Design of Reciprocating Rack and Pinion Mechanism
Dual Working Mechanism

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Abstract— Rack and pinion are most widely used mechanism in so many industries, but it is only used for back and forth motion. Innovative mechanism for the combination of reciprocating and rotary motion and vice versa is described. The research work is aimed to characterized the working of mechanism and investigate its potential application in different industries. The mechanism is applied in some industries where there is a usage of two different types of mechanism to reduce the current usage and to increase the efficiency. The mechanism significantly reduces unfavorable defects and increase the life time period of the system. Which subsequently result in a more efficient motion conversion. Also, evaluation of the mechanisms geometry leads to the conclusion that this mechanism is able to withstand in higher wear and tear condition Compared to existing bearing used for the rotational motion.

Keywords— Mechanism; Rack; Pinion; Reciprocative; Two in One Mechanism.

I. INTRODUCTION
A mechanism is the combination of force and movement defines power and a mechanism manages power to achieve a desired set of forces and movement. A mechanism is usually a piece of larger process or mechanical system. Multiple mechanisms are machines. The term mechanism is applied to the combination of geometrical bodies which constitute a machine or part of machine., incorporating the applicable criteria that follow. A mechanism may therefore be defined as a combination of rigid or resistant bodies, formed or connected so that they move with define relative motions with respect to one another.

II. METHODOLOGY
A. Modification made in Rack
It consists of a double rack and pinion where the racks are fixed on a base plate at a distance equal to the addendum of the pinion. The pinion used is a semi toothed gear which has the tooth on one half of its perimeter and rest of the portion is left blank. A path is provided at the center of the base plate for the pinion to make a translational motion. The pinion is attached with a motor. When the pinion starts to rotate, it will mesh with either one of the rack’s teeth one by one. When it meshes with a final teeth, it turns around and then starts to mesh with the another rack’s teeth. At the end of the meshing the pinion will be in its original position. Therefore “The back and forth” movement is obtained easily. This complete displacement of pinion will gives the rotary and reciprocating motion, at the same time.

B. Modification made in Pinion
Base circle of a gear is the base circle for the involute curve. An involute curve is the trace of a point at the end of a taut string that unwinds from a cylinder, and this cylinder is called the base circle. The tangent lines to the involute curve and the base circle have the characteristic of being always perpendicular to each other. As a result, the direction of the force acting at the contact point of the gears with involute curves is constantly along the common tangent to the two base circles.
The base circle diameter is given by the equation,
\[ db = d \cos \alpha. \]

Where,
- \( d \) -pitch circle diameter, \( d = mz \)
- \( \alpha \) -pressure angle
- \( m \) -module
- \( z \) -number of teeth

C. Experimental setup

The rack and pinion where made using PTC Creo software (version 3.0). The pinion is mounted at the center of both the racks and a centre hole is made to attach the shaft with the pinion which ease to free rotation of pinion to the starting point of rack to the end.

D. Material needed

- Rack - 2 nos
- Pinion - 1 nos
- No of teeth in rack - 11 teeth
- No of teeth in pinion - 11 teeth
- Shaft - 1 nos
- Base plate - 1 nos

E. Equations

When a pair of gears mesh, the distance between the centers of the meshing gears shafts is called its Center Distance and it is calculated as the half of the sum of two gears pitch diameters.

- Formula for Center Distance, \( a = \frac{(d_1 + d_2)}{2} \) (1.1)
- Working Pressure Angle \( \alpha = 20^\circ, z = 12, x = 0 \) (1.2)
- Center Distance \( x (zm/2) + H + xw \) (1.3)
- Working Pitch Diameter \( w \frac{d \ b}{\cos \alpha} \) (1.4)
- 11 Addendum \( a_m (1 + x) \) (1.5)

III DESIGN DETAILS OF RACK AND PINION

A. Rack

The rack are the mechanical devices which converts the rotational motion into linear motion. They are mostly use in steering system of cars and many industries in which the machines need the linear horizontal or vertical motion. The designs are made use of PTC Creo software (Version 3.0) and assembled using the same software.

![Figure 4](image4)

No of teeth in rack = 10, 
Length of rack = 75mm, 
Width of rack = 20mm,

B. Pinion

![Figure 5](image5)

Pinion diameter = 30mm, 
No of teeth = 8, 
Centre hole = 4mm, 
Thickness = 12mm

A pinion is a round gear used in several applications usually the smaller gear in a gear drive train, although in the first commercially successful steam locomotive the pinion was rather large. In many cases, such as remote controlled toys, the pinion is also the drive gear. The smaller gear that drives in a 90-degree angle towards a crown gear in a drive. The small front sprocket on a chain driven motorcycle.

C. Base plate

The base plate is the part where the rack is mounted on the both edges with the equal distance. The hole is made at the center of the base plate for the movement of shaft which is connected to the semi toothed pinion.

Length = 100mm, 
Width = 60mm, 
Centre hole diameter = 4mm, 
Thickness = 20mm, 
Material = mild steel.

3.2.4 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...
Shaft diameter =8mm, Shaft length =40mm. Power to a machine which absorbs power. The various members such as pulleys and gears are mounted on it.

III. ANALYSIS OF WEAR ALONG TOOTH FLANK

The wear characteristics can be calculated by implementing the formula for local wear on the flank in a gear contact analysis. This makes it possible to define the shape of abraded tooth flank. Initially, this approach did not provide any usable result, if the wear starting perfect tooth form, was determined in a single calculation step. The wear characteristic must be calculated step by step because the tooth form changes as it becomes worn, and therefore the load distribution moves across the meshing.

Very useful result can be achieved by running the calculation at sufficient number of small increments. The maximum permitted wear per iterative step must be predefined, so that the iterative progression of wear can be calculated method has been used to compare a range of gears that have been subjected to testing and then measured in ansys.

IV ANALYSIS OF BENDING MOMENT

A bending moment is the reaction induced in a structural element when an external force or moment is applied to the element causing the element to bend. The most common or simplest structural element subjected to bending moments is the beam. The example shows a beam which is simply supported at both ends. Simply supported means that each end of the beam can rotate; therefore each end support has no bending moment. The ends can only react to the shear loads. Other beams can have both ends fixed; therefore each end support has both bending moment and shear reaction loads. Beams can also have one end fixed and one end simply supported. The simplest type of beam is the cantilever, which is fixed at one end and is free at the other end (neither simple or fixed). In reality, beam supports are usually neither absolutely fixed nor absolutely rotating freely.
The internal reaction loads in a cross-section of the structural element can be resolved into a resultant force and a resultant couple. For equilibrium, the moment created by external forces (and external moments) must be balanced by the couple induced by the internal loads. The resultant internal couple is called the bending moment while the resultant internal force is called the shear force (if it is transverse to the plane of element) or the normal force (if it is along the plane of the element).

<table>
<thead>
<tr>
<th>No of teeth</th>
<th>Contact of teeth</th>
<th>Assumed RPM</th>
<th>Module</th>
<th>Pitch(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td></td>
<td>2</td>
<td>1.25</td>
<td>16</td>
</tr>
</tbody>
</table>

V FACTOR OF SAFETY

Factors of safety (FoS), is also known as (and used interchangeably with) safety factor (SF), is a term describing the load carrying capacity of a system beyond the expected or actual loads. Essentially, the factor of safety is how much stronger the system is usually that needs to be for an intended load. Safety factors are often calculated using detailed analysis because comprehensive testing is impractical on many projects, such as bridges and buildings, but the structure’s ability to carry load must be determined to a reasonable accuracy.

There are two definitions for the factor of safety: One as a ratio of absolute strength (structural capacity) to actual applied load, this is a measure of the reliability of a particular design. The other use of FoS is a constant value imposed by law, standard, specification, contract or custom to which a structure must confirm or exceed.

The first use is generally referred to as a factor of safety or, to be explicit, a realized factor of safety. The second use as a design factor, design factor of safety or required factor of safety. The realized factor of safety must be greater than the required design factor of safety. It is important to be aware of which definition are being used. The cause of much confusion is that various reference books and standards agencies use the factor of safety definitions and terms differently. Design codes and structural and mechanical engineering textbooks often use “Factor of Safety” to mean the fraction of total structural capability over that needed and are realized factor of safety. Many undergraduate Strength of Materials books use “Factor of Safety” as a constant value intended as a minimum target for design

The difference between the safety factor and design factor (design safety factor) is as follows: The safety factor is how much the designed part actually will be able to withstand. The design factor is what the item is required to be able to withstand. The design factor is defined for an application (generally provided in advance and often set by regulatory code or policy) and is not an actual calculation, the safety factor is a ratio of maximum strength to intended load for the actual item that was designed.

FS = Yield stress / Working stress

FS < 1 for a system that should fail
FS = 1 for a critical system (likely to fail)
FS = 2 for a reasonable design
FS = 5 for a safe design
FS >10 is overdesigned

VI CONCLUSION

The reciprocating Rack and Pinion is an innovative mechanism which can give both translational and rotational motion at the same time. It can be replaced for hydraulic piston which gives reciprocating motion and PLC switch which gives rotational motion. It finds many applications in hydraulic and pneumatic industries. In this project, modelling and assembling of reciprocating rack and pinion is carried out using Creo 3.0 to replace the hydraulic cylinder and actuator. For future work, we will identify the scope of this project in industrial application.
REFERENCES


