SPEED BREAKER POWER GENERATION WITH PIEZOELECTRIC SENSOR

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

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ABSTRACT

This project presents an advanced system for harvesting energy from speed breakers in urban environments. By incorporating piezoelectric sensors and a DC generator, the mechanical energy from vehicles passing over speed breakers is efficiently converted into electrical power. A load cell is employed to measure the load applied, providing crucial data for optimizing power generation. Additionally, a voltage sensor monitors the generated voltage, ensuring the system's efficiency. The integration of these components into a comprehensive control mechanism enhances the reliability and performance of the energy harvesting process. This multifaceted approach not only maximizes power output but also provides valuable insights into the dynamics of urban traffic, contributing to sustainable energy solutions and urban planning. This comprehensive approach not only makes a contribution to the generation of electricity in a sustainable manner, but it also provides a one-of-a-kind opportunity to collect data in real time on the characteristics of traffic patterns and variations in demand. It is essential to have such insights in order to improve the effectiveness of energy harvesting systems and to provide direction for urban planning and development projects.

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LIST OF ABBREVIATION

AC	Alternating Current
DC	Direct Current
SBPG	Speed Breaker Power Generation
IDE	Integrated Development Environment
LED	Light Emitting Diode
PWM	Pulse Width Modulation
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
IGBT	Insulated-Gate Bipolar Transistor
ICSP	In-Circuit Serial Programming
MHz	Mega Hertz
I/O	Input/Output
AVR	Automatic Voltage Regulator
RISC	Reduced Instruction Set Computer
MIPS	Million Instructions Per Second
SRAM	Static Random Access Memory
ADC	Analog to Digital Controller
EEPROM	Electrically Erasable Programmable Read Only Memory

TQFP	Thin Quad Flat Pack
QFN	Quad Flat No-Lead Package
MLF	Micro Lead Frame Package
PDIP	Plastic Dual In-Line Package
USART	Universal Synchronous Asynchronous Receiver Transmitter
SPI	Serial Peripheral Interface
KB	Kilobytes
CNC	Computerized Numerical Control
EMF	Electromagnetic Force
AH	Ampere-Hour
AM	Amplitude Modulation
FM	Frequency Modulation
GND	Ground
VCC	Voltage Common Collector
PZT	Lead Zirconate Titanate
GPL	General Public License
LGPL	Lesser General Public License
CPU	Central Processing Unit

CHAPTER 1

INTRODUCTION

In the current climate of energy consumption and sustainability, the development of novel approaches to the utilization of renewable energy sources has become an absolute necessity. A one-of-a-kind opportunity for energy harvesting is presented by urban surroundings, which are typified by high levels of motor traffic. The purpose of this project is to design a sophisticated system that incorporates piezoelectric sensors and a direct current (DC) generator in order to effectively capture and convert the mechanical energy that is generated by automobiles as they pass over speed breakers into electrical power.

The purpose of speed breakers has traditionally been to serve as traffic control measures, with the goal of reducing the speed of cars and improving road safety. Nevertheless, the majority of their potential as sources of renewable energy has not yet been fully realized. In this scenario, the mechanical stress that is caused by the weight and motion of cars is converted into electrical energy through the utilization of piezoelectric sensors. Additionally, a DC generator is utilized in order to increase the amount of power that is produced using this method.

In order to maximize the effectiveness of the energy harvesting process, the project integrates a load cell that measures the load that is applied during vehicle passage. This provides vital data that can be used for system calibration and efficiency enhancement. In addition to this, the system incorporates a voltage sensor that is responsible for monitoring the voltage that is created. This helps to ensure that the power output is consistent and reliable.

It is essential to have such insights in order to improve the effectiveness of energy harvesting systems and to provide direction for urban planning and development projects.

1.1 LITERATURE REVIEW

E. Naveen, et.al, June 2022, "Design and Fabrication of Power Generation Through Smart Speed Breakers", ResearchGate.

It is very significant to design pollution free energy generation system. Speed breaker Power Generator (SBPG) is the most emerging technique which produces electrical power with minimum input. ❖ An experimental study to generate the electricity by SBPG is described in this paper. The generated power can be used for the domestic purpose or commercially, which are present near the speed breaker. We can tap the energy generated and produce power by using the speed breaker as power generating unit. Further, it is found that the total power generated from the rotational induction generators is 691 kW while that from the translational induction generators is 8.2922 kW per day on 12-hour basis. In this paper it is mainly focused on the working of the newly developed rack and ratchet (pinion) mechanism which is used to develop the power from speed breakers, its practical implementation. It generates about 43 watts from one push of 65 kg weight. which can convert into electric energy by generator and later stores in batteries. In this particular study gear, rack and pinion were used for fabrication of the experimental setup. Contact stresses of rack and spur gear were analyzed under static loading and finite element analysis ABSTRACT 138 International Journal for Modern Trends in Science and Technology.

Kafi Mohammad Ullah, et.al, December 2016, "Electrical power generation through speed breaker", ResearchGate.

In the present situation power becomes basic need for human life. Energy is responsible for major developments of any country's economy. Conventional energy sources generate most of the energy of today's world. But the population is increasing day by day and the conventional energy sources are diminishing.

Moreover, these conventional energy sources are polluting and responsible for global warming. So, non-conventional sources are needed to be developed for power generation which are clean, environment friendly and sustainable. In this research we propose a renewable non-conventional energy source based on speed breaker mechanism. Our project is to enlighten the streets utilizing the jerking pressure which is wasted during the vehicles passes over speed breaker in roadside. We can tap the energy generated by moving vehicles and produce power by using the speed breaker as power generating unit. The kinetic energy of the moving vehicles can be converted into mechanical energy through rack and pinion mechanism and this mechanical energy will be converted to electrical energy using generator which will be used for lighting the street lights. Therefore, by using this mechanism we can save lot of energy which can fulfill our future demands.

Murtaza Topiwala, June 2022, "Design and Analysis of Power Generating Speed Breaker", ResearchGate.

Energy is the primary need for the survival of all organisms in the universe. Everything that happens in the surrounding area is the expression of the flow of energy in one of the forms but in this fast-moving world population is increasing day by day and conventional energy sources are decreasing. The extensive use of energy resulted in the energy crisis in a few years. Therefore to overcome this problem we need to implement the techniques of optimal utilisation of conventional sources for the conservation of energy. This project includes how to utilise the energy which is wasted when the vehicle passes over the speed breaker. There are four mechanisms to generate electricity through speed breakers via, Rack and Pinion mechanism, etc.

Praful Nandankar, et.al, April 2019, "Piezoelectric Generator using Speed Breaker", IJLESJournal.

The piezoelectric plates produce electric power which feeds a low power system. The piezoelectric effect is utilized to produce an electric power from Piezo-plates. The piezoelectric plates operate as a generator for the production of electricity. The piezoelectric plates convert mechanical energy in the form of deformation into an electrical energy. The deformation is applied to piezoelectric plates which deforms the piezoelectric material. The deformation in piezoelectric material changes an inherent resistance which in turn produces ac voltage. This paper proposes a mathematical analysis, design and hardware implementation of piezoelectric generator. The piezoelectric generator produces an electric power when a force exerted on speed breaker of road. The piezoelectric material is utilized in this paper to produce a voltage for street lights. The hardware implementation of piezoelectric generator is done and accurate results are found out experimentally.

Suhrud Joglekar, et.al, June 2021, "Energy Generation in Speed Breakers by using Piezoelectric Sensors", IRJET.

The demand for power is increasing day by day. To meet the current necessity of an undisrupted power supply we need to think of multiple renewable resources. One such solution to the energy crisis could be energy generation using piezoelectric effect. This effect is incorporated in our speed breaker model to harness electricity. The electricity generated by the configuration is stored in the batteries for later use in the day to day applications.

M Palanivendhan, et.al, 2020, "Design and fabrication of Speed Bump for Energy Generation", IOPScience.

Electricity is a basic part of nature and it is one of the most widely used forms of energy across the globe. Fossil fuels pollute the environment.

Nuclear energy requires careful handling of both raw as well as waste material. Therefore, the focus now is shifting more and more towards the renewable sources of energy, which are essential and non-polluting. Energy conservation and conversion are the cheapest new sources of energy. This work includes how to utilize the energy which is wasted when the vehicles passes over a speed breaker. Lots of energy is generated when vehicle passes over it. We can tap the energy generated and produce power by using the speed breaker as power generating unit and installing a rack and pinion mechanism. The vertical force of the moving vehicles will cause the action of rack and pinion mechanism. Then, using a set of gear the produced will be transferred to the generator and power will be generated with its rotation. The energy we save during the day light can be used in the night time for lighting street lights. The electricity generated from such a machine can be used to light up street lights, traffic signals etc. In case of busy streets and densely populated areas, it can also be used store energy or charge automobile batteries etc.

Vishal Gupta, et.al, 2021, "Design and Fabrication of Power Generation through Speed Breaker", GlobalJournals.

In the present scenario energy is the primary need for human life. Energy is responsible for development of any country's economy. But in this fast-moving world, population is increasing day by day and the conventional energy sources are diminishing. Moreover, these non-renewable energy sources are polluting and responsible for global warming. So non-conventional sources are needed to be developed for power generation which are clean environment friendly and sustainable. So, this project includes how to utilize the energy which is wasted when the vehicle passes over a speed breaker. Our project is to enlighten the street utilizing the jerking pressure which is wasted during the vehicle passes over speed breaker in roadside. We can tap the energy generated and produce power by using the speed breaker as power generating unit.

1.2 EXISTING SYSTEM

The existing system of power generation using speed breakers typically involves installing mechanisms beneath the speed breakers that convert the kinetic energy from vehicles passing over them into electrical energy. This energy is then stored or used to power nearby infrastructure such as streetlights or traffic signals. It's a form of renewable energy generation that utilizes existing infrastructure for sustainability purposes**.** Existing system - there is no active power generation system in India either in mechanical or electrical in India.Piezoelectric crystal are used in a city to generate power through pedestrian walking. In order to maximize the effectiveness of the energy harvesting process, the project integrates a load cell that measures the load that is applied during vehicle passage. This provides vital data that can be used for system calibration and efficiency enhancement. In addition to this, the system incorporates a voltage sensor that is responsible for monitoring the voltage that is created. This helps to ensure that the power output is consistent and reliable. . It is essential to have such insights in order to improve the effectiveness of energy harvesting systems and to provide direction for urban planning and development projects.

1.3 PROPOSED SYSTEM

The proposed energy harvesting system utilizes a comprehensive design that incorporates a rack and pinion mechanism, chain drive assembly, and advanced components for efficient power generation from speed breakers in urban environments. The system is aimed at harnessing the kinetic energy from passing vehicles to produce a stable and usable electrical output.

- A robust rack and pinion assembly is strategically positioned beneath the speed breaker to capture the linear motion generated by passing vehicles.
- The rotational force produced by the pinion in the rack and pinion mechanism is transferred to a larger sprocket using a chain drive assembly.
- A flywheel is integrated to increase the rotational speed of the system, providing additional momentum. Gears are employed for controlled and synchronized transfer of motion to the DC generator.
- The heart of the system, a permanent magnet DC generator, converts the rotational motion into electrical energy, producing a stable 12 Volt DC output.
- Load cells are strategically placed within the system to measure and analyze the force or load applied during the passage of vehicles over the speed breaker.
- An advanced voltage monitoring system is incorporated to ensure the stability and reliability of the generated electrical power. This system provides real-time feedback on voltage levels.
- The generated DC voltage is stored in a lead-acid battery, providing a reservoir for energy storage and ensuring a continuous power supply even when vehicles are not actively passing over the speed breaker.

CHAPTER 2
SYSTEM DESCRIPTION

2.1 HARDWARE REQUIREMENTS

- Rack and pinion arrangement
- Sprocket and chain Drive
- Fly wheel
- D.C generator
- Battery
- Inverter Circuit and
- Arduino
- Volatge sensor
- Piezolectric sensor
- Loadcell

2.2 SOFTWARE REQUIREMENTS

- ARDUINO-IDE
- EMBEDDED C- LANGUAGE

2.3 MODULES

- Speed breaker
- Rack and pinion gear
- Spring arrangement
- Chain drive
- Shaft
- Flywheel
- Generator
- Battery and load cell

2.3.1 MODULES DESCRIPTION

1. **Speed Breaker**:

   It is the system's top portion, which is made of iron in a curved shape. The primary function of this speed breaker is to hold vehicle pressure and squeeze it as a vehicle passes past it.

2. **Rack and Pinion Gear**:

   This is one of the most basic types of equipment and can be customized to meet one's specific requirements. The rack is a linear gear, and the pinion is a circular gear.As the name implies,this type of gear has two components the rack and pinion gear.

3. **Spring Arrangement**:

   When spring is loaded, it distorts and returns to its original shape when the load is removed. Its cushions absorb or manage the energy emitted by shocks or vibrations.

4. **Chain Drive**:

   It is a method of transferring mechanical power from one location to another.

5. **Shaft:**

   A shaft is a spinning machine element with a circular cross-section that is used to transfer power from one part to another or from a power- producing machine to a power- absorbing machine.

6. **FlyWheel**:

   The flywheel's primary function is to act as an energy accumulator. It reduces speed fluctuations.When demand is low, it absorbs energy and releases it when it is needed.

7. **Generator**:

   A device that generates alternating current (AC) by mixing stationary (stator) and moving parts is known as an alternating current generator . The rotor is linked to the gear.The torque produced by the gear rotates the generator's rotor.

8. **Battery**:

   An electric battery is a device that stores energy in the form of one or more electrochemical cells.

9. **Piezolectric sensor:**

   A piezoelectric sensor converts physical parameters like acceleration, strain or pressure into an electrical charge which can then be measured.

10. **Load cell:**

    It measures and analyze the force applied during the vehicle passage, providing crucia.

CHAPTER 3
3.1 HARDWARE AND SOFTWARE DESCRIPTION

3.1.1 ARDUINO
1 DESCRIPTION

Arduino is an open source, computer hardware and software company, project,and user community that designs and manufactures Single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs- light on a sensor, a finger on a button, or a Twitter message - and turn it into an output – activating a motor, turning on an LED, publishing something online. The Arduino Uno is a microcontroller board based on the ATmega328(datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and are set button.

Fig 3.1 Auduino UNO

3.2.1 ARDUINOUNO

1 DESCRIPTION:

Arduino is an open-source project that created microcontroller-based kits for building digital devices and interactive objects that can sense and control physical devices.The project is based on microcontroller rboard designs, produced by several vendors, using various microcontrollers. These systems provide sets of digital and analog input/output (I/O) pins that can interface tovarious expansion boards (termed shields) and other circuits. The boards feature serial communication interfaces, including Universal Serial Bus (USB) on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino project provides an integrated development environment (IDE) based on a programming language named Processing, which also supports the languages C and C++.

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and are set button.It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter.ArduinoUno has number of facilities for communicating with a computer, another Arduino board, or other microcontrollers.

ATMEGA328P-PU microcontroller

The most important element in Arduino Uno R3 is ATMEGA328P-PU is an 8-bit Microcontroller with flash memory reach to 32k bytes.

It’s features as follow:

a. High Performance, Low Power AVR
b. Advanced RISC Architecture
    i. 131 Powerful Instructions – Most Single Clock Cycle Execution
    ii. 32 x 8 General Purpose Working Registers
    iii. Up to 20 MIPS Throughput at 20 MHz
    iv. On-chip 2-cycle Multiplier

- High Endurance Non-volatile Memory Segments
    - 4/8/16/32K Bytes of In-System Self-Programmable Flash program memory
    - 256/512/512/1K Bytes EEPROM
    - 512/1K/1K/2K Bytes Internal SRAM
    - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
    - Data retention: 20 years at 85°C/100 years at 25°C
    - Optional Boot Code Section with Independent Lock Bits
    - In-System Programming by On-chip Boot Program
    - True Read-While-Write Operation
    - Programming Lock for Software Security

- Peripheral Features
    - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
    - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
    - Real Time Counter with Separate Oscillator
    - Six PWM Channels
    - 8-channel 10-bit ADC in TQFP and QFN/MLF package

- Temperature Measurement
- 6-channel 10-bit ADC in PDIP Package
- Temperature Measurement
- Programmable Serial USART
- Master/Slave SPI Serial Interface
- Byte-oriented 2-wire Serial Interface (Philips I2 C compatible)
- Programmable Watchdog Timer with Separate On-chip Oscillator
- On-chip Analog Comparator
- Interrupt and Wake-up on Pin Change

- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby

- I/O and Packages
  - 23 Programmable I/O Lines
  - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF

- Operating Voltage
  - 1.8 - 5.5V

- Temperature Range
  - -40°C to 85°C

- Speed Grade
  - 0 - 4 MHz@1.8 - 5.5V, 0 - 10 MHz@2.7 - 5.5.V, 0 - 20 MHz @ 4.5 - 5.5V

- Power Consumption at 1 MHz, 1.8V, 25°C
  - Active Mode: 0.2 mA
  - Power-down Mode: 0.1 μA
  - Power-save Mode: 0.75 μA (Including 32 kHz RTC)

2. FEATURES

- Microcontroller: ATmega328P
- Operatingvoltage:3V
- Inputvoltage:7-12V
- Flashmemory:32KB
- SRAM:2KB and EEPROM: 1KB

3. APPLICATIONS

- Real time biometrics
- Robotic applications
- Academic applications

3.3.1 RACK AND PINION

1 DESCRIPTION

A rack and pinion are used when converting rotational movement to linear motion (or vice versa). A bar shaped gear with an infinite (flat surface) radius of a cylindrical gear is called a rack, and a meshed spur gear is called a pinion. A rack can be used by extending it combining as many racks with machining operation on the end faces when necessary. Gear racks are utilized to convert rotating movement into linear motion. A gear rack has straight teeth cut into one surface of a square or round section of rod and operates with a pinion, which is a small cylindrical gear meshing with the gear rack. Generally, gear rack and pinion are collectively called “rack and pinion”. Rack and pinions are used for lifting mechanisms (vertical movement), horizontal movement, positioning mechanisms, stoppers and to permit the synchronous rotation of several shafts in general industrial machinery.

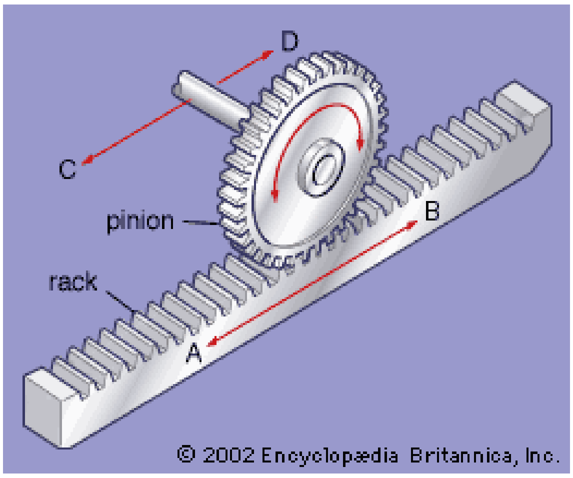


Fig 3.2 Rack and pinion

1. TYPES

A piston coaxial to the rack provides the hydraulic assist force, and an open-centered rotary valve regulates the assist level. A rack and pinion gear system is made up of two gears. The pinion gear is a conventional round gear, and the rack can be straight or flat. The pinion gear's teeth mesh with the teeth cut into the rack.

Types of Rack and Pinion Gears

Two gears make up a rack and pinion gears system. The pinion gear is a standard round gear, and the rack is straight or flat. The rack has teeth carved into it that mesh with the pinion gear's teeth. The differential's critical point of power transfer is a ring and pinion gear. There are three types of rack and pinion gears.

Straight Teeth

Straight teeth have a tooth axis perpendicular to the rotation axis. Straight teeth that go straight to the gear's axis. Manual or walk-behind load movement or transfer is used.

Helical Tooth Gears

Helical tooth gears are frequently quieter and more efficient than straight tooth gears because they allow continuous engagement over the tooth length. In the plane of rotation, helical tooth gears are similar to spur gears, but they have teeth twisted along a helical path in the axial direction.

Roller Pinion

Roller pinion drives employ bearing-supported rollers that mesh with the rack's teeth to provide minimal to no backlash.

2. MECHANISM

By encasing the rack and pinion gearset in a metal tube and coupling each end of the rack to an axial rod, the rack and pinion works. When the steering wheel is turned, the rack moves as a result of the pinion gear spinning because it is connected to the steering shaft. The components of the rack and pinion steering system are:

α. Rack
β. Tubular casing
χ. Pinion
δ. Track rod
ε. Ball and socket joint
ϕ. Adjusting screw.

Rack

Rack is a metal enclosure containing a toothed bar. Like the parallelogram center link, the rack moves sideways in the housing, pulling or pushing the tie-rods to change the wheel direction.

Pinion

Pinion is a toothed or worm gear positioned at the base of the steering column assembly and moved by the steering wheel. The pinion gear meshes with the rack's teeth, causing the rack to move sideways in reaction to the pinion turning.

3. APPLICATIONS

α. Gear racks turn rotary motion into linear motion.
β. Gear rack and pinion are called ack and pinion.

χ. Gears can be utilized in a variety of applications.

δ. Automotive Industry

ε. Robotics

ϕ. Industrial Automation

γ. Steering in Vehicles

η. CNC Machinery

ι. Industrial Automation

φ. Elevators

κ. Linear Actuators

3.4.1 SPROCKET AND CHAIN DRIVE

1. DESCRIPTION

A chain and sprocket drive is one way of conveying power to the wheels of a vehicle. Though many hundreds of years old, chain and sprocket drives are still used in bicycles and motorcycles as well as other forms of machinery.

.**Chain drive** is a way of transmitting mechanical power from one place to another. It is often used to convey power, particularly bicycles and motorcycles. It is also used in a wide variety of machines besides vehicles.

Most often, the power is conveyed by a roller chain, known as the **drive chain** or **transmission chain**, passing over a sprocket gear, with the teeth of the gear meshing with the holes in the links of the chain. The gear is turned, and this pulls the chain putting mechanical force into the system. Instead of using belts to transfer power from the engine to the wheels, a conveyor chain drive uses chains.

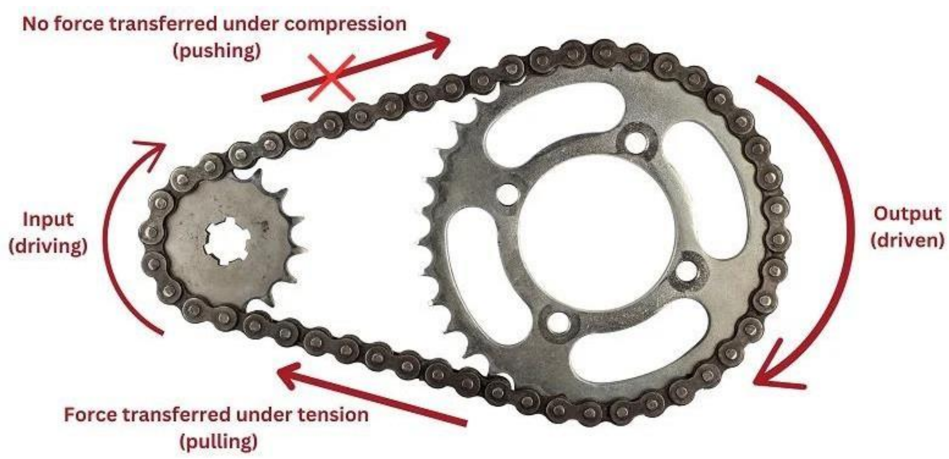


Fig 3.3 Sprocket and chain drive

2. TYPES

There's a wide variety of different chain drive designs developed due to finding use in many different mechanical applications. They can be classified into various categories depending on what we choose as a yardstick. When classifying based on their function, chain drives can be divided into three main types.

- Power transmission chain drive
- Conveyor chain drive
- Hoisting and hauling chain drive

Power transmission chain drive

This type of chain drive is specifically used for transmitting power between two shafts. Most machines that produce power cannot consume it at the same place, e.g. pumps with attached motors. Transmission systems convey power to the consumer through different methods. When chains are used for this process, they are known as power transmission chains.

Common examples are bikes, agricultural machinery, compressors, engine camshafts, etc. All these applications use chain drives for power transmission.

Conveyor chain drive

Another common application for chain drives is conveyor chains. Conveyors use chain drives that are crafted especially for material transportation. They come in hundreds of different designs and sport features such as low friction, high temperature- and chemical resistance. They can also be anti-static and magnetic.

Conveyor chain drives find use in industries such as packaging, automotive, food and beverage production, pharmaceuticals and textiles. Attachments can be fitted to conveyor chains to adapt them for various uses.

Hoisting and hauling chain drive

Chain hoists are probably the most common piece of machinery used to lift and lower equipment. They can lift massive weights with very little effort using pulleys.

Hand chain hoists or chain blocks are a common sight in garages, workshops, construction sites, ship engine rooms and in many factories. They can lift/lower heavy loads going up to 20 tonnes. Hoisting chains can be pneumatic, electrical or manual.

We will be focusing on the different types of chains in the next section but since hoisting chains are rather straightforward in their design and field of application, we'll be covering them here. Hoist chains can be divided into two categories:

- **Oval link chains**: Oval link chains are also known as coil chains. They are commonly used as hoisting chains for low to medium loads and are generally meant to be used in low-speed lifting applications. The chain link is oval-shaped and each one is welded after interlocking.
- **Stud link chains:** Stud link chains are a better alternative for high-load applications**.** Each chain link is fitted with a stud across its inner width. The

studs prevent kinking and increase strength and durability. Stud link chains find use in ship anchors and in other heavy-duty lifting machines.

Types of Chains used in Chain Drives

There exist several types of chains used in chain drives, each with its unique strengths and weaknesses. The five most prevalent types include:

1. **Roller Chain** (Bush Roller Chain)

Fig 3.4 Roller chain

Roller chains, commonly associated with power transmission, are widely employed in bicycles, motorcycles, and various transportation applications. Typically crafted from plain carbon steel or steel alloys, they comprise inner and outer plates, bushes, pins, and rollers. These rollers, evenly spaced between chain links, engage with sprocket teeth, efficiently transferring power. Notably, roller chains minimise power losses by rotating precisely when contacting sprocket teeth. In transmission chains, the height of the roller chain link plates exceeds that of the rollers, preventing contact with sprockets while acting as guides. For conveyor roller chains, larger roller diameters compared to sidebars enhance efficiency by reducing translational friction. Multi-strand roller chains accommodate higher power requirements.

2. Silent Chain (Inverted Tooth Chain)

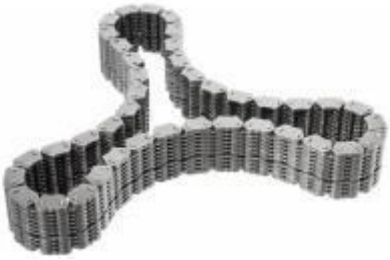


Fig 3.5 Silent chain

In environments sensitive to noise, silent chains, also known as inverted tooth chains, excel. They facilitate quiet operation while transmitting substantial power at high speeds. Silent chains feature flat plates arranged in rows, interconnected by pins. Each link mimics sprocket gear teeth contours on the underside, engaging with sprocket teeth. The load capacity of a silent chain increases with the number of flat plates per link, enhancing tensile strength and chain width.

3. Leaf Chain

Fig 3.6 Leaf chain

Simplicity defines leaf chains, consisting solely of pins and link plates, with alternating pin and articulated links. They don't mesh with sprocket teeth, instead running over sheaves for guidance. Leaf chains are prominent in lifting and counterbalancing applications and are found in equipment like lifts, lift trucks, forklifts, and straddle carriers.

These low-speed machines place high static loads on the lift's chain, which leaf chains handle adeptly, particularly in managing shock and inertia.

4. **Flat-Top Chain**

Fig 3.7: Flat Top chain

Designed exclusively for conveying, flat-top chains can replace conveyor belts and belt drives. Each link typically comprises a steel plate with barrel-shaped hollow protrusions on its underside, connected by pins through these protrusions. These joints allow movement in a single direction. Some flat-top chain variations offer sideways flexibility, enabling navigation around curves. Low-speed conveyor machines in assembly lines commonly utilise flat-top chains for material transportation.

5. **Engineering Steel Chain**

Fig:3.8 steel chain

Originating in the 1880s, engineering steel chains were engineered to withstand the harshest environments and the most demanding applications. Comprising links and pin joints, they feature larger component clearances to accommodate dust, dirt, and abrasives and operate under typical conditions. Today's engineering steel chains offer increased strength, wear resistance, loading capacity, and pitch to align with modern industrial requirements. These chains function as conveyor chains for material handling and are integral in applications such as conveyors, forklifts, bucket elevators, and drilling machines.

3. MECHANISM

The output from power sources such as electric motors, car engines and wind generators is rotary motion of a drive shaft. The output rotary motion and force must be transmitted from the power source to a mechanism that will use the energy in some way. The usual ways of transmitting motion and force from the output drive shaft to a shaft in a mechanism is through:

- gears
- belt and pulleys
- chain and sprockets
- a crank
- couplings.

This section will explain how motion and force is transmitted from the output shaft of a power source through a chain and sprocket to other parts of a mechanism. Chain and sprocket mechanisms perform the same task as a belt and pulley system, i.e. they transfer motion and force from one shaft to another. A belt can slip on a pulley but the teeth on the sprocket prevent the chain from slipping. A chain and sprocket is used wherever a positive, non-slip drive is required, e.g. bicycles, motorcycles, forklift mechanisms, and the camshaft drives in car petrol engines. A chain and sprocket drive is one way of conveying power to the wheels of a vehicle. Though many hundreds of years old, chain and sprocket drives are still used in bicycles and motorcycles as well as other forms of machinery.and environmentally resistant chains with special corrosion resistance

There are 6 major groups of power transmission chains:

• standard general purpose roller chains, widely used in industry

• high performance roller chains, these roller chains are stronger than general purpose roller chains

• lube-free chains, these chains can be used without lubrication

• environmentally resistant chains with special corrosion resistance

• specialty chains,

Type 1, used as bicycle chains, motor cycle chains, automotive chains • specialty chains,

Type 2, including miniature chains, leaf chains and inverted tooth chain, i.e. silent chains. Most of these chains are the roller type, i.e. they are composed of link plates, pins that join the link plates and also rollers and bushes.

Fig 3.9 Roller chain parts

4. APPLICATIONS

- Automotive timing systems.
- Bicycles for pedal-to-wheel power transfer.
- Conveyor systems for material handling.
- Industrial machinery in manufacturing.
- Agricultural equipment like tractors.
- Lifting and hoisting in cranes and hoists.
- Mining equipment for conveyors and rigs.

3.5.1. FLY WHEEL

1. DESCRIPTION

Flywheel, heavy wheel attached to a rotating shaft so as to smooth out delivery of power from a motor to a machine. The inertia of the flywheel opposes and moderates fluctuations in the speed of the engine and stores the excess energy for intermittent use. To oppose speed fluctuations effectively, a flywheel is given a high rotational inertia; *i.e.*, most of its weight is well out from the axis. A wheel with a heavy rim connected to the central hub by spokes or a web (wheel A in the Figure) has a high rotational inertia. Many flywheels used on reciprocating engines to smooth out the flow of power are made in this way. The energy stored in a flywheel, however, depends on both the weight distribution and the rotary speed; if the speed is doubled, the kinetic energy is quadrupled. A rim-type flywheel will burst at a much lower rotary speed than a disk-type wheel of the same weight and diameter. For minimum weight and high energy-storing capacity, a flywheel may be made of high-strength steel and designed as a tapered disk, thick at the centre and thin at the rim

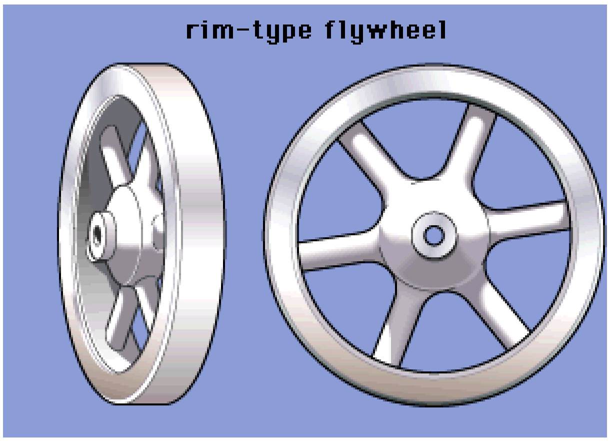


Fig 3.10 Rim type flywheel

2. CONSTRUCTION

Flywheels are commonly manufactured through casting, ensuring the device's structural integrity and strength. The following is a depiction of the construction of an armed flywheel.

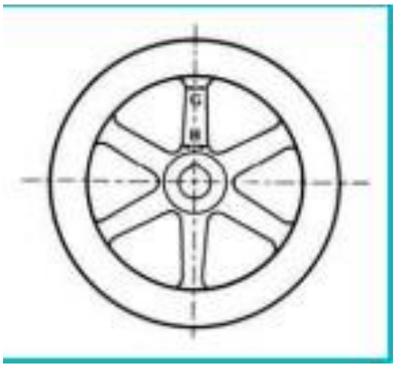


Fig 3.11 flywheel contruction

Rim

The flywheel consists of an outer circular disc known as the rim, which is intentionally made heavier than the inner body to enhance the transfer of kinetic energy. Additionally, the rim is equipped with teeth on its outer surface that engages with an electric motor, aiding in the engine's startup process.

Once the engine is operational, the rotating motion of the motor is utilised to generate electricity, effectively transforming it into a generator. This allows the flywheel to serve the dual purpose of facilitating engine startup and harnessing rotational energy for electricity generation.

Web

The type of flywheel, whether it should be an arm type or a web type, is determined by its size. If the diameter of the flywheel is less than 600mm, it is classified as a web type and cast as a single piece. The flywheel is considered an arm type and cast as a single piece for diameters greater than 600mm but less than 2.5 m. However, if the diameter exceeds 2.5m, it is still an arm type, but the rim and body are cast separately to accommodate the larger size.

Bore

The bore of a flywheel refers to the central opening or hollow space within the flywheel structure. It is the cylindrical space where the flywheel is mounted or attached to the engine's output shaft. The bore is typically designed to have a specific diameter and depth corresponding to the engine shaft's dimensions, ensuring a secure and precise fit.

Structure of a Modern Flywheel

Modern Flywheel comprises the following parts:

- Cover
- Springs
- Planetary wheel
- Axial and radial bearings
- Support disc and
- Sliding shoe

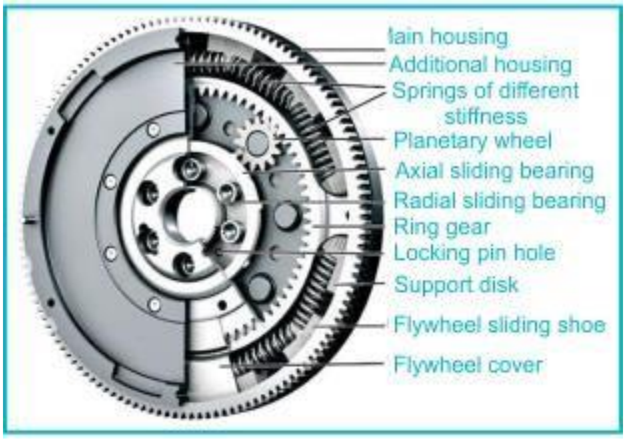


Fig 3.12 Structure of flywheel

Flywheel Cover

The cove serves as a sturdy and robust structural casing. It provides a protective barrier that encloses the flywheel, shielding it from external obstacles or hazards. Additionally, the cover rotates along with the flywheel, contributing to its overall stability and safeguarding it from potential damage. Its rigid construction ensures the durability and integrity of the flywheel, maintaining its functionality and protecting it from external forces.

Spring

Spring serves as a damping mechanism to mitigate abrupt vibrations, effectively safeguarding against sudden jolts or shocks. By absorbing and dissipating energy, the spring helps prevent any disruptive or harsh movements, contributing to a smoother and more stable operation. Its presence adds a protective element that reduces the impact of sudden jerks, enhancing overall safety and comfort.

Planetary wheel

A planetary wheel is positioned in conjunction with a planetary gear system. As the gear rotates, it generates a combined rotational force among the internal gears within the system. This compound moment created by the planetary gear arrangement enables the transmission of torque and power across the mechanism, facilitating efficient and effective operation.

Axial and Radial Bearings

The bearings come into play to compensate for any imbalances in the radial forces. They work to counteract and equalise these forces, ensuring a more balanced and stable operation within the system. By providing support and distributing loads effectively, the bearings help to minimise any adverse effects caused by radial force imbalances, thereby promoting smooth and reliable functioning.

Support disc

Within the system, an internal support disc is strategically positioned to provide stability and support for the springs and other movable components. This support disc serves as a structural foundation, ensuring proper alignment and functioning of the various moving parts. By offering a secure base for the springs and other elements, it helps maintain their integrity and facilitates their optimal performance within the system.

Sliding Shoe

Located on the inner wall of the flywheel, a protective lining is implemented to minimise wear and tear. Its purpose is to mitigate the friction and abrasion that can occur during operation, thereby extending the lifespan of the flywheel. By acting as a barrier between the rotating components and the inner wall, this lining effectively reduces the detrimental effects of wear, promoting durability and preserving the integrity of the flywheel.

3. WORKING

- The fundamental operational principle of a flywheel lies in its ability to store rotational energy during the power stroke and subsequently release it during the remaining strokes (suction, compression, and exhaust) of the engine cycle.
- The energy equation governing the flywheel relies on two key factors: the angular velocity (rotational speed) and the moment of inertia (resistance to changes in rotational motion) of the flywheel. These variables play a crucial role in determining the amount of energy the flywheel can store and deliver.
- By harnessing these principles, the flywheel ensures a more balanced and consistent operation of the engine, smoothing out power fluctuations and contributing to overall efficiency and stability.

Ek=12Iω2

ω= Angular Velocity

I= Momentof inertia

I=1/2mr2

With a change in the speed, the kinetic energy associated with the flywheel also gets altered, and this change in the kinetic energy of the flywheel is given by Change in Kinetic Energy Kinetic energy at initial Kinetic energy at final During the initial stage, the electric motor provides power to the flywheel, initiating its movement. This motion, in turn, prompts the piston to move, enabling the combustion of fuel within the combustion chamber.

- As the power stroke is activated, the flywheel extracts energy from this stroke and stores it. Subsequently, this stored energy is utilised to support the remaining three strokes of the engine cycle.
- By efficiently regulating and distributing power throughout the engine's operation, the flywheel plays a vital role in stabilising the rotational movement of the transmission system. It helps to minimise fluctuations and maintain a more consistent and smooth rotation, contributing to the overall efficiency and performance of the system.

4. TYPES

The different types of Flywheels include:

- Solid Disc Flywheel
- Rimmed Flywheel
- High Velocity Flywheel
- Low-velocity Flywheel

Solid disc Flywheel

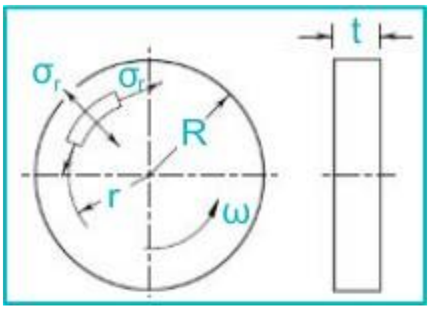


Fig 3.13 Solid disc flywheel

A solid disc flywheel is crafted from cast iron material, imparting robustness and durability. Its solid cross-section design ensures enhanced strength and stability, making it a reliable component within the system. By utilising cast iron, the solid disc flywheel offers a sturdy construction that can withstand the demanding forces and pressures encountered during operation, contributing to its overall performance and longevity.

Rimmed Flywheel

Fig 3.14 Rimmed flywheel

In comparison to a solid disc of the same dimensions, a rimmed flywheel exhibits wear at lower RPM levels. This characteristic makes it well-suited for low-capacity engines that operate at high torque but low velocity. Due to its design, the rimmed flywheel is optimised to effectively handle the specific demands of such engines, ensuring reliable performance and longevity while operating within the desired RPM range. Its construction allows for efficient energy transfer and enhanced durability, making it an ideal choice for engines characterised by high torque and lower rotational speeds.

High-velocity Flywheel

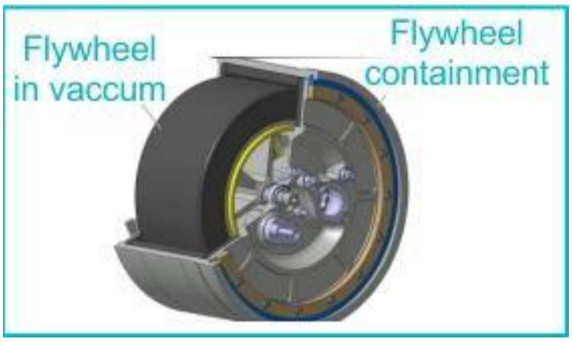


Fig 3.15 High velocity flywheel

High-velocity ranges typically span from 30,000 RPM to 80,000 RPM. These components are designed to be lighter in weight, enabling them to rotate at elevated speeds. The emphasis on reduced weight facilitates the ability of these high-velocity components to attain and sustain the desired rotational velocities. By optimising their design for lighter construction, they are engineered to operate efficiently and safely within the specified high RPM range, meeting the demands of applications that require rapid rotational motion.

5. APPLICATIONS

- **Energy Storage:** Flywheels are used in energy storage systems, allowing for the accumulation and release of rotational kinetic energy to provide backup power or stabilise electrical grids.
- **Transportation:** Flywheels are employed in vehicles, such as hybrid buses and trains, to store and deliver energy, improving fuel efficiency and reducing emissions.
- **Renewable Energy**: Flywheels can be utilised in renewable energy systems, such as wind and solar power, to store excess energy during peak production and release it during periods of high demand.
- **Power Generation:** Flywheel-based generators are used in remote areas or as backup power sources, providing reliable electricity when conventional power supply is limited or unavailable.
- **Mechanical Engineering:** Flywheels are commonly employed in various mechanical systems, including engines, to provide smooth power delivery, reduce vibrations, and enhance overall performance.
- **Manufacturing:** Flywheels are used in industrial machinery and manufacturing processes that require rotational energy storage and controlled release for tasks such as machining, stamping, or cutting.

3.6.1 DC GENERATOR

1. DESCRIPTION

An electromechanical energy converter that uses electromagnetic induction to transform mechanical power into DC electrical power is known as a DC generator. It is a rotating machine that provides an electrical output with unidirectional voltage and current.

In this article, we will learn about DC generators, their construction, working principle, types and uses along with real-life examples of DC generators.

A direct current (DC) generator is a type of electrical machine used to transform mechanical energy into DC electricity. The principle of energetically induced electromotive force is used in the energy alteration process.

According to the electromagnetic induction principle of Faraday's Laws, when a conductor cuts magnetic flux, an energetically induced electromotive force is produced in it. Even if the conductor circuit is not opened, this electromotive force can still result in a current flow.

2. CONSTRUCTION

A DC generator is also referred to as a DC machine. The main components of a DC generator are given below:

Stator-It is the stationary component of the system. The stator also has a core, stator winding, and an outer frame. The stator is an essential feature of dc generators and serves as the source of magnetic fields around which the coils spin. There are two stable magnets in this that have opposite poles facing each other.

Rotor-The rotor or armature core, which is made up of a fan, an armature, a commutator, and a shaft, is another crucial component of a DC generator. This component rotates in the magnetic field produced by the stator but is movable, unlike the stator. Iron slot laminations with slots that have been layered to create a cylindrical armature core make up the armature core. This lamination decreases the energy loss caused due to eddy current.

Armature Windings- The armature core slots are primarily utilized to hold the armature windings. To increase the quantity of produced current, they are connected in series to parallel in the form of a closed-circuit winding. The armature winding, a unique configuration of conductors, is regarded as the brain or centre of a DC generator. Armature windings can be either lap winding or wave winding, depending on the type of connections.

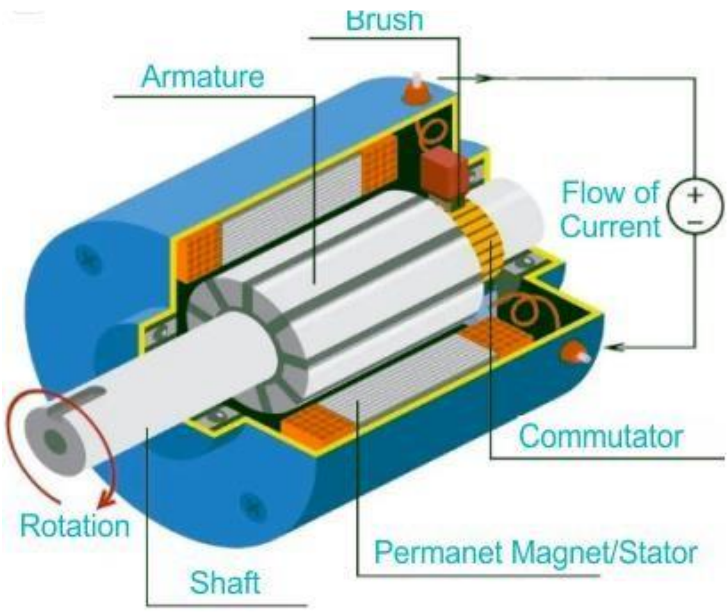


Fig 3.16 Generator DC

Bearings- A system uses bearings to provide smooth movement of the different parts of the DC machine. The friction between the machine's spinning and stationary components is reduced with the help of bearings. As a result, the system's components don't require constant lubrication and will last longer.

Roller bearings and ball bearings are the two most prevalent types of bearings used in a dc generator.

Yoke- The yoke is the outside cover made up of cast iron or steel that not only secures the inner assembly to the machine’s base and offers mechanical protection for it, but also provides a conduit for the magnetic flow that the field winding generates.

Poles- The main purpose of poles is to maintain the field windings. Typically, these windings are wound on the poles and connected to the armature windings in a specific order. As a result, the poles attach the welding procedure to the yoke using screws.

Pole Shoe- An iron or steel plate called a pole shoe is used primarily to spread the magnetic flux and prevent the spinning field coil from dropping.

Commutator- In order to reinforce the armature winding, the commutator converts AC voltage to DC voltage similarly to a rectifier. Mica sheets are used to protect each copper segment in this conductive metal from the other.

Brushes- One of the key components of the DC generator is brushes. These carbon blocks make it possible to guarantee the electrical connection between the commutator and the external load circuit.

Shaft- In a DC machine, the shaft is a mechanical component that causes rotation by producing torque. It has a maximum breaking strength and is made of mild steel. The shaft is one of the components of a DC generator that aids in the generator’s ability to transfer mechanical energy. The commutator, cooling fan, armature centre, and other rotating components are keyed into the shaft.

3. WORKING

An electromagnetic field (emf) is induced in a current-carrying conductor when it is put in a changing magnetic field according to Faraday's law of electromagnetic induction and Fleming's right-hand rule states that as the conductor's direction of motion alters, so does the direction of the induced current. According to Faraday's law of electromagnetic induction, we know that when a current-carrying conductor is placed in a varying magnetic field, an emf is induced in the conductor. According to Fleming's right-hand rule, the direction of the induced current changes whenever the direction of motion of the conductor changes. Let us consider an armature rotating clockwise and a conductor at the left moving upwards. When the armature completes a half rotation, the direction of the motion of the conductor will be reversed downward. Hence, the direction of the current in every armature will be alternating.The induced current will flow along the closed path of the conductor when the situation is provided. The armature conductors are spun into the electromagnetic field created by the field coils in a DC generator. As a result, the conductors in the armature produce an electromagnetically induced emf.

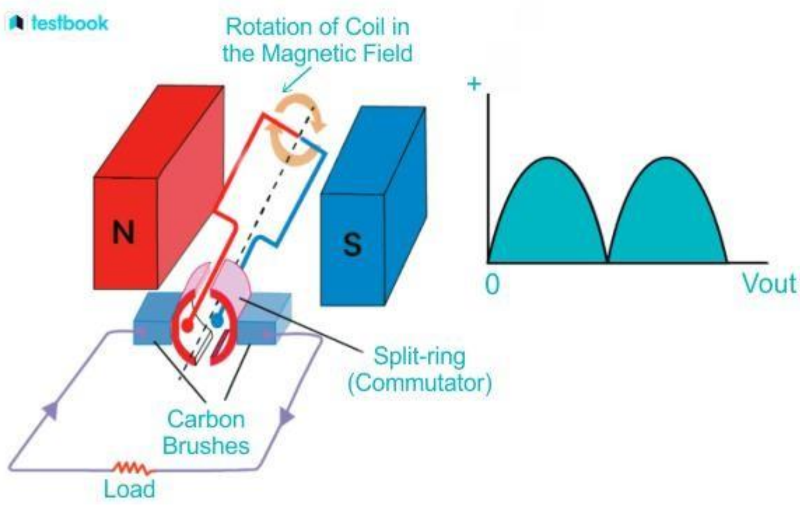


Fig 3.17 Working of generator

Consider an armature revolving in a clockwise direction while a conductor is travelling upward from the left. The direction of that specific conductor's motion will change to downward after the armature completes a half rotation. As a result, the current will flow through each armature conductor in an alternating fashion. However, a split ring commutator also reverses the connections of the armature conductors when the current is reversed. As a result, the terminals experience unidirectional current.

4. TYPES

The DC generator can be classified into two main categories as separately excited and self excited.

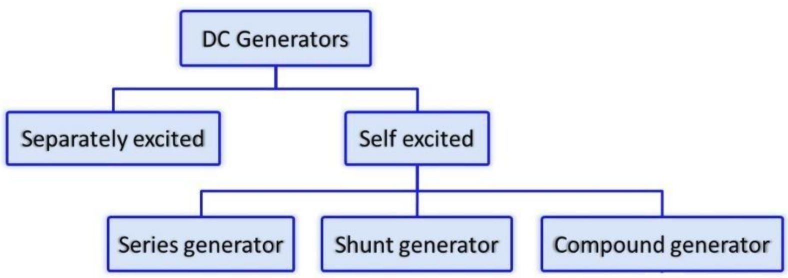


Fig 3.18 Types of generator

Separately Excited

The field coils are energized from an independent exterior DC source in a separately excited type generator.

Self Excited

In a self-excited type, the field coils are energized from the generated current within the generator. These types of generators can further be classified into *a* **series of wounds**, **shunt-wound**, and **compound wound**.

5. EMF EQUATION

The emf equation of the DC generator is given by the equation:

$e = \Phi pzn/60 \times A$ volts

where

Z is the total number of armature conductor

P is the number of poles in a generator

A is the number of parallel lanes within the armature

N is the rotation of armature in r.p.m

E is the induced e.m.f in any parallel lane within the armature

$\mathbf{E_g}$ is the generated e.m.f in any one of the parallel lane

N/60 is the number of turns per second

The time for one turn will be dt=60/N sec.

6. CHARACTERISTICS

The speed of a DC generator is made constant by the prime mover. Under such conditions, the performance of the generator is given by the relation among the excitation, terminal voltage and load. These relations are given graphically in the form of curves, which are called as characteristics of DC generators. These characteristics show the behaviour of the DC generator under different load conditions.

The following are the main characteristics of a DC generator

Open Circuit Characteristics or Magnetisation Curve

This is the graph plotted between the generated EMF at no-load (E_0) and the field current (I_f) at a given constant speed. It is also known as no-load saturation curve. Its shape being practically the same for all types of DC generators whether separately-excited or self-excited.

Internal Characteristics

It is the graph plotted between generated EMF (E) on-load and the armature current. Because of the effect of armature reaction, the magnetic flux on-load will be less than the flux at no load. Therefore, the generated EMF (E) under loaded condition will be less than the EMF generated (E_0) at no-load. As a result of this, the internal characteristics curve lies just below the open circuit characteristics.

External Characteristics or Load Characteristics

The external characteristics or load characteristics is the plot between the terminal voltage (V) and load current (I_L). Since, the terminal voltage is less than the generated voltage due to armature and series field copper losses. Hence, the external characteristics curve will lie below the internal characteristics curve by an equal amount to voltage drop due to copper losses in the machine.

7. APPLICATIONS

- The separately excited type DC generators are used for power and lighting purposes.
- The series DC generator is used in arc lamps for lighting, stable current generator and booster.
- DC generators are used to reimburse the voltage drop within Feeders.

- DC generators are used to provide a power supply for hostels, lodges, offices, etc.

3.7.1 BATTERY

1. INTRODUCTION

A battery can be defined as an electrochemical device (consisting of one or more electrochemical cells) which can be charged with an electric current and discharged whenever required. Batteries are usually devices that are made up of multiple electrochemical cells that are connected to external inputs and outputs. A battery is a device that converts chemical energy to electrical energy. A battery's chemical reactions involve the flow of electrons from one material (electrode) to another via an external circuit. The flow of electrons generates an electric current, which can be used to perform work.

Batteries are broadly classified into two categories, namely primary batteries and secondary batteries. Primary batteries can only be charged once. When these batteries are completely discharged, they become useless and must be discarded. The most common reason why primary batteries cannot be recharged is that the electrochemical reaction that takes place inside of them is irreversible in nature. It is important to note that primary batteries are also referred to as use-and-throw batteries. Therefore, secondary batteries are also known as rechargeable batteries. When discharging, the reactants combine to form products, resulting in the flow of electricity. When charging, the flow of electrons into the battery facilitates the reverse reaction, in which the products react to form the reactants. The cell or battery must be capable of providing a constant voltage.

2. TYPES

There are three different types of batteries that are commonly used - Alkaline, Nickel Metal Hydride (NiMH), and Lithium Ion. The use of different metals and electrolytes in these batteries gives them different properties which means they are suited to different contexts.

Alkaline batteries:

Alkaline batteries are the most popular type of single-use battery. The cheapest category of battery, these non-rechargeble batteries maintain a consistent discharge throughout their lifetime, leading to reliable performance. While convenient, the disposable nature of alkaline batteries means that they are not an environmentally friendly option.

NiMH Batteries:

NiMH batteries were the first rechargable batteries to be developed. This ability is an advantage in terms of efficiency and financial impact. NiMH batteries can take a long time to charge, and the more times they have been recharged, the less power they produce.

Lithium Ion Batteries :

Lithium Ion batteries are a newer development in rechargeable batteries and have become commonly used in laptops and phones. More expensive than NiMH at the point of purchase, the amount of possible recharges means that they will save money over time. Quick charging and more consistent power output throughout their lifetime also contribute to the popularity of lithium batteries.

Where high values of load current are necessary, the lead-acid cell is the type most commonly used. The electrolyte is a dilute solution of sulfuric 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 shortends the useful life to about 3 to 5 years for an automobile battery. Of the different types of secondary cells, the lead-acid type has the highest output voltage, which allows fewer cells for a specified battery voltage.

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 sulfuric acid. Each plate is a grid or framework, made of a lead-antimony alloy.

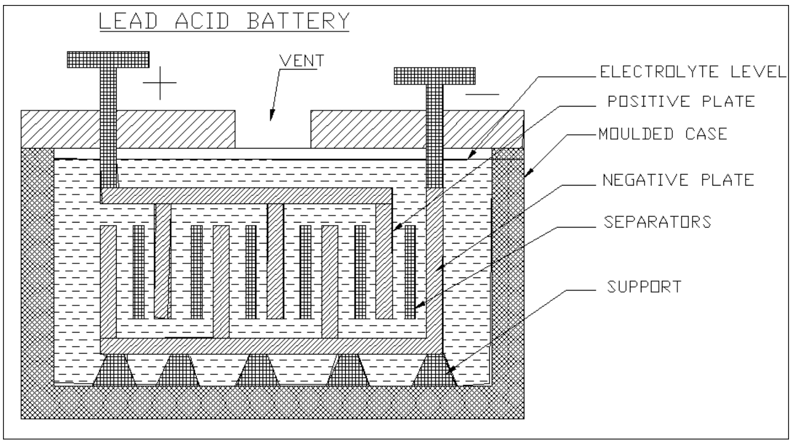


Fig 3.19 Lead acid battery

This construction enables the active material, which is lead oxide, to be pasted into the grid. In manufacture of the cell, a 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.

CHEMICAL ACTION:

Sulfuric acid is a combination of hydrogen and sulfate ions. When the cell discharges, lead peroxide from the positive electrode combines with hydrogen ions to form water and with sulfate ions to form lead sulfate. Combining lead on the negative plate with sulfate ions also produces he sulfate.

There fore, the net result of discharge is to produce more water, which dilutes the electrolyte, and to form lead sulfate on the plates. As the discharge continues, the sulfate fills the pores of the grids, retarding circulation of acid in the active material. Lead sulfate is the powder often seen on the outside terminals of old batteries. When the combination of weak electrolyte and sulfating on the plate lowers the output of the battery, charging is necessary.

On charge, the external D.C. source reverses the current in the battery. The reversed direction of ions flows in the electrolyte result in a reversal of the chemical reactions. Now the lead sulfates on the positive plate reactive with the water and sulfate ions to produce lead peroxide and sulfuric acid. This action re-forms the positive plates and makes the electrolyte stronger by adding sulfuric acid.

At the same time, charging enables the lead sulfate on the negative plate to react with hydrogen ions; this also forms sulfuric acid while reforming lead on the negative plate to react with hydrogen ions; this also forms currents can restore the cell to full output, with lead peroxide on the positive plates, spongy lead on the negative plate, and the required concentration of sulfuric acid in the electrolyte.

The chemical equation for the lead-acid cell is

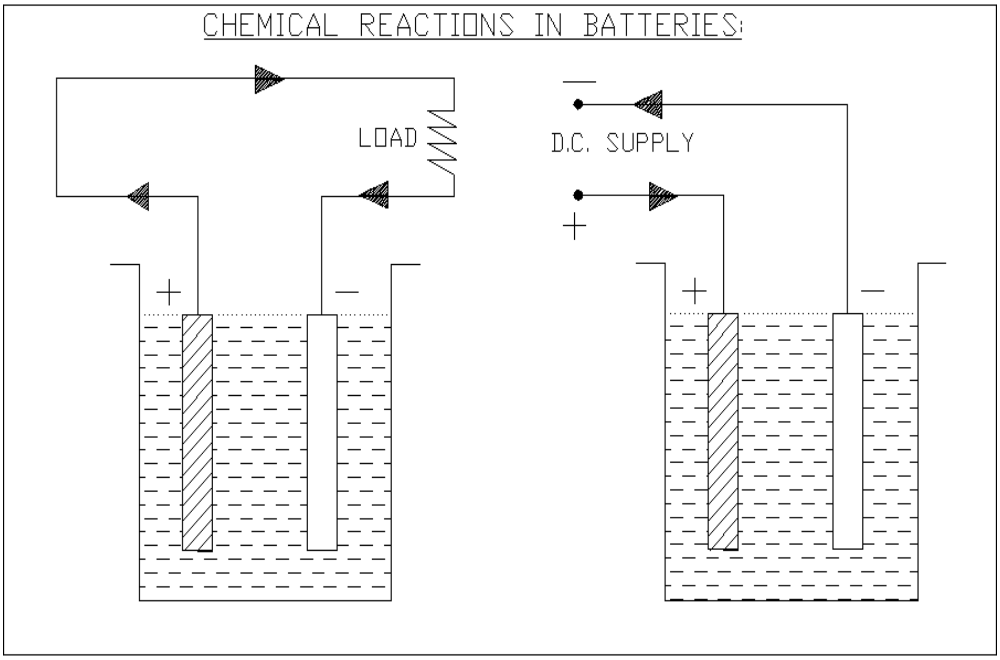


Fig 3.20 Chemical reactions in batteries

$$Pb + pbO_2 + 2H_2SO_4 \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftarrows}} 2pbSO_4 + 2H_2O$$

On discharge, the pb and pbo_2 combine with the SO_4 ions at the left side of the equation to form lead sulfate ($pbSO_4$) and water (H_2O) at the right side of the equation. One battery consists of 6 cell, each have an output voltage of 2.1V, which are connected in series to get an voltage of 12V and the same 12V battery is connected in series, to get an 24 V battery. They are placed in the water proof iron casing box.

CURRENT RATINGS:

Lead-acid batteries are generally rated in terms of how much discharge currents they can supply for a specified period of time; the output voltage must be maintained above a minimum level, which is 1.5 to 1.8V per cell. A common rating is ampere-hours (A.h.) based on a specific discharge time, which is often 8h. Typical values for automobile batteries are 100 to 300 A.h.

As an example, a 200 A.h battery can supply a load current of 200/8 or 25A, used on 8h discharge. The battery can supply less current for a longer time or more current for a shorter time. Automobile batteries may be rated for "cold cranking power", which is related to the job of starting the engine. A typical rating is 450A for 30s at a temperature of 0 degree F.

Note that the ampere-hour unit specifies coulombs of charge. For instance, 200 A.h. corresponds to 200A*3600s (1h=3600s). the equals 720,000 A.S, or coulombs. One ampere-second is equal to one coulomb. Then the charge equals 720,000 or 7.2*10^5ºC. To put this much charge back into the battery would require 20 hours with a charging current of 10A.

The ratings for lead-acid batteries are given for a temperature range of 77 to 80ºF. Higher temperature increase the chemical reaction, but operation above 110ºF shortens the battery life.

Low temperatures reduce the current capacity and voltage output. The ampere-hour capacity is reduced approximately 0.75% for each decreases of 1º F below normal temperature rating. At 0ºF the available output is only 60 % of the ampere-hour battery rating.

In cold weather, therefore, it is very important to have an automobile battery unto full charge. In addition, the electrolyte freezes more easily when diluted by water in the discharged condition.

SPECIFIC GRAVITY:

Measuring the specific gravity of the electrolyte generally checks the state of discharge for a lead-acid cell. Specific gravity is a ratio comparing the weight of a substance with the weight of a substance with the weight of water. For instance, concentrated sulfuric acid is 1.835 times as heavy as water for the same volume. Therefore, its specific gravity equals 1.835. The specific gravity of water is 1, since it is the reference.

In a fully charged automotive cell, mixture of sulfuric acid and water results in a specific gravity of 1.280 at room temperatures of 70 to 80°F. as the cell discharges, more water is formed, lowering the specific gravity. When it is down to about 1.150, the cell is completely discharged.

Specific-gravity readings are taken with a battery hydrometer, such as one in figure (7). Note that the calibrated float with the specific gravity marks will rest higher in an electrolyte of higher specific gravity. The decimal point is often omitted for convenience. For example, the value of 1.220 in figure (7) is simply read "twelve twenty". A hydrometer reading of 1260 to 1280 indicates full charge, approximately 12.50 are half charge, and 1150 to 1200 indicates complete discharge.

The importance of the specific gravity can be seen from the fact that the open-circuit voltage of the lead-acid cell is approximately equal to

$$V = \text{Specific gravity} + 0.84$$

For the specific gravity of 1.280, the voltage is 1.280 = 0.84 = 2.12V, as an example. These values are for a fully charged battery.

CHARGING THE LEAD-ACID BATERY:

The requirements are illustrated in figure. An external D.C. voltage source is necessary to produce current in one direction. Also, the charging voltage must be more than the battery e.m.f. Approximately 2.5 per cell are enough to over the cell e.m.f. so that the charging voltage can produce current opposite to the direction of discharge current.

Note that the reversal of current is obtained just by connecting the battery VB and charging source VG with + to + and –to-, as shown in figure. The charging current is reversed because the battery effectively becomes a load resistance for VG when it higher than VB. In this example, the net voltage available to produce charging currents is 15-12=3V.

A commercial charger for automobile batteries is essentially a D.C. power supply, rectifying input from the AC power line to provide D.C. output for charging batteries. Float charging refers to a method in which the charger and the battery are always connected to each other for supplying current to the load. In figure the charger provides current for the load and the current necessary to keep the battery fully charged. The battery here is an auxiliary source for D.C. power.

It may be of interest to note that an automobile battery is in a floating-charge circuit. The battery charger is an AC generator or alternator with rectifier diodes, driver by a belt from the engine. When you start the car, the battery supplies the cranking power. Once the engine is running, the alternator charges he battery. It is not necessary for the car to be moving. A voltage regulator is used in this system to maintain the output at approximately 13 to 15 V.

The constant voltage of 24V comes from the solar panel controlled by the charge controller so for storing this energy we need a 24V battery so two 12V battery are connected in series. It is a good idea to do an equalizing charge when some cells show a variation of 0.05 specific gravity from each other.

This is a long steady overcharge, bringing the battery to a gassing or bubbling state. Do not equalize sealed or gel type batteries. With proper care, lead-acid batteries will have a long service life and work very well in almost any power system. Unfortunately, with poor treatment lead-acid battery life will be very short.

3. WORKING

A battery is a device, which consists of a various voltaic cells. Each voltaic cell consists of two half cells connected in series by a conductive electrolyte holding anions and cat ions. One half-cell includes electrolyte and the electrode to which anions move, i.e. the anode or negative electrode; the other half-cell includes electrolyte and the electrode to which cat ions move, i.e. the cathode or positive electrode.In the redox reaction that powers the battery, reduction occurs to cations at the cathode, while oxidation occurs to anions at the anode. The electrodes do not touch one another but are electrically connected by the electrolyte. Mostly the half cells have different electrolytes. All things considered every half-cell is enclosed in a container and a separator that is porous to ions but not the bulk of the electrolytes prevent mixing.

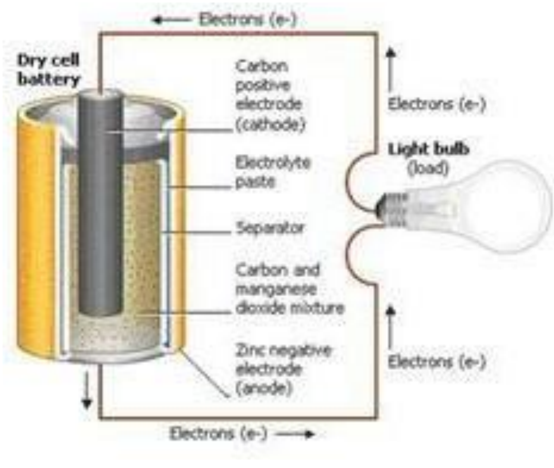


Fig 3.21 Battery Structure

Each half cell has an electromotive force (Emf), determined by its capacity to drive electric current from the interior to the exterior of the cell. The net emf of the cell is the difference between the emf of its half-cells. In this way, if the electrodes have emf and in other words, the net emf is the difference between the reduction potentials of the half-reactions. An electrical load is a device that uses electricity to do work or to perform a job. If an electrical load—such as a light bulb—is placed along the wire, the electricity can do work as it flows through the wire and the light bulb. Electrons flow from the negative end of the battery through the wire and the light bulb and back to the positive end of the battery. The metal that frees more electrons develops a positive charge, and the other metal develops a negative charge. If an electrical *conductor*, or wire, connects one end of the battery to the other, electrons flow through the wire to balance the electrical charge.

4. APPLICATIONS

The small essential components that can operate many devices are the batteries. It has become one of the key components in our everyday lives. There are some batteries which can be recharged and are used in mostly each and every sector. Some of the applications of the batteries are given below.

- House
- Health Instruments
- Medical
- Logistics and construction
- Firefighting and Emergency
- Military

3.8.1 INVERTER

1. INTRODUCTION

An inverter can be defined as it is a compact and rectangular shaped electrical equipment used to convert direct current (DC) voltage to alternating current (AC) voltage in common appliances. The applications of DC involves several small types of equipment like solar power systems. Direct current is used in many of the small electrical equipment such as solar power systems, power batteries, power-sources, fuel cells because these are simply produced direct current.

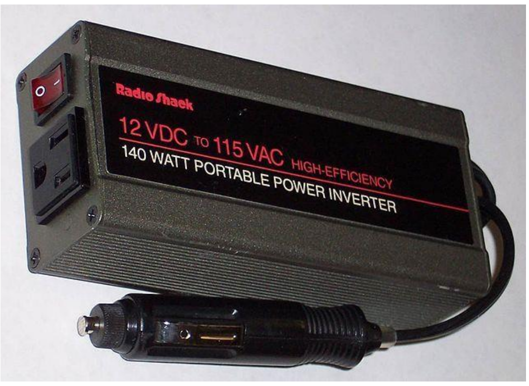


Fig 3.22 Power inverter

The basic role of an inverter is to change DC power into AC power. The AC power can be supplied to homes, and industries using the public utility otherwise power grid, the alternating-power systems of the batteries can store only DC power. In addition, almost all the household appliances, as well as other electrical equipment can be functioned by depending on AC power.

In some cases, generally, the input voltage is lesser whenever the output voltage is equivalent to the grid supply voltage of either 120 V otherwise 240 V based on the country. These devices are standalone devices for some applications like solar power. There are different types of inverters available in the market based on the switching waveform shape. An inverter uses DC power sources to provide an AC voltage to giving the supply to the electronic as well as electrical equipment. he inverter is a device that converts DC electricity (battery, storage battery) into AC power with a fixed frequency and voltage or with frequency modulation and voltage management (usually 220V, 50Hz sine wave). It is made up of semiconductor power devices as well as drive and circuits for inverters, The creation of new high-power semiconductor devices and drive control circuits has been aided by the advancement of microelectronic and power electronics technologies.

2. TYPES

Inverters are classified into two type's namely single phase and three phases

Single Phase Inverter

Single phase inverters are classified into two types namely half-bridge inverter & full bridge inverter

Half Bridge Inverter :

The half-bridge inverter is an essential building block in the full bridge inverter. It can be built with two switches where each one of its capacitors includes an o/p voltage which is equivalent to Vdc2. Additionally, the switches balance each other, if one switch is activated then automatically another switch will deactivate.

Full Bridge Inverter :

The full bridge inverter circuit converts direct current to alternate current. It can be achieved by opening as well as closing the switches within the correct series. This type of inverter has dissimilar operating states which depend on closed switches.

Three Phase Inverter

A three-phase inverter is used to alter an input DC to a 3-phase output AC. Generally, its 3-arms are deferred with 120° of an angle to produce a 3-phase AC supply. The inverter control which has a 50% of the ratio as well as controlling can take place after every T/6 of the time T. The switches used in the inverter complement each other.

The 3-single phase inverters place across the similar DC source, and the pole voltages within a 3-phase inverter are equivalent to the pole voltages within 1-phase half-bridge inverter. These inverters have two conduction modes such as 120°-mode of conduction & 180° mode of conduction.

3. WORKING

The working of an inverter is, it converts DC to AC, and these devices never generate any kind of power because the power is generated by the DC source. In some situations like when the DC voltage is low then we cannot use the low DC voltage in a home appliance. So due to this reason, an inverter can be used whenever we utilize solar power panel. the converter circuit used in the front part constantly converts alternating current to direct current. This process is called rectification. The wave's direction and magnitude changes periodically over time since alternating current is a sine wave. Therefore a diode, which is a semiconductor device, is used so as to pass electricity in a forward direction to convert it into direct current, but not in the reverse direction.

When direct current goes through the diode, only the forward direction passes electricity and a positive peak appears. However, the other half of the cycle will be wasted because it does not pass the peak in the negative direction. The reason why the diode's structure is shaped like a bridge is so that it can pass the negative peak in a forward direction. This is called full-wave rectification due to the fact that it transforms both the forward and negative wave peaks.

The inverter circuit then outputs alternating current with varying voltage and frequency. The DC/AC conversion mechanism switches power transistors such as "IGBT (Insulated Gate Bipolar Transistor)" and changes the ON/OFF intervals to create pulse waves with different widths. It then combines them into a pseudo sine wave. This is called “Pulse Width Modulation (PWM)”.

4. CIRCUIT DIAGRAM

There are many basic electrical circuits for the power devices, a transformer, and switching devices. The DC alteration to an AC can be attained by stored energy within the DC source like the battery. The entire process can be done with the help of switching devices which are constantly turned ON & OFF, and then stepping-up with the transformer. There are many basic electrical circuits for the power devices, a transformer, and switching devices. An easy push-pull direct current to an alternating current inverter by center tap transformer circuit

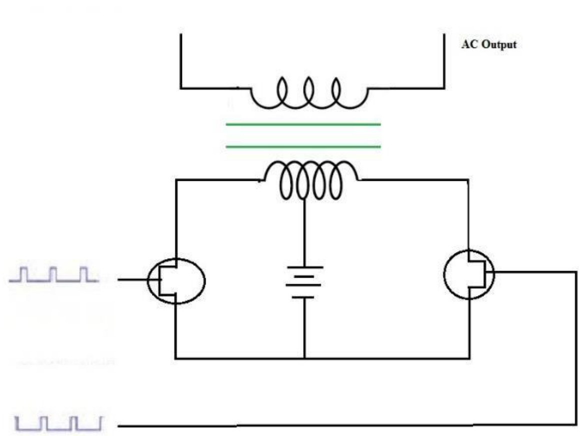


Fig 3.23 Inverter circuit

The input DC voltage can be turned ON/OFF by using power devices like **MOSFETs** otherwise power transistors. The changing voltage within the primary makes an alternating voltage at resultant winding. The working of the transformer is equivalent to an amplifier where the output can be increased from the voltage supply by the batteries to 120 V otherwise 240 V.

There are three frequently used inverter o/p stages are, a push-pull by center tap transformer, push-pull by half-bridge, and push-pull by the full bridge. This is most popular because of its ease and, definite results; but, it employs a huge transformer with lower efficiency. An easy push-pull direct current to an alternating current inverter by center tap transformer circuit can be shown in the below figure.

5. APPLICATIONS

These are used in a variety of applications like tiny car adapters to the office, household applications, as well as large-grid systems.

- Inverters can be used as an UPS-Uninterruptible power supplies
- These can be used as standalone inverters
- These can be used in solar power systems
- An inverter is the basic building block of an SMPS- switched mode power supply.
- These can be used in Centrifugal fans, pumps, mixers, extruders, test stands. conveyors, metering pumps. and Web-handling equipment.
- adapters to the office, household applications, as well as large-grid systems.

3.9.1 VOLTAGE SENSOR

1. DESCRIPTION

A voltage sensor is a device that measures voltage. Voltage sensors can measure the voltage in various ways, from measuring high voltages to detecting low current levels. These devices are essential for many applications, including industrial controls and power systems. This sensor is used to monitor, calculate and determine the voltage supply. This sensor can determine the AC or DC voltage level. The input of this sensor can be the voltage whereas the output is the switches, analog voltage signal, a current signal, an audible signal, etc. Some sensors provide sine waveforms or pulse waveforms like output & others can generate outputs like AM (Amplitude Modulation), PWM (Pulse Width Modulation) or FM(Frequency modulation).

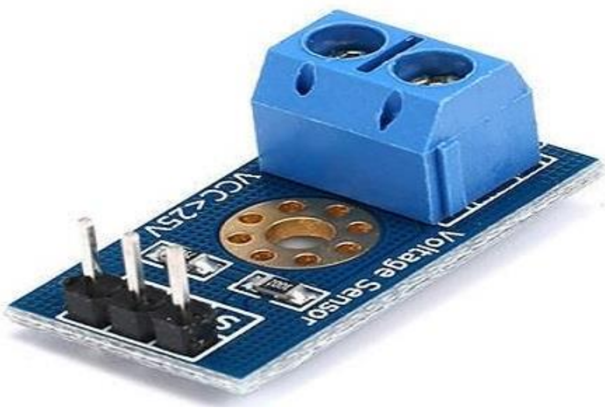


Fig 3.24 Voltage Sensor

This sensor includes input and output. The input side mainly includes two pins namely positive and negative pins. The two pins of the device can be connected to the positive & negative pins of the sensor. The device positive & negative pins can be connected to the positive & negative pins of the sensor. The output of this sensor mainly includes supply voltage (Vcc), ground (GND), analog output data.

2. TYPES

These sensors are classified into two types like a resistive type sensor and capacitive type sensor.

1) Resistive Type Sensor

This sensor mainly includes two circuits like a voltage divider & bridge circuit. The resistor in the circuit works as a sensing element. The voltage can be separated into two resistors like a reference voltage & variable resistor to make a circuit of the voltage divider. A voltage supply is applied to this circuit. The output voltage can be decided by the resistance used in the circuit. So the voltage change can be amplified.

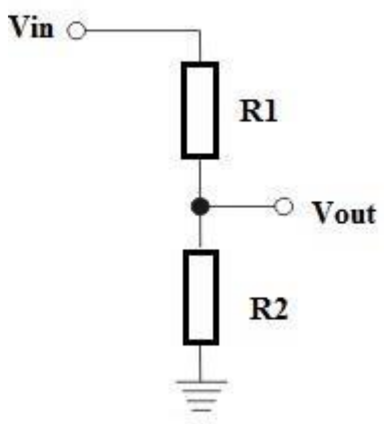


Fig 3.25 Resistive-type-voltage-sensor

The bridge circuit can be designed with four resistors. One of these resistors can be subjected to the voltage detector device. The change in voltage can be directly exhibited. This difference alone can be amplified but the difference within the voltage divider circuit not only amplified.

2) Capacitor Type Sensor

This type of sensor consists of an insulator and two conductors within the center. As the capacitor is power-driven with 5 Volt, then the flow of current will be there in the capacitor. This can create revulsion of electrons within the capacitor. The difference in capacitance indicates the voltage and the capacitor can be connected within the series.

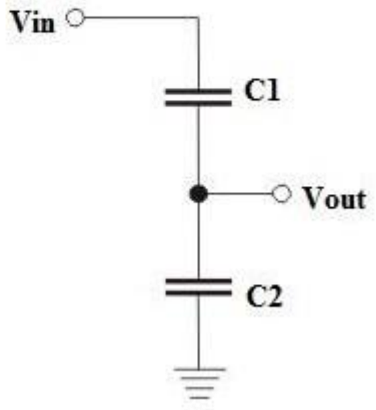


Fig 3.26 Capacitor-type-voltage-sensor

Vout = (C1/C1 + C2) * Vin

3. WORKING

Voltage sensors are wireless tools that can be attached to any number of assets, machinery or equipment. They provide 24/7 monitoring, constantly watching for voltage data that could indicate a problem. Low voltage may signal a potential issue, while other assets may be in danger when voltage is too high. When thresholds are exceeded, alerts are immediately sent to a centralized computer system. Voltage sensors are used in various industries, including the automotive, manufacturing, maintenance, and medical fields.

1. **Power failure detection:** the process of detecting a power failure so that the system can safely switch to an alternate power source.
2. **Load sensing:** a method of measuring the load on a motor and adjusting its speed accordingly.
3. **Safety switching:** refers to a device that shuts off power in case of an overload or fault condition to prevent equipment damage.
4. **Motor overload control:** a technique for preventing motor damage due to overloading by using thermal sensors, pressure sensors, current sensors, or other methods to detect the condition of the motor and avoid damage.
5. **Temperature control:** refers to controlling temperature by regulating airflow or adding insulation around machinery components.
6. **Fault detection:** refers to identifying faults within machinery components using sensors, alarms, or other devices to perform maintenance before severe damage occurs.

4. FEATURES

- Input Voltage: 0 to 25V
- Voltage Detection Range: 0.02445 to 25
- Analog Voltage Resolution: 0.00489V
- Needs no external components
- Easy to use with Microcontrollers
- Small, cheap and easily available
- Dimensions: 4 × 3 × 2 cm

5. APPLICATIONS

The applications of this sensor include the following.

- Detection of power failure
- Detecting of load
- Safety switching
- Controlling temperature
- Controlling of power demand
- Detection of fault
- Variation of load measurement of Temperature.

3.10.1 PIEZOLECTRIC SENSOR

1. DESCRIPTION

A Piezoelectric Sensor requires no external voltage or current source, they are able to generate an output signal from the strain applied. This makes them a popular choice for many applications.

The use of them is growing significantly throughout different industries and they are sometimes incorporated into other sensors. “Piezo” is Greek for “press” or “squeeze” so a piezoelectric sensor effectively measures compression using the piezoelectric effect.

A piezoelectric sensor converts physical parameters - for example, acceleration, strain or pressure into an electrical charge which can then be measured. They are highly sensitive and very small in size making them well suited to everyday objects. Piezo sensors are part of our product range here at Variohm; we can offer piezo cables**,** film elements**,** piezo film sheets and piezo switches**.**

2. WORKING AND OPERATION

Piezoelectric sensors work on the principle of the piezoelectric effect. Piezoelectric originates from the Greek word piezein, which literally means to squeeze or press. As the latter suggests, we are squeezing quartz crystals to make an electric voltage. Hence, piezoelectric sensors work by applying mechanical energy to a crystal in the following steps:

1. A piezoelectric crystal is placed between two metal plates that are in a perfect balance (even if they're not symmetrically arranged) and does not conduct an electric current.
2. Metal plates apply Mechanical force or stress to the material. Electric charges forced within the crystal are out of balance. Excess negative and positive charges appear on opposite sides of the crystal face.
3. The metal plate collects these charges and produces a voltage that sends an electrical current through a circuit. This transforms to piezoelectricity.

It is important to understand the behaviour of the piezoelectric crystals when determining the piezoelectric effect. Piezoelectric Sensors based on the piezoelectric effect can operate from transverse, longitudinal, or shear forces, and are insensitive to electric fields and electromagnetic radiation. The response is also very linear over wide temperature ranges, making it an ideal sensor for rugged environments.

Piezoelectric Sensor Circuit

The piezoelectric sensor circuit is shown below. It consists of internal Resistance R_i which is also known as insulator resistance. An inductor is connected which produces inductance due to inertia of sensor. The value of capacitance C_e is inversely proportional to the elasticity of the sensor material. To obtain the complete response of the sensor, load and leakage resistance should be larger enough such that low frequency is maintained.

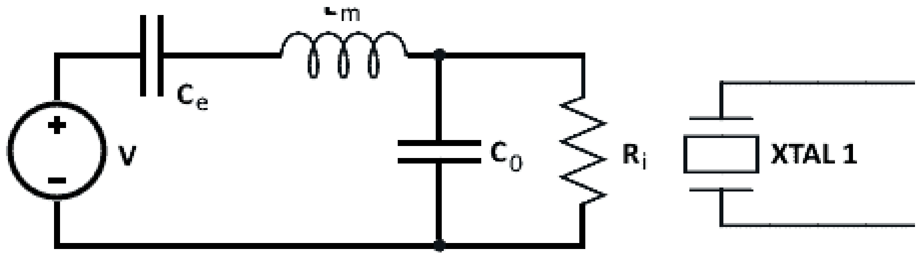


Fig 3.27 Piezoletric circuit

3. CONSTRUCTION

Most force sensors are based on an elastic or spring element: the force generates a deformation that is measured by some displacement sensor (as discussed in previous chapters). The elasticity of the spring element determines the sensitivity of such sensors. A high sensitivity requires a large deformation, which is achieved by a low stiffness of the spring element. Such a large displacement, however, could unintentionally affect the structure in which the force has to be measured. A piezoelectric force sensor, on the other hand, responds directly to an applied force: the associated deformation is in most cases negligibly small, assuring small loading errors in the force measurement. Although force is the primary quantity that is measured by a piezoelectric sensor, other quantities such as pressure, strain, and acceleration can easily be measured as well, using a proper construction.

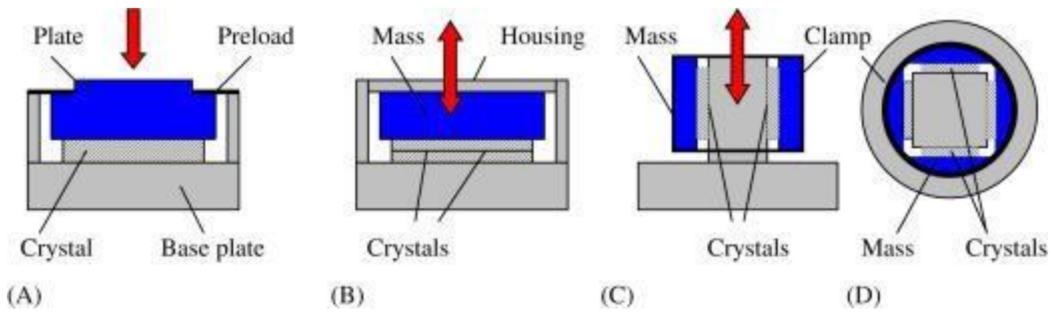


Fig 3.28 Construction of Piezolectric

When pressure or acceleration is applied to the PZT material, an equivalent amount of electrical charge gets generated across the crystal faces. Electrical charge will be proportional to the applied pressure. Piezoelectric sensor cannot be used to measure static pressure. At the constant pressure, the output signal will be zero.

4. APPLICATIONS

- In Industrial Applications piezoelectric sensor is used in engine knock sensors, pressure sensors, Sonar Equipment, etc.
- Piezoelectric actuators are applied in Diesel fuel injectors, optical adjustment, Ultrasonic cleaning and welding.
- Sensor is used in electrical appliances like dot matrix printer, inkjet printer, Piezo speaker, buzzers, humidifiers, etc.
- In musical instruments like Instrument pickups and microphone

3.11.1 LOAD CELL

1. DESCRIPTION

A load cell is a transducer which converts force into a measurable electrical output. Although there are many varieties of load cells, strain gage based load cells are the most commonly used type.Except for certain laboratories where precision mechanical balances are still used, strain gage load cells dominate the weighing industry. Pneumatic load cells are sometimes used where intrinsic safety and hygiene are desired, and hydraulic load cells are considered in remote locations, as they do not require a power supply. Strain gage load cells offer accuracies from within 0.03% to 0.25% full scale and are suitable for almost all industrial applications. A load cell is an electro-mechanical sensor used to measure force or weight. It has a simple yet effective design which relies upon the well-known transference between an applied force, material deformation and the flow of electricity. They are incredibly versatile devices that offer accurate and robust performance across a diverse range of applications.

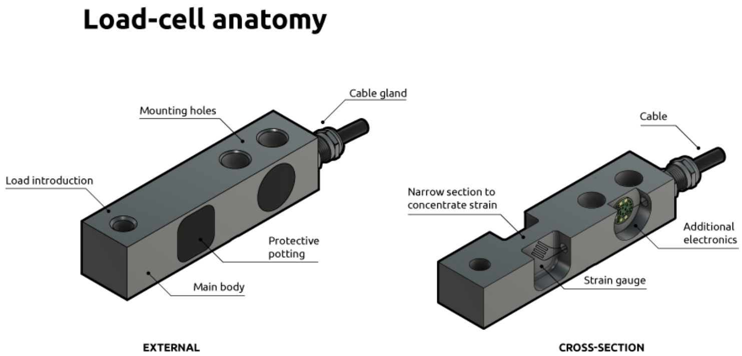


Fig 3.29 Load cell anatomy

2. TYPES

There are four common types of these sensors; they are:

– Pneumatic

– Hydraulic

– Strain gauge

– Capacitance

1. Pneumatic Load Cells

A pneumatic load cell consists of an elastic diaphragm which is attached to a platform surface where the weight will be measured.There will be an air regulator that will limit the flow of air pressure to the system and a pressure gauge. Thus, when an object is placed on a pneumatic load cell it uses pressurized air or gas to balance out the weight of the object.The air required to balance out the weight will determine how heavy the object weights. The pressure gauge can convert the air pressure reading into an electrical signal.

2. Hydraulic Load Cells

The word hydraulic should let us know that this sensor will work by using fluid, whether water or oil.These load cells are similar to pneumatic load cells but instead of air, they use the pressurized liquid.Hydraulic load cells are consisting of:

– An elastic diaphragm

– A piston with a loading platform on top of the diaphragm

– Oil or water that will be inside the piston

– A bourdon tube pressure gauge

3 Strain Gauge Load Cells

A strain gauge load cell is a transducer that changes in electrical resistance when under stress or strain.The electrical resistance is proportional to the stress or strain placed on the cell making it easy to calibrate into an accurate measurement.The electrical resistance from the strain gauge is linear therefore it can be converted into a force and then a weight if needed.

4.Capacitive Load Cells

Capacitive load cells work on the principle of capacitance, which is the ability of a system to store a charge.The load cell is made up of two flat plates parallel to each other. The plates will have a current applied to them and once the charge is stable it gets stored between the plates.The amount of charge stored, the capacitance, depends on how large of a gap between the plates.When a load is placed on the plate the gap shrinks giving us a change in the capacitance which can be calculated into a weight.

3. WORKING

When we use load cells, one end is usually secured to a frame or base, while the other end is free to attach the weight or weight-bearing element. When force is applied to the body of the load cell, it flexes slightly under the strain When this action happens to a load sensor, the deformation is very subtle and not visible to the naked eye. To measure the deformation, strain gages are tightly bonded to the body of the load cell at pre-determined points, causing them to deform in unison with the body. The resulting movement alters the electrical resistance of the strain gages in proportion to the amount of deformation caused by the applied load. To measure the deformation, strain gages are tightly bonded to the body of the load cell at pre-determined points, causing them to deform in unison with the body. The resulting movement alters the electrical resistance of the strain gages in proportion to the amount of deformation caused by the applied load.

Using signal conditioning electronics, the electrical resistance of the strain gages can be measured with the resulting signal being output as a weight or force reading. A load cell is an electro-mechanical sensor used to measure force or weight. It has a simple yet effective design which relies upon the well-known transference between an applied force, material deformation and the flow of electricity.

4. APPLICATIONS

- To determine the load in rock bolts, tiebacks, foundation anchors, cables, or struts.
- Proof testing and long-term performance monitoring of different kinds of anchor systems.
- Compressive load measurement between structural members i.e. tunnel supports or at the junction between a beam and the top of a pile strut.
- Used extensively for correlating data obtained from borehole extensometers.
- To determine the load in experimental research, pile testing, and measurement of the thrust of rocks.
- Compressive load measurement between structural members.
- Measurement of compressive load and axial forces in struts.
- Load testing in piles.
- Determination of roof convergence in underground mines.

3.2 DESIGN AND DRAWINGS

DESIGN OF PINION

$d_{min} >$ $(0.59/\sigma_{cmax})\ x\ [[Mt]/((1/E1)+(1/E2))^{2}]^{(1/3}$ ____________ **(1)**

Where,

σ_{cmax} = maximum contact compressive stress N/m^2

E1, E2 = Young's modulus N/m^2

Mt = Torque N-m

$E1 = E2 = 1.1x10^6\ N/m^2$

Calculation of σ_{cmax}

σ_{cmax} = H_B x C_B x Kcl ———————— (2)

Where,

H_B = Brinell hardness number

C_B = coefficient depends on hardness

K_{cl} = life factor

. $K_{cl} = \{[1\ x\ 10^7]/N\}^{1/6}$ ___________ (3)

N = 60 x n x T

Where

n = rpm

N= life in no. Of cycles

T = life in hours.

= 8000 hours.

From P.S.G design data book (page no.2.4),

$C_{B} = 20$

$H_{B} = 200$

Substituting the values of N, n, T in the equation [3],

The value of k_{cl} is obtained as 1.139.

K_{cl} = 1.139.

Substituting the values in equation [2]

σ_{cmax} = 20 x 200 x 1.1309

= 4520 x10^5 N/m^2

Calculation of Mt

Mt = 97420 x (Kw/n). ———— (4)

For power calculation

Centrifugal force, f_c = m ω^2 r ———— (5)

M = 7kg

W = m x g

ω = 2Πn/60

R = 1m

Substituting the values of m, ω, r in equation [4]

f_c= 7.56 N.

Downward force, f_d= m x g

= 7 x 9.81

= 68.6N.

Centrifugal force, f = fc + fd

= 68.6 + 7.56

= 76.17N

Torque = f x r = 76.17 x 1

= 76.2Nm.

Power = Torque x angular velocity.

= 76.2 x 1.05

= 79.7w

Substituting the value of k_w and n in equation in [3],

Mt = 776.7

[Mt] = 1.4 x Mt

= 1.4 x 776.7

$= 1087.1$ N-m

Substituting the values of σ_{cmax}, [Mt], E_1,E_2 in equation [1],

The minimum diameter of the pinion is calculated to be 78.7mm.

We have taken the standard diameter of pinion as 75mm.

SPECIFICATION OF PINION

Material	: cast-iron
Outside diameter	: 75mm
Circular pitch	: 4.7mm
Tooth depth	: 3.375mm
Module	: 1.5mm
Pressure angle	: 21°
Pitch circle diameter	: 72mm
Addendum	: 1.5mm
Dedendum	: 1.875mm
Circular tooth Thickness	: 2.355mm
Fillet radius	: 0.45mm
Clearance	: 0.375mm

DESIGN OF RACK

Pitch circle diameter of the gear is $= 72$mm

Circumference of the gear is $= \prod \times$ pitch circle diameter

$= \prod \times 72 = 226$mm

The dimension is for 360° rotation

For 180°rotation the rack length is 113 mm

SPECIFICATION OF RACK

Material : cast iron

Module : 1.5mm

Cross-section :75×25mm

Teeth on the rack is adjusted for 113mm

OUTPUT POWER CALCULATION:

Let us consider,

The mass of a body = 60 Kg (Approximately)

Height of speed brake = 10 cm

∴Work done = Force x Distance

Here,

Force = Weight of the Body

= 60 Kg x 9.81

= 588.6 N

Distance traveled by the body = Height of the speed brake

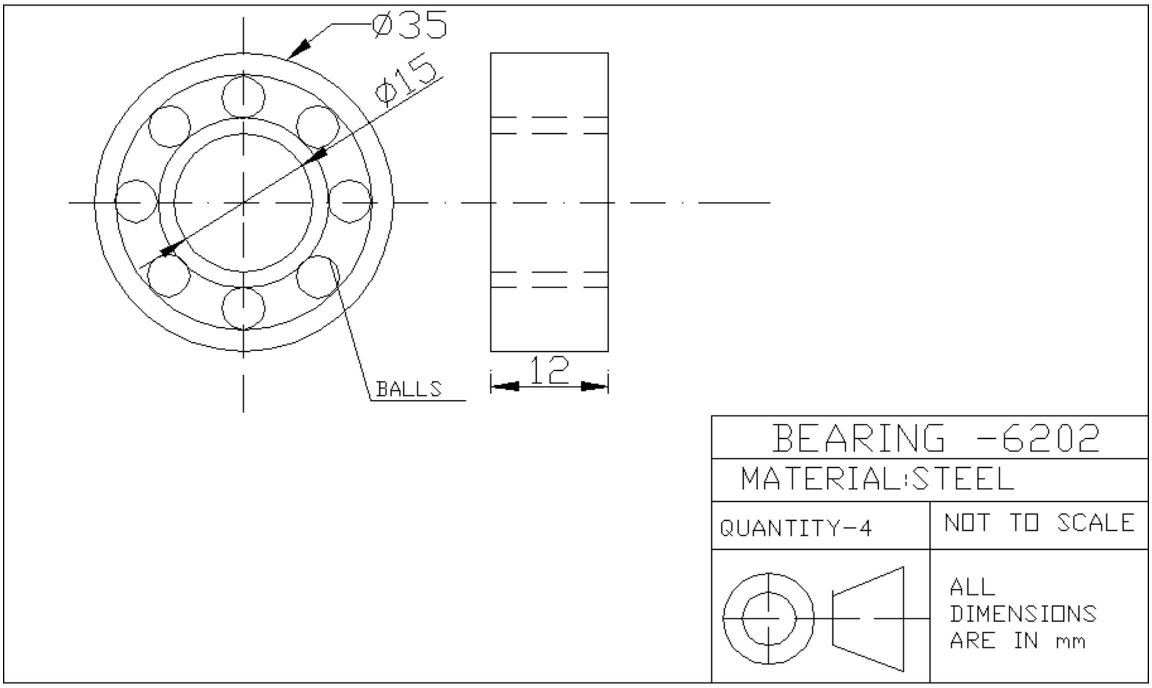
= 10 cm = 0.10 m

∴Output power = Work done/Sec

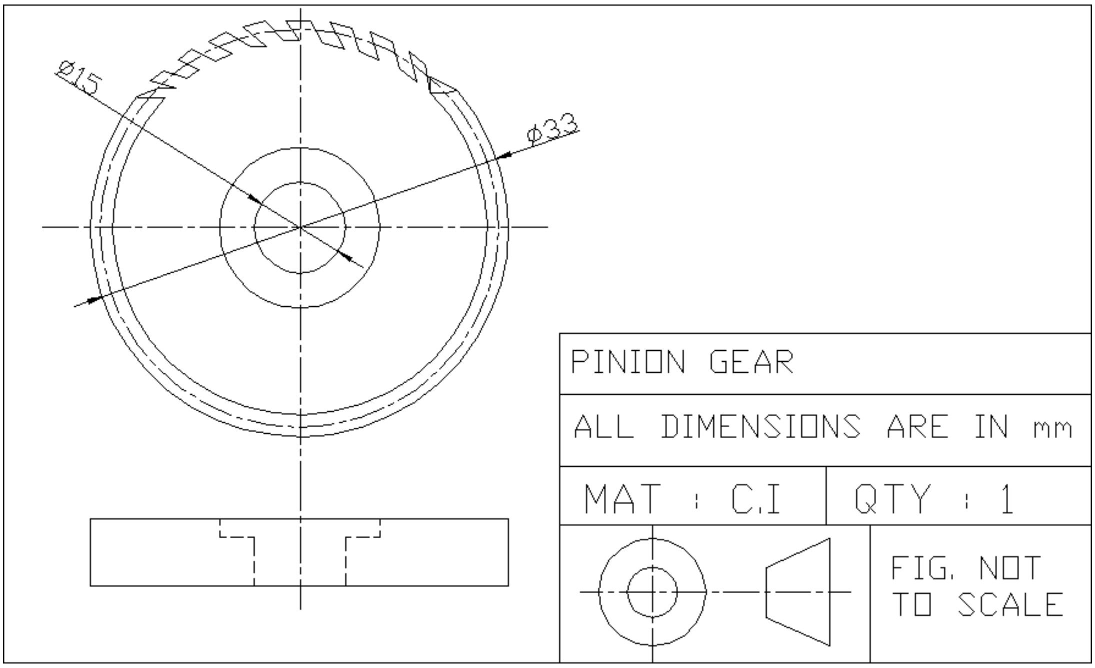
= (588.6 x 0.10)/60

= 0.98 Watts(For One pushingforce)

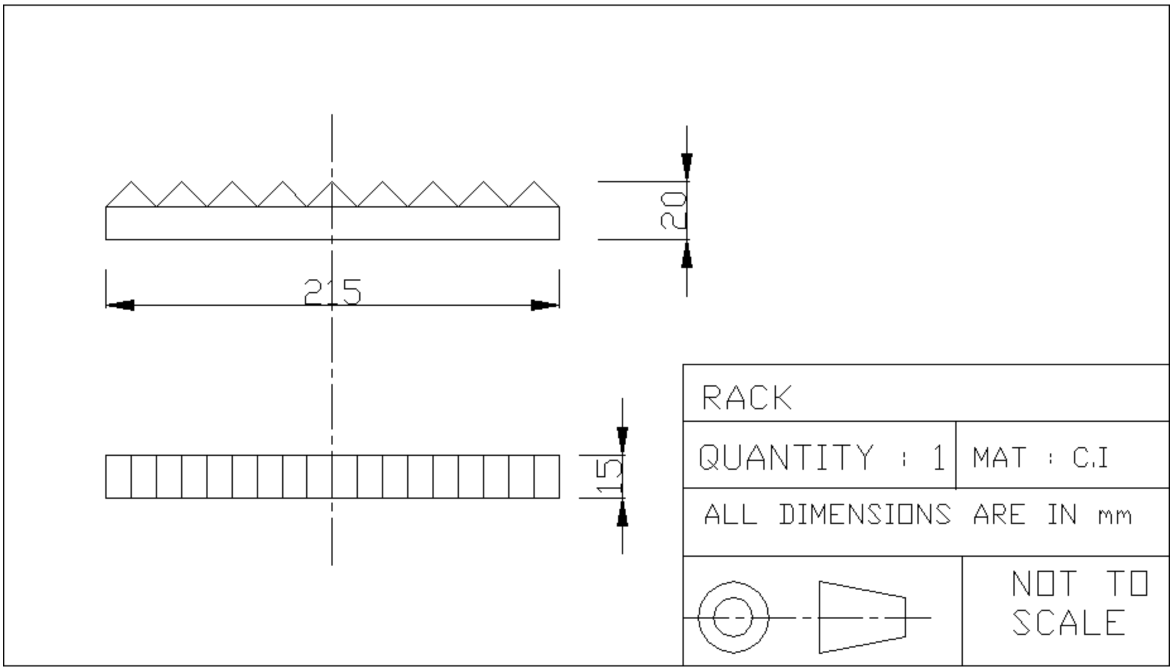
However, this much power produced, it cannot be tapped fully. From the above purpose we have select to generate electricity by permanent magnet type D.C generator and store it by 12V lead-acid battery cell.

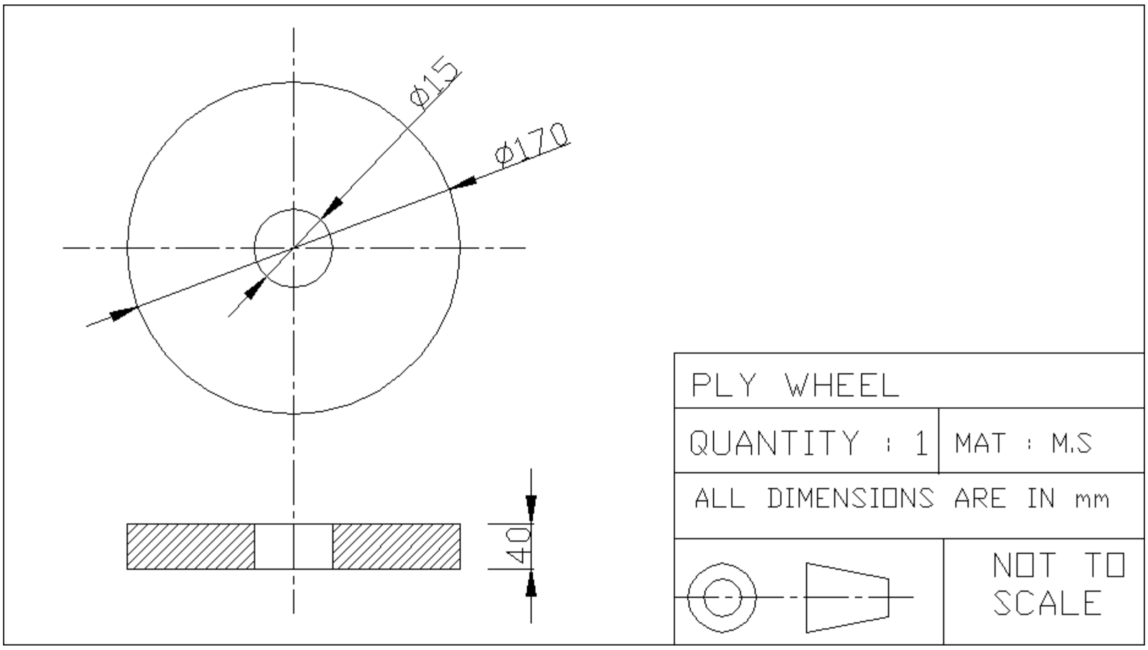


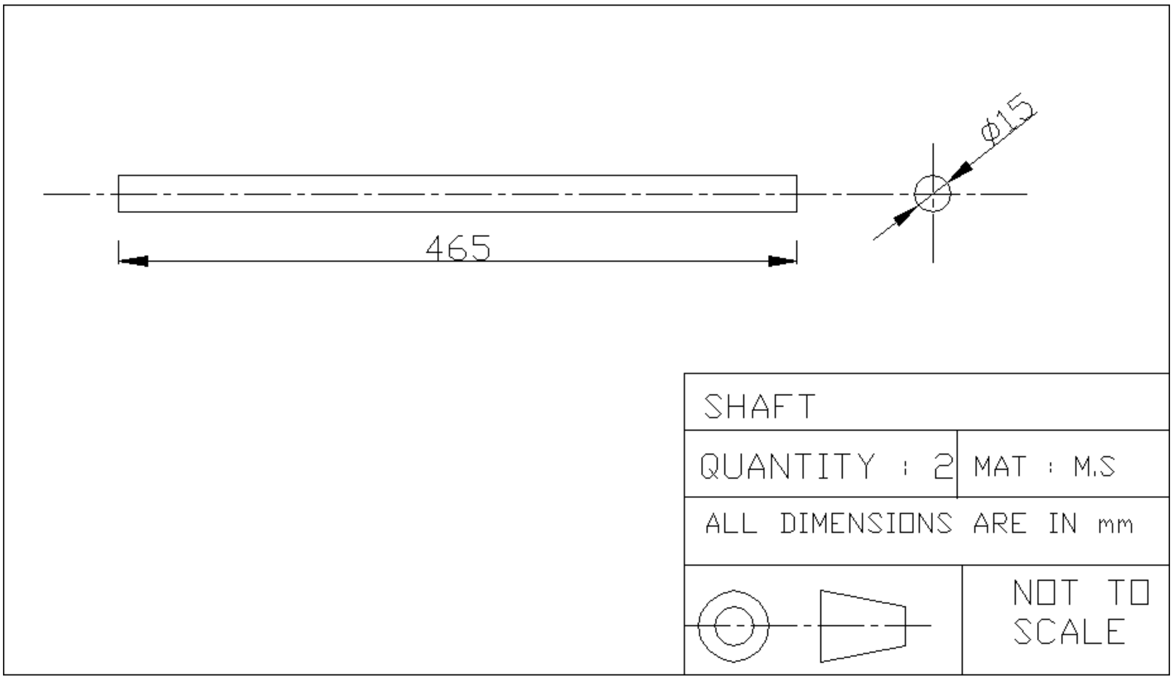
Ø35
Ø15
BALLS
12
BEARING -6202
MATERIAL:STEEL
QUANTITY-4
NOT TO SCALE
ALL DIMENSIONS ARE IN mm

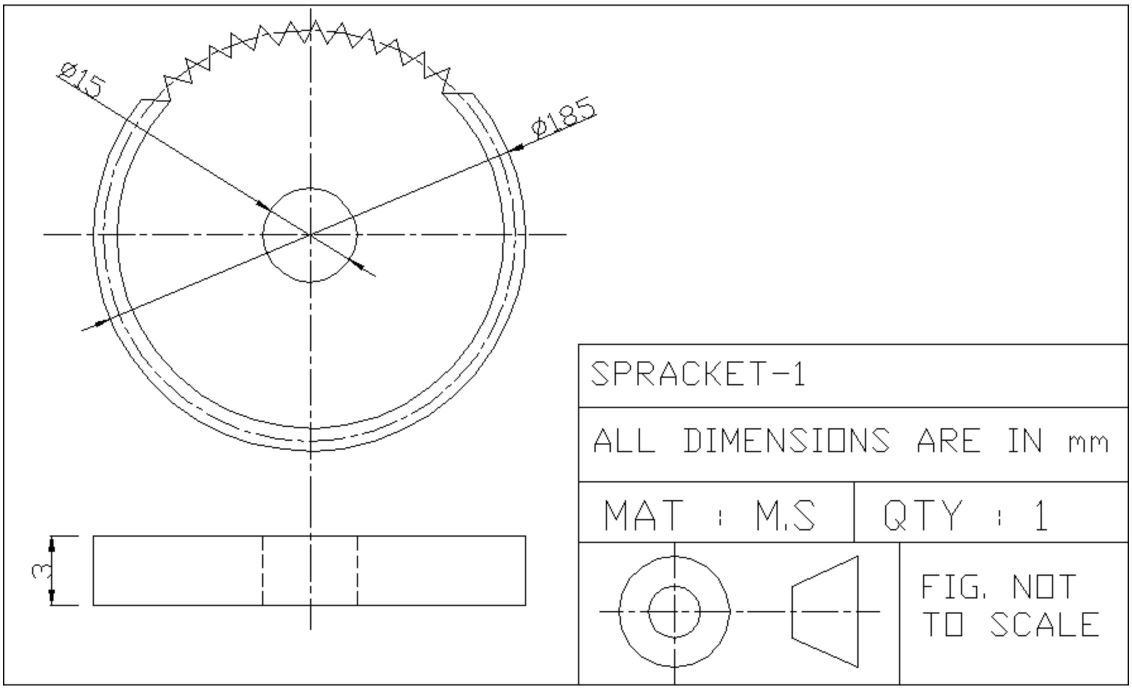


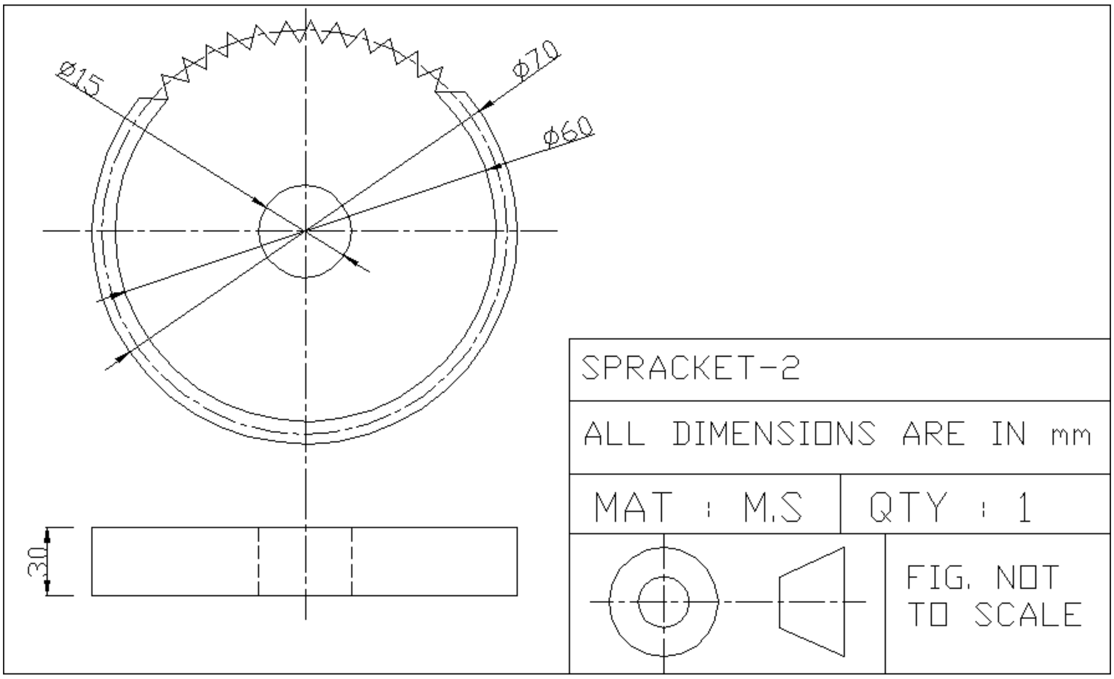
Ø15
Ø33
PINION GEAR
ALL DIMENSIONS ARE IN mm
MAT : C.I
QTY : 1
FIG. NOT TO SCALE

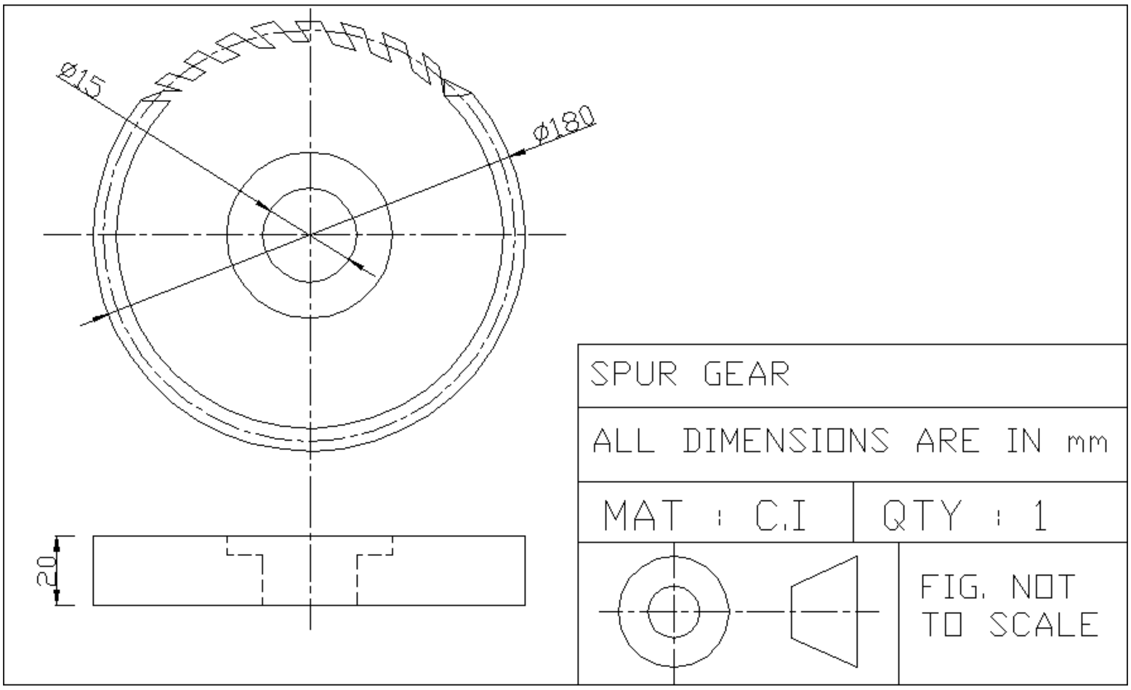

20
215
15
RACK
QUANTITY : 1
MAT : C.I
ALL DIMENSIONS ARE IN mm
NOT TO SCALE


Ø15
Ø170
40
PLY WHEEL
QUANTITY : 1
MAT : M.S
ALL DIMENSIONS ARE IN mm
NOT TO SCALE


Ø15
465
SHAFT
QUANTITY : 2
MAT : M.S
ALL DIMENSIONS ARE IN mm
NOT TO SCALE


Ø15
Ø185
3
SPRACKET-1
ALL DIMENSIONS ARE IN mm
MAT : M.S
QTY : 1
FIG. NOT TO SCALE


Ø15
Ø70
Ø60
30
SPRACKET-2
ALL DIMENSIONS ARE IN mm
MAT : M.S
QTY : 1
FIG. NOT TO SCALE


Ø15
Ø180
20
SPUR GEAR
ALL DIMENSIONS ARE IN mm
MAT : C.I
QTY : 1
FIG. NOT TO SCALE

3.3 SOFTWARE DESCRIPTION

3.3.1 ARDUINO IDE

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino board.The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom right hand corner of the window displays the configured board and serial port. The toolbar buttonsallow you to verify and upload programs, create, open, and save sketches, andopen the serial monitor.Before uploading your sketch, you need to select the correct items fromthe Tools > Board and Tools > Port menus.

The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board.

Arduino is an open-source hardware and software company, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical and digital world. Its products are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form or as do-it-yourself (DIY) kits.

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards or breadboards (shields) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

The Arduino project started in 2003 as a program for students at the Interaction Design Institute Ivrea in Ivrea, Italy, aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators. Common examples of such devices intended for beginner hobbyists include simple robots, thermostats and motion detectors.

The name Arduino comes from a bar in Ivrea, Italy, where some of the founders of the project used to meet. The bar was named after Arduin of Ivrea, who was the margrave of the March of Ivrea and King of Italy from 1002 to 1014.

3.3.2 EMBEDDED C

Embedded C is a set of language extensions for the C programming language by the C Standards Committee to address commonality issues that exist between C extensions for different embedded systems. Embedded systems control many devices in common use today. Ninety-eight percent of all microprocessors are manufactured as components of embedded systems.

Historically, embedded C programming requires nonstandard extensions to the C language in order to support exotic features such as fixed-point arithmetic, multiple distinct memory banks, and basic I/O operations. In 2008, the C Standards Committee extended the C language to address these issues by providing a common standard for all implementations to adhere to. It includes a number of features not available in normal C, such as fixed-point arithmetic, named address spaces and basic I/O hardware addressing. Embedded C uses most of the syntax and semantics of standard C, e.g., main() function, variable definition, data type declaration, conditional statements (if, switch case), loops (while, for), functions, arrays and strings, structures and union, bit operations, macros, etc

Modern embedded systems are often based on microcontrollers (i.e. CPU'swith integrated memory or peripheral interfaces), but ordinary microprocessors (using external chips for memory and peripheral interface circuits) are also common, especially in more-complex systems. In either case, the processors used may be types ranging from generalpurpose to those specialized in certain class of computations, or even custom designed for the application at hand. A common standard class of dedicated processors is the digital signal processor (DSP).

CHAPTER 4

4.1 BLOCK DIAGRAM

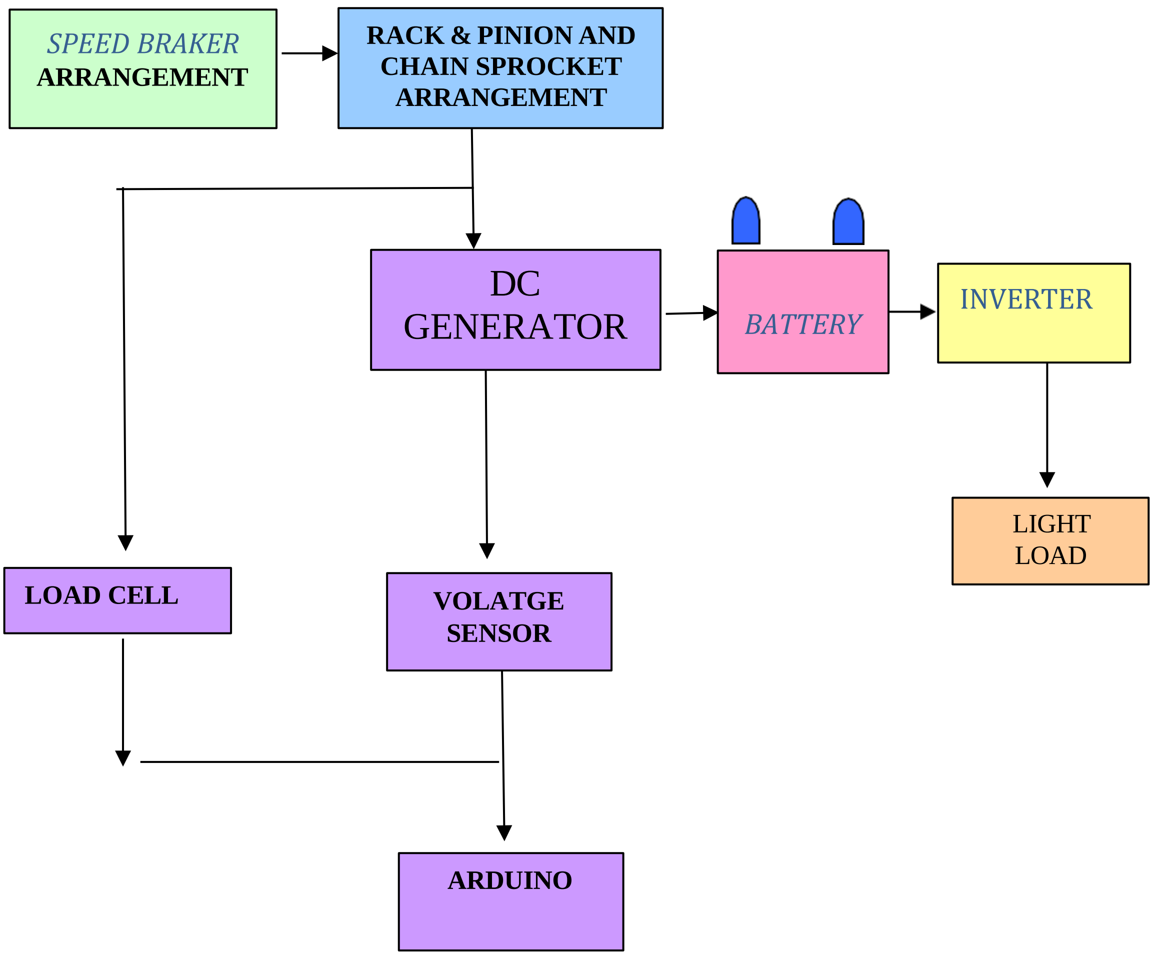


Fig 4.1 Block diagram

4.2 WORKING

As a vehicle traverses the speed breaker, the rack and pinion mechanism converts the linear motion into rotational movement. The rotational force is transferred to a larger sprocket through the chain drive assembly .The flywheel increases the rotational speed, providing additional momentum to the system. Gears synchronize the rotational motion and transfer it to the DC generator shaft. The DC generator converts the mechanical energy into a stable 12 Volt DC electrical output. Load cells measure and analyze the force applied during the vehicle passage, providing crucial data for system optimization. The voltage monitoring system ensures the stability and reliability of the generated electrical power. The DC voltage is stored in a lead-acid battery, serving as an energy reservoir for continuous power supply. The stored energy can be inverted to 230 Volt AC using an inverter, allowing for various practical applications such as street lighting or powering nearby infrastructure.

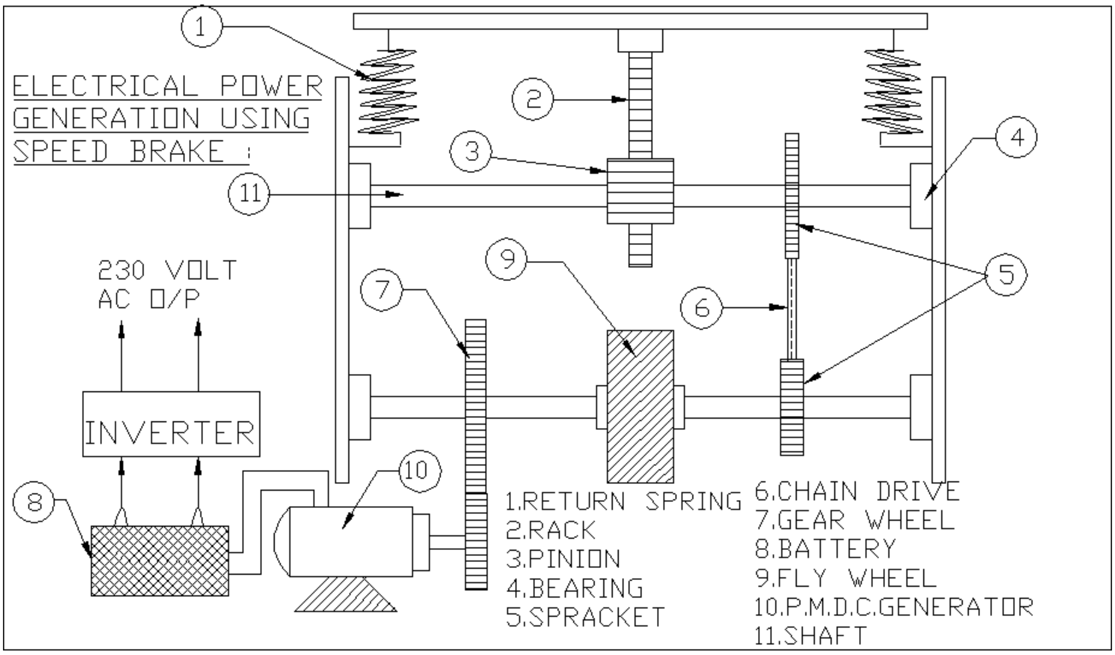


Fig 4.2 Working Block diagram

Fig 4.3 Output Results

4.3 ADVANTAGES

- Harnesses kinetic energy from speed breakers for sustainable power generation.
- Efficient use of the rack and pinion mechanism, chain drive, and advanced components ensures optimal energy conversion.
- Load cells and voltage monitoring enhance system performance and reliability.
- Battery storage provides a continuous power supply, even during periods of low vehicle activity.

CHAPTER 5

CONCLUSION

The proposed energy harvesting system, which includes a complex rack and pinion mechanism with a chain drive assembly, has great potential as a sustainable power generation option in metropolitan areas. The incorporation of sophisticated elements, such as load cells and a voltage monitoring system, improves the effectiveness, dependability, and flexibility of the system. The device efficiently captures and converts the kinetic energy generated by passing vehicles, providing a practical solution to meet the growing energy needs in urban areas and promoting the use of cleaner energy sources. The use of a permanent magnet DC generator, along with battery storage, guarantees a consistent and uninterrupted power provision, rendering the system well-suited for practical uses like street lighting and powering adjacent infrastructure. By including load cells, significant information about the force exerted during vehicle passage is obtained, which helps in continuously improving and refining the system. The voltage monitoring system additionally guarantees the reliability of the produced electrical power, providing a real-time feedback mechanism for evaluating performance. As urbanization persists in shaping our landscapes, the suggested system not only offers a creative option for extracting energy from current infrastructure but also contributes to the wider objectives of sustainable urban development. It demonstrates the possibility to incorporate renewable energy sources into common infrastructure. By conducting ongoing evaluations of its efficiency and ability to handle increased demands, this system has the capacity to become a crucial element of urban energy solutions, thereby aiding in the creation of a more environmentally friendly and adaptable future.

CHAPTER 6
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APPENDIX

CODE FOR PROTOTYPE

```
#include <LiquidCrystal.h>
const int rs = 13, en = 12, d4 = 11, d5 = 10, d6 = 9, d7 = 8;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
#define load A1
#define ANALOG_IN_PIN A0
float R1 = 30000.0;
float R2 = 7500.0;
float ref_voltage = 5.0;
float adc_voltage = 0.0;
int in_voltage = 0.0;
int adc_value = 0, l = 0, m = 4;
float Volt = 0.0;
int AvarVolt = 0;
float load_val = 0.0;
unsigned int initval;

void setup()
{
  lcd.begin(16, 2);
  Serial.begin(9600);
  lcd.setCursor(0, 0);
  lcd.print("    WELCOME      ");
  delay(2000);
```

```
  lcd.setCursor(0, 0);
  lcd.print(" SPEED BRAKER ");
  lcd.setCursor(0, 1);
  lcd.print("POWER GENERATION");
  delay(2000);
  lcd.clear();
}

void loop()
{
  load_val = analogRead(A1);
  load_val = load_val - 647;
  load_val = load_val / 10;
  Serial.println(load_val);
  adc_value = analogRead(ANALOG_IN_PIN);
  adc_voltage  = (adc_value * ref_voltage) / 1024.0;
  in_voltage = adc_voltage * (R1 + R2) / R2;
  lcd.setCursor(0, 0);
  lcd.print("Voltage = ");
  lcd.print(in_voltage);
  Volt = Volt + in_voltage;
  lcd.print("          ");

  lcd.setCursor(0, 1);
  lcd.print("Load = ");
  lcd.print(load_val);
```

```
  lcd.print(" kg  ");

  delay(500);
  l++;

  if ( l > 60 )
  {
    AvarVolt = Volt / (l);
    Serial.print(AvarVolt);
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Average Voltage");
    lcd.setCursor(6, 1);
    lcd.print(AvarVolt);
    delay(2000);
    l = 0;
  }
}
```