Design and fabrication of Speed Bump for Energy Generation

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Abstract.
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. Such a set-up can be placed independently across city lanes, or along tolls on highways and other inter-city roads, or coupled with speed breakers anywhere in the world. 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.

Keywords: Generator, Environment, Rack and pinion mechanism

1.Introduction
“Power Bump” is a child of the imaginations, of three fourth year engineers, and their academic capability. A machine made with the vision and intention to aid the human race in its own way, by taking in its input from vehicles that are almost unaffected by its presence and converting it into electricity. But, given the fact that we are living in the 21st century, it would’t be fruitful to further discuss this innovation without knowing the answers to three very important questions. Mohamad Ramadan et al, [1] designed the energy recovery system to make the pollution free environment as its goal. And they proposed Speed Bump Power Generator (SBPG) system. By utilizing the movement of vehicles, this system produces the electricity. Here, the kinematic energy is converted into electricity energy. In the experimental analysis rack and pinion is used and the results shows that the 80 kg of mass on the bump producing 45W of electricity by using the SBPG system. Mohammadreza Ghokhlanhi et al, [2] studied two types of energy sources that is Solar and kinetic energy. Prototype model of electromagnetic speed bump energy harvester (ESE) was developed to harvest kinetic energy from passing vehicles. Passing vehicles generates deflection in the energy harvester and it trigger the embedded generator. ESE of the experimental results shows the average power of 3.21 mW.
This ESE was modeled by using different materials like steel, aluminum or heavy-duty rubber and the bottom were given steel or aluminum properties. Aditya Sinha et al, [3] analyzed the power generation from bump, here installed the speed breakers in the aim of producing electrical power using weight and momentum of vehicle passing on it. And it conserves the wasted energy. The strut introduced in the in the design to restore the bump to its original position. Slider crank mechanism is used to convert the reciprocating motion to rotary to drive a gear to transmit power. The result shows the 64.25W of energy is generated by 27.54 passenger car unit (PCU) per min. Speed breaker designed in the form of versatile and economical design. Song et al, [4] has proposed a harvesting technology by introducing piezoelectric energy which installed in a roadway speed bump. Piezoelectric module installed on actual road with speed bump. High integrated module of 40 piezo-generators was fixed and installed at the center of the speed bump. Vehicle passed at the speed of 30 km/h and the module gives an output voltage of $14 \text{V}_{\text{max}}$, output current of 45.2 mA$_{\text{max}}$.

1.1 The Why, What & Will!
The answers to these 3Ws are of critical importance. The first W (why) will answer for the need of the work. The second W (what) will answer for the basic idea of the work, and the third W (will) will answer for the plausibility of the implementation of this work in the future in real time.

Starting with the world in general, it is a well-known fact that we are running low on the reserves of fossil fuel. Be it fuel for our cars or electricity for our home, the consumption and demand are rising, but the supply is struggling to keep pace. Even though the prices are rising, all the money in the world would not be able to solve the problem once the fuel vanishes. Also, even as a few new reserves are being found, world politics and problems like insider trading are keeping the associated benefits at bay. Coming in particular to our country India, it is just a simple matter of fact that India faces energy crisis more chronically than many parts of the world. Even in the year 2018, we have places in India that are still yet to see what electricity is. The fuel prices are another source of perpetual havoc in our country. Even worse so, India still depends majorly on the fossil fuel coal for generation of electricity.

In such times, what if streets were guided by lights (from traffic signals to street lights) that do not need the support of coal and the investment of solar power? What if the consumers were the generators of electricity without even knowing about it? What if, that, which destroyed coal reserves, does what coal is supposed to do? Such is the idea behind this work.

In simple words, power bump converts the kinetic energy of moving vehicles (irrespective of speed) into electrical energy, using a set of gears, including the rack & pinion mechanism, and a generator, in a structure designed specifically for this purpose. By the ending of the FY 2014-15, the number of registered vehicles in India was more than 200 million. We have all seen speed breakers which placed in order to regulate traffic speed. Power bump is very similar to a speed breaker in looks and can be placed alongside one or even independently. From toll booths to highways to city streets, the machine can be placed anywhere and can be used to light up the nearby street lights and traffic signals, or to simply store energy or recharge batteries etc.

Honestly, the answer to the future of this invention lies in the hands of the government. Although, with proper R&D, implementation, and investment, this invention can bring about a revolution in the way we look at things.
2. Methodology
A rack is fixed below the upper part of the speed breaker which is in constant mesh with a pinion. The rotation of pinion activates the rotation of a geartrain which increases the rpm about 16 times. A dc motor is the last stop of the extracted energy after which it becomes direct current, hence the motor will rotate whenever a vehicle passes over the bump and generate direct current.

2.1 Power Bump
*Rack and Pinion mechanism*
A rectangular bar consisting of teeth on one side that mesh with a small circular gear is known as the rack and pinion. A pinion can have teeth that are straight or helical that mesh with those inclined to the axis of the pinion-shaft. When the pinion moves about a fixed axis, the rack translates by moving in a straight path.

![Figure 1: Rack and pinion gear system](image)

3. Working principle
Whenever a vehicle passes over the bump, a lot of force is exerted. This can be tapped with a suitable setup which can convert some mechanical energy in electrical energy efficiently. This component generates energy by taking weight as the input from the movement of motor vehicles. Below the bump, a rack is fixed rigidly which is in constant mesh with a pinion. The pinion is fixed on a shaft with another spur gear with multiple no. of teeth, to increase the rpm. The motor pinion is in mesh with the bigger spur gear on the adjacent shaft to further increase the rpm at the motor pinion.

3.1 Spur Gear manufacturing
Spur Gears or moderate speed gears are the most widely recognized kind of gears. They are cylindrical gears with parallel and co-planer shafts. The teeth on such gears are straight and parallel to the wheel pivot. The benefits of goad gears is their outline, the economy of make and support, and non-appearance of end push. They force just outspread loads in the direction.

*Advantages*
1) Higher efficiency of power transmission.
2) Easy to setup due to its compact size.
3) Offers a velocity ratio that is constant.
4) Highly reliable.
3.2. PILLOW BLOCK

A pillow block is a housing that consists an anti-friction bearing. A bearing with the shaft mounted in a parallel plane to the surface and perpendicular to the mounting holes is known as a pillow block. Such a block may contain a bearing with a rolling element such as balls, cylindrical rollers, spherical rollers, tapered rollers, or metallic or synthetic bushings. The type of pillow block is defined by the rolling element in it.

The fundamental objective is to safely mount a bearing so as to enable the outer ring to remain stationary and permitting free rotation of the ring on the inside. The housing and foundations are coupled together via the holes on the base. Bearing housings are of two kinds i.e., split or solid type. A two-piece housings wherein the cap and base may be detached is called Split type. A solid housing only has a single piece. In order to prevent dust and other contaminants from entering the housing multiple sealing provisions are made. A sealed housing provides a clean environment for the bearing to move freely without any obstruction from dust particles and contaminants. Such a seal also helps retain lubrication, thereby increasing performance and duty cycle. Bearing housings are mostly manufactured using grey cast iron. However, various other materials can also be used to manufacture the same. These include ductile iron, steel, stainless steel, and various types of thermoplastics and polyethylene-based plastics. Bearing elements are most commonly manufactured using 52100 chromium steel alloy, stainless steel, plastic, or bushing materials such as SAE660 cast bronze, or SAE841 oil impregnated sintered bronze, or synthetic materials.
4. DC Motor
A DC motor is a device that converts electrical energy in the form of direct current into mechanical energy and vice versa. A DC motor consists of a current carrying armature that is linked to the supply end via brushes and commutator segments. The armature is placed in the middle of the north and south poles of a permanent or an electromagnet. When current is supplied to the armature, the electromagnetic effect of the magnets generates mechanical force. The working of a dc motor is governed by Fleming's left-hand rule. The Left-hand rule states that “if a current carrying conductor is placed in a magnetic field perpendicularly, then the conductor experiences a force in the direction mutually perpendicular to both the direction of field and the current carrying conductor.” Fleming’s rule says that if the index finger, middle finger and thumb of our left-hand are extended perpendicularly to each other, in a way that the middle finger is in the direction of the current carried by the conductor, the index finger points in the direction of the magnetic field generated i.e., north to south, the thumb would indicate the direction of mechanical force generated.

Figure 3: Friction Bearing

Figure 4: DC motor conceptual diagram
5. CALCULATIONS

**Gear Strength Calculations**

Strength of gear tooth, $F_s = 6b^* b^* y^* P_c$

- $6b^*$ = design bending stress
- phase width, $b^* = 10m$
- $m$ = module
- $y^*$ = form factor
- circular pitch, $P_c = 3.14m$

Now, $y^* = 0.154 - .912/64 = 0.13975$

$$F_s = 6b^* 10m^* 0.13975^* 3.14m$$

For both directions

$$Bb = \frac{kbl}{n} K_6 \times B^*$$

here $kbl$ = life factor for bending

$kbl = 1$ for $>10^7$ (life in no. of cycles)

$n$ = factor of safety

for case hardened steel $n = 2$

$K_6$ = fillet concentration $= 1.2$ (for steel case hardened)

$B^*=1$ = endurance limit $= 0.35 B_u + 1200$

$B_u$ = ultimate strength

$$= 600 \text{ N/mm}^2 \text{ for EN8}$$

$$= 600*9.8 = 5886 \text{ Kgf/cm}^2$$

$$B^*=1 = 0.35*5886+1200 = 3260.1 \text{ Kgf/cm}^2$$

$$= 332.324 \text{ N/mm}^2$$

$$Bb = 0.5^*1.2^*332.324 = 138.46 \text{ N/mm}^2$$

Now $F_s = 138.46 \times 10m^* 0.13975^* 3.14m$

$$= 607.89 \text{ m}^2$$

Comparing with $F_t = 1960 \text{ N}$

$1960 = 607.89m^2$

This implies that, $m = 1.79$

Therefore, for ease of manufacturing, $m = 2$ is widely used.
5.1 Specification of required gear by above calculations:
Module, \( m = \frac{2a}{z_1+z_2} \)
\[ a = m \times \frac{z_1+z_2}{2} = 80 \]

Bottom clearance, \( c = 0.25m = 0.025 \times 2 = 0.5 \text{mm} \)

Pitch diameter:
\[ d_1 \text{ for bigger gear} = 2 \times 64 = 128 \text{mm} \]
\[ d_2 \text{ for pinion gear} = 2 \times 16 = 32 \text{mm} \]

Tip diameter:
\[ d_{a1} = (z_1+2f_o) \times m = (64+2.1) \times 2 = 132 \text{mm} \]
\[ d_{a2} = (z_2+2f_o) \times m = (16+2.1) \times 2 = 36 \text{mm} \]

Root diameter:
\[ d_{f1} = (z_1-2f_o) \times m - 2c = (64-2.1) \times 2 - 2 \times 0.5 = 123 \text{mm} \]
\[ d_{f2} = (z_2-2f_o) \times m - 2 = (16-2.1) \times 2 - 2 \times 0.5 = 27 \text{mm} \]

5.2 Power calculations:
On an average, 5 bikes will pass in a minute, low-balling our results from our count on the highway, over the speed breaker and assuming the total operating time to be 5 hours, then:
Total number of vehicles passing over the breaker: \( 5 \times 60 \times 5 = 1500 \)

For one vehicle:
- Estimated mass of the vehicles: 200kg
- Height of the speed breaker: 7cm
- Work done = \( 200 \times 9.81 \times 0.07 = 137.34 \text{ J} \)

Now, Power = Work Done/Time Taken
\[ = \frac{137.34}{4} = 34.335 \text{ W} \]
So, for 1500 vehicles, power = \( 34.335 \times 1500 = 51502.5 \text{ W} \)

Therefore, total energy = \( \frac{(4 \times 51502.5)}{3600} = 57.225 \text{ W-Hr} \)

Now, the vertical force coming on the rack by the vehicle is, \( F = m \times g \)
\[ F = 200 \times 9.81 = 1962 \text{ N} \]
This force will have a tangential and a radial component acting on the pinion.
\[ F_t = F \times \cos(20) = 1843.67 \text{ N} \]
\[ F_r = F \times \sin(20) = 671.043 \text{ N} \]
So, torque on the (rack) pinion will be
\[ = \text{tangential force} \times \text{radius of the pinion} \]
\[ = 1843.67 \times 0.015 \]
\[ = 27.655 \text{ Nm} \]

Power is torque multiplied by omega i.e.
\[ 34.335 = \text{torque} \times 2 \times 3.14 \times \text{(rpm)}/60 \]
This implies that \( \text{rpm} \approx 11.8 \sim 12 \).

**Gear Ratio**

\[ \text{Gear Ratio} = \frac{T_2}{T_1} \times \frac{T_4}{T_3} = \frac{16}{64} \times \frac{16}{64} = \frac{1}{16} \]

Here, \( T_1 \& T_3 = \text{Driver Gears} \)
\( T_2 \& T_4 = \text{Driven Gears} \)
**Torque Losses**

Rpm of first shaft is 12
Hence, \( \omega (w) = 2 \times 3.14 \times \text{rpm} / 60 \)
\[ = 1.25 \text{ rad/s} \]
Angular acceleration = \( \omega / \text{time taken} \)
\[ = 1.25/1 = 1.25 \text{ rad/s}^2 \]

Torque consumed in rotating the first shaft = Angular acc. * inertia
\[ = 1.25 \times 0.1 = 0.125 \text{ Nm} \]

Torque losses for 2nd shaft.
Rpm of 2nd shaft = 48
Hence, angular velocity (w) = \( 2 \times 3.14 \times 48 / 60 = 5.024 \text{ rad/s} \)
Angular acc. = angular velocity/time taken
\[ = 5.024/1 = 5.024 \text{ rad/s}^2 \]
Torque consumed by 2nd shaft = angular acc. * inertia
\[ = 5.024 \times 0.1 = 0.5 \text{ Nm} \]

Total loss of torque by rotation of shafts and gears = 0.5 + 0.125 = 0.625 Nm
Torque achieved after losses = 27.655 - 0.625 = 27 Nm.

Now using two sets of gears having gear ratio of 4, we can achieve a higher rpm at the final pinion i.e. torque will be reduced by 16 times and rpm will be increased by 16 times, when the motion reaches the generator.

Since torque is inversely proportional to rpm.
Hence rpm at the generator pinion will be: \( 12 \times 16 = 192 \text{ rpm} \)
And torque on the generator will be = \( 27/16 = 1.7 \text{ Nm} \).
Current generated = torque / torque constant of the motor
\[ = 1.7/0.25 = 6.8 \text{ amps} \]
Voltage generated = rpm/rpm constant of the motor
\[ = 192 \times 12/1000 = 2.4 \text{ V} \]

**6. Fabrication process**

**6.1 ARC WELDING**

Arc welding is a process used to join two similar or dissimilar metals. This method uses electrical power to generate adequate heat to dissolve metals. On cooling, the metals get fused together. The welding power supply is used create a circular segment between the cathode and the base material to liquefy the metals at the point of welding. Different forms of gases cover the welding region forming slag around it.
LATHE OPERATIONS

A machine that holds a workpiece between two rigid supports known as centers or on a face plate that revolves at high speed is known as a Lathe. The cutting tool is held and supported in a tool post which is fed against the revolving work. Cutting operations on a lathe are performed with the cutting tool fed parallel or at a right angle to the work. Tapers and angles can be made on the workpiece by feeding the tool at an angle relative to the axis of the work. Turning process is the elimination of metal from the outer diameter of a workpiece. Turning helps decrease the diameter to a specified dimension. It assists in creating a desirable finish on the metallic workpiece.

FINAL PRODUCT

The working model as a result of design and fabrication of Power Bump is shown in fig. 7. In this figure entire fabrication was completed this may be attached in vehicle for power generation.
7. Conclusion
Energy generated and power produced by using the speed breaker as power generating unit and installing a rack and pinion mechanism. The energy we save during the day light can be used in the night time for lighting street lights. Such a set-up can be placed independently across city lanes, or along tolls on highways and other inter-city roads, or coupled with speed breakers anywhere in the world. Final prototype model was fabricated; a maximum output of 3.87 volts was recorded.

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