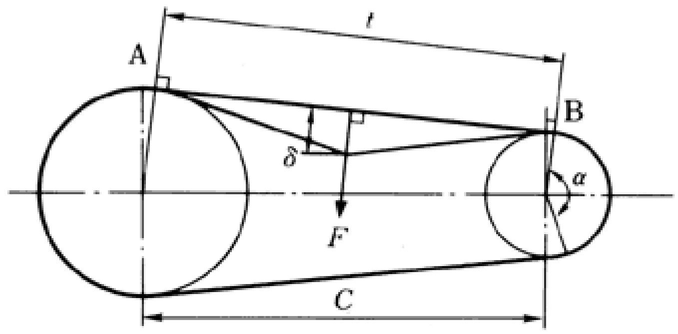


Fig 5.17: Back Tension on a Toothed Belt

Chain Wear and Jumping Sprocket Teeth:

The key factor causing chain to jump sprocket teeth is chain wear elongation. Because of wear elongation, the chain creeps up on the sprocket teeth until it starts jumping sprocket teeth and can no longer engage with the sprocket. Fig 5.18 shows sprocket tooth shape and positions of engagement. Figure 5.19 shows the engagement of a sprocket with an elongated chain.

In Fig 5.18 there are three sections on the sprocket tooth face:

a: Bottom curve of tooth, where the roller falls into place;

b: Working curve, where the roller and the sprocket are working together;

c: Where the tooth can guide the roller but can't transmit tension. If the roller, which should transmit tension, only engages with C, it causes jumped sprocket teeth

The chain's wear elongation limit varies according to the number of sprocket teeth and their shape, as shown in Figure 5.20. Upon calculation, we see that sprockets with large numbers of teeth are very limited in stretch percentage. Smaller sprockets are limited by other harmful effects, such as high vibration and decreasing strength; therefore, in the case of less than 60 teeth, the stretch limit ratio is limited to 1.5 percent (in transmission chain).

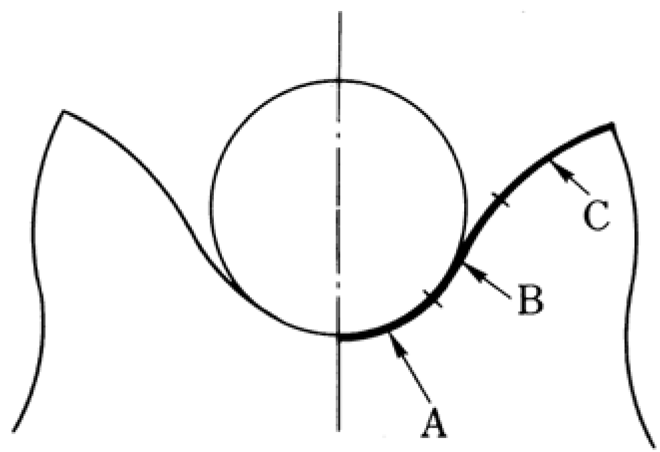


Fig 5.18: Sprocket Tooth Shape and Positions of Engagement

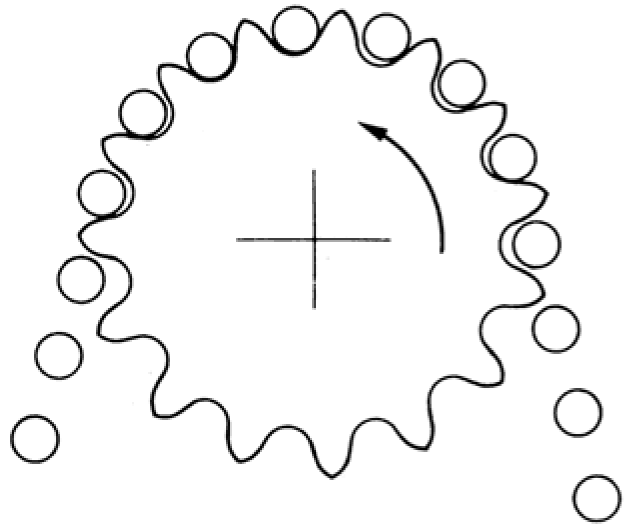


Fig 5.19: The Engagement between a Sprocket and an Elongated chain

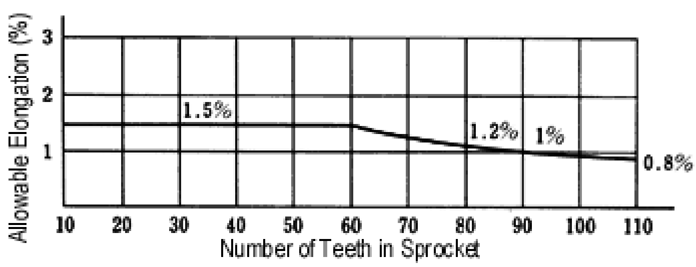


Fig 5.20: Elongation Versus the Number of Sprocket Teeth

In conveyor chains, in which the number of working teeth in sprockets is less than transmission chains, the stretch ratio is limited to 2 percent. Large pitch conveyor chains use a straight line in place of curve B in the sprocket tooth face.

A chain is a reliable machine component, which transmits power by means of tensile forces, and is used primarily for power transmission and conveyance systems. The function and uses of chain are similar to a belt. There are many kinds of chain. It is convenient to sort types of chain by either material of composition or method of construction.

We can sort chains into five types:

- Cast iron chain.
- Cast steel chain.
- Forged chain.
- Steel chain.
- Plastic chain.

Chains sorted according to their uses, which can be broadly divided into six types:

- Power transmission chain.
- Small pitch conveyor chain.
- Precision conveyor chain.
- Top chain.
- Free flow chain.
- Large pitch conveyor chain.

The first one is used for power transmission; the other five are used for conveyance. In the Applications section of this book, we will describe the uses and features of each chain type by following the above classification. In the following section, we will explain the composition of power transmission chain, small pitch chain, and large pitch conveyor chain. Because there are special features in the composition of precision conveyor chain, top chain, and free flow chain, checks the appropriate pages in the Applications section about these features.

Basic Structure of Power Transmission Chain:

A typical configuration for RS60-type chain is shown in Figure 5.21.

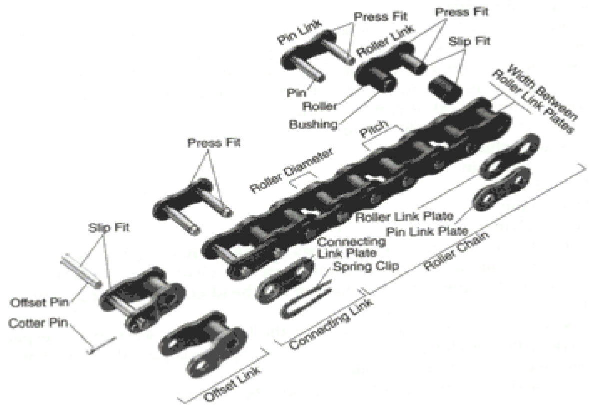


Fig 5.21: The Basic Components of Transmission Chain

Connecting Link:

This is the ordinary type of connecting link. The pin and link plate are slip fit in the connecting link for ease of assembly. This type of connecting link is 20 percent lower in fatigue strength than the chain itself. There are also some special connecting links which have the same strength as the chain itself.

Tap Fit Connecting Link

In this link, the pin and the tap fit connecting link plate are press fit. It has fatigue strength almost equal to that of the chain itself.

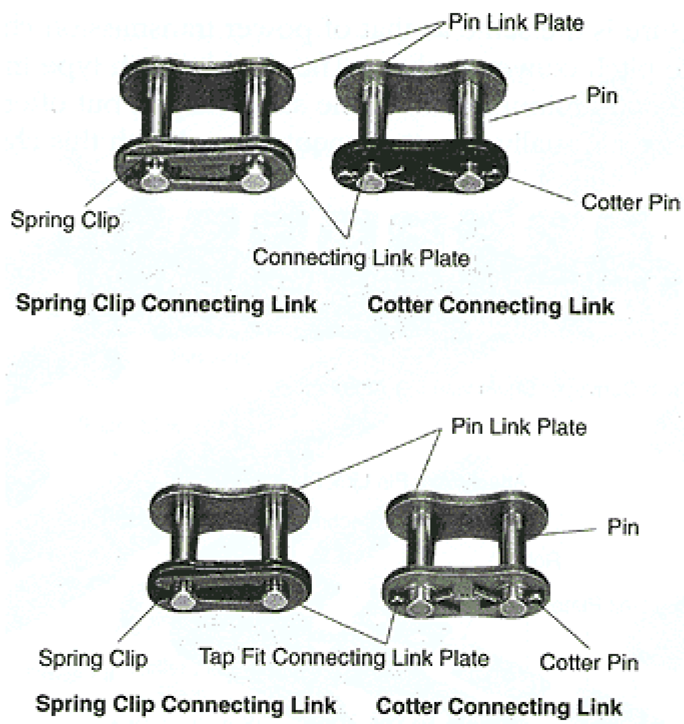


Fig 5.22: The Basic Components of Transmission Chain

Offset Link:

An offset link is used when an odd number of chain links is required. It is 35 percent lower in fatigue strength than the chain itself. The pin and two plates are slip fit. There is also a two-pitch offset link available that has fatigue strength as great as the chain itself. (See Figure 1.3)

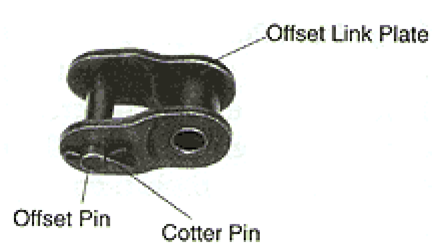


Fig 5.23: Offset Link

5.6 Frame Work:

Mild Steel:

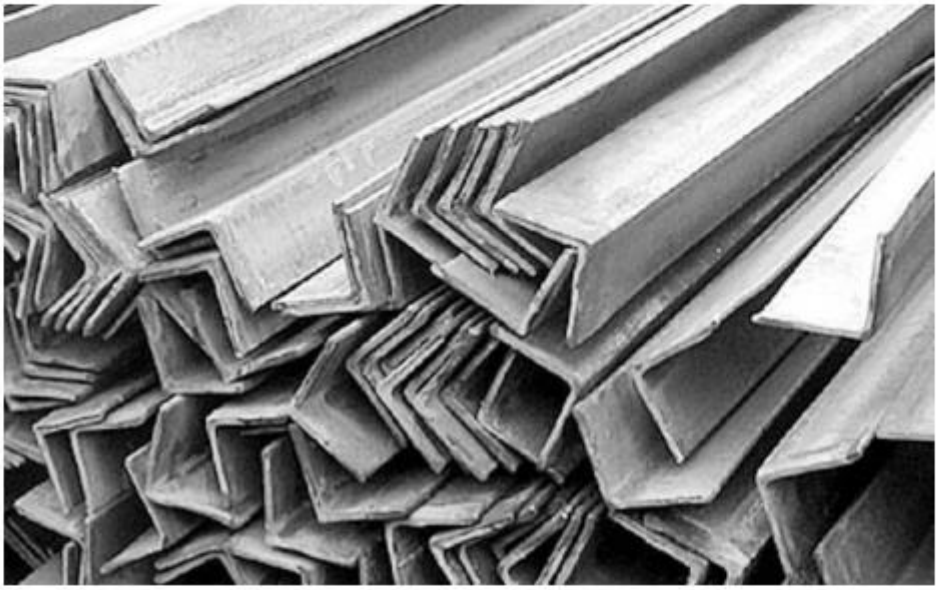


Fig 5.24 Mild Steel

Mild steel is a carbon steel typically with a maximum of 0.25% Carbon and 0.4%-0.7% manganese, 0.1%-0.5% Silicon and some + traces of other elements such as phosphorous, it may also contain lead (free cutting mild steel) or sulphur (again free cutting steel called re-sulphurised mild steel). It is used everywhere, diesel pump injector parts, loudspeaker pole pieces, automated packing machinery parts.

NUT AND BOLT:

Fig 5.25 Nut and Bolt

A nut is a type of fastener with a threaded hole. Nuts are almost always used in conjunction with a mating bolt to fasten two or more parts together. The two partners are kept together by a combination of their threads' friction (with slight elastic deformation), a slight stretching of the bolt, and compression of the parts to be held together. In applications where vibration or rotation may work a nut loose, various locking mechanisms may be employed: lock washers, jam nuts, specialist adhesive thread-locking fluid such as Loctite, safety pins (split pins) or lock wire in conjunction with castellated nuts, nylon inserts (Nyloc nut), or slightly oval-shaped threads. The most common shape is hexagonal, for similar reasons as the bolt head-6 sides give a good granularity of angles for a tool to approach from (good in tight spots), but more (and smaller) corners would be vulnerable to being rounded off. It takes only 1/6th of a rotation to obtain the next side of the hexagon and grip is optimal. However polygons with more than 6 sides do not give the requisite grip and polygons with fewer than 6 sides take more time to be given a complete rotation. Other specialized shapes exist for certain needs, such as wing nuts for finger adjustment and captive nuts (e.g. cage nuts) for inaccessible areas.

ARC WELD:

Fig. 5.26 Arc Welding

Arc welding is a process that is used to join metal to metal by using electricity to create enough heat to melt metal, and the melted metals when cool result in a binding of the metals. It is a type of welding that uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The welding region is usually protected by some type of shielding gas, vapor, or slag. Arc welding processes may be manual, semi-automatic, or fully automated. First developed in the late part of the 19th century, arc welding became commercially important in shipbuilding during the Second World War. Today it remains an important process for the fabrication of steel structures and vehicles.

ARC WELD EQUIPMENTS:

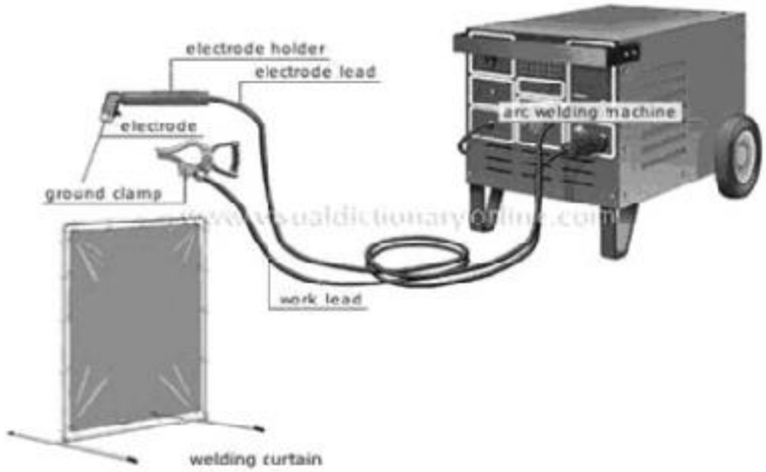


Fig 5.27 Arc Welding Equipments

Welding is the joining of metals through coalescence by the use of either heat or pressure or both. Coalescence is a term that means the joining of two materials to become as one piece. The basic arc welder components consist of the machine that generates the power, the electrode holder or wire feed gun, a means of shielding the weld as it forms, and protective equipment for the user. The process begins in all types when the wire or rod makes contact with the piece to be welded. This completes an electric circuit and creates an arc through which the transfer of the metal from the wire or rod to the piece is facilitated. Spatter occurs during transfer; some of the molten drops of metal become airborne and cover the piece and surrounding area with small globules that solidify on cooling. Spatter may be minimized depending on the skill of the operator and the welding method being used.

CORROSION PREVENTION

The following methods are used for corrosion prevention of the various components of the Multipurpose sowing machine.

RUST CLEANING

Oxidation creates a scale formation on the surface of the material. Scale formation gives rough structure of surface of iron oxide. This iron oxide formation penetrates into the surface and makes the metal weak and reduces the life of the components. Different grades of emery sheets are used to remove the rust formed on the surface of the steel and cleaned properly.

RED OXIDE COATING

This Red Oxide Paint Coating is to prevent the action of corrosion and protect the Surface of the components from atmospheric corrosion. Red Oxide Paint and Thinner liquid are mixed in proper proportion and coated on the surface of the components. The purpose of thinner is to reduce the viscosity of the paint and free flow of the paint over the surface of the components.

FINISH COATING

Milky white color paint is applied over the surface of the machine after the application of the above coatings in a smooth manner using a paint sprayer. This final finish coating of the milky white color of the paint gives good pleasing appearance and effective corrosion prevention.

Chapter 6

METHODOLOGY

6.1 DESIGNING OF MODEL:

The system consists of an internally threaded pinion and one externally threaded lead screw which are engaged like nut and bolt arrangement. C-clamp is used to transfer the motion of lead screw.

A rack is connected to C-clamp. The rack is engaged to first pinion. This pinion is centrally aligned with second pinion. One more rack is connected to this pinion to convert rotary motion into linear motion. The wheels are at both ends of the rack. Initially the pinion is rotated in clockwise direction by using left foot. Due to this motion, the lead screw moves to the left side.

C-clamp transfers the motion to rack. Rack moves along with C-clamp. The first pinion which is engaged with rack will start rotating in clockwise direction due to motion of rack. The second pinion also rotates in same direction as the first. The second pinion again transfers motion to another rack which has wheels at its both the ends and rack will move in right direction.

Due to the motion of rack, the wheels will move to right direction and vehicle will take right turn. Similarly, when driver rotates pinion in anticlockwise direction the exact opposite mechanism will occur and vehicle will take left turn. This system can be mounted in cars having automatic gear system because the clutch of the vehicle is to be replaced by lead screw and pinion pair.

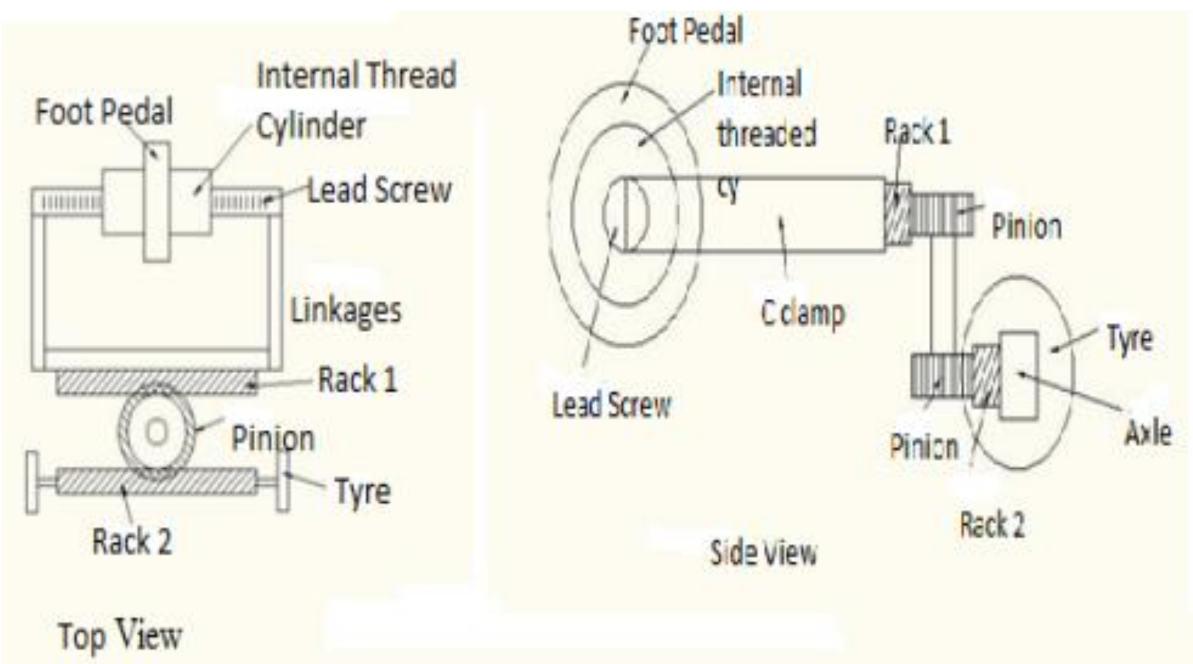


Fig 6.1 Steering System

6.2 CALCULATIONS:

Pinion and rack are same material and so pinion is weaker. So based design on pinion.

Unknown diameter case,

- Calculation of Diameter of teeth,

  Module selected from the standard module series.

  $D_p = n_p \times m_n$

- Calculation of Torque (M_t)

  $M_t = F_t \times D_p$

- Calculation of pitch line velocity (V)

  The pitch line velocity can be calculated by

  $V = \frac{\pi \times Dp \times Np}{60}$

  $n_f = \frac{np}{cos3\ \varphi}$

  $y_p = 0.175 - 0.841/n_f$

- Calculation of allowable stress, S_{all}

  Allowable stress can be calculated by

  $S_{all} = S_o \times [\frac{3}{3+V}]$

- Calculation of endurance stress, S_o

  $S_o = S_u/3$

The actual induced stress can be calculated by using Lewis equation

$S_{ind} = \frac{2M_t}{m^3.k.\pi^2.y_p.n_p\ .cos\varphi}$

Strength Check, Compare S_{all} and S_{ind}

If $S_{all} > S_{ind}$, Design is satisfied.

If not so, keeping on calculating by increasing the module until it is satisfied need to be done.

- Calculation of the face width of helical gear, b

  The face width of helical gear can be calculated as,

  $b_{min} = k_{red} . \pi . m_n$

  $b_{max} = k . \pi . m_n$

- Dynamic Check,

The transmitted load in (N) can be calculated as

$$F_t = \frac{2M_t}{Dp}$$

Calculation of dynamic load, F_d

$$F_d = F_t + \frac{21V((bC\cos\psi\ F)\cos\psi}{21V+\sqrt{bC\cos 2\varphi}+Ft}$$

- Calculation of limiting endurance load, F_0

$$F_0 = S_0 .b.y_P\ \pi.m.\cos(\psi)$$

- Calculation of limiting wear load, F_w

$$F_w = \frac{Dp\times b\times K\times Q}{cos^2\varphi}$$

$$K = \frac{S_{es}^2 \times sin\varphi_n}{1.4} \quad \frac{2}{E}$$

The required condition to satisfy the dynamic check is F_0 ,F_w>F_d.

If not so, keeping on calculating by increasing the module until it is satisfied need to be done.

	Symbol	Value	Unit
No. of teeth	n_p	6	-
module	m_n	2.5	mm
Pitch circle diameter	D_p	15	mm
Face width	b	47	mm
Applied Force	F_t	2610	N
Torsional Moment	M_t (T)	19.575	Nm

No	Item	Symbol	Formula	Result	
				Pinion	Rack
1.	Module	m_n		2.5	
2.	Pressure angle	α		20°	
3.	Number of teeth	n		6	28
4.	Height of Pitch Line	H		-	23
5.	Addendum	H_a	$h_a = 0.8m_n$	2	
6.	Pitch Diameter	D_p	$D_p = n_p \times m_n$	15	-
7.	Diametric Pitch	P_d	$P_d = n_p /D_p$	0.4	-
8.	Tooth Thickness	t	$t = 1.5708/P_d$	0.628	
9.	whole Depth	H_t	$h_t = 1.8m_n$	4.5	
10.	Clearance	C	$C = 0.2m$	0.5	
11.	Outside Diameter	D_0	$D_0 = D_p + 2h_a$	19	-
12.	Dedendum	H_d	$h_d = 1m_n$	2.5	
13.	Root Diameter	D_R	$D_R = D_p - 2h_d$	10	-
14.	Center Distance	a	$a = D_p /2 + H$	-	30.5

Table 6.1 DESIGN RESULTS FOR RACK AND PINION TEETH

6.2.1 Contact Stress Analysis of Steering Gear by Using AGMA Equation:

One of the main gear tooth failure is pitting which is a surface fatigue failure due to repetition of high contact stresses occurring in the gear tooth surface while a pair of teeth is transmitting power .

- The contact stress equation is given as

$$\sigma_C = C_p \sqrt{\frac{F_t}{b_{dl}} \left(\frac{\cos\psi}{0.95CR} \right) K_v K_0 \left(0.93 K_m \right)}$$

- The elastic coefficient factor equation is given as

$$C_p = 0.564 \sqrt{\frac{1}{\frac{1-v12}{E1} + \frac{1-v22}{E2}}}$$

- The geometry factor I is given by

$$I = \frac{\sin\varphi \cos\varphi}{2} \times \frac{i}{i+1}$$

- The speed ratio is given by

$$i = \frac{n_1}{n_2} = \frac{d_2}{d_1}$$

- The contact ratio equation is given as

$$CR = \left[\frac{\sqrt{r_o^2 - r_R^2} + \frac{h_{ar}}{\sin\emptyset} - r_p \sin\emptyset}{\pi m_n \cos\emptyset} \right]$$

In the principle stress theory failure will occur when the principle stress in the complex system reaches the value of the maximum stress at the elastic limit in simple tension.

- The principal stresses are determined by the following equation.

$$\sigma 1, \sigma 2 = \frac{\sigma x + \sigma y}{2} \pm 0.5\sqrt{((\sigma_x - \sigma_y)2 + 4\tau_{xy}^2)}$$

With either yield criterion, it is useful to define an effective stress denoted as σ_v which is a function of the applied stresses. If the magnitude of σ_v reaches a critical value, then the applied stress state will cause yielding, in essence, it has reached an effective level. The von-Mises stress is calculated by the following equation:

- The von-Mises stress is,

$$\sigma_v = \frac{1}{\sqrt{2}}[(\sigma 1 - \sigma 2)^2 + (\sigma 2 - \sigma 3)^2 + (\sigma 3 - \sigma 1)^2\}1^{\frac{1}{2}}$$

Parameter	Results
Von Mises Stress (max)	944.31 MPa
Strain (max)	4.04×10^{-3}

Table 6.2: THEORETICAL RESULT OF VON-MISES STRESSES AND STRAIN FOR GEAR PAIR

6.2.2 Theoretical Calculations of Rack Bending Stress and Deflection:

Rack is subject to not only the axial load but also the vertical loading. The vertical load causes the bending stress and if the load is higher than critical load then it will be lead to breakage. Consider the vehicle load front axle weight of 740N. The rack vehicle load (W) come on rack end is calculated. The assembly is considered as cantilever beam.

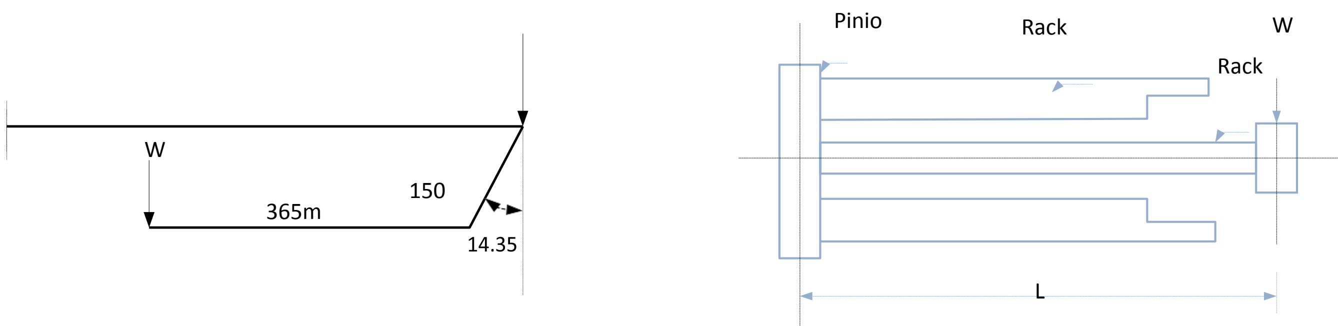


Fig 6.2 Rack Assembly and Loading Condition

PARAMETER	SYMBOL	VALUE	UNIT
Rack Diameter	D_r	23	mm
Center of Gravity of Sector Area	y	8.289	mm
Moment of Inertia	I	5299.80	mm^4
Rack Tip Max. Bend Load	W	294.35	N
Rack Length	L_r	210	mm
Young's Modulus	E	207	GPa

Table 6.3 SPECIFICATION DATA OF RACK AND RACK HOUSING ASSEMBLY

1. To find the centre of gravity of sector area, y

   $y=\frac{4r}{3}\left(\frac{\sin 3\frac{\theta}{2}}{\theta-\sin\theta}\right)$

2. To find the moment of inertia, I

   $I=\frac{r^4}{8}\left(\theta-\sin\theta+2\sin\theta\sin 2\,\frac{\theta}{2}\right)$

3. To find the Rack Plane coefficient, Z

   $Z=\frac{I}{y}$

4. To find the Rack Stress, σ

   $$\sigma=\frac{W.L}{Z}$$

5. To find the Deflection, δ

$$\delta = \frac{W.L^3}{3EI}$$

Parameter	Results
Von Mises Stress (max)	967.82 MPa
Deformation (max)	0.828 mm

Table 6.4 THEORETICAL RESULT OF VON-MISES STRESSES AND DEFORMATION FOR RACK

6.3 Gear Tooth Strength Analysis of Steering Pinion Gear:

The material properties of AISI 4340 Steel is given.

Material Properties	Value
Young modulus	207 GPa
Poisson ratio	0.3
Density	7850 kg/m3
Coefficient of Thermal Expansion	1.15e-05 C^{-1}
Tensile Yield Strength	1570 MPa
Tensile Ultimate Strength	1950 MPa

Table 6.5 MATERIAL PROPERTIES OF AISI 4340 Steel.

Contact Stress Analysis of Steering Rack and Pinion Gear

- Simulation Result (Boundary Condition)

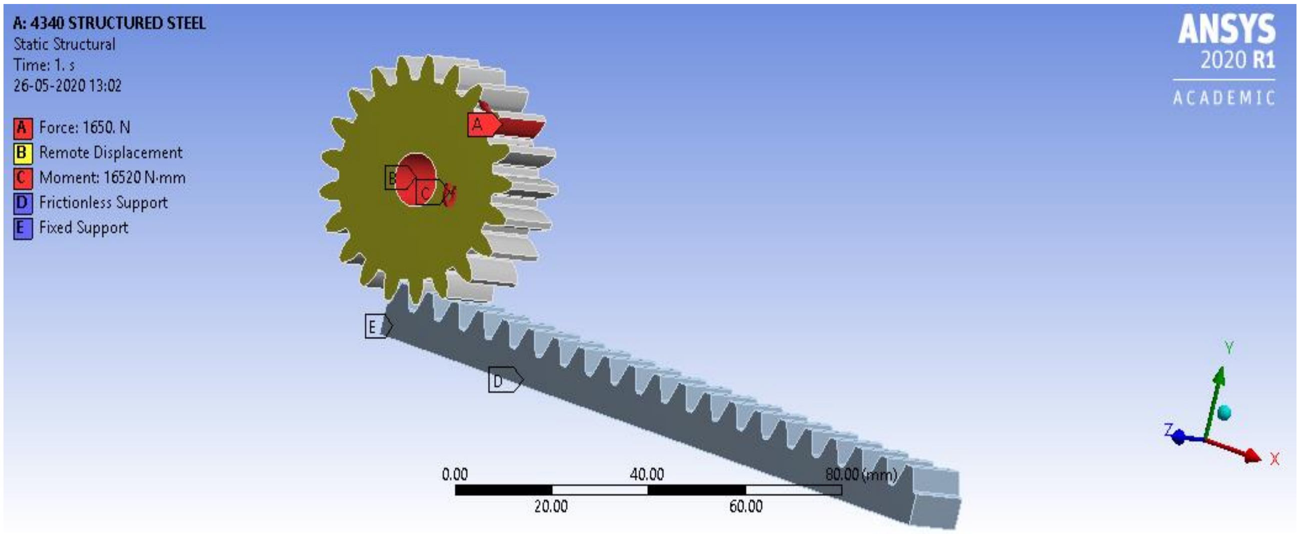


Figure 6.3 Fixed and forced Condition of Rack and Pinion Gear Assembly

- Simulation Result (Contact Stress)

Stress analysis is used to determine equivalent stress and the strain of the rack and pinion gear assembly contact point. The numerical results of stress analysis are carried out by using ANSYS 2020 R1 software. The numerical results of von-Mises stress and strain are compared with different materials of rack and pinion gear (AISI 4340 steel, aluminum alloy and gray cast iron).

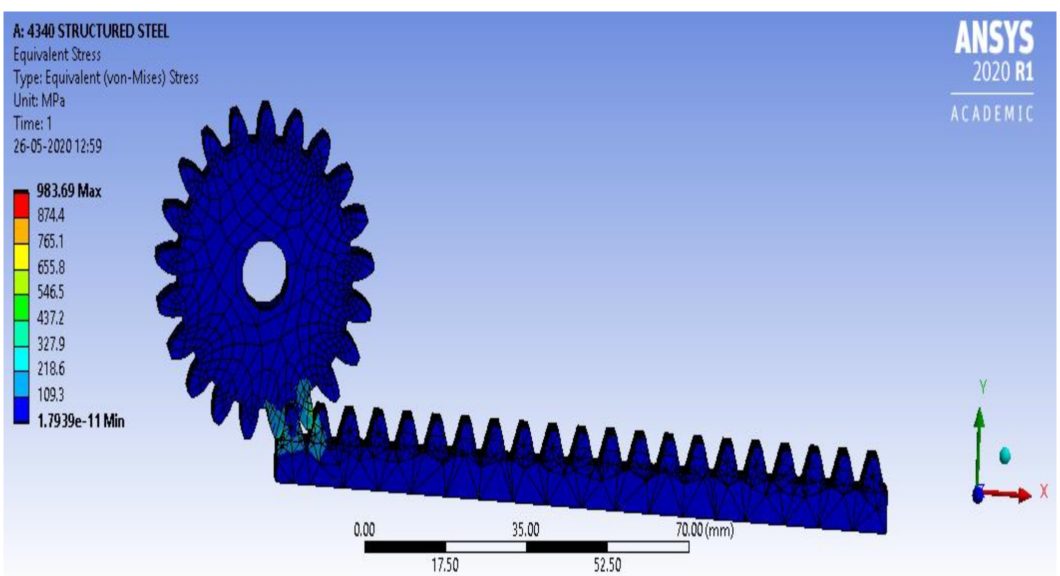


Figure 6.4 Equivalent (von-Mises) Stress on Rack and Pinion Gear Assembly using AISI 4340 Steel

Figure shows the equivalent (von-Mises) stress on rack and pinion gear assembly using AISI 4340 steel. The maximum equivalent (von-Mises) stress on contact point is 983.69 MPa and location of maximum stress is at the meshing area of the rack and pinion while the yield strength of the structural steel is 1570 MPa. The steering gear will work safely at this stress.

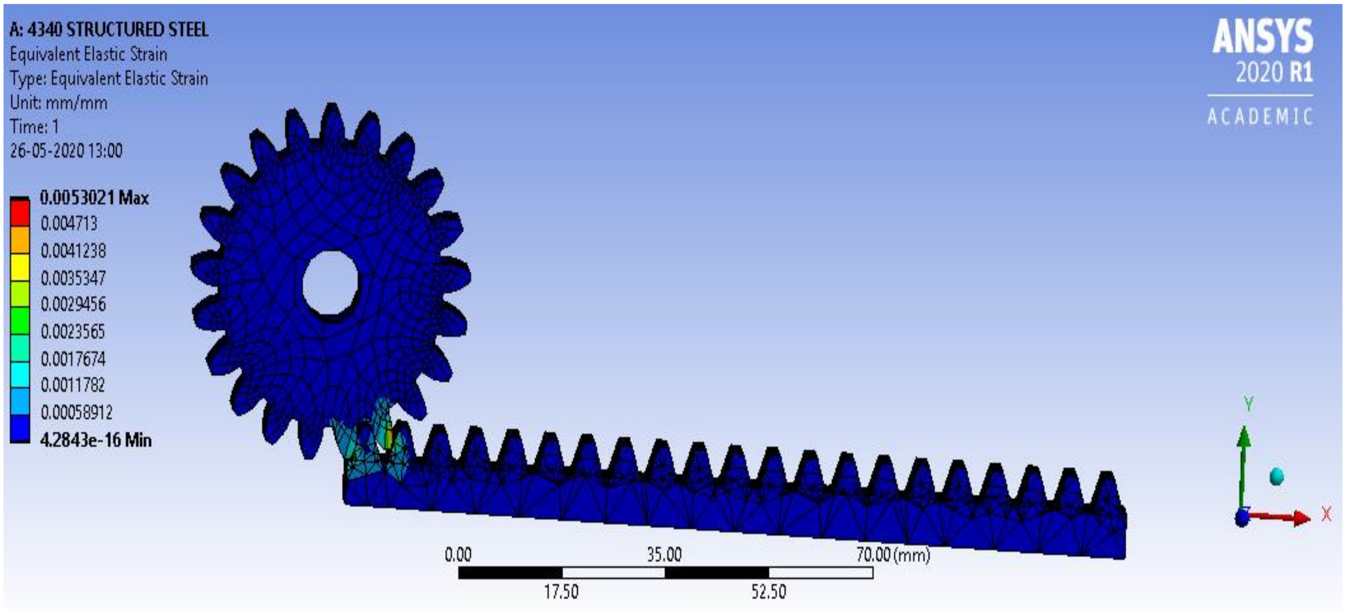


Figure 6.5 Equivalent Strain of Rack and Pinion Gear Assembly using AISI 4340 steel

The equivalent strain on rack and pinion gear pair using AISI 4340 steel is 0.0053021 and occurs at meshing area of the rack and pinion.

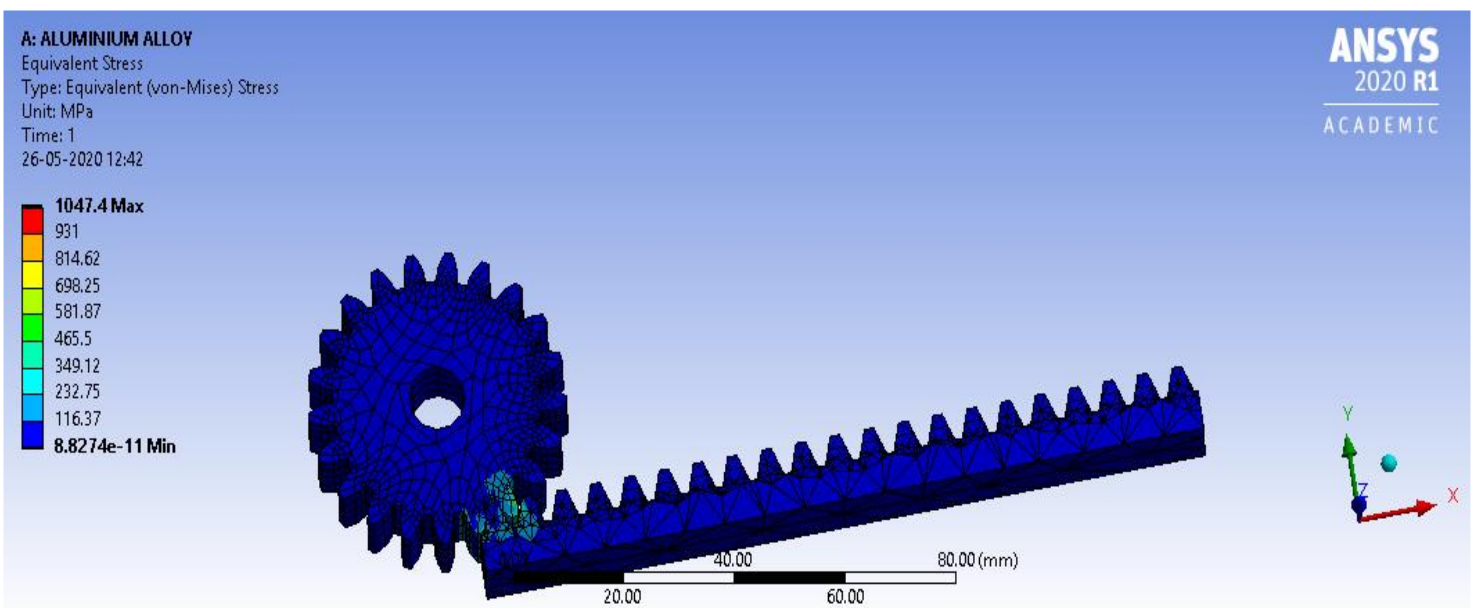


Figure 6.6 Equivalent (von-Mises) Stress on Rack and Pinion Gear Assembly using Aluminum Alloy

Figure shows the equivalent (von-Mises) stress on rack and pinion gear assembly using Aluminum. The maximum equivalent (von- Mises) stress on contact point is 1047.4 MPa and location of maximum stress is at the meshing area of the rack and pinion while the yield strength of the Aluminium alloy is 225 MPa. The steering gear will not work safely at this stress.

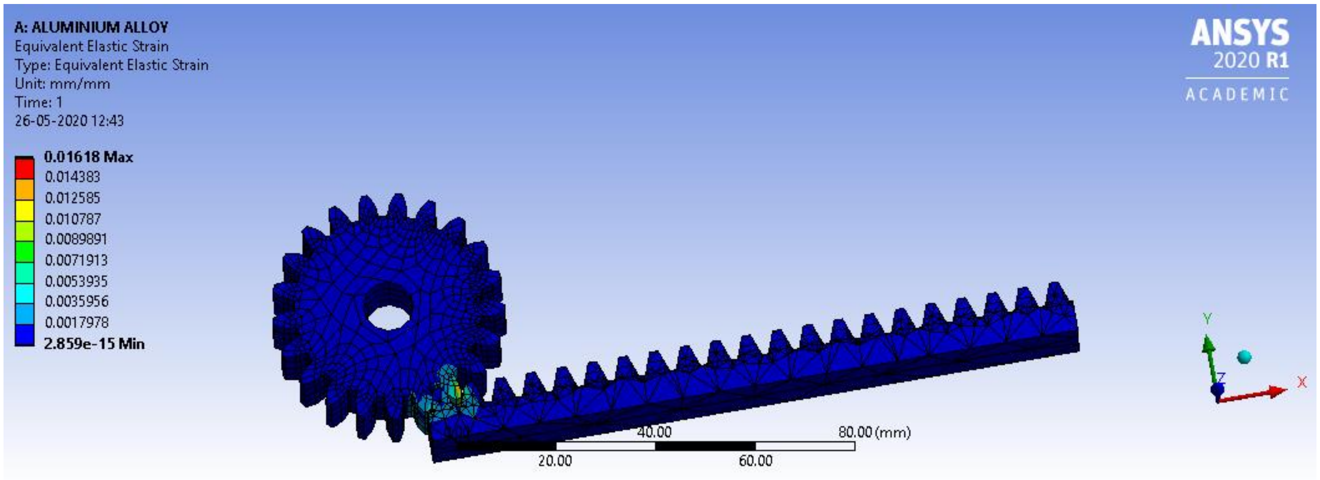


Figure 6.7 Equivalent Strain of Rack and Pinion Gear Assembly using Aluminum Alloy

The equivalent strain on rack and pinion gear pair using Aluminum is 0.01618 and occurs at meshing area of the rack and pinion.

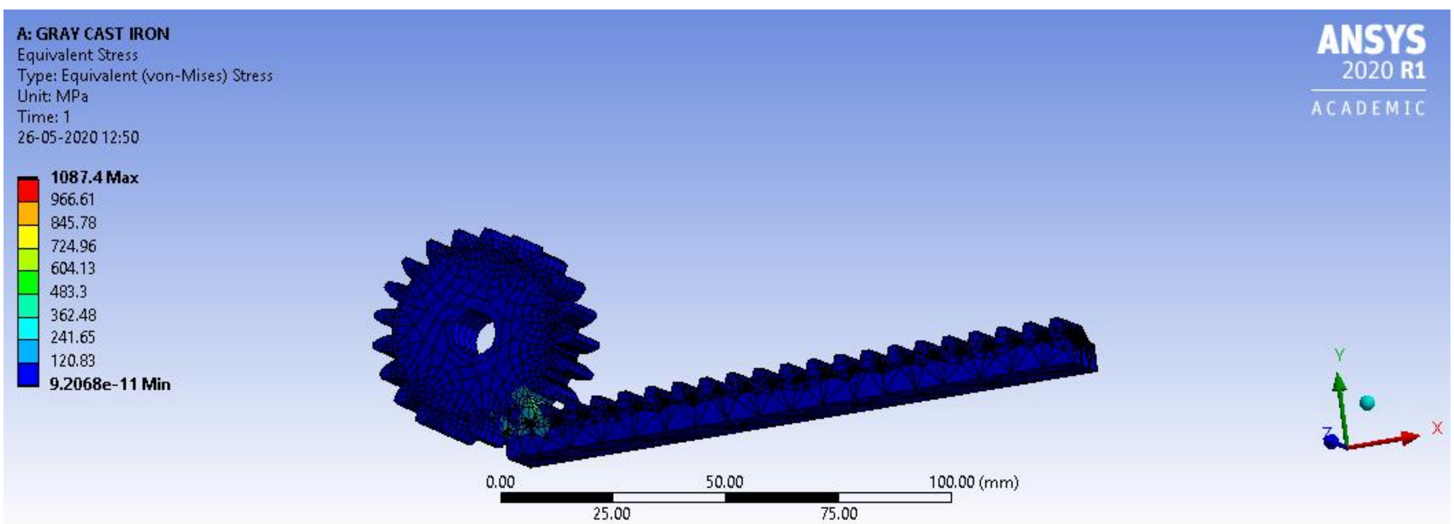


Figure 6.8 Equivalent (von-Mises) Stress on Rack and Pinion Gear Assembly using Gray Cast Iron

Figure shows the equivalent (von-Mises) stress on rack and pinion gear assembly using Gray Cast Iron. The maximum equivalent (von-Mises) stress on contact point is 1087.4 MPa and location of maximum stress is at the meshing area of the rack and pinion while the yield strength of the Gray Cast Iron is 170 MPa. The steering gear will not work safely at this stress.

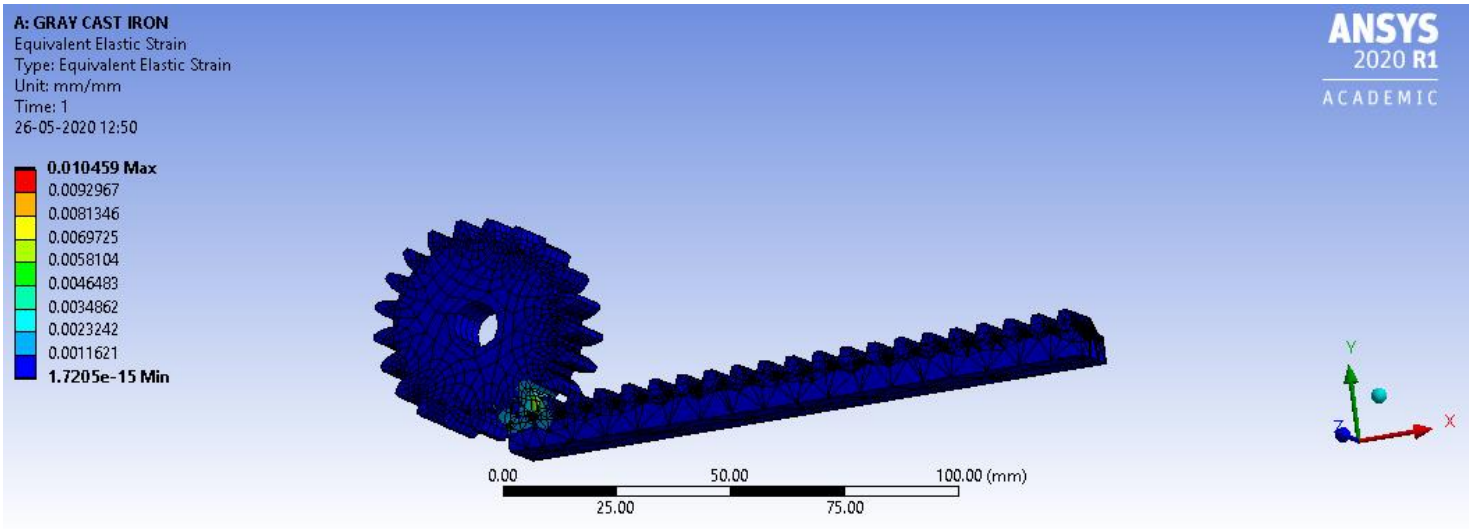


Figure 6.9 Equivalent Strain of Rack and Pinion Gear Assembly using Gray Cast Iron

The equivalent strain on rack and pinion gear pair using Gray Cast Iron is 0.010459 and occurs at meshing area of the rack and pinion.

Parameter	Results		
	Theoretical calculation	Simulation	% Error
Von Mises Stress (max)	944.031 MPa	983.69 MPa	4.2%
Strain (max)	4.04×10^{-3}	5.3×10^{-3}	23%

Table 6.6 COMPARISON OF THEORETICAL AND SIMULATION RESULT FOR GEAR ASSEMBLY

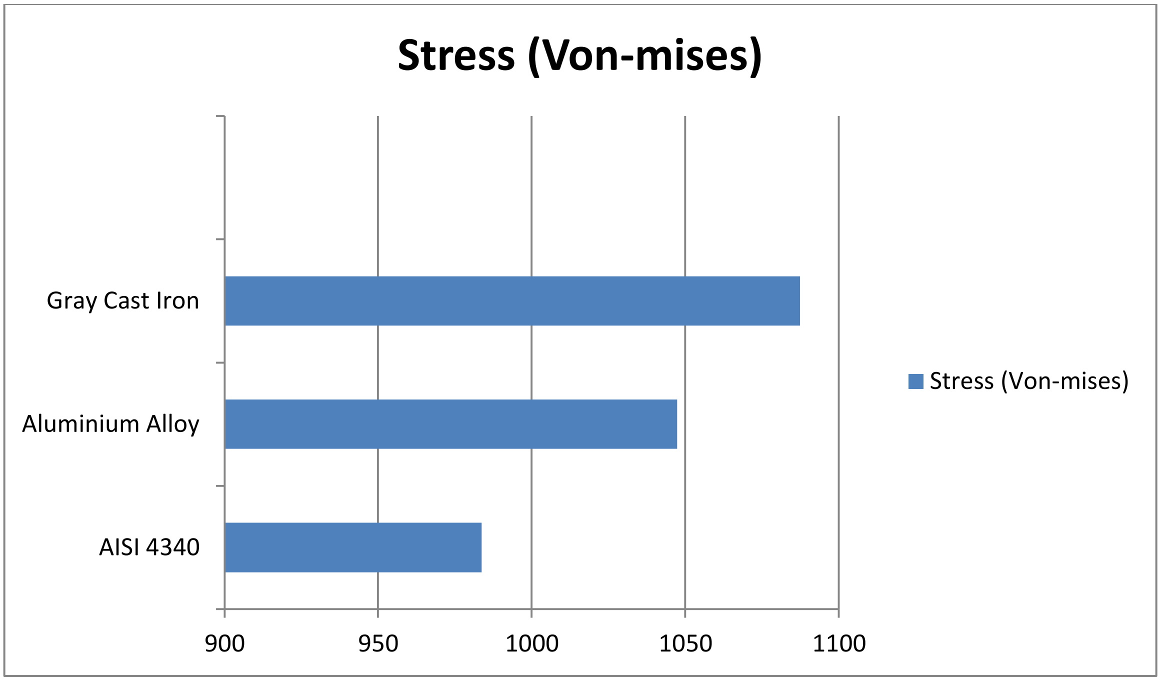


Fig. 6.10 Comparison of Result for Equivalent (von-Mises) Stress

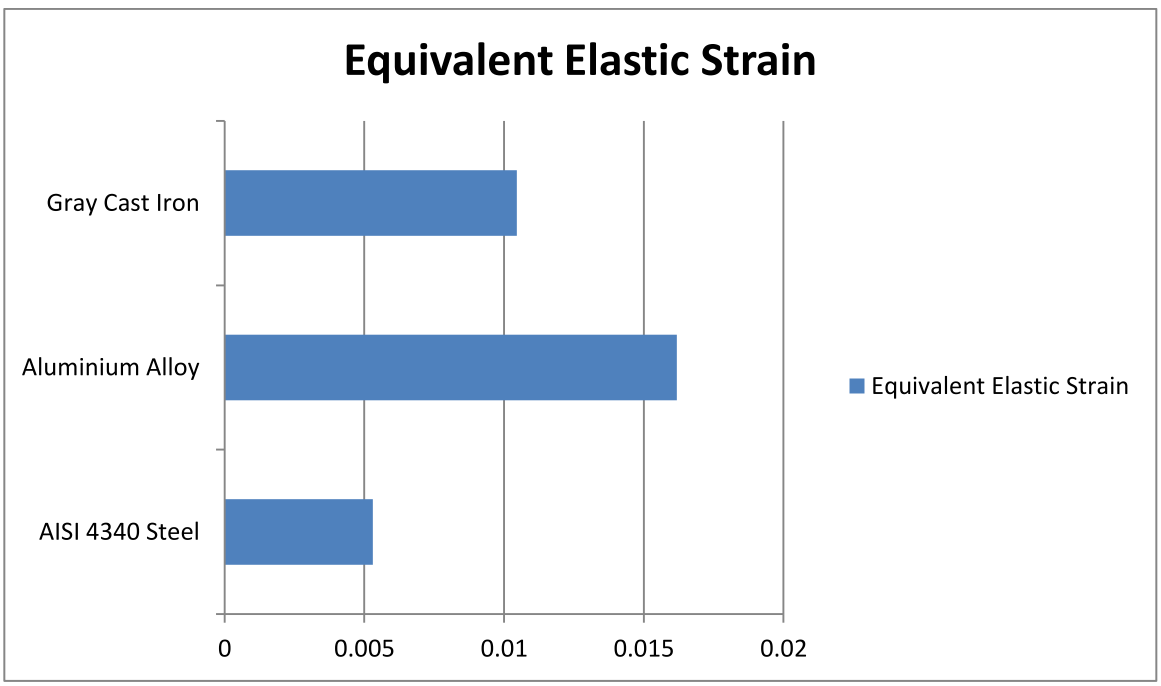


Fig. 6.11 Comparison of Result for Equivalent Strain

6.4 CONCLUSION

Manual rack and pinion steering system is suitable for the car. In steering gear design, the diameter of pinion 15mm and face width 47mm and module 2.5mm was satisfied.

From analysis of rack and pinion gear pair, the von-Mises stress for 4340 Steel was 983.69 MPa, Aluminum Alloy was 1047.4 MPa and Gray Cast Iron was 1087.4 MPa.

In structural analysis, Steel Rack And Pinion Steering Gear pair is having least strain value. Hence steel rack and pinion steering gear pair was safe for design.

Chapter 7

SCOPE OF FUTURE WORK

- For further enhancement we can make the car foldable for ease of parking and portability purposes.
- Power steering can be installed in the Steering system.
- Digital information screen could be also added to show the distance run and the distance it can further go.
- The steering wheel could be designed in such a way that It could be used in existing cars with the normal system so that it can be used by more than one person in a family.
- We can install solar panels to charge the batteries thus making the electric vehicle more efficient.
- If we can convert the existing conventional vehicles to electric vehicles that will be more cost efficient.
- Furthermore, the storage capacity and charging time can also be improved which will increase the reliability and efficiency of the system.

Chapter 8

CONCLUSION AND DISCUSSIONS

In this venture we have considered the problems faced by the handicapped people with no arms and executed a foot operating steering system in an E-kart framework. This foot operating steering in E-kart system is going to help a lot of handicapped individuals in their day to day journeys.

BLDC Motor of high power rating is not available easily. When compared with other motor, cost of BLDC motor is really high. BLDC Motor and its controller should be matched to each other. Coupling the motor with the sprocket of the existing vehicle was tiresome and time consuming. Thus by providing BLDC drive we can achieve smooth operation with high efficiency, high torque and easy speed regulation. The major part was the instalment of the foot operating steering system. In which we faced a lot of difficulties from the design to the arrangement of the steering wheel, break and the accelerator. This system can now be installed in a regular car also.

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