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# Fabrication of Prototype for Power Generation at Speed Breakers using Rack and Pinion Mechanism

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**ABSTRACT**

**Electricity is the form of energy, Electricity is a basic part of nature and it is one of our most widely used forms of energy. Generating electricity by speed breakers is innovative and useful concept. The number of vehicles passing over the speed breaker in roads is increasing day by day. There is possibility of tapping the energy** and **generating power by making the speed breaker as a power generation unit. The generated power can be used for the lamps near the speed breakers and this will be a great boon for the rural villages as well as for urban areas.**

**The kinetic energy of the moving vehicles can be converted into mechanical energy of the shaft through rack and pinion mechanism. Then, this mechanical energy will be converted to electrical energy using generator which will be saved with the use of a battery. Therefore, by using this type of arrangement lot of energy is saved, which can be used for the fulfillment of future demands.**

**Design of each component has been carried out using standard procedures, and the components have been fabricated and assembled. A similar model of the system has been modeled using SOLIDWORKS. Practical testing of the system has been done. Theoretical calculations has been done.**

***Keywords***-- Rack and Pinion, power generation, design,fabrication

## I. INTRODUCTION

Energy in the form of electricity plays a very important role in the life of a normal man. Electricity is one of the greatest wonders of science. Today whole life style is dependent on electricity with the increasing population the use of electric power is also increasing. But the resources to generate electricity are limited, and this has leads to the energy crisis. Depletion of conventional sources becomes a problem in present world. And ever rising cost of conventional fuel may be major impediment in economic and social growth of third world nations. All the developing and developed nations are searching for new and newer sources of energy and its efficient use. One of the method is generating electricity at speed bakers.

Whenever a vehicle slows down, it is dissipating energy through its brakes. With the current technological focus on energy efficiency, a system that could recapture some of this energy could be a great benefit for areas that experience heavy traffic and could make use of an influx of extra energy, which is not necessarily attached to the power grid. Additionally, the static nature of speed breaker makes them hard on drivers regardless of the speed they are traveling. A collapsing speed breaker could potentially provide a means of speed selecting vehicles as far as the rigidity of the speed breaker is concerned, as in it is easier on slower drivers than speeding driver.

During this scenario one can generate electricity from things used in day-to-day life. In this project work the electricity is generate through speed breakers present on roads. As the vehicles on road are increasing day by day, while these vehicles pass over the speed breakers by small arrangement at the speed breaker, electricity can be produced. This electricity generated can be used for different purpose such as lighting of signals and streetlights on road etc. This set up requires very basic mechanical components such as gears, shafts bearings, freewheel (pinion) and chain welded to rod (rack). There are also some electrical components such generator, battery, inverter etc.

Many models were introduced according to condition. The few models are mentioned below

1. Rack- Pinion mechanism
2. Roller mechanism
3. Crank-shaft mechanism
4. Pneumatic mechanism

In this project Rack and pinion mechanism is selected, because of its high power generation capacity when compared to other alternatives and also easy to magnify the output by using series of gears of required speed ratio and in gear power transmissions the loss of

energy is less compared to chain drive compared to crank-shaft alignment its alignment is simple.

## II. MODEL DESIGN PROCESS

The specification of the components used in this project for designing a proto type power generation equipment at speed breaker are as follow:

### *2.1 RACK-CYCLE CHAIN WELDED WITH IRON BAR*

A bicycle chain is a roller chain that transfers power from the pedals to the drive-wheel of a bicycle, thus propelling it.

**SPECIFICATIONS**
Material—high carbon steel
Total length of rack --520 mm
Active length of rack--280mm
Chain designation --06A-3
Chain pitch--12.7mm
Average tensile strength--51.20KN
Weight/meter--1.90kg
Rod (b×h=10×10mm^2)

**Fig: 2.1 Rack and Pinion Mechanism and its Specifications**

### *2.2 PINION-FREEWHEEL*

Clutch is a device in a transmission that engages with chain and transmits power in one direction where as for other direction it disengages and became in power transmission.

**SPECIFICATIONS**
Material—cast iron
No of teeth--18
Face width--14mm
Width of teeth--3mm
Pitch circle diameter--70.7mm
Inner diameter –34mm

**Fig: 2.2 Pinion –Freewheel**

### *2.3 BALL BEARINGS*

Ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races.The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads.

**SPECIFICATIONS**
Material-stainless steel
Designation --6201
Inner diameter –12mm
Outer diameter—32mm
Axial width—10mm
Dynamic load capacity—6890N

**Fig: 2.3 Ball Bearing**

### *2.4 SPRING*

A spring is a device that changes its shape in response to an external force, returning to its original shape when the force is removed. The energy expended in deforming the spring is stored in it and can be recovered when the spring returns to its original shape.

SPECIFICATIONS
Material—carbon steel
No of active coils—19
Wire diameter—3.5mm
Mean coil diameter—46mm
Length of the spring –240mm
(under no load condition)

**Fig: 2.4 Spring**

### *2.5 SPUR GEAR*

They have straight teeth, and are mounted on parallel shafts. Sometimes, many spur gears are used at once to create very large gear reductions.

**SPECIFICATIONS**
Material—grey cast iron
Pitch circle diameter—115mm
No of teeth –46
Addendum circle diameter—120mm
Dedendum circle diameter—108.75mm
Face width—14 mm
Type –20 degree full depth

**Fig: 2.5 Big gear**

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| | |
|---|---|
|  | **SPECIFICATIONS**<br>Material— grey cast iron<br>Pitch circle diameter—40mm<br>No of teeth –16<br>Addendum circle diameter—45mm<br>Dedendum circle diameter—33.75mm<br>Face width—14 mm<br>Type –20 degree full depth |

**Fig: 2.6 Small gear**

### *2.6 SHAFT*

It is a rotating element, which is used to transmit power from one place to another place. It supports the rotating elements like gears and flywheels. It must have high torsional rigidity and lateral rigidity.

| | |
|---|---|
|  | **SPECIFICATIONS**<br>Material— mild steel<br>Diameter—12mm(shaft-2) &13mm(shaft-1)<br>Length of shaft—325mm |

**Fig: 2.7 Shaft**

### *2.7 GENERATOR*

Generator is a device that converts mechanical energy to electrical energy reverse conversion of electrical energy into mechanical energy is done by an electric motor, and motors and generators have many similarities.

| | |
|---|---|
|  | **SPECIFICATIONS**<br>Type –geared and non-concentric<br>alignment shaft<br>Speed –200 rpm<br>Torque—5kgf-cm |
| | Voltage--12v dc<br>Amps –1.5A |

**Fig:2.8 Generator**

### *2.8 BATTERY*

An electric battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy.

| | |
|---|---|
|  | **SPECIFICATIONS**<br>Type—lead cid(rechargeable)<br>Voltage--12v,dc<br>Amps--1.2 A |

**Fig: 2.9 DC battery**

### *2.9 BULB*

It is an electrical device which shows the output in the form of light energy by converting electrical energy into electrical energy .these are of two types AC and DC. Since we are producing dc current a 12w dc LED bulb is used to show the generated power output.

| | |
|---|---|
|  | **SPECIFICATIONS**<br>Bulb type--LED, (dc strong style color b82220 12v strong 10 watt high power led with epistar 45 x 45 mil chip light)<br>Watts-10w<br>Amps--0.8A |

**Fig: 2.10 Bulb**

## III. EXPERIMENTAL SETUP AND ASSEMBLING OF COMPONENTS

### *3.1 RACKROD AND FREEWHEEL ALIGNMENT*

Here the rack rod made up of iron bar of (520×10×10) mm^3 is welded with bicycle chain of 270mm length and which had a pitch of 12.7mm is placed vertically at a distance of (150×200) from the corner of base wooden piece. Freewheel of 18teeth is taken as pinion

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and this rack rod and freewheel are engaged by rack and pinion alignment.

**Fig: 3.1 Rack rod and freewheel alignment**

### *3.2 SHAFT-1*

Shaft-1 is engaged with two bearings-6201 (1&2) separated by 305mm and a freewheel of 18teeth is placed at a distance of 143mm from bearing-1 and gear-2 of 46 teeth is placed at a distance of 50mm from freewheel as well as 84mm from bearing-2.These freewheel and gear-2 are welded to shaft-1 in order to transmit power from freewheel to gear-2. Shaft-1is made to immovable with the rigid structure by placing the bearings (1&2) in the holes of the vertical wooden pieces(380×150×20)mm^3.

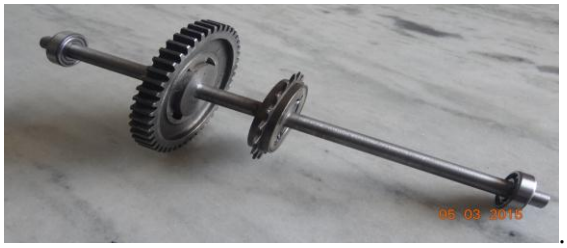

**Fig: 3.2 Shaft-1**

### *3.3 SHAFT-2*

Shaft-2 is engaged with two bearings-6201 (1&2) separated by 305mm and a gear-4 of 46 teeth is placed at a distance of 93mm from bearing-4 and gear-3 of 16 teeth is placed at a distance of 100mm from freewheel as well as 84mm from bearing-3.These gear-4 and gear-3 are welded to shaft-2 in order to transmit power from gear-3 to gear-4,where gear-3 on shaft-2 is meshed with gear-2 on shaft-1. Shaft-2 are made to immovable with the rigid structure by placing the bearings (3&4) in the holes of vertical wooden pieces (380×150×20) mm^3.

**Fig: 3.3 Shaft-2**

### *3.4 GENERATOR AND GEAR-5*

Generator and gear-5 are made to concentric mate by welding the shaft of generator to gear-5 hole. And the generator is made to rigid by placing in the hole of 34mm diameter of vertical wooden piece (380*80*20) mm^3.

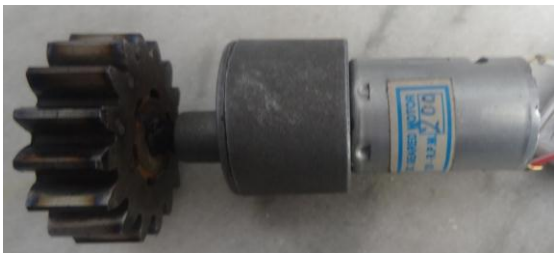

**Fig: 3.5 Generator and gear-5**

### *3.6 SPRING ALIGNMENT*

Spring of 240mm length is placed in between the base and platform of rack rod by making fixed with nails to bottom wooden support of 70mm diameter and 20mm height and top wooden support of 64mm diameter and 20mm height. A hollow pipe is used as a guide way to the spring for the movement of up and down motion freely.

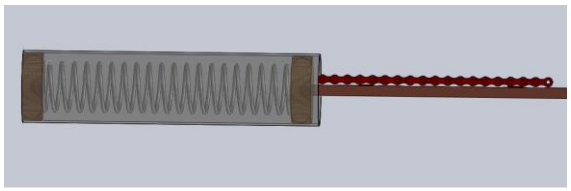

**Fig:3.6 Spring alignment**

### *3.7 GEAR TRAIN ALIGNMENT*

The alignment of gear train is made in such a way that the gear 2 (freewheel) is connected to gear 3 by shaft-1. Gear-2 (46 teeth) is engaged to gear-3 (16 teeth ) by meshing each other. Gear-3 (16 teeth) is connected to gear-4 (46 teeth) by shaft-2. Gear-4 (46 teeth) is engaged to gear-5 (16 teeth ) by meshing each other.

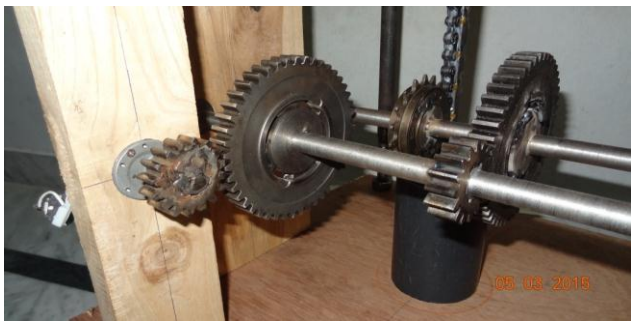

**Fig:3.7 Gear train alignment**

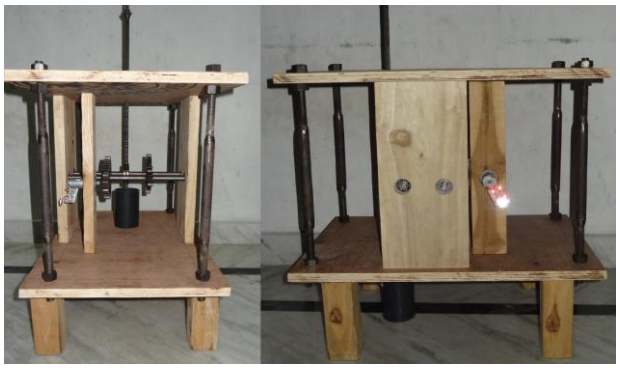

**Fig: 3.8 Final assembly of model**

## IV. THEORETICAL CALCULATIONS OF COMPONENTS OF THE MODEL

### *4.1 FACTOR OF SAFETY*

The Factor of safety calculations carried out for the gear trains are as follows:

Torque of the generator is taken as 5 Kgf-cm T=490.5 N-mm

Speed of the generator N=200 rpm

Power attained at the generator $P = \frac{(2\pi NT)}{60000} = 10.273$ Watts

Specifications for pinion attached to the generator

No. of teeth on the pinion (gear-5) $Z_p = 16$

Module of pinion m=2.5mm

Pitch circle diameter of pinion $d_p = m\,Z_p = 40mm$

Face width of the pinion b =14mm

Ultimate tensile strength $S_{ut}$ =250 Mpa

Data for the gear-4 meshed with pinion attached to generator

No. of teeth on gear $Z_g$=46

Module of the gear m=2.5mm

Pitch circle diameter of the gear $d_g = mZ_g = 115mm$

Face width of the gear b= 14mm

Ultimate tensile strength $S_{ut}$=250Mpa

Lewis form factor for the gear $y = \left(0.154 - \frac{0.912}{z_p}\right) = 0.097$

Pitch line velocity $V = \left(\frac{\pi dN}{60}\right) = 418.879$ mm/sec

Tangential component of velocity $P_t = \frac{2T}{mZ_p} = 24.525N$

Endurance limit for gear is taken as $\sigma = \frac{S_{ut}}{3} = 83.33MPa$

Service factor $C_s$=1.5

Beam strength $S_b$ = (m×b×σ×y)

Tolerance factor for pinion gear-5 $\Phi = (m + (0.25\times\sqrt{d}))$

Tolerance factor for gear-4 $\varphi = (m + (0.25\times\sqrt{d_g}))$

Error for pinion gear-5 $e_p = (5+0.4\times\phi)$

Error for gear-4 $e_g = (5+0.4\times\varphi)$

Constant depending upon form of tooth K=0.111 for 20° full depth

Sum of errors between two meshing teeth $e = (e_p + e_g) = 13.705$ mm

The Dynamic loading on gear teeth $P_d = \frac{21V(Ceb+P_t)}{21V+\sqrt{Ceb+P_t}}$ = 45.787N

The Effective load on gear teeth $P_{eff} = (C_s P_t) + P_d = 82.575N$

Factor of safety for the gear 4 and gear 5 meshing

$FOS = \frac{S_b}{P_{eff}} = 3.426$

Similarly

Factor of safety for the gear- 2 and gear 3 meshing $FOS = 1.434$


**Fig: 4.1 Gear train from rack to generator**

### *4.2 TANGENTIAL FORCES ACTING ON GEAR TRAIN*

If the Torque at gear- 3 is equal to gear- 4 $T_3 = T_4$

Tangential component at gear-4 $P_{t4} = \frac{2\times T_4}{2.5\times 46} = 24.525N$

Tangential component at gear- 3 $P_{t3} = \frac{2\times T_4}{2.5\times 16} = 70.51N$

Torque at gear – 2 $T_2 = 2.875\times T_3$ $T_2 = 4.054\times 10^3$ N-mm

If the Torque at gear- 2 equal to free wheel $T_1 = T_2$

Tangential component at gear- 2 $P_{t2} = \frac{2\times T_2}{2.5\times 46} = 70.51$

Tangential component at free wheel $P_{t1} = \frac{T_2}{35.35} = 114.69N$

∴ minimum required load to drive generator load $\frac{P_{t1}}{9.81} = \frac{114.69}{9.81} = 11.69Kg$

The tangential force or driving force acting on gear-1 (FREEWHEEL) is 11.69 kg

## V. RESULT

1. Minimum generated power from the generator of 14.4 watts of power is generated by rotating the shaft of generator at 200 rpm.
2. On considering that load acting per second of time it rotates the shaft of generator with 330.625 rpm which produces 16.97 watts of power which is more than sufficient to glow the 12w LED bulb

3. The tangential force or driving force acting on gear-1 (FREEWHEEL) is 11.691kg.From the calculations it is confirmed that shaft−1 of 13 mm diameter and shaft−2 of 12 mm diameter is enough to produce minimum conditioned power generation.
4. From the calculations the minimum load to get required deflection of 150mm in spring is, P=12.624 kg
5. Hence when minimum required load is placed it can easily generate the rated power of the generator since minimum load of 11.691kg is sufficient but here we are giving 12.624 kg of load.
6. It is also confirmed that power generated is depends upon mass of vehicle for the initial load conditions but then it doesn't depends upon mass of vehicle since minimum required load condition is crossed and further it depends upon the speed of vehicle as vehicle had more speed it decreases power generation since it's load

## VI. CONCLUSION

This method had many advantages such as Power generation does not require any fuel input, Running cost is very less, This is a non-conventional form of energy and therefore very useful in the present scenario of energy crisis. As coin has two faces in the same way there are also some disadvantages such as Mechanical moving parts are high and therefore there are very large frictional losses and therefore require more maintenance, Initial cost of this arrangement is very high. The overall efficiency is quite low as compared to other techniques.

The power that is generated at appreciable rate and so the technology is easily feasible.This technique will help to conserve our natural resources. The energy is an important input to sustain industrial growth and standard of living of a country can be directly related to energy consumption. The conventional energy sources energy like coal, oil, uranium etc. are depleting very fast and by the turn of the century man will have to depend upon non-conventional sources of energy for power generation. In this world where is shortage of electric power supply, the project will be helpful to solve some of the problems.

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