MILITARY INSTITUTE OF SCIENCE & TECHNOLOGY (MIST)

DESIGN AND CONSTRUCTION OF A MECHANICAL MOTION RECTIFIER (MMR)

A thesis submitted to the Department of Mechanical Engineering, Military Institute of Science and technology, Dhaka, in December, 2015 in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering.

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STUDENT DECLARATION

It is hereby declared that the work presented in this project titled , **"DESIGN AND CONSTRUCTION OF A MECHANICAL MOTION RECTIFIER(MMR)"** is an outcome of the investigation carried out by the author under the supervision of **Prof Dr. Dipak Kanti Das,** Professor, Department of Mechanical Engineering, MIST. This project and thesis or any part of it has not been submitted to elsewhere for the award of any other degree or diploma or other similar title or prize.

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SUPERVISOR CERTIFICATION

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I wish their ever success in life.

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ABSTRACT

The mechanical rectifier is used to convert bidirectional reciprocating motion into unidirectional rotating motion. In this project we have used two input shafts and one output shaft. The rack and pinion mechanism is used to convert reciprocating motion into rotary motion. Two opposite ratchet wheels are fitted with the input shafts. The output shaft is coupled with the input shafts with chain sprocket mechanism. The ratchet wheels are placed inside the sprockets of the two input shafts. So the rotary movement performed either clockwise or counterclockwise direction on input shafts will result unidirectional motion on the output shaft. Mechanical energy is surrounding us in different forms like vehicle's vibration, ocean waves, vibrating train tracks etc. These energies are found in irregular and oscillatory form. But energy harvesting works best with regular, unidirectional motion. To harness those energies a device is necessary. In this regard, this project can be used as an efficient energy harnessing device.

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Chapter-1

Introduction

1.1 Introduction

There are a lot of sources from where we can get mechanical motions. These motions are found in various forms. We use plenty of machines in industries and also in our houses. In different parts of these machines there are vibrations. These vibrations are of course a kind of motion. Vehicles also vibrate when running in the roads. Specially when running on the bad roads and passing a spread breakers the vehicles vibrate more. The train tracks vibrate when the trains move through it. The mechanical motions can also be found from wind flow, ocean waves etc. All these motion can be converted to useful energy.

Energy is the most important element of the modern world. With the advancement of the science and technology the total energy demand is increasing day by day. To meet the increasing demand conventional energy is not enough. So we need to harness energy from other sources like renewable energy.

Mechanical motions are usually found in oscillatory bidirectional form. But to harness energy from these motions we need to convert it in unidirectional or rotary form. With a view to overcome this problem we have come with a device named Mechanical Motion Rectifier(MMR).This project emphasizes on the design and construction of An MMR. An MMR can be designed in many ways. Different power transmission technique can be used here. We have used a simple system of transmission which consists of rack pinion and chain-sprocket mechanism.

1.2 Motivation:

We are surrounding a lot of mechanical motions around us. The main obstruction to use these motions are that they are uneven and has variation in amplitude.The motivation of this project comes basically to convert these irregular and uneven motions into regular unidirectional motion.So we came up with an idea of mechanical motion rectifier which can easily work with these uneven and ever changing motions or oscillations by converting them into unidirectional rotation of a shaft which can possibly be useful.

1.3 Objectives:

- To Use oscillations from different sources which are uneven and convert them into useful works.
- To Generate unidirectional mechanical movements .
- Making a device works without the need of biofuel or any other means which can harm the environment.
- Making a device which is able to convert irregular vibration into regular motion.
- Generating mechanical motion free of cost.
- Using unequal but large forces to useful work through rectifier.
- Converting both clockwise and anti clockwise rotation into clockwise rotation.

Chapter-2

Literature Review

2.1 Toothed Gearing:

2.1.1 Definition:

Gears are wheels with teeth. Gears mesh together and make things turn. Gears are use to transfer motion or power from one moving part to another.

2.1.2 Classification:

According to the Position of Axis of Shaft
(a) Parallel
(b) Intersecting
(c) Non-intersecting and non-parallel

According to the peripheral velocity of the gears
(a) Low velocity, less than 3 m/s
(b) Medium velocity, between 3 and 15 m/s
(c) High velocity. more than 15 m

According to the Position of Axis of Shaft
(a) Parallel
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(b) Medium velocity, between 3 and 15 m/s
(c) High velocity. more than 15 m

According to the type of gearing
(a)External gearing
(b) Internal gearing
(c) Rack and pinion

Fig 2.1 Internal Gearing

Fig 2.2 Rack and Pinion

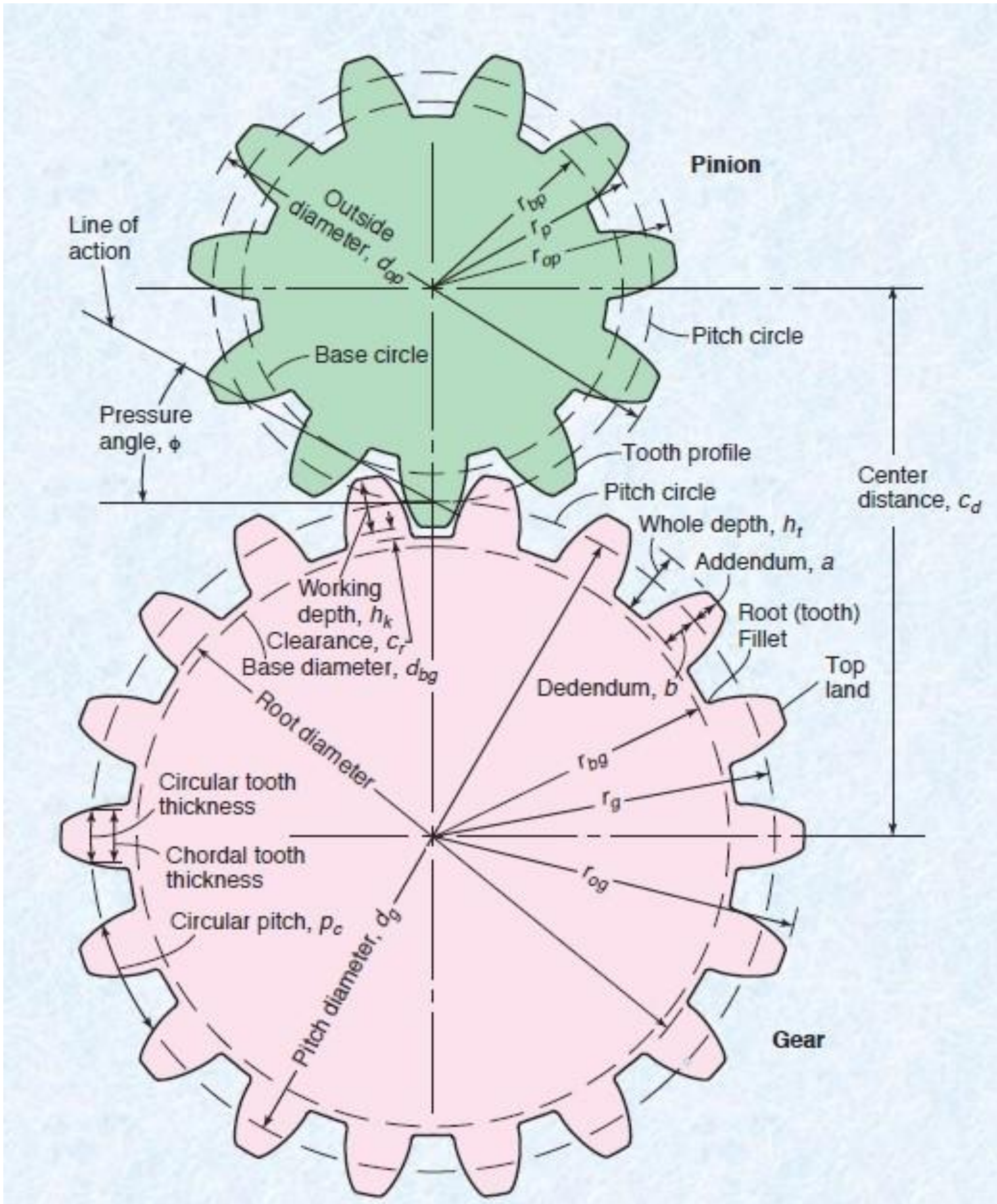

Fig 2.3 External gearing with terms used in gear

2.1.3 Rack and pinion mesh:

Sometimes, the gear of a shaft meshes externally and internally with the gears in a straight line, as shown in Figure. Such a type of gear is called *rack* and *pinion*. The straight line gear is called *rack* and the circular wheel is called *pinion.* A little consideration will show that with the help of a rack and pinion, we can convert linear motion into rotary motion and *vice-versa* as shown in Figure.

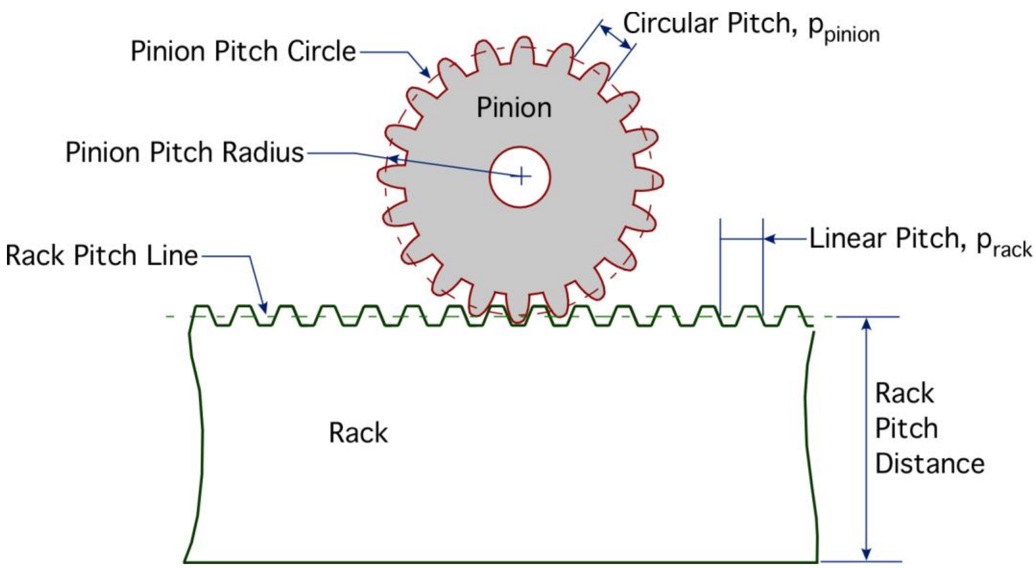

Fig 2.4 Rack and pinion mesh

2.1.4 Types of Rack and Pinion meshing:

Rack and pinion gears are available in three variations:

- Straight teeth have the tooth axis parallel to the axis of rotation. Straight teeth that run parallel to the axis of the gear. Load movement or transfer is manual or walk-behind.
  We Used Straight teeth Meshing in our setup.

Fig 2.5 Straight Tooth

- Helical teeth gears provide continuous engagement along the tooth length and are often quieter and more efficient than straight tooth gears. Helical tooth gears resemble spur gears in the plane of rotation, but include teeth that are twisted along a helical path in the axial direction.

Fig 2.6 Helical Tooth

- Roller pinion drives use bearing supported rollers that mesh with the teeth of that rack in orderto provide minimal to no backlash.

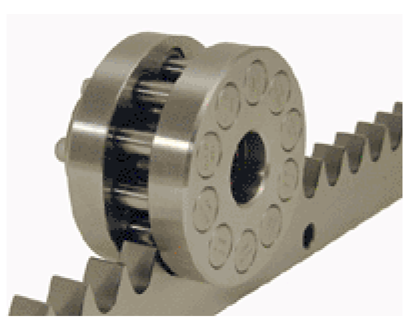

Fig 2.7 Roller Pinion

2.1.5 Quality

Rack and pinion gears variations are available in different qualities,

- 9/10 milled teeth are milled and hardened quality
- 7/8 precision cut or precision cut and hardened quality
- 5/6 teeth hardened and ground quality

2.1.6 Advantages and Disadvantages of Gear Drive:

The following are the advantages and disadvantages of the gear drive as compared to belt, rope and chain drives :

Advantages

1. It transmits exact velocity ratio.

2. It may be used to transmit large power.

3. It has high efficiency.

4. It has reliable service.

5. It has compact layout.

Disadvantages:

1. The manufacture of gears require special tools and equipment.

2. The error in cutting teeth may cause vibrations and noise during operation.

2.1.6 Gear Materials:

The material used for the manufacture of gears depends upon the strength and service conditions like wear, noise etc. The gears may be manufactured from metallic or non-metallic materials.The metallic gears with cut teeth are commercially obtainable in cast iron, steel and bronze. The nonmetallic materials like wood, raw hide, compressed paper and synthetic resins like nylon are used for gears, especially for reducing noise.The cast iron is widely used for the manufacture of gears due to its good wearing properties, excellent machinability and ease of producing complicated shapes by casting method. The cast iron gears with cut teeth may be employed, where smooth action is not important. The steel is used for high strength gears and steel may be plain carbon steel or alloy steel. The steel gears are usually heat treated in order to combine properly the toughness and tooth hardness. The phosphor bronze is widely used for worm gears in order to reduce wear of the worms which will be excessive with cast iron or steel.

2.1.7 Involute Teeth:

An involute of a circle is a plane curve generated by apoint on a tangent, which rolls on the circle without slipping or by a point on a taut string which in unwrapped from a reel as shown in Fig. 12.9. In connection with toothed wheels, the circle is known as base circle. The involute is traced as follows :

Let *A* be the starting point of the involute. The base circle is divided into equal number of parts *e.g. AP*1, *P*1*P*2, *P*2*P*3 etc. The tangents at *P*1, *P*2, *P*3 etc. are drawn and the length *P*1*A*1, *P*2*A*2, *P*3*A*3 equal to the arcs *AP*1, *AP*2 and *AP*3 are set off. Joining the points *A*, *A*1, *A*2, *A*3 etc. we obtain the involute curve *AR*. A little consideration will show that at any instant

*A*3, the tangent *A*3*T* to the involute is perpendicular to *P*3*A*3 and *P*3*A*3 is the normal to the involute. In other words, *normal at any point of an involute is a tangent to the circle*. Now, let *O*1 and *O*2 be the fixed centres of the two base circles as shown in Fig. 12.10 (*a*). Let

the corresponding involutes *AB* and *A*1*B*1 be in contact at point *Q*. *MQ* and *NQ* are normals to the involutes at *Q* and are tangents to base circles. Since the normal of an involute at a given point is the tangent drawn from that point to the base circle, therefore the common normal *MN* at *Q* is also the common tangent to the two base circles. We see that the common normal *MN* intersects the line of centres *O*1*O*2 at the fixed point *P* (called pitch point). Therefore the involute teeth satisfy the fundamental condition of constant velocity ratio.

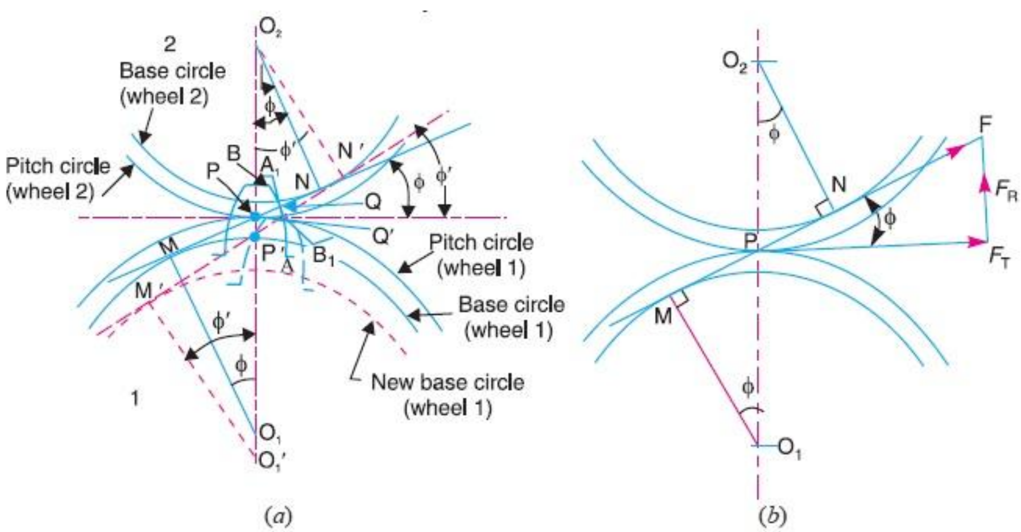

Fig 2.8 Involute Teeth

2.2 Gear Train:

2.2.1 Definition:

Sometimes, two or more gears are made to mesh with each other to transmit power from one shaft to another. Such a combination is called *gear train* or *train of toothed wheels*. The nature of the train used depends upon the velocity ratio required and the relative position of the axes of shafts. A gear train may consist of spur, bevel or spiral gears.

2.2.2 Types of Gear Trains:

Following are the different types of gear trains, depending upon the arrangement of wheels :

1. Simple gear train,
2. Compound gear train,
3. Reverted gear train, and
4. Epicyclic gear train.

In the first three types of gear trains, the axes of the shafts over which the gears are mounted are fixed relative to each other. But in case of epicyclic gear trains, the axes of the shafts on which the gears are mounted may move relative to a fixed axis.

2.2.3 Simple Gear Train:

When there is only one gear on each shaft, as shown in Fig. 2.9, it is known as simple gear train. The gears are represented by their pitch circles. When the distance between the two shafts is small, the two gears 1 and 2 are made to mesh with each other to transmit motion from one shaft to the other, as shown in Fig. 2.9 (a). Since the gear 1 drives the gear 2, therefore gear 1 is called the driver and the gear 2 is called the driven or follower. It may be noted that the motion of the driven gear is opposite to the motion of driving gear.

Let , N1 = Speed of gear 1(or driver) in r.p.m.,

N2 = Speed of gear 2 (or driven or follower) in r.p.m.,

T1 = Number of teeth on gear 1, and

T2 = Number of teeth on gear 2.

Speed ratio $= \frac{N_1}{N_2} = \frac{T_1}{T_2}$

Train value $= \frac{N_2}{N_1} = \frac{T_1}{T_2}$

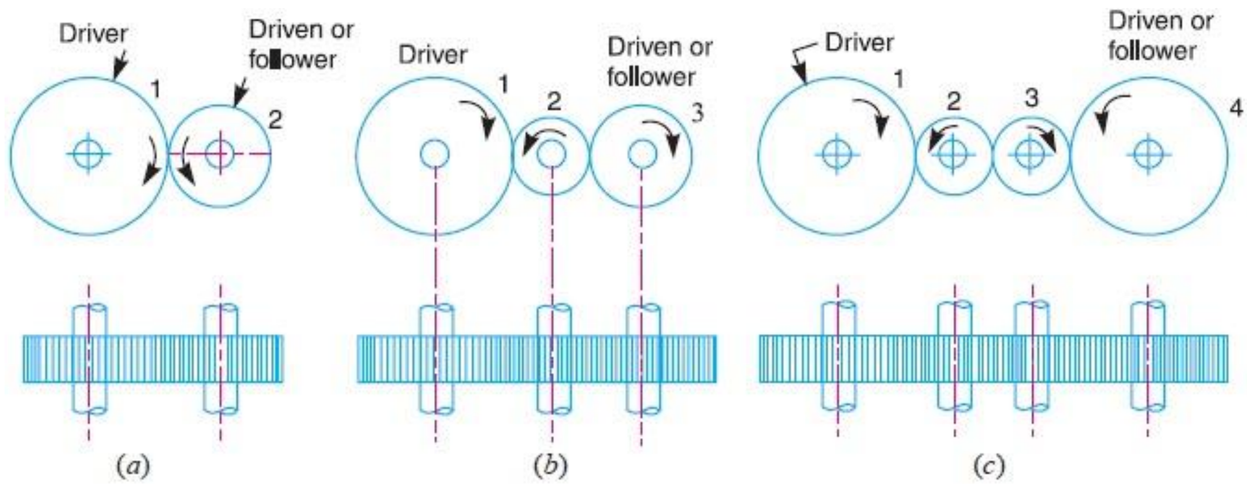

Fig 2.9 Simple Gear Train

2.2.4 Compound Gear Train:

When there are more than one gear on a shaft, as shown in Fig. 2.10, it is called a compound train of gear. We have seen the idle gears, in a simple train of gears do not effect the speed ratio of the system. But these gears are useful in bridging over the space between the driver and the driven. But whenever the distance between the driver and the driven or follower has to be bridged over by intermediate gears and at the same time a great (or much less) speed ratio is required, then the advantage of intermediate gears is intensified by providing compound gears on intermediate shafts. In this case, each intermediate shaft has two gears rigidly fixed to it so that they may have the same speed. One of these two gears meshes with the driver and the other with the driven or follower attached to the next shaft as shown in Fig.2.10.

Let, N1 = Speed of driving gear 1,

T1 = Number of teeth on driving gear 1,

N2 ,N3 ..., N6 = Speed of respective gears in r.p.m., and

T2 ,T3..., T6 = Number of teeth on respective gears.

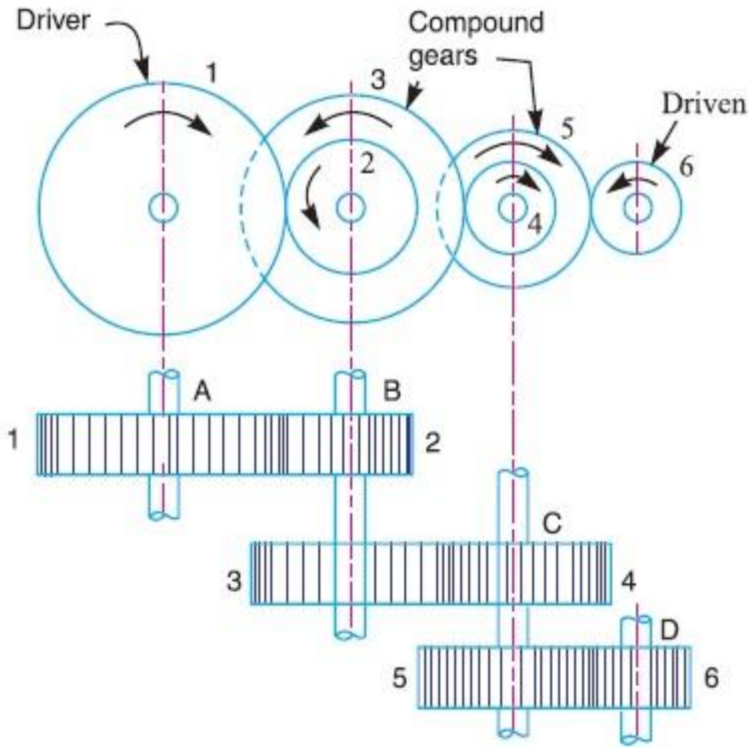

Fig 2.10 Compound Gear Train

The speed ratio of compound gear train is obtained by,

$$\frac{N_1}{N_2} \times \frac{N_3}{N_4} \times \frac{N_5}{N_6} = \frac{T_2}{T_1} \times \frac{T_4}{T_3} \times \frac{T_6}{T_5}$$

$$\frac{N_1}{N_6} = \frac{T_2 \times T_4 \times T_6}{T_1 \times T_3 \times T_5}$$

2.2.5 Reverted Gear Train:

When the axes of the first gear (i.e. first driver) and the last gear (i.e. last driven or follower) are co-axial, then the gear train is known as reverted gear train as shown in Fig. 2.11

Let, T1 = Number of teeth on gear 1,

r1 = Pitch circle radius of gear 1, and

N1 = Speed of gear 1 in r.p.m.

Similarly,

T2, T3, T4 = Number of teeth on respective gears,

r2, r3, r4 = Pitch circle radii of respective gears, and

N2, N3, N4 = Speed of respective gears in r.p.m.

Speed ratio = $\frac{N_1}{N_4} = \frac{T_2 \times T_4}{T_1 \times T_3}$

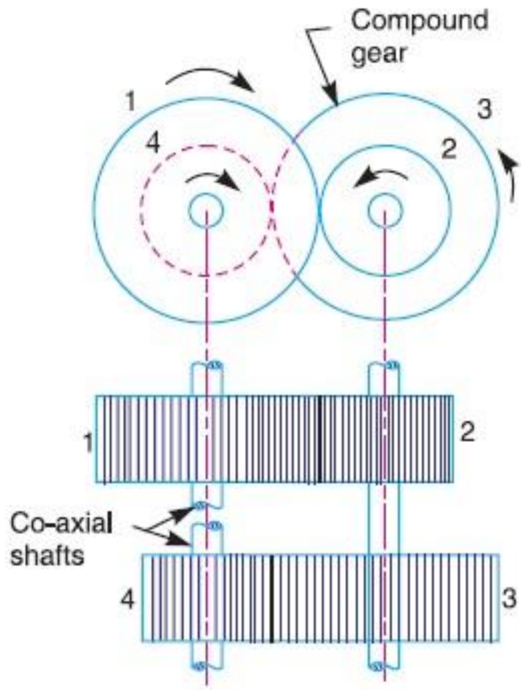

Fig 2.11 Reverted Gear Train

2.2.6 Epicyclic Gear Train:

We have already discussed that in an epicyclic gear train, the axes of the shafts, over which the gears are mounted, may move relative to a fixed axis. A simple epicyclic gear train is shown in Fig. 13.6, where a gear *A* and the arm *C* have a common axis at *O*1 about which they can rotate. The gear *B* meshes with gear *A* and has its axis on the arm at *O*2, about which the gear *B* can rotate. If the arm is fixed, the gear train is simple and gear A can drive gear B or vice- versa, but if gear A is fixed and the arm is rotated about the axis of gear A (i.e. O1), then the gear B is forced to rotate upon and around gear A. Such a motion is called epicyclic and the gear trains arranged in such a manner that one or more of their members move upon and around another member are known as epicyclic gear trains (epi. means upon and cyclic
means around). The epicyclic gear trains may be simple or compound. The epicyclic gear trains are useful for transmitting high velocity ratios with gears of moderate size in a comparatively lesser space. The epicyclic gear trains are used in the back gear of lathe, differential gears of the automobiles, hoists, pulley blocks, wrist watches etc

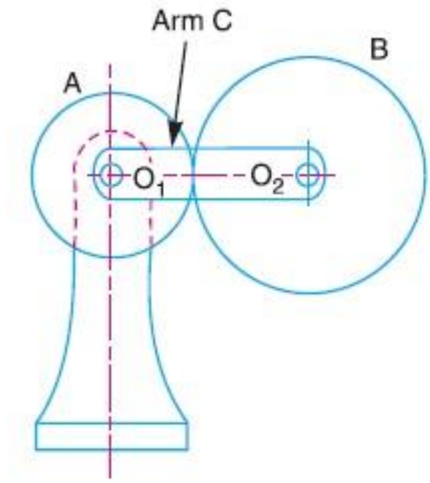

Fig 2.12 Epicyclic Gear Train

Speed ratio = $\frac{\text{Speed of first driver}}{\text{Speed of first driver}} = \frac{N_A}{N_D}$

Also, $\frac{N_A}{N_D} = \frac{N_A}{N_B} \times \frac{N_C}{N_D}$

Chapter-3

Drawings

1. Mechanical Motion Rectifier (Isometric view):

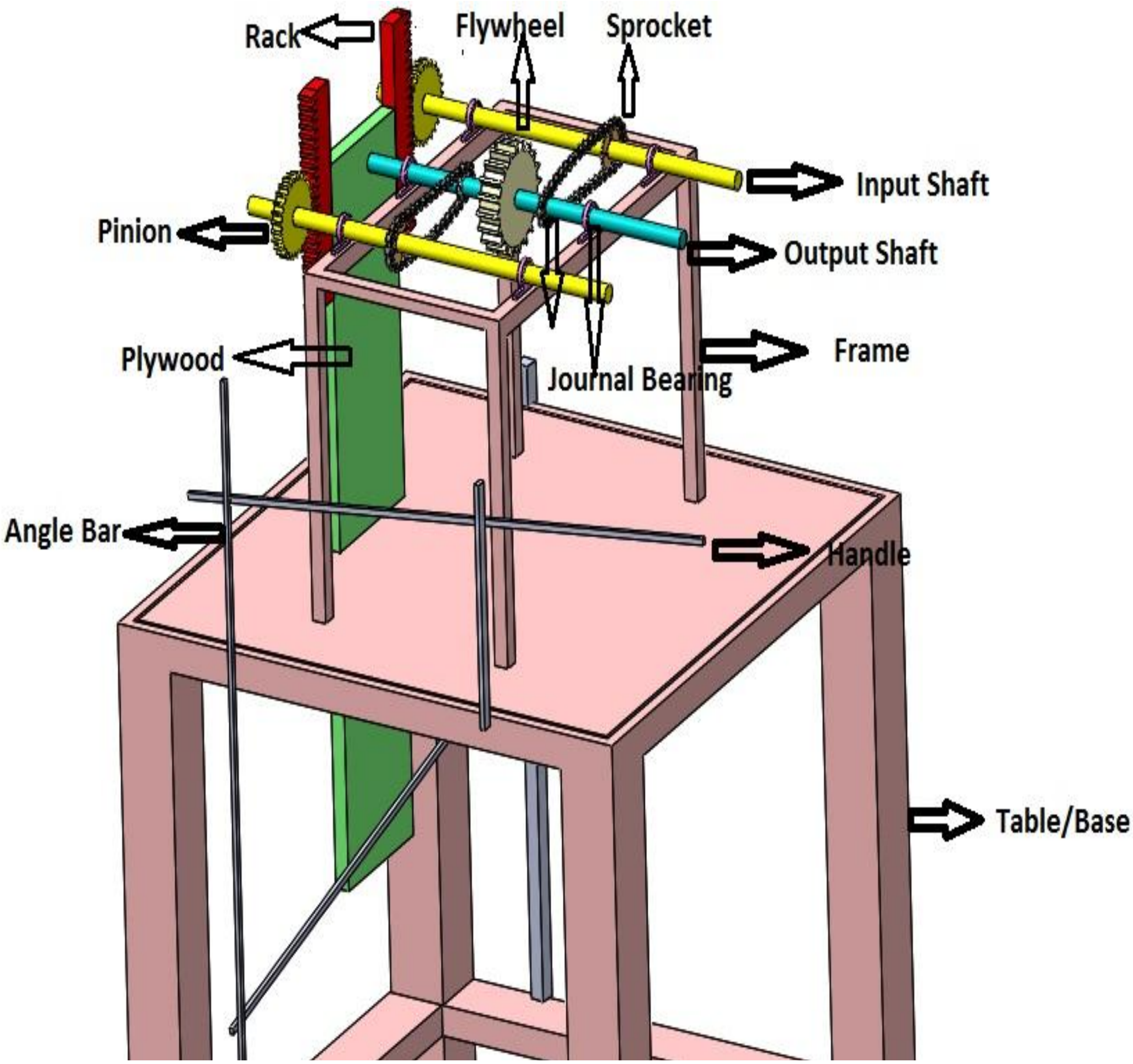

Fig 3.1: Isometric View of MMR

2. Top View:

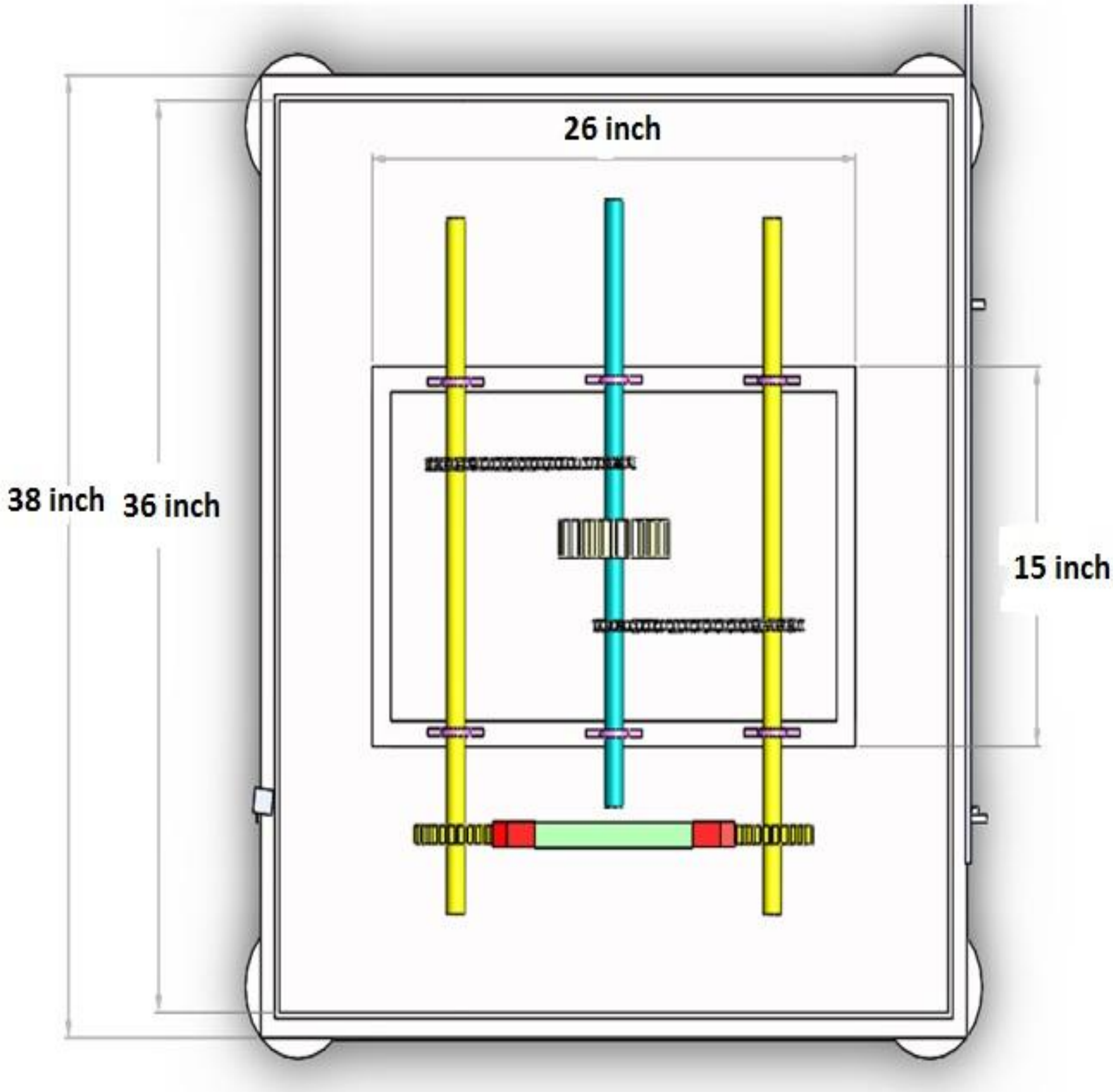

Fig 3.2: Top View of MMR

3. Right View:

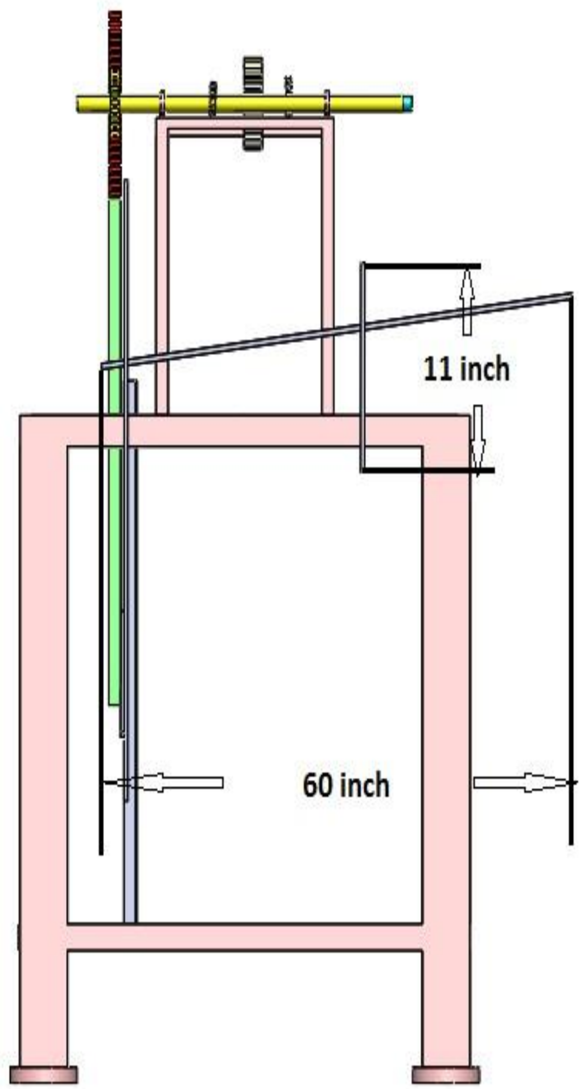

Fig 3.3: Right View of MMR

4. Left View:

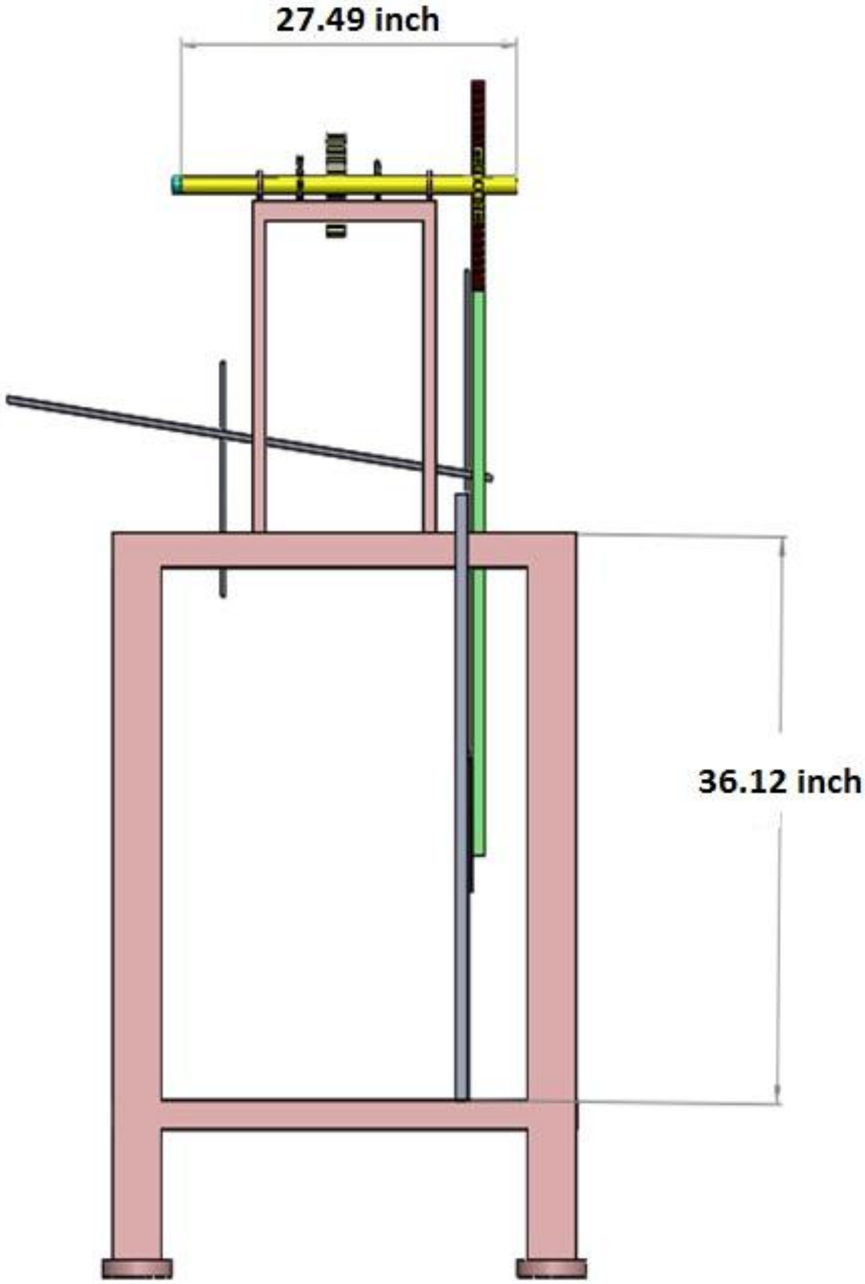

Fig 3.4: Left View of MMR

5. Front View:

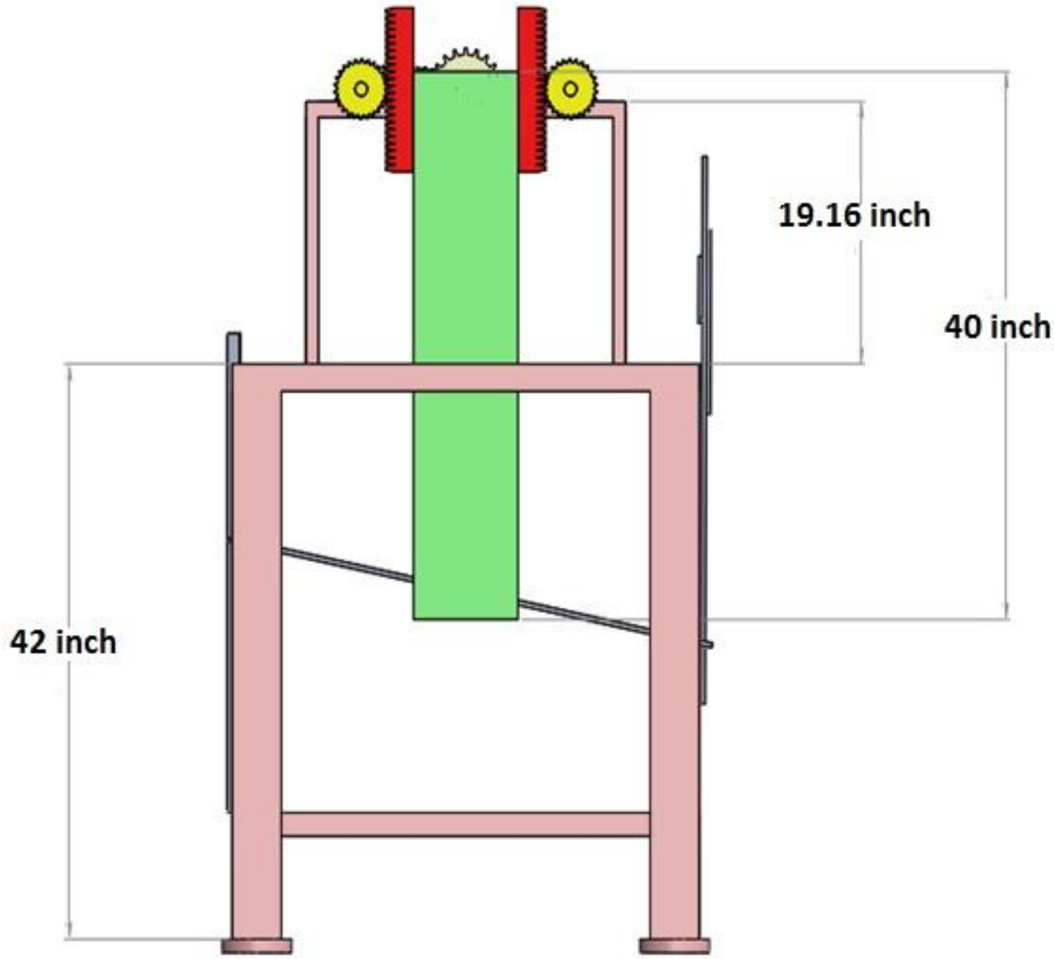

Fig 3.5: Front View of MMR

6. Backside View:

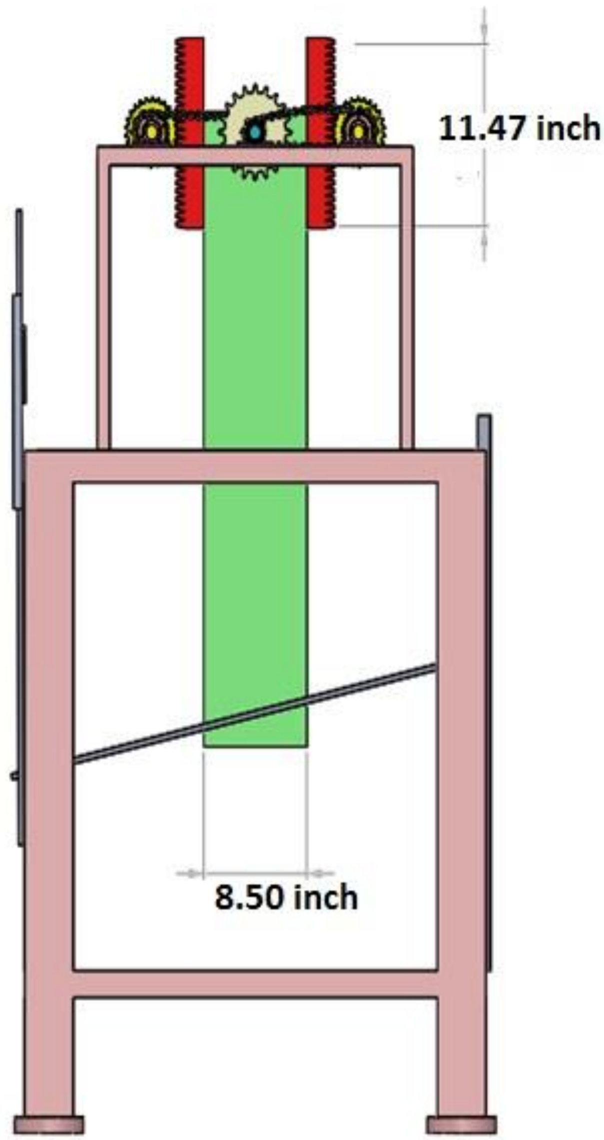

Fig 3.6: Back Side View of MMR

7. Angle Bar Positional view:

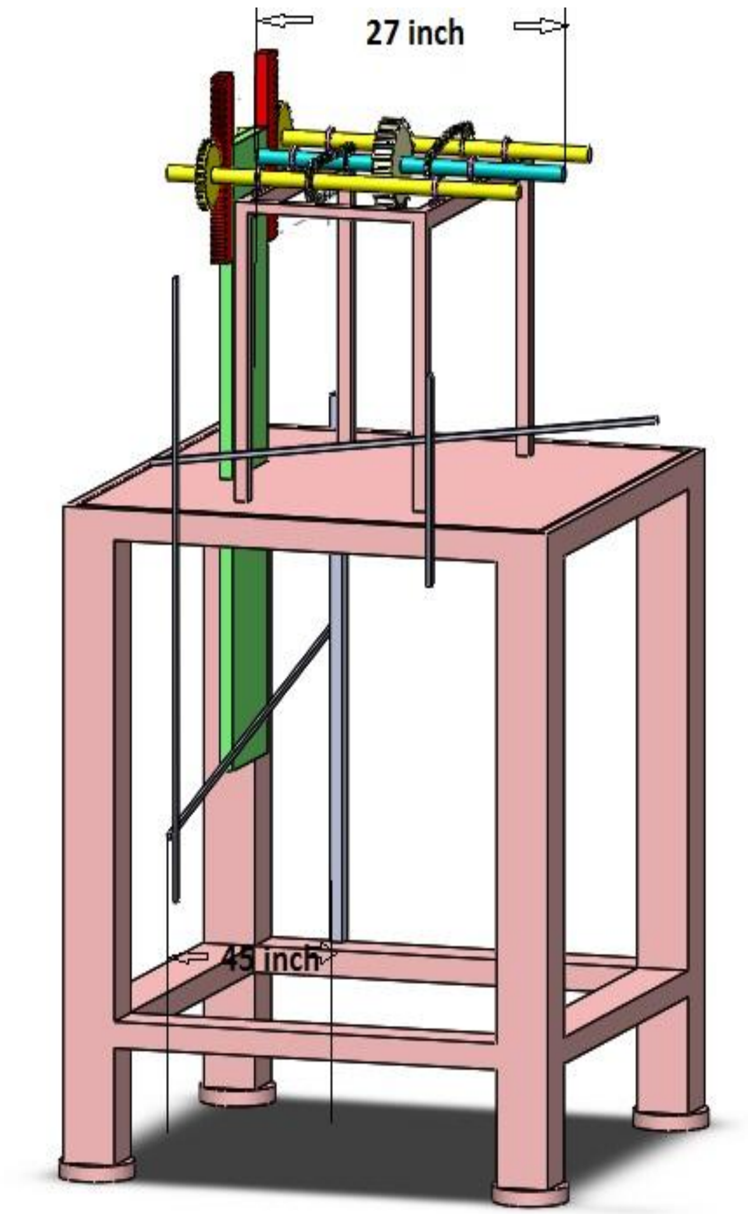

Fig 3.7: Angle Bar Positional View

Chapter-4

Machine Parts

This Mechanical Motion Rectifier consist of different types of machine parts which are interrelated with each other according to the design and construction. So the outcome of this project lies on their function and how well they can connect with each other when input is given to them. Let’s have the briefing regarding these machine parts:

4.1 Rack and Pinion:

A **rack and pinion** is a type of linear actuator that comprises a pair of gears which convert rotational motion into linear motion. A circular gear called "the pinion" engages teeth on a linear "gear" bar called "the rack"; rotational motion applied to the pinion causes the rack to move relative to the pinion, thereby translating the rotational motion of the pinion into linear motion.

Fig4.1: Rack and Pinion

Function:

Racks are attached to the plywood. So they will move back and forth with the movement of the Plywood. Pinions are meshed with the racks to convert the linear motion of the racks into rotational movement

4.2 Shaft:

A **shaft** is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power.[1] The various members such as pulleys and gears are mounted on it.

Types of Shaft:

Transmission shafts: are used to transmit power between the source and the machine absorbing power

Machine shafts: are the integral parts of the machine itself

We use hollow **transmission shaft of 25 mm** in our device

Fig4.2: A transmission hollow shaft

Function:

Input Shafts are internally connected to the gears. So they will rotate at the same direction that the gear rotates and transfer that eventually to the output shaft

4.3 Sprocket:

A **sprocket** or **sprocket-wheel** is a profiled wheel with teeth, cogs, or even sprockets that mesh with a chain, track or other perforated or indented material. The name 'sprocket' applies generally to any wheel upon which radial projections engage a chain passing over it. It is distinguished from a gear in that sprockets are never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth.

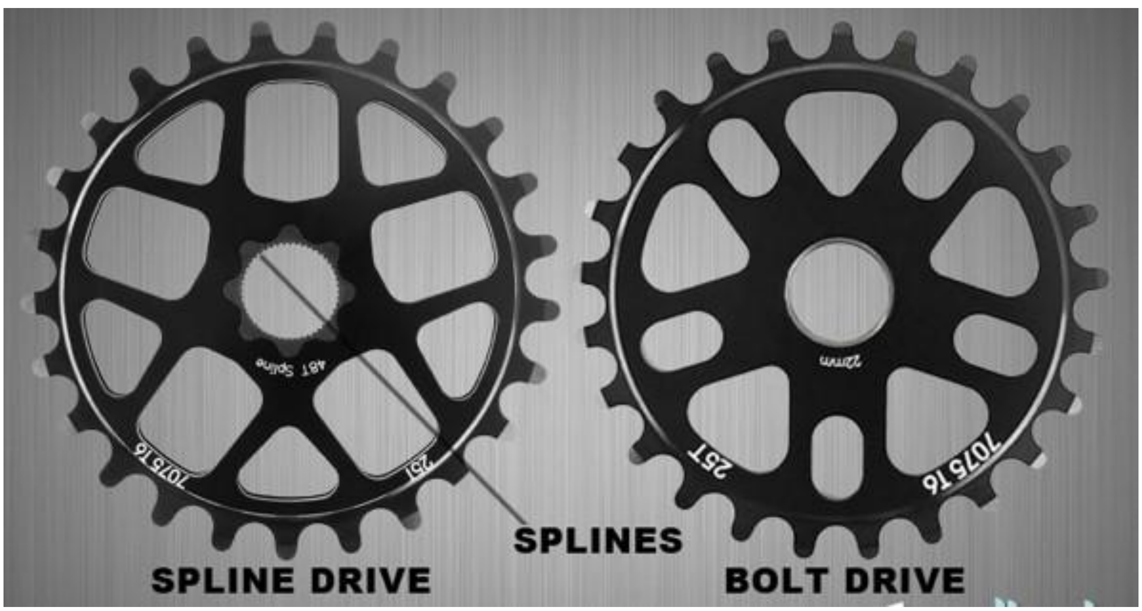

Fig 4.3 : Sprocket

Function:

Sprockets are connected to the rach.ets with chain mechanism. They are also connected with the input shafts. So they rotate at the same direction as the input shaft rotates

4.4 Journal bearing:

A plain **bearing** (in railroading sometimes called a solid **bearing**) is the simplest type of **bearing**, comprising just a **bearing** surface and no rolling elements. Therefore, the **journal** (i.e., the part of the shaft in contact with the **bearing**) slides over the **bearing** surface.

Fig 4.4 : Journal Bearing

Function:

Journal bearing is attached to the frame and it holds down the shafts so that the shaft gets to rotate freely without having huge amount of bending or torsional stress.

4.5 Ratchet/ Freewheel:

A device consisting of a bar or wheel with a set of angled teeth in which a pawl, cog, or tooth engages, allowing motion in one direction only.

Fig4.5: Ratchet or Freewheel

Function:

Ratchets are connected internally to the output shaft. They rotate the output shaft in one direction and rotate freely without rotating the output shaft to the other direction. Initially they are connected with sprockets by chain. So with the rotation of the sprocket the rach.ets start to rotate

4.6 Flywheel:

a heavy revolving wheel in a machine that is used to increase the machine's momentum and thereby provide greater stability or a reserve of available power during interruptions in the delivery of power to the machine.

Fig4.6: Flywheel

Function:

It’s connected to the output shaft for the continuous and better rotation of the shaft.

4.7 Angle bar:

An **angle bar** is also known as an “L-bracket” or an “**angle** iron,” is a metal bracket in the form of a right **angle**. It is made of galvanized steel and often used in masonry or applied to different surfaces through welding or drilling.

Fig 4.7: Angle Bar

Function:

There are numerous no. of angle bar used in this set up. They are attached with each other at different angle by bolts and screws. One of the angle bar is attached to the plywood and the input handle is attached with another angle bar in such a way that when the handle moves up and down the plywood starts to move to the same linear direction

4.8 Plywood:

We used Softwood Plywood in our setup

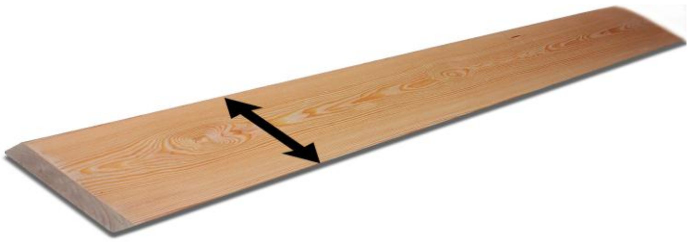

Fig 4.8: Plywood

Function:

Rack is attached to the Plywood and it generates linear motion due to upward and downward movement of Plywood

4.9 Chain:

Fig 4.9: Chain

Function:

Chain transmit power from the sprocket to the ratchet which roates the output shaft

4.10 Table/Base:

A table is used as support of the whole machine. It is made of wood and a steel frame. It is placed at the bottom part of the machine.

4.11 Steel Frame:

A steel frame is used to hold the input and output shafts with journal bearing. The housing of the journal bearing was attached with the frame.

Chapter-5

Working Principle

1. At first the handle attached with the plywood should be moved up and down.

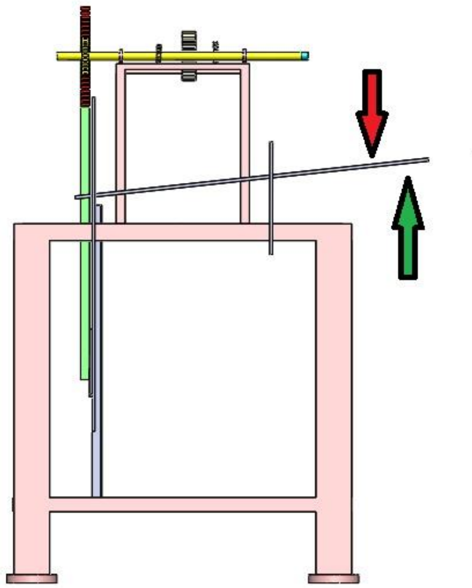

Fig 5.1: Handle Movement

2. By moving the plywood the two racks attached with it also moves linearly.

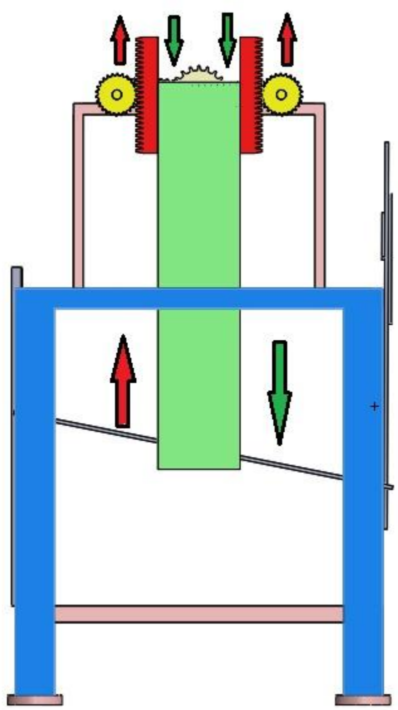

Fig 5.2: Plywood and Rack Movement

3. Then the power is transmitted to both the pinions which are meshed with the racks.

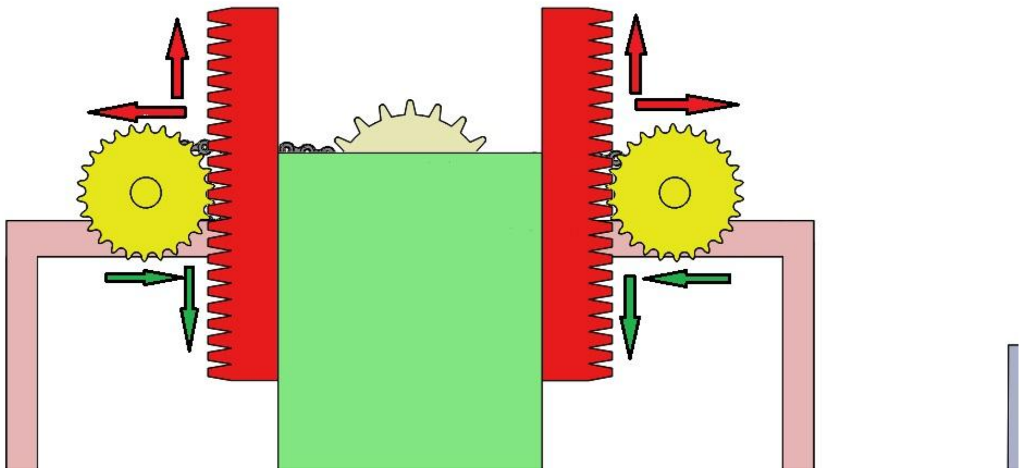

Fig 5.3: Pinion Movement

4. With the rotation of the pinions the input shafts attached with it also rotates.

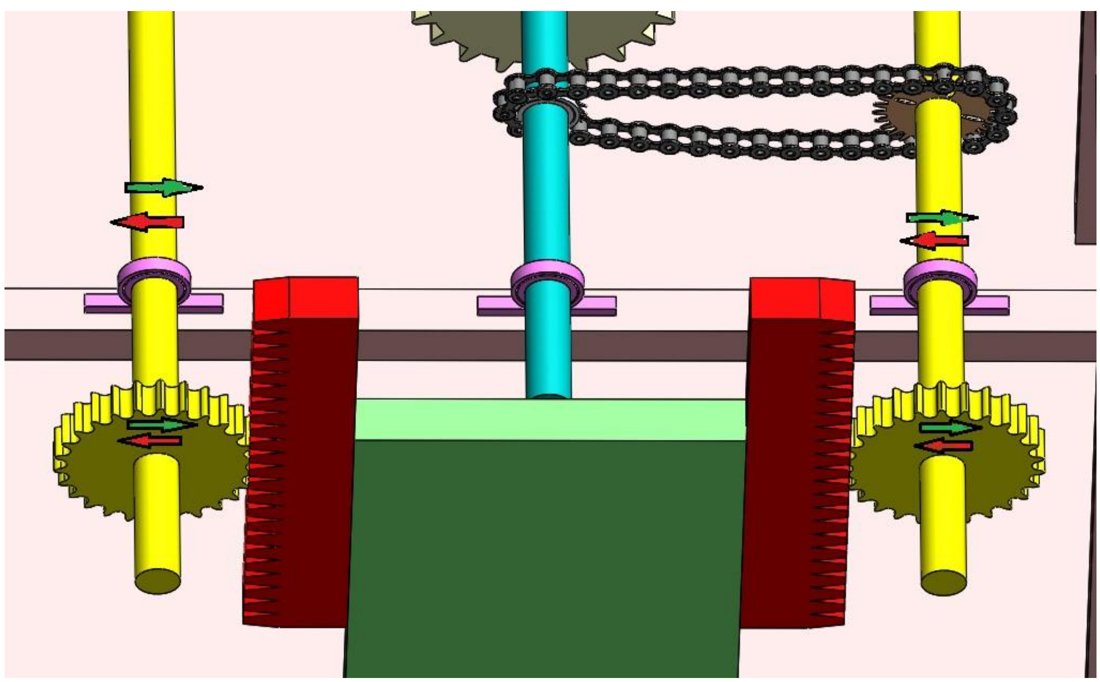

Fig 5.4: Input Shaft Movement

5. The output shaft is placed at the middle of the two input shafts.

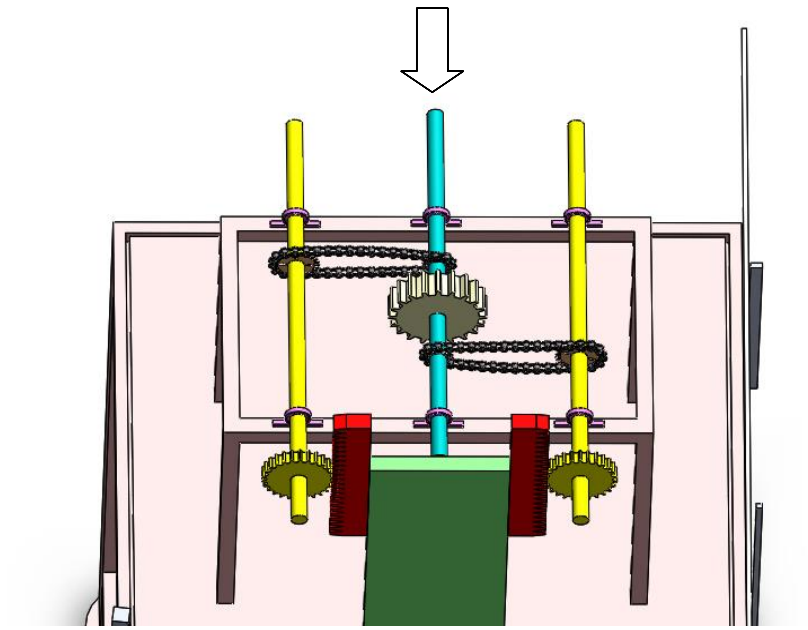

Fig 5.5: Output Shaft Placement

6. The power is transmitted from the input shaft to the output shaft by chain sprocket mechanism.

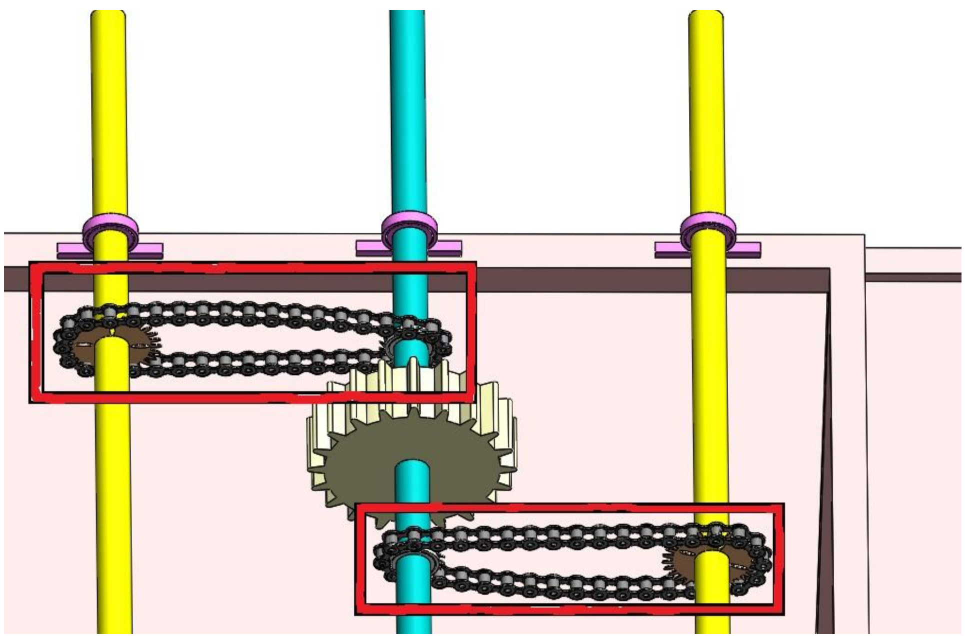

Fig 5.6: Chain and Sprocket Mechanis

7. A sprocket which works according to the mechanism of ratchet wheel. A ratchet wheel can only turn in one direction.

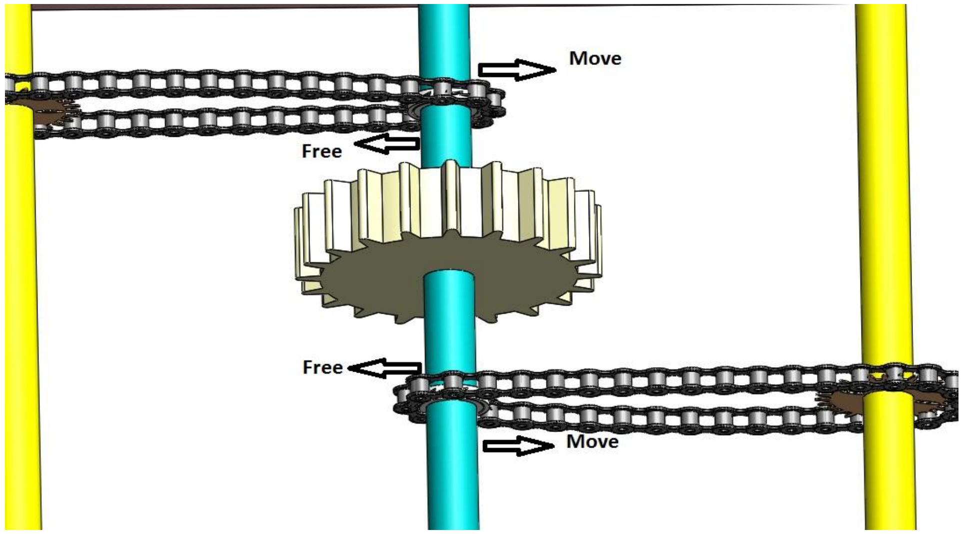

Fig 5.7: Ratchet Movement

8. When Plywood moves in upward direction **shaft 1** moves into **clockwise direction** which makes the rach.et rotates to the same direction with the help of chain sprocket mechanism and **shaft 2** rotates into **anti-clockwise** direction which moves the rach.et connected with it rotates freely. The output shaft connected with both rach.ets, as a result it moves into **clockwise direction**

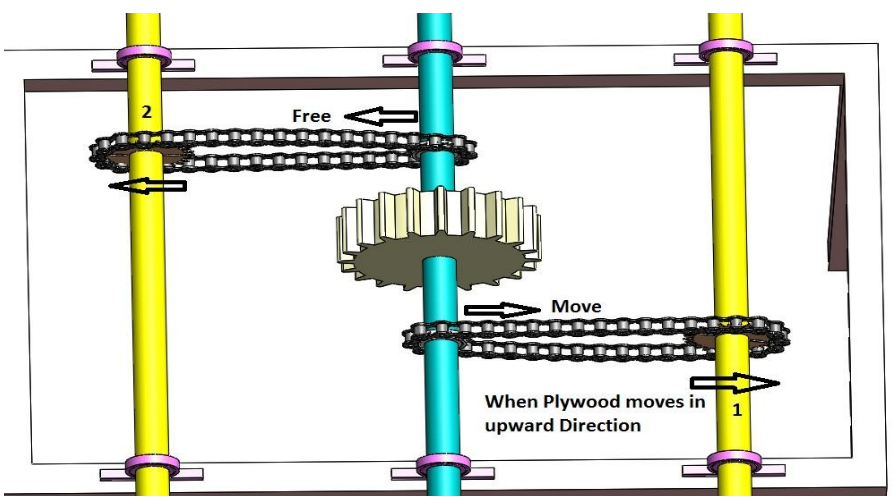

Fig 5.8: Main Mechanism in Upward linear motion

9.When Plywood moves in downward direction **shaft 1** moves into **anti-clockwise direction** which makes the rach.et rotates freely to the same direction with the help of chain sprocket mechanism and **shaft 2** rotates into **clockwise** direction which moves the rach.et connected with it rotate into **clockwise direction**. The output shaft connected with both rach.ets, as a result it rachets into **clockwise direction**

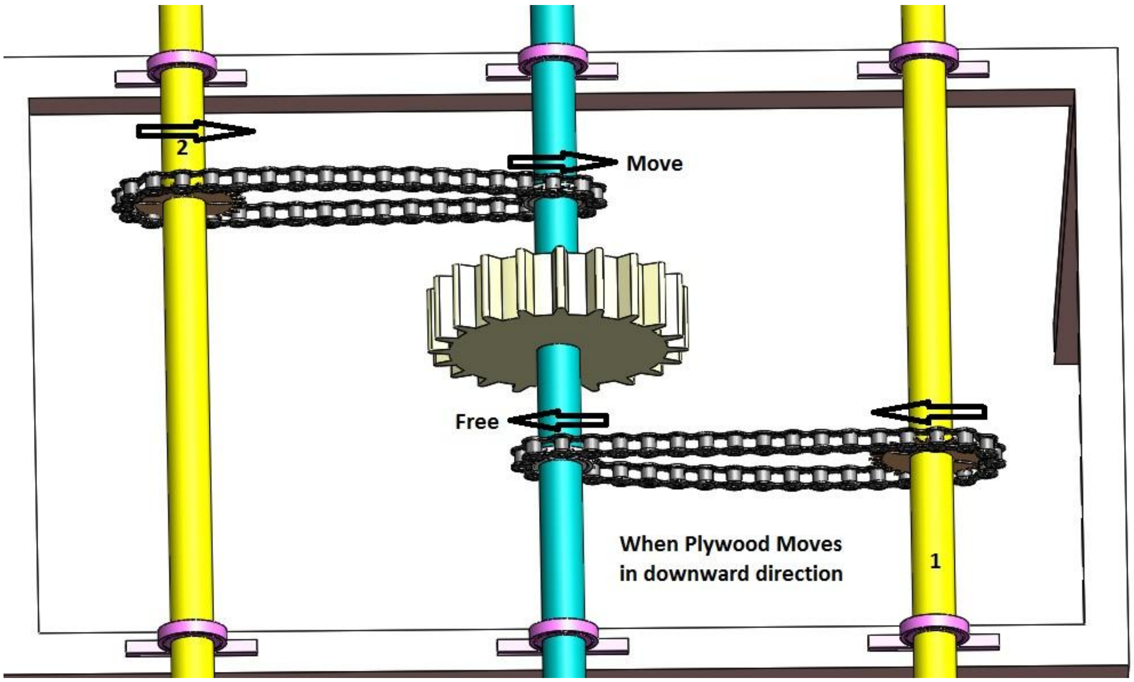

Fig 5.9: Main Mechanism in downward linear motion

10. If we connect both rach.et in **anticlockwise direction** to rotate the output shaft and and make them free in opposite direction we can get the same unidirectional motion of the output shaft in **anticlockwise direction** with the help of same mechanism

Chapter-6

Machine Dimension &Materials

Table 6.1 Machine Dimensions:

Parameter	Quantity
1. Table height	40 inch
2. Table Width	36 inch
3. Table Length	36 inch
4. Frame height	19.16 inch
5. Frame Width	15 inch
6. Shaft length	27inch
7. Shaft Inside dia	0.69 inch
8. Shaft Outside dia	0.98 inch
9. Handle length	60 inch
10. Handle Bracket	11 inch
11. Plywood Height	40 inch
12. Plywood width	8.3 inch
13. Total Rack length	12.4 inch
14. Rack length from first to last teeth	11.47 inch
15. Pinion dia	5.6 inch
16. No. of Pinion teeth	55
17. No. of Rack teeth	29
18. Flywheel dia	5.07 inch
19. Rack Width	0.7 inch
20. No. of Sprocket teeth	18
21. Freewheel dia	3.34 inch
22. Sprocket dia	4.52 inch

Parameter	Quantity
23.Angle bar attached to handle	32 inch
24.Angle bar attached to plywood	45 inch
25.Circular Pitch of Pinion	0.51 inch
26.Linear Pitch of Rack	028 inch

Table 6.2 Machine Materials:

Machine Parts	Material Used
1. Plywood	Softwood
2. Table/Base	Wood & Mild Steel
3. Frame	Mild steel
4. Shaft	Mild steel
5. Freewheel	Stainless Steel
6. Pinion	Mild Steel
7. Rack	Mild Steel
8. Sprocket	Stainless Steel

Chapter-7

Manufacturing Process

7.1 Gear Cutting Methods:

7.1.1 Broaching:

For very large gears or spline, a vertical broach is used. It consists of a vertical rail that carries a single tooth cutter formed to create the tooth shape. A rotary table and a Y axis are the cusomary axes available. Some machines will cut to a depth on the Y axis and index the rotary table automatically. The largest gears are produced on these machines.

Other operations such as broaching work particularly well for cutting teeth on the inside. The downside to this is that it is expensive and different broach sticks are required to make different sized gears. Therefore, it is mostly used in very high production runs.

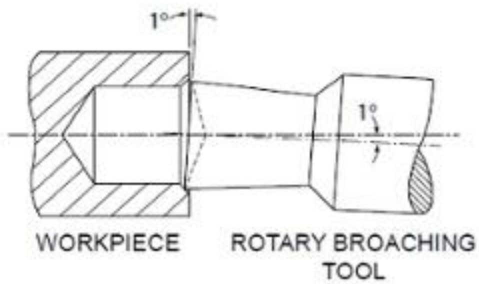

Fig 7.1: Broaching

7.1.2Hobbing:

Hobbing is a method by which a hob is used to cut teeth into a blank. The cutter and gear blank are rotated at the same time to transfer the profile of the hob onto the gear blank. The hob must make one revolution to create each tooth of the gear. Used very often for all sizes of production runs, but works best for medium to high.

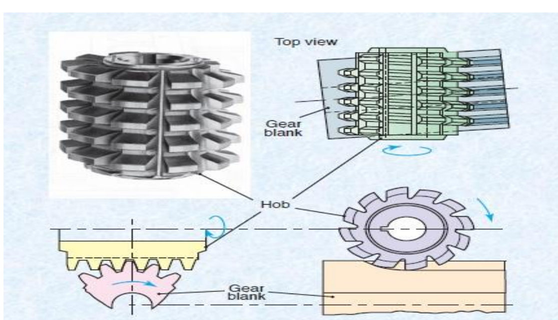

Fig7.2 : Hobbing

7.1.3 Milling or grinding:

Spur may be cut or ground on a milling machine or jig grinder utilizing a numbered gear cutter, and any indexing head or rotary table. The number of the gear cutter is determined by the tooth count of the gear to be cut.

To machine a helical gear on a manual machine, a true indexing fixture must be used. Indexing fixtures can disengage the drive worm, and be attached via an external gear train to the machine table's handle (like a power feed). It then operates similarly to a carriage on a lathe. As the table moves on the X axis, the fixture will rotate in a fixed ratio with the table. The indexing fixture itself receives its name from the original purpose of the tool: moving the table in precise, fixed increments. If the indexing worm is not disengaged from the table, one can move the table in a highly controlled fashion via the indexing plate to produce linear movement of great precision (such as a vernier scale).

There are a few different types of cutters used when creating gears. One is a rack shaper. These are straight and move in a direction tangent to the gear, while the gear is fixed. They have six to twelve teeth and eventually have to be moved back to the starting point to begin another cut.

A popular way to build gears is by form cutting. This is done by taking a blank gear and rotating a cutter, with the desired tooth pattern, around its periphery. This ensures that the gear will fit when the operation is finished.

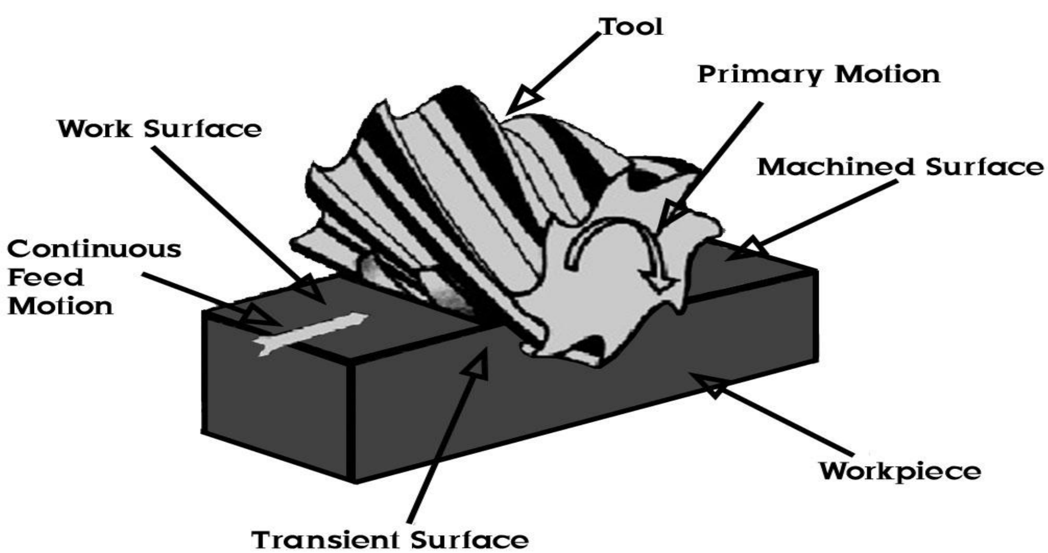

Fig 7.3 Milling Process

7.1.4 Shaping:

The old method of gear cutting is mounting a gear blank in a shaper and using a tool shaped in the profile of the tooth to be cut. This method also works for cutting internal splines.

Another is a pinion-shaped cutter that is used in a gear shaper machine. It is basically when a cutter that looks similar to a gear cuts a gear blank. The cutter and the blank must have a rotating axis parallel to each other. This process works well for low and high production runs.

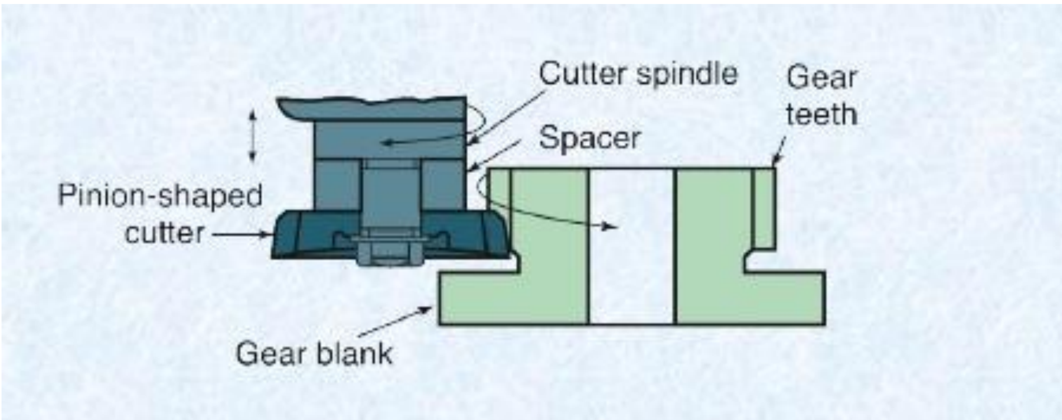

Fig 7.4 Shaping

7.1.5 Finishing:

After being cut the gear can be finished by shaving, burnishing, grinding, honing or lapping

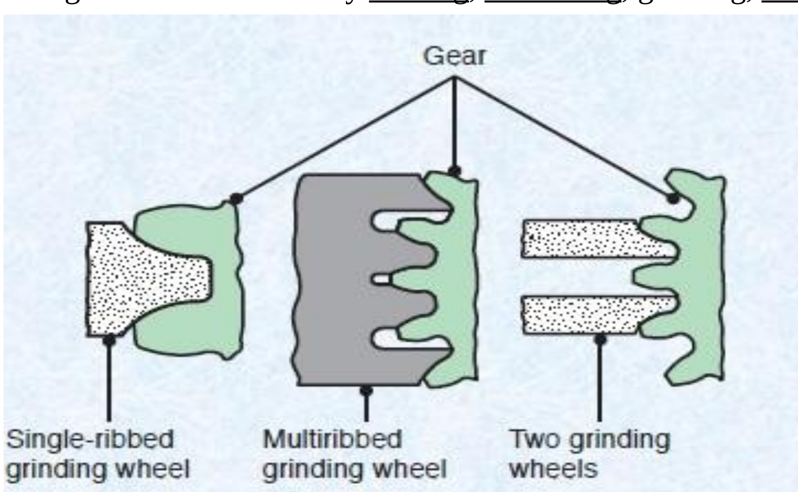

Fig 7.5: Finishing

7.2 Method Used In This Project:

We used Milling and Finishing process for our gear (pinion) cutting because Milling is more suitable for spur gear and we used spur gear as pinion in our set up. Moreover Shaping has become an obsolete and time consuming process. Hobbing is more likely to be used in helical gear which we didn’t use so we eliminate this process as well. We used Finishing process to get good surface finish so that the pinions get good surface contact with rack and rotate along with its movement.

7.3 Heat treatment of gear:

Heat treatment is a critical and complex element in the manufacturing of gears that greatly impacts how each will perform in transmitting power or carrying motion to other components in an assembly. Heat treatments optimize the performance and extend the life of gears in service by altering their chemical, metallurgical, and physical properties. These properties are determined by considering the gear’s geometry, power transmission requirements, stresses at different points within a gear under load, load cycling rates, material type, mating part designs, and other operating conditions.

7.3.1 Importance:

Heat treatments improve physical properties such as surface hardness, which imparts wear resistance to prevent tooth and bearing surfaces from simply wearing out. Heat treatments also improve a gear’s fatigue life by generating subsurface compressive stresses to prevent pitting and deformation from high contact stresses on gear teeth. These same compressive stresses prevent fatigue failures in gear roots from cyclic tooth bending. Physical properties such as surface hardness, core hardness, case depth, ductility, strength, wear resistance and compressive stress profiles can vary greatly depending on the type of heat treatment applied. For any given type of heat treatment the results can be tailored by modifying process parameters such as heating source, temperatures, cycle times, atmospheres, quench media, and tempering cycles to meet specific application requirements.

7.3.2 Working procedure:

To understand the basic working mechanism a basic knowledge of metallurgy is needed. Iron, when combined with small percentages of carbon, forms steel. Plain carbon steels typically contain 1 percent or less carbon in combination with iron. The maximum hardness that any plain carbon steel can achieve during heat treatment is primarily a function of its carbon content. Higher carbon content steels are capable of being hardened to higher hardness values than lower carbon content steels. To make alloy steels, small percentages of other elements such as Cr, Ni, Mo, Si, B, V, Ti, Al, N, Nb, W, and Cu (to name the most common) are added to steel. These alloying elements are added in order to increase hardenability or enhance specific properties such as toughness or resistance to softening from heat build-up. For heat treaters the higher hardenability allows for slower quenching, which means distortion can be kept to lower levels in more highly alloyed steels. Steels can be annealed by thermally processing at a high temperature and slow cooling to soften it. In this soft and malleable state it can be machined, formed, hobbed, and ground easily into a desired shape. What makes steel industrially important is that it can be hardened after the material has been formed or shaped in the soft state to a desired geometry. By use of a thermal processing cycle where steel is heated to austenitizing temperatures and rapidly quenched, the near-finished components can be hardened to improve wear resistance, strength, and hardness. After quenching to the maximum hardness achievable, which is determined by the steel’s carbon content, the steel may then be tempered down to a lower hardness to improve ductility and toughness at the expense of slightly reducing the strength, hardness, and wear characteristics of the material.

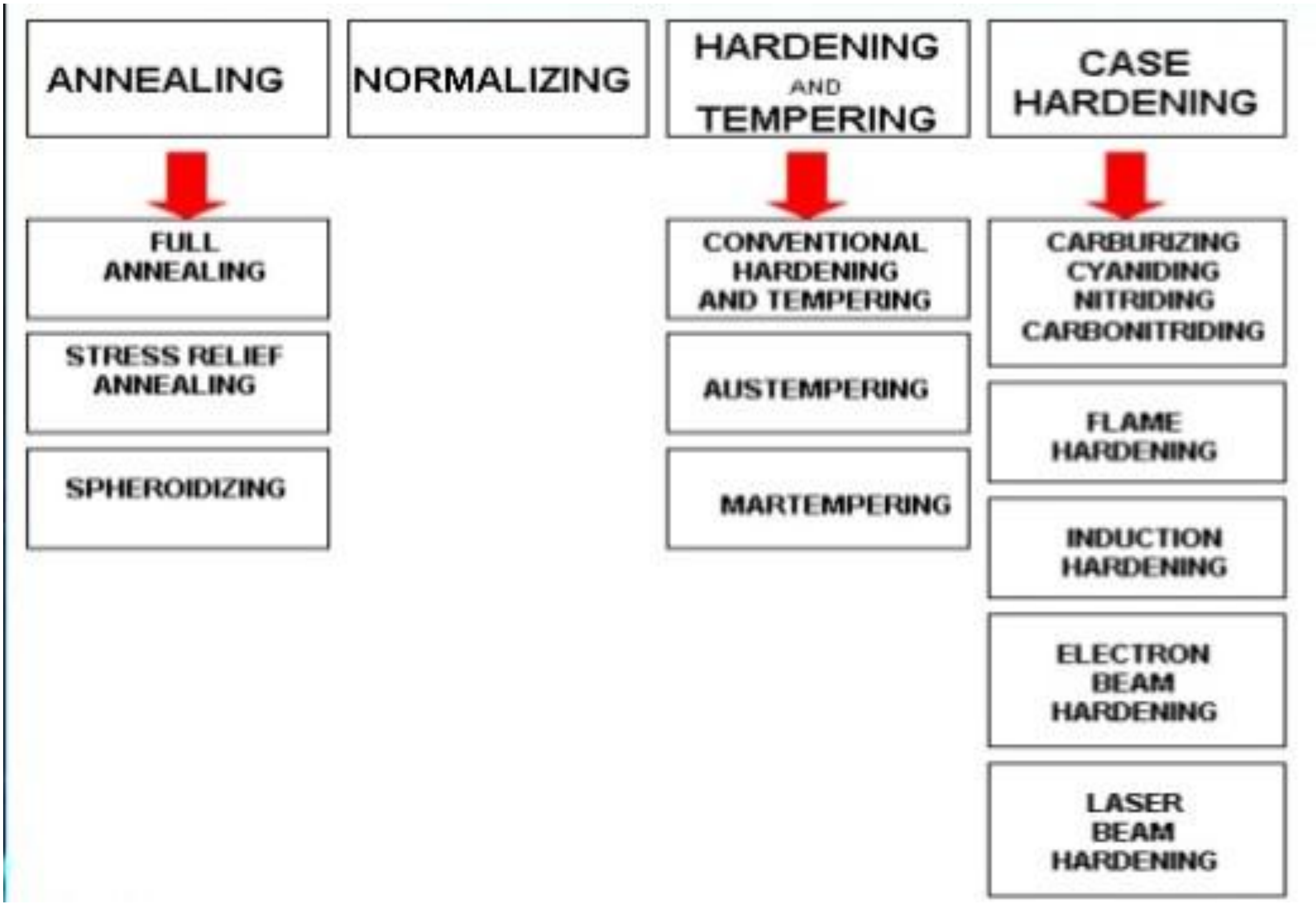

Fig 7.6: Heat treatment process

Temperature Parameters of Heat treatment of gear:

Fig 7.7: Heat treatment at different Temperature

7.3.4 Stages of Heat treatment:

1. Heating the gear metal slowly ensure a uniform temperature
2. Soaking the gear metal at a given temperature for a given period of time
3. Cooling the gear metal to room temperature

Soaking period:

Table 7.1 Soaking Period

Thickness of Gear Metal (inches)	Time of Heating (min)	Soaking time (min)
Up to 1	45	30
1-2	75	30
2-3	105	45
3-4	135	60
4-5	165	60
5-8	210	90

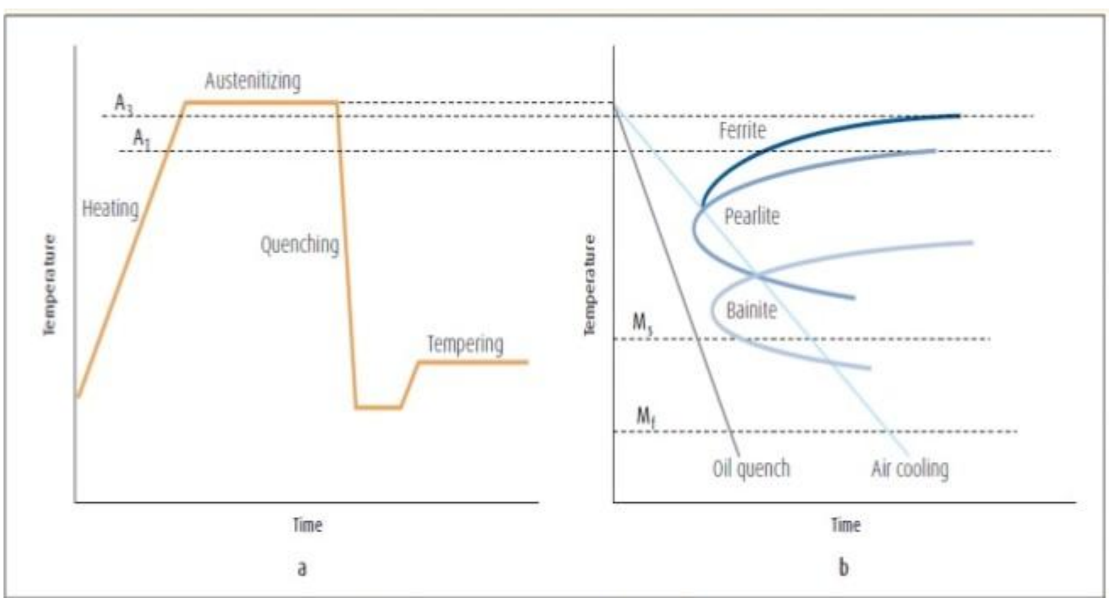

Fig 7.8 Temp to time cycle at different stages of heat treatment of gear metals

7.4 MACHINING Of THE GEAR:

Table 7.2 Cutter Selection Criteria

Range of Teeth	NO. of Cutter
135 or above	1
55-134	**2**
35-54	3
26-34	4
21-25	**5**
17-20	6
14-16	7
12-13	8

- The machining of the gear was done with a column and knee type milling machine.
- The workpiece made of mild steel was placed on the vice of the milling machine.
- The workpiece was placed in horizontal direction. End mill cutter was used as a cutting tool of the machine.
- Then the operation was started.
- There are six types of indexing. Simple indexing was used in this project.
- Workpiece was positioned by means of crank, index plate, and sector arms.
- Worm attached to crank must be engaged with worm wheel on dividing head spindle.
- There are 40 teeth on worm wheel.
- One complete turn on index crank cause spindle and work to rotate one-fortieth of a turn (40:1).
- Calculating the indexing or number of turns of crank for most divisions to be cut or

  Indexing = $\frac{40}{N}$

7.5 The indexing required to cut 55 teeth:

$$\frac{40}{N} = \frac{40}{55} = \frac{8}{11}$$

The eight-eleventh turn was involved use of an index plate and sector arms.

- Circular plate provided with series of equally spaced holes into which index crank pin engaged was known as index plate.

Table 7.3 Index Plate Hole Circle

Plate 1	15-16-17-18-19-20
Plate 2	21-23-27-29-31-33
Plate 3	37-39-41-43-49

- Plate 2 was used for 33 holes. So 24 full turns of 33 hole circle was done for cutting gear of 55 teeth.
- Sector arms is the fit on front of plate and may be set to any portion of a complete turn.

7.6 Lubrication:

Basically there are two mechanism works in our set up for which we need good lubrication They are:

1. Rack and Pinion Mechanism
2. Chain and sprocket Mechanism

7.6.1 Lubrication for Rack and Pinion:

In order to achieve a long service life, our rack and pinion systems require adequate lubrication. So we use grease as a lubricant. This ensures an optimal lubricating film on the rack and pinion. In addition to the supply of lubricant, the lubricating pinion also ensures cleaning of the open toothing.

7.6.2 Grease as a Lubricant:

There are three components that form lubricating grease. These components are oil, thickener and additives. The base oil and additive package are the major components in grease formulations, and as such, exert considerable influence on the behavior of the grease. The thickener is often referred to as a sponge that holds the lubricant (base oil plus additives).

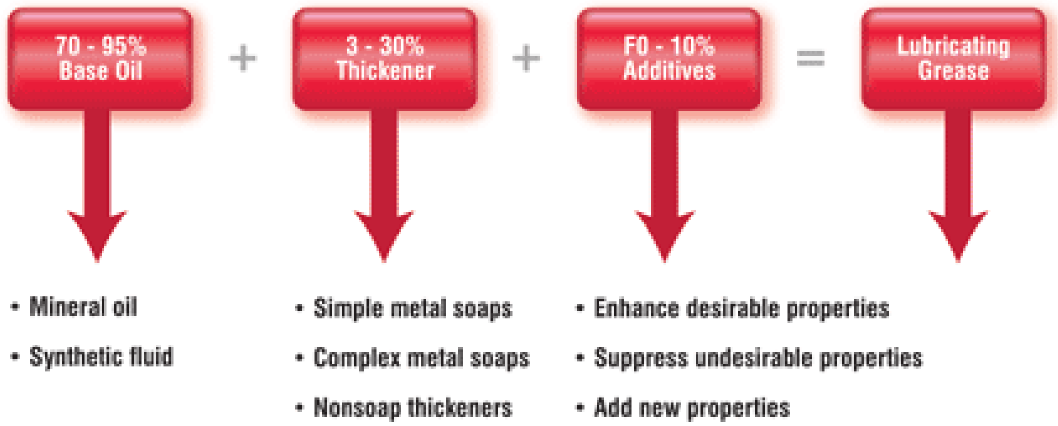

Fig 7.9 : Grease Anatomy

7.6.3 Applications Suitable for Grease:

Grease and oil are not interchangeable. Grease is used when it is not practical or convenient to use oil. The lubricant choice for a specific application is determined by matching the machinery design and operating conditions with desired lubricant characteristics. Grease is generally used for:

1. Machinery that runs intermittently or is in storage for an extended period of time. Because grease remains in place, a lubricating film can instantly form.
2. Machinery that is not easily accessible for frequent lubrication. High-quality greases can lubricate isolated or relatively inaccessible components for extended periods of time without frequent replenishing. These greases are also used in sealed-for-life applications such as some electrical motors and gearboxes.
3. Machinery operating under extreme conditions such as high temperatures and pressures, shock loads or slow speed under heavy load.

4. Worn components. Grease maintains thicker films in clearances enlarged by wear and can extend the life of worn parts that were previously lubricated by oil.

7.6.4 Functional Properties of Grease:

1. Grease functions as a sealant to minimize leakage and to keep out contaminants. Because of its consistency, grease acts as a sealant to prevent lubricant leakage and also to prevent entrance of corrosive contaminants and foreign materials. It also acts to keep deteriorated seals effective.
2. Grease is easier to contain than oil. Oil lubrication can require an expensive system of circulating equipment and complex retention devices. In comparison, grease, by virtue of its rigidity, is easily confined with simplified, less costly retention devices.
3. Grease holds solid lubricants in suspension. Finely ground solid lubricants, such as molybdenum disulfide (moly) and graphite, are mixed with grease in high-temperature service or in extreme high-pressure applications. Grease holds solids in suspension while solids will settle out of oils.
4. Fluid level does not have to be controlled and monitored.

7.6.5 Advantages for this design:

1. Significantly increase service life
2. Reduce maintenance requirements
3. No hardening owing to the lubricating medium or contamination or during long term use
4. The sliding bush ensures low wear even at high speeds
5. Virtually with no limitations regard to this use
6. More compact connection through greater degrees of freedom in design

7.6.6 Lubrication for Chain and Sprocket:

Lubrication of roller chains is extremely important. Without proper lubrication, the chain will run through its lifespan much more quickly. It is becoming more common for standard roller chains to be used in very harsh conditions, making lubrication even more important than before. In some cases, the usage environment may make lubrication impossible Generally recommend high grade lubricate oil. Appropriate oil with appropriate character, light or heavy, depending on ambient temperature, lubrication method, chain size, and speed, needs to be selected. **In our setup we use manual lubrication by manually applying oil with oil filler or brush usually every 8 hours**

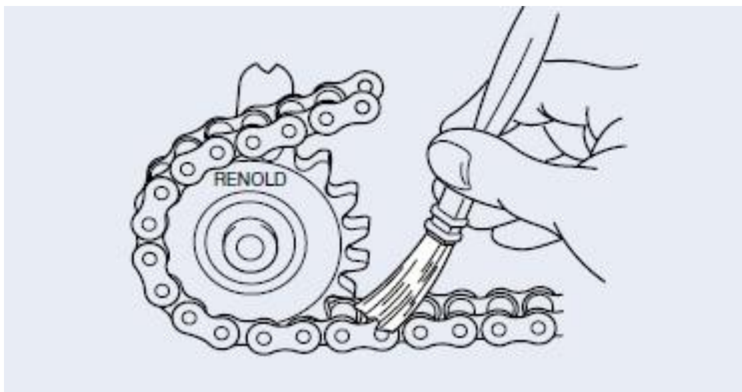

Fig 7.10: Manual Lubrication

7.6.7 Lubricating Oil as a lubricant:

We use High grade lub oil in our roller chain because Chain lubricants should have the following characteristics:

- Sufficiently low viscosity to reach the internal surfaces – a carrier solvent or penetrating component helps to achieve this without lowering the operating viscosity.
- Sufficient body to maintain the lubricating film under the bearing pressures – solid lubricants can help.
- Freedom from corrosive ingredients.
- Ability to maintain lubricating qualities under different temperatures, moistures, etc.

7.6.8 Effect of Temperature:

We mainly use Lub Oil of SAE 20- SAE 50 due to ambient temp.

Table 7.4 Lubricating oil selection criteria

Ambient Temperature °F	Ambient Temperature °C	Lubricant SAE	Rating BS4231
23 to 41	-5 to +5	20	46 to 68
41 to 104	5 to 40	30	100
104 to 122	40 to 50	40	150 to 220
122 to 140	50 to 60	50	320

7.6.9 Precaution for lubrication:

During operation an important factor to control in a drive system is the chain and chain case temperature. Depending on the severity of the drive service, continuity of use, etc., special attention to the lubrication method may be required. Chain temperatures above 212°F (100°C) should be avoided if possible due to lubricant limitations, although chain can generally give acceptable performance up to approximately 482°F (250°C) in some circumstances. One way of improving the effectiveness of the lubrication and its cooling effect is to increase the oil volume (up to 1.2 gallons per minute or 4.5 liters per minute per chain strand) and incorporate a method of external cooling for the oil.

7.7 Fabrication:

Fabrication means to assemble all the parts of the machine. The fabrication process of this project was done by the following steps.

- All the parts were collected to make the machine at first.
- The rack and pinion was produced by knee and column type milling machine.
- The pinion was made with 55 teeth.
- The rack was made with 29 teeth.
- To support the machine a support of wooden table was made with a frame of angle bar.
- For the three shaft in the project MMR six journal bearing with housing was used on both sides of the shafts.
- To place and support the shafts a frame was made on the table. The housing of the bearings were attached with the frame with bolt and screw.
- Then sprockets and ratchets were attached with the input and output shaft.
- After that two chain was attached them.
- The pinions was then attached with the input shaft.
- A plywood was used to attach with the racks which was then meshed with the pinions.
- So the plywood was become our input shaft. It was placed in such a way that it can move up and down.
- Then to move the plywood up and down a handle was made. The handle used in this project was by crank mechanism. Two cranks and a handle was used there. The cranks were made with angle bar.
- The cranks and the handle were hinged in four position.
- The whole process was done with good precision.

CHAPTER- 8

Prospects

8.1 Advantages:

1. Economical
2. Pollution free
3. Works with any oscillation
4. Simple mechanism
5. Easy to use
6. Provide steady power output
7. It never stops rotating the shaft even if there is very less oscillation
8. Easy to maintain and install
9. The rotational speed of shaft can be controlled in terms of external input other than waves oscillation
10. Source is unlimited.
11. It solves the challenge of large scale vibration energy harvesting due to irregular oscillation.
12. It could be used in regenerative shock absorber in oscillatory motion
13. Provides greater design freedom by offering more positioning options for the motor, Driving and driven components
14. The model is capable of analyzing electrical and mechanical components at the same time.
15. It can work as a controllable damper as well as an energy generator
16. This design can provide integrated power solution to microelectronics, sensor networks and portable devices.
17. It can easily generate electricity in obsolete places through its handling mechanism

8.2 Disadvantages:

1. Initial cost is high
2. Strong structure is necessary which is quite difficult to build on sea bed
3. Efficiency is low
4. Generally power transmission is done by one or rare cases two shaft but in this set up we have to use three shafts
5. Friction between the plywood and frame surface reduces the efficiency in little margin
6. Not very compact in size

8.3 Comparison with other devices:

We use Mechanical Motion Rectifier as **Electromagnetic** harvester because it has same characteristics such as:

1. well suited for micro generator
2. do not require smart materials
3. no need external voltage source to start generating
4. output voltage is low
5. bulky in size
6. difficult to manufacture in micro scale

If we compare it with **Electrostatic** harvester :

Similarities:

1. Do not require smart materials
2. Low output current

Dissimilarities:

1. High output voltage
2. High output impedance
3. Need initial voltage from external voltage source

If we compare it with **Piezoelectric** harvester:

Similarities:

1. Require no external voltage source

Dissimilarities:

1. Compact in dimension
2. Output voltage relatively high
3. Poor mechanical properties

If we compare it with **Magnetostrictive** harvester:

Similarities:

1. High flexibility
2. Suited to high frequency Vibration
3. Need of pick up coil

Dissimilarities:

1. Non linear effect
2. Difficult to integrate with fabrication process

8.4 Applications:

1. It can be used for vibration in road roughness
2. It can be used in a film projector whereby linear motion of a solenoid is converted into unidirectional rotary motion of the film drive shaft to advance a frame of the film in the projector
3. It can be used in different water resources like pond or river or even in dam apart from ocean
4. It can be employed in a particular strapping tool
5. The output shaft can be used as a flexible shaft to control the speed of large rollers of different machine tools by connecting or meshing with them.
6. It can be used in conventional regenerative shock absorber
7. This motion rectifier can be used electromagnetic vibration energy harvesting process
8. It can also be used in tall buildings and long bridges to use the vibration energy from them
9. It can be used in self power wireless sensor
10. It can be used in railroad tracks to recover energy from the vibration induced by the passing trains

Chapter-9

Research & Future Scope

9.1 Researches and Present works:

- State University of New York have already done a project regarding the fact of Mechanical Motion Rectifier. Their project title was **Energy Harvesting from Rail Track for Transportation Safety and Monitoring**. In this project they designed an efficient electromagnetic energy harvester featured with mechanical motion rectifier (MMR) to recover energy from the vibration-like railroad track deflections induced by passing trains. The main reason behind this project was to monitor the trackside electrical infrastructure which requires a power supply of 10-100 Watts, such as warning signals, switches, and health monitoring systems. So they designed and proposed a mechanical motion rectifier to power major track-side accessories and possibly make railroad independent from national grid. This rectifier uses motion conversion mechanism which transforms pulse-like bidirectional linear vibration into unidirectional rotational motion at a high efficiency

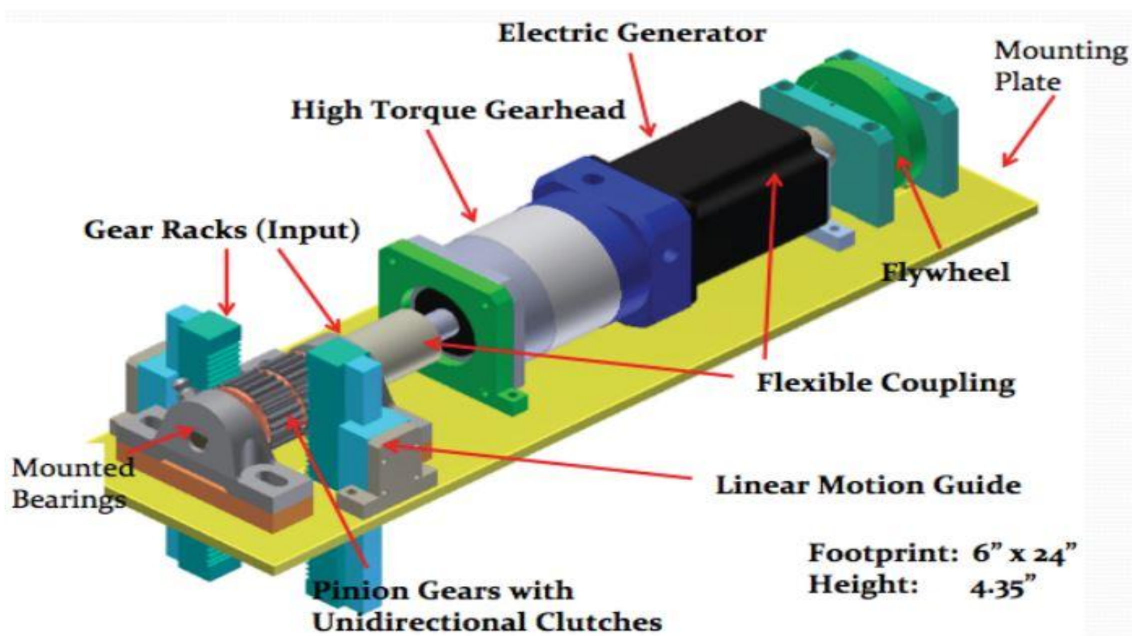

Fig 9.1: The patented mechanical motion rectifier to converts the up and down vibration into unidirectional rotation with high efficiency and high output power

- Lei Zuo a mechanical Engineer and an **Associate Professor at Virginia Tech** also works on this Mechanical Motion Rectifier concept by viewing the unlimited, cheap and clean energy contained in ocean. He uses the up and down and back and forth oscillation of wave energy and turns it into a unidirectional rotation to drive the generator. This design also uses a ball screw and highly efficient power electronics, will be placed in a metal or composite housing, which is placed in the water in the same way as a buoy. Energy generation begins almost immediately as the waves move the buoy and the components inside. He said about the challenges behind this energy harvesting process that "Waves are very irregular and change quickly and frequently, so we needed to come up with a mechanism that would be able to maximize the energy output from the various oscillatory inputs of wave energy." So far his team has built a small, 1.2-meter proof-of-concept device using rack pinion, which was tested off the coast of Long Island

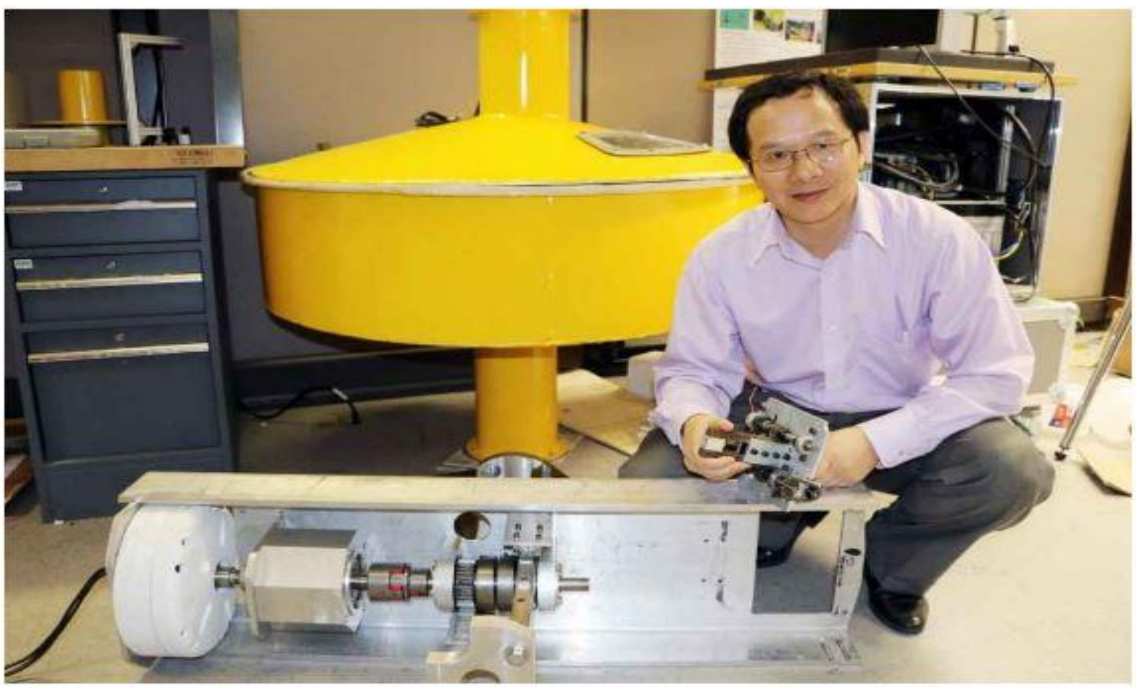

Fig 9.2: Lei Zuo, associate professor of mechanical engineering in Virginia tech., holds the first iteration of a mechanism designed to harvest wave energy. The larger version at his feet will use a multi-directional system that gathers energy as waves move back and forth. The apparatus will be housed in a buoy similar to the yellow one behind him.

9.2 Future development:

For the United States, where 53 percent of the population lives within 50 miles of the coast, energy potential from ocean waves could make up 64 percent of the electricity generated from all sources in the country in 2010. That's why The U.S. Department of Energy (DOE) recently confirmed a $2 million grant for Zuo to produce a prototype new generation of ocean wave generator and make further development of that design. According to the research, the team of Lei Zuo will build and test a 500-watt unit using ball screw and Mechanical Motion Rectifier mechanism and then will develop and test a 10 kilowatt device housed in a container about 5 meters in diameter. Ultimately, a full-sized wave energy converter can be scaled up to about 25 meters in diameter and able to generate about half a megawatt of power. Then they will put the 500W wave energy converter in the water off Hampton Roads, Virginia, by November and collect the data which will help them to improve the larger unit which will be tested, probably in Hawaii at the Navy's Wave Energy Test Site, in 2017.

Chapter-10

Conclusion & Recommendation

10.1 Conclusion:

Mechanical motion rectifier is an useful tool for converting different unused mechanical motions into usable form. The output shaft gives rotary motion in one direction. Throughout the project we have tried to design a machine which can make rotary motion in output shaft. During designing we have tried to get an efficient mechanism within the short time period. During construction of the machine all the measurement was done in highest precision. The gear meshing, chain-sprocket setting was done with as much perfection as possible.

10.2 Recommendation:

1. Use of ball bearing in place of journal bearing will make the shaft rotation more smooth and continuous
2. More compact size of this machine will make it easy to handle
3. Lesser weight and more rigidity of the plywood will increase the efficiency.
4. Axial stretch of the shafts can be minimized as it contributes to shaft helixing which reduces torsional stiffness of the shafts
5. In place of hollow shaft solid shaft can be used for continuous and better rotation
6. The prototype of this motion rectifier can be constructed to achieve efficiency upto 60%
7. Multiple output shafts can be designed easily with its mechanism to increase its efficiency
8. Use of motion sensor can easily work with the handling system and automatically generate electricity
9. No of teeth of pinion and rack can be increased without changing diameter for better motion transmission

Reference

List of Reference

No	About
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3.	www.gearsolutions.com for Article on Heat Treatment of Gear
4.	www.machinerylubrication.com for Article on Grease Basics
5.	www.wikipedia.com for machine parts description
6.	Research Paper Reg. No- 2014DN06 submitted by Shambhu Kumar on Mechanical Motion rectifier
7.	www.vtnews.vt.edu/articles/2016/03/032316-me-waveharvest.html for article on ocean wave energy harvesting nets 2 million Department of Energy Grant
8.	www.globalspec.com/learnmore/motion_controls/power_transmission/gears/rack_pinion_gears on the Article of Rack and Pinion Gears Information
9.	www.green-mechanic.com Article on Classification of Gear Toothed Wheels
10.	A Text book of Machine Design by R.S. Khurmi and J.K.Gupta
11.	A Text book of Theory of Machine by R.S. Khurmi and J.K.Gupta
12.	Shigley's Mechanical Engineering Design by Richard G.Budynas and J.Keith Nisbett

Appendix

MATH CONVERSION CHART – LENGTHS

METRIC CONVERSIONS					
1 centimeter	=	10 millimeters	1 cm	=	10 mm
1 meter	=	100 centimeters	1 m	=	100 cm
1 kilometer	=	1000 meters	1 km	=	1000 m

STANDARD CONVERSIONS					
1 foot	=	12 inches	1 ft	=	12 in
1 yard	=	3 feet	1 yd	=	3 ft
1 yard	=	36 inches	1 yd	=	36 in
1 mile	=	1760 yards	1 mi	=	1760 yd

METRIC -> STANDARD CONVERSIONS					
1 millimeter	=	0.03937 inches	1 mm	=	0.03937 in
1 centimeter	=	0.39370 inches	1 cm	=	0.39370 in
1 meter	=	39.37008 inches	1 m	=	39.37008 in
1 meter	=	3.28084 feet	1 m	=	3.28084 ft
1 meter	=	1.09361 yards	1 m	=	1.09361 yd
1 kilometer	=	1093.6133 yards	1 km	=	1093.6133 yd
1 kilometer	=	0.62137 miles	1 km	=	0.62137 mi

STANDARD -> METRIC CONVERSIONS					
1 inch	=	2.54 centimeters	1 in	=	2.54 cm
1 foot	=	30.48 centimeters	1 ft	=	30.48 cm
1 yard	=	91.44 centimeters	1 yd	=	91.44 cm
1 yard	=	0.9144 meters	1 yd	=	0.9144 m
1 mile	=	1609.344 meters	1 mi	=	1609.344 m
1 mile	=	1.609344 kilometers	1 mi	=	1.609344 km

	Welded	Bolted	Things to Consider
Mass	✓		This is often the driving force behind the welded ring gear
Serviceability		✓	A common complaint among the welded ring gear is that the entire differential must be replaced if anything needs replaced
Customizing		✓	There are many enthusiasts who will immediately replace a ring gear set with a high performance gear. Again with the welded, the entire differential must be replaced.
Strength		✓	Usually the brute strength winner will be the bolted assembly, though both will be designed to meet the intended usage of the vehicle.
Development		✓	Welding takes considerable development in weld placement, interface design, distortion, material types, etc. Bolted joints tend to be much more straightforward.
Production Equipment		✓	Welding equipment will run at least 2x the cost of a bolting station.
Production Cost		✓	Between electrical cost, welding material and maintenance, production is generally more expensive with welding.
Scrap Rate		✓	This is also driven by need to replace the differential and ring gear if anything happens to either one.
Complexity	✓		Welding is the winner in complexity just due to having 10-15 fewer parts (bolts) in the assembly.
Reliability	✓	✓	We'll call this one a tie since both will be designed to meet the reliability requirements of the vehicle.

MATERIAL SAFETY DATA SHEET - 9 SECTIONS

SECTION 1 - PRODUCT INFORMATION

Product Name
Product Use
Manufacturer's Name
Physical and Mailing Address
Emergency Contact Phone Number

WHMIS Classification (optional)

Supplier's Name
Physical and Mailing Address
Emergency Contact Phone Number

SECTION 2 - HAZARDOUS INGREDIENTS

Hazardous Ingredients (very specific)

SECTION 3 - PHYSICAL DATA

Physical State (What does it look like? Is it a liquid, gas, or solid?)
What happens to it under a variety of circumstances? (i.e. heat, freezing, dropping, etc.)
Flammability and how to extinguish. Includes a wide variety of details concerning how easily this product

SECTION 4 - FIRE AND EXPLOSION DATA

will ignite / explode and how to deal with it.
How stabile is this product?

How it reacts under various conditions.

SECTION 5 - REACTIVITY DATA

Incompatibility with other substances.

Hazardous Decomposition Products

Information about how the product affects and enters the body. Immediate affect. Long term toxic affect.

SECTION 6 - TOXICOLOGICAL PROPERTIES

Exposure limits. In summery, immediate and long term affects to the human body.

SECTION 7 - PREVENTIVE MEASURES

Personal Protective Gear; ventilation, etc.; leak and spill info; waste disposal; handling and storage; special shipping instructions

SECTION 8 - FIRST AID MEASURES

Information for immediate first aid treatment. Usually always ends with "contact a Doctor"

SECTION 9 - PREPARATION INFORMATION / *Who prepared this and contact info*