Design of Rack and Pinion Mechanism for Power Generation at Speed Breakers

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***Abstract*--Need is the mother of all inventions and innovations. Man has improved the standards of everything around him to his comfort, need and desire. In the long run of science, since the time that science has taken a rigid form, man has stated, restated, invented, modified, discovered and re-discovered many facts, concepts and methods. In such a venture, a country's growth in the world economy largely bases upon its power generation rate, per-capita consumption rate and most importantly, efficiency of the both. As technology is advancing, the consumption of power is steadily rising. So the challenges of power generation and its cost of production, play an important role in the countries competence in the world economy. Thus "The need of the hour is power". So the problem identified is power generation and means to make it cheaper. The world is growing at a rapid pace. Among many vital sectors of our social life, transportation sector has a key role to play. It is an ever growing sector with the escalating population, growing needs and creeping number of vehicle users. The traffic on the roads becomes doubled or tripled, at alarming rates. If vehicular motion can be put to generate useful power, it can be put to effective use. This idea has mothered the invention of "power generation through speed breakers", inspired by various other existing designs. In this paper an attempt has been made to generate power using speed breakers through rack and pinion mechanism by tapping the energy and utilizing it for various purposes such as lightening the street lights, etc.**

***Key Words*-- Power generation, Rack and pinion mechanism, Vehicles, Energy.**

1. INTRODUCTION

The conventional sources of energy are generally non-renewable sources of energy, which are being used since a long time. To improve the power generation technologies and to make them more sustainable, non – conventional technologies have been discovered. Energy generated by using wind, tides, solar, geothermal heat, and biomass including farm and animal waste is known as non-conventional energy. All these sources are natural, renewable or inexhaustible and do not cause environmental pollution and are eco-friendly. More over they do not require heavy expenditure. The non-conventional sources of energy are abundant in nature. Most of the non – conventional sources have been boons at hand only to the well developed countries. The developing countries that lag behind in technical assets and financial limitations are striving to install the technologies of the latest trends and advanced versions. With the vast development of the technologies and understanding them, many other creative techniques of power generation have been emerged. The newly developed techniques are aimed at cost effectiveness. Thus they become more affordable to the countries like India, where installation cost and space occupancy are serious issues. One such creative technique is power generation through speed breakers. The idea is to tap the potential energy that a vehicle would acquire when it is lifted over the speed breaker as it rolls over it. It is achieved in three possible ways. The ways are

- Use of lever mechanism
- Use of roller mechanism and
- Use of rack and pinion mechanism.

The rack and pinion mechanism has advantages over the other two. When compared with roller mechanism, the slip of the tyres over the speed breaker is avoided as is possible in roller mechanism. The slip of the tyres would pose more trouble to the vehicle user than the power generated. Now our project is to completely utilize the technique of using rack and pinion mechanism for power generation.

The various components for rack and pinion mechanism required are as follows:

1. Rack and Pinion – replaced by a sprocket and a chain attached to a column
2. Spur Gears – a) G1 35-teeth

   b) G2 18-teeth
3. Shafts – Φ20mm, made of aluminum
4. Needle Bearings – a) 18mm b) 15mm
5. Dc motor – 500rpm and 1kg torque
6. Frame – to hold the components together
7. Freewheeling sprocket and chain drive
8. Spring

II. DESIGN CALCULATIONS

A. Introduction to MathCAD

MathCAD is a software program that uses a unique method to manipulate formulas, numbers, text, and graphs.

Unlike programming languages, the equations are written as they would appear in a mathematics reference book, against a background screen in which descriptive text may be placed arbitrarily. The equations may be solved analytically or numerically by using functions from a pull-down menu bar. Descriptive text may be placed anywhere inside the document. MathCAD also produces one, two, or three-dimensional plots which may be embedded anywhere in the document. There is also an on-line reference system to assist users. Any document on the screen can be printed out on any windows compatible printer. The combination of equations, text, and diagrams in an open-screen environment makes application development easy. Students in particular would benefit from the interactive development of MathCAD documents for studying various topics in physical chemistry.

B. Spur Gear wheel design

In the design of the project, two types of gear wheels have been used. They are spur gear wheels and sprocket gear wheels.
The gear specifications are as follows:

1. Spur gears – 2
2. Number of Teeth – 35 and 18
3. Addendum diameter – 74.22mm and 43.3mm
4. Module – 2.0mm
5. Face width at base – 4.16mm and 4.3mm
6. Pressure angle –20^0 full depth teeth
7. Material – hardened steel

1) *MathCAD interface for design of spur gears (Fig.1)*

User interface for calculating various parameters in the design procedure is prepared using MathCAD software and the user interface is shown in Fig. 2 .Factor of safety is obtained from the given design parameters is 5.07. Hence the design is considered to be safe.

Fig.1 Spur Gears

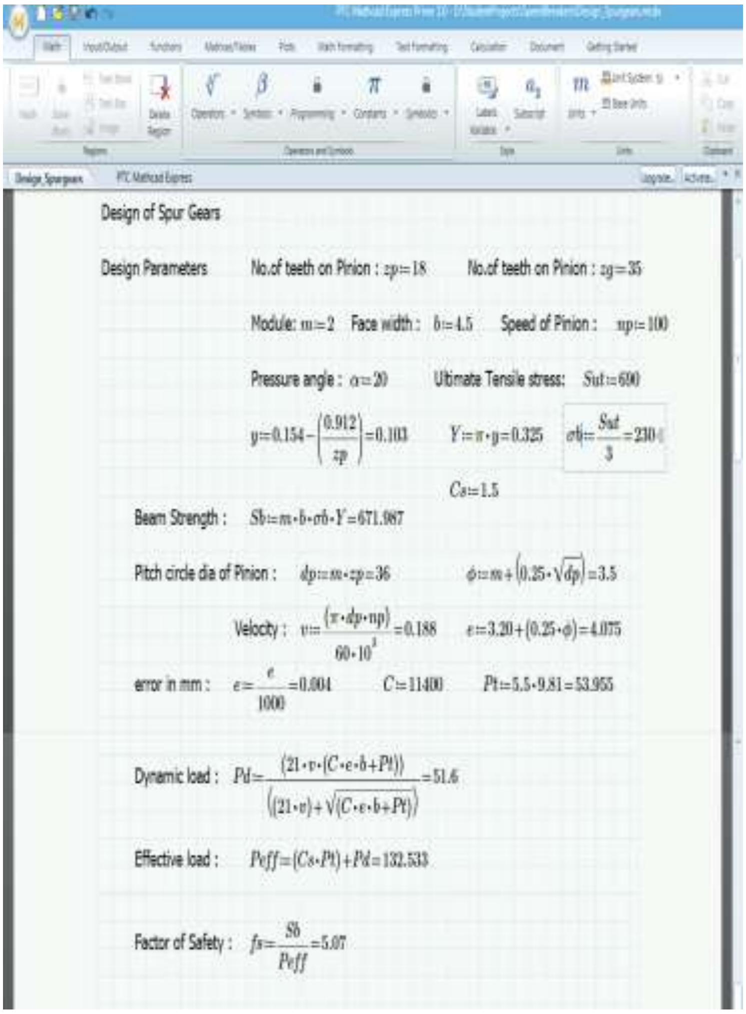

Fig. 2 Math CAD user interface for design of spur gears.

C. Sprocket Wheels

Two regular sprocket wheels and a freewheeling sprocket wheel have been used in the model.
The specifications of the regular sprocket wheels are as follows:

1. Material – mild steel (tempered) and stainless steel
2. Addendum diameter –78mm and 182mm
3. Number of teeth – 16 and 44
4. Pitch – 12.7mm

Freewheel specifications:

1) Material – mild steel (hardened)
2) Addendum diameter – 50mm
3) Number of teeth – 18
4) Freewheeling – one direction
5) Pitch – 14.6mm

D. Chain drive design

The chain drive is used between the freewheeling sprocket and the largest of the rest of the two sprockets. The specifications are as follows

1. Pitch –12.7mm
2. Roller diameter – 7.95mm
3. Width – 7.85mm
4. Breaking load – 13,800 N (min, ISO Standards for chain number 08A (ANSI-40))

1) Math CAD interface for design of Chain drive

Design procedure of chain drives is used in design of chain which transmitting torque from driving sprocket to driven pinion connected to the generator. User interface for calculating various parameters in the design procedure is prepared in MathCAD software and the user interfaces are shown in Fig. 3. Factor of safety is obtained from the given design parameters is 162. Hence the design is considered to be safe for static and fluctuating loads.

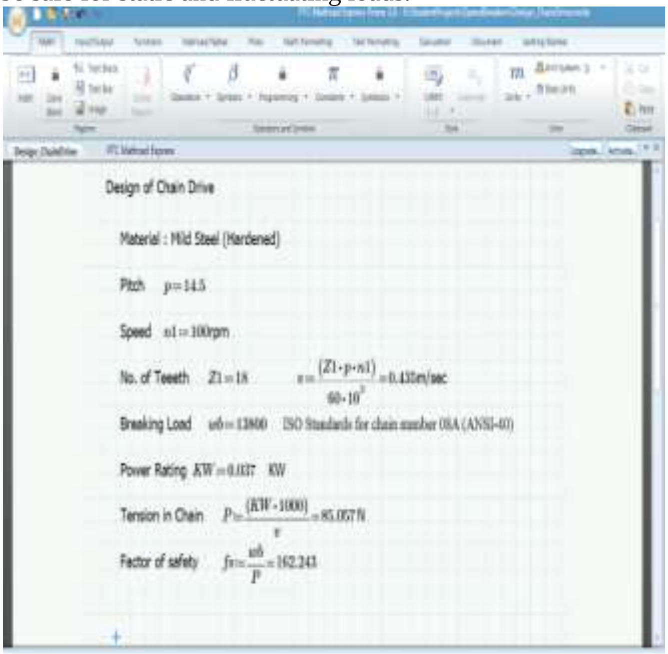

Fig. 3 MathCAD user interface for design of chain drive.

E. Spring design

The rack when pressed down has to be reset for the next incoming pair of wheels or next incoming vehicle. For this the rack has to retrace its downward motion in upward direction. This can be achieved by using springs under the rack. The springs are to be selected such that in downward motion most of the force due to weight of the vehicle has to be transferred to the pinion and the spring should deform easily. It should not pose any shock to the rack or the entire assembly because of its nature. As the weight on the rack is released the spring should reset the rack to its original position. So the spring selected should be of less stiffness with appreciable compressive strength to withstand the heavily loads possible.

The specifications of the spring selected are:

1. Wire diameter – 3.36mm
2. Spring index –15.76
3. Mean coil diameter – 51.05mm
4. Number of active coils – 8

1) Math CAD interface for design of Springs

Design procedure of helical coil springs is used to design spring which is restoring position of the rack, after getting displacement due to loads acting on the speed breakers. User interface for calculating various parameters in the design procedure is prepared using MathCAD software and the user interfaces are shown in Fig. 4. Factor of safety is obtained from the given design parameters is 2.87. Hence the design is considered to be safe.

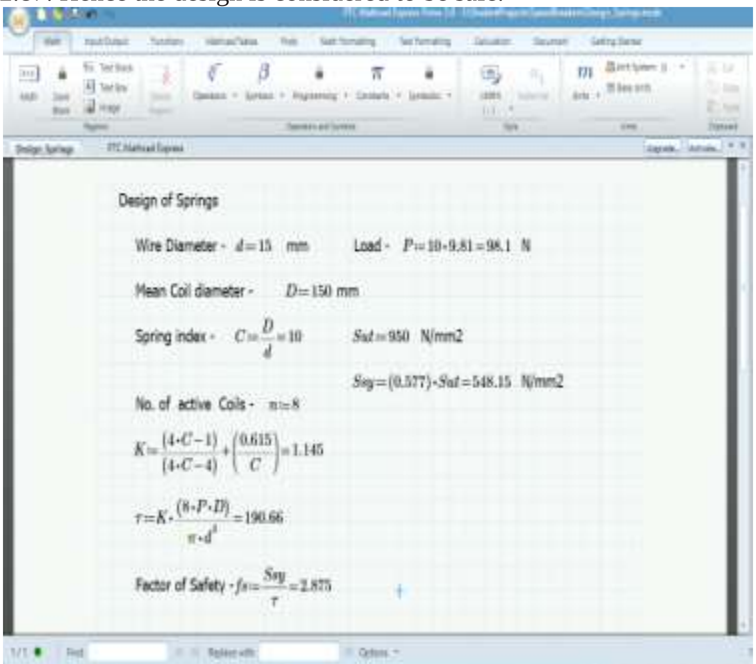

Fig.4 MathCAD user interface for design of springs.

F. Shaft

In the present model an aluminium shaft of 20mm diameter has been used to mount the gears. The shaft has been mounted on bearings to provide for resistance free rotation about its own axis. The loads acting on the shaft are that of the weights of the components mounted on the shaft, transmission loads and self-weight of the shaft. The colour gradation shows the change from minimum value at blue to maximum value at red. It doesn't mean that the shaft is at risk according to the load. It is just a way of representing the change in the response of the shaft at various locations of the beam along its length. The shear force and bending moment diagrams (Fig.5and Fig.6) of the shafts would be almost identical and resemble the following diagrams drawn to shaft -1:

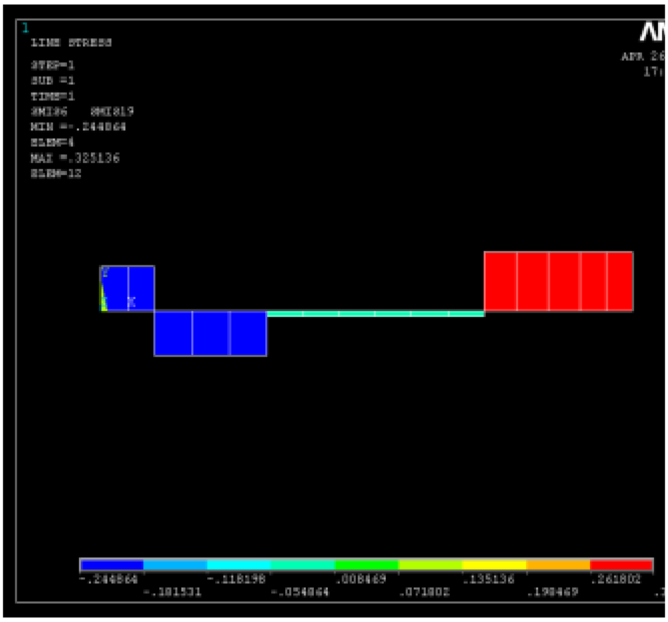

Fig.5. Shear force diagram

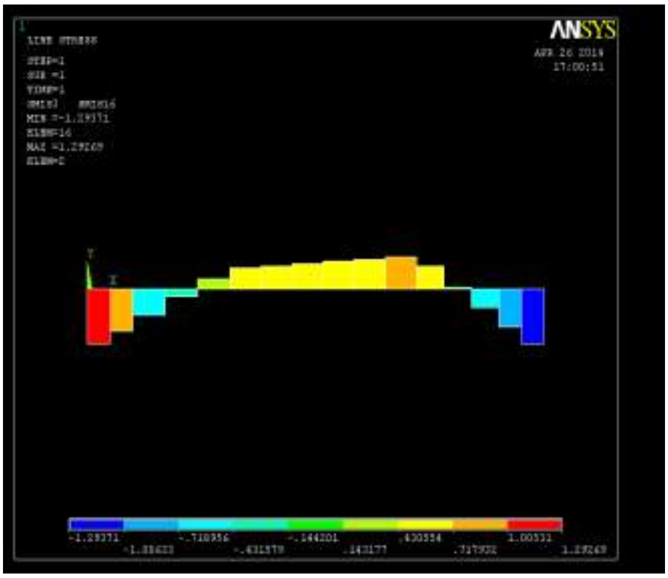

Fig.6. Bending moment diagram

G. Bearings

To support the rotation of the shaft in its seat in the wooden frame, single sleeve needle roller bearings have been employed. They are a type of cylindrical roller bearings.

The diameter of the shaft is reduced to that of the inner diameter of the bearing and thus providing a step in front of the bearing on the shaft to allow for locking of the movements along the axis of the shaft and also prevents any eccentricity possible in the rotation of the shaft. Each set of bearings bear the weight of the components mounted on the respective shaft and transmission loads.

H. Rack

The model demands the conversion of the linear motion of the speed breaker to be converted into rotary motion for the generation of power. A mechanism that best does this job is the use of rack and pinion. Thus the rack employed meshes with the sprocket and does its job of motion conversion.

To make the model cost effective and stronger, the usual rack and pinion mechanism is replaced by a chain tightly stranded to a wooden piece and a sprocket that meshes with the chain as shown below:

III. ASSEMBLY AND WORKING

A. Assembly of the model

Fig.7. Assembly of the model from one side

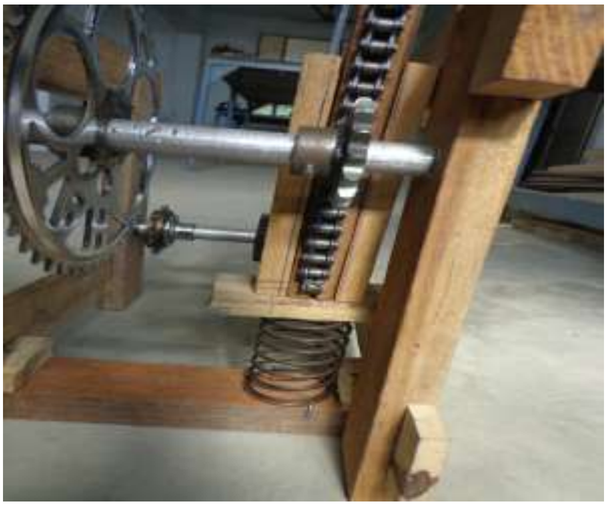

Fig.8. Assembly of the model from other side

B. Working Procedure

When the vehicle runs over the speed breaker, the vehicle usually lifts up by the maximum height of the speed breaker. If the speed breaker is free to move, the bump would be displaced vertically down, instead of vehicle moving up. The moving bump pushes the rack downwards. The rack, meshed with the sprocket (S_1) switches the linear motion to rotary motion. This motion is transferred to the shaft of the sprocket. The sprocket (S_2) that sits on the same shaft also rotates with the same shaft. This sprocket is in mesh with the sprocket (S_3) through the chain. The chain drive rotates the second shaft. The gear (G_1) on this second shaft rotates along with the shaft. This gear is in mesh with the gear(G_2). This gear sits on the generator shaft. Thus the generator shaft is driven by the whole mechanism with the motion of the bump.

C. Experimentation and Evaluation

In the model certain assumptions are made for the sake of model testing. The assumptions are as follows:

1. The vehicle weight is assumed to be the standard weights that are used to test the performance.
2. The load on the speed breaker is assumed to be vertical and no horizontal components are present.
3. The loads are all sudden loads

The maximum compression of the spring is calculated as "L". Now a series of known weights are placed on the top of the rack one by one. For each weight, time taken to reach the maximum compression position is measured as "t". Thus for each weight we have an average velocity "V". Thus for each weight we can calculate the mechanical power transmitted to the generator shaft with the help of equations derived earlier.

The input mechanical power is the potential energy and the output is the current and voltage that is obtained at the generator terminals. Thus for every weight used corresponding voltage and current are obtained at the multimeter. The motion of the rack is sine function. Thus the voltage obtained at the generator terminals is also a function of sine as the voltage is directly related to the velocity of the rack as obtained earlier. Thus we have a peak voltage value for every weight used.

Fig.9.Figure showing experimental setup

D.*Experimental Results*

Fig.10. Without the load acting effectively

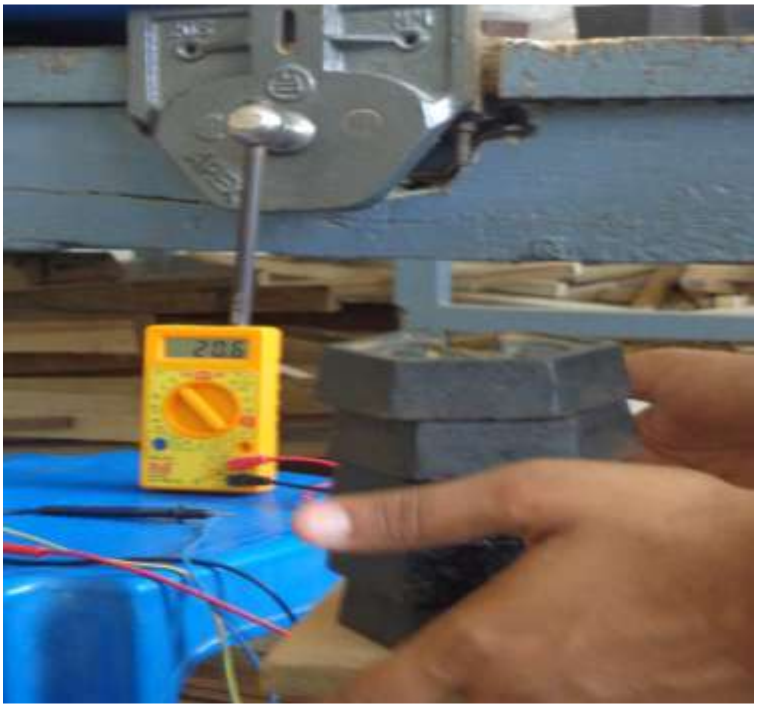

Fig.11. Peak voltage in a trail for 5 kg load

The load is allowed to act as sudden load but not impact or gradual. A fixed load is released on the mechanism and the peak of the voltage reading shown on the multimeter is noted. The experiment is repeated at least five times and the average of the readings noted is considered to be the voltage generated by the device when corresponding load is applied

TABLE 1

Load(kg) X-axis	Voltage(v) Y-axis
3	9.9
3.5	12.4
4	18.8
4.5	20.2
5	21
5.5	23.5

From the table 1 and experimental procedure the

1. With the increase in the load on the rack the output voltage increases.

2. The dependency of the velocity of the rack and output on the load on the rack is proved.

3. The output varies with the position of the rack also and if analysed with a CRO, the nature of the signal can be studied. Then the RMS value can be recorded and used as the output of the device

E. For Realization of Model

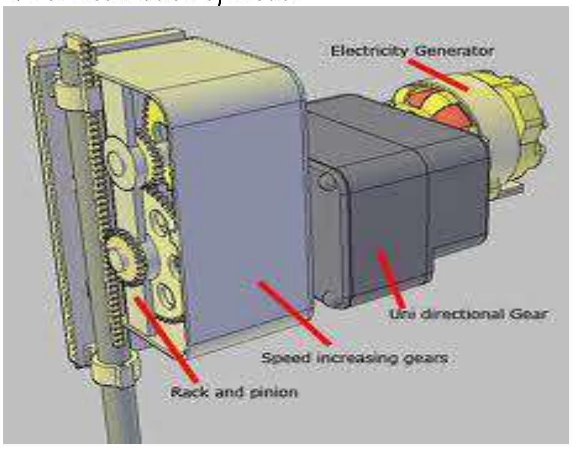

Fig.12.Rack and pinion mechanism with real time application

The effectiveness of the model requires a busy road with vehicles that move at average speeds, road data and effective planning of the usage or storage of the power developed.

1) Positioning Of The Device:

The output of the model is intermittent and is obtained as each vehicle runs over the speed breaker and thus the power developed depends directly on the frequency of the vehicle movement. Thus it is necessary to select the appropriate location for installing the model for useful outputs.

The positioning of the speed breaker has to be strategic considering following aspects.

1. The vehicle user has to be cautious about the presence of the speed breaker
2. The speed breaker can be positioned at necessary points like zebra crossings, school zones, accident prone areas etc.
3. Speed breakers are to be employed where vehicles usually go slow or the drivers are forced to go slow naturally.
4. The speed breaker should not cause damage to the vehicle's performance by its presence.

The various dimensions of the mechanism depend on the average load expected on the speed breaker. The mechanism can be used in groups along each speed breaker thus multiplying the output and sharing the load that acts on the mechanism due to vehicular movement. The average load depends on the vehicular frequency for each type of a vehicle which is called road data.

The weight of a vehicle without any passenger or load over it is termed as laden mass of the vehicle. It sometimes also excludes the weight of the battery in electric powered vehicles and fuel in usual vehicles.

F. Applications

The energy developed may be used later by storing into a battery. The later use can be made by street lights, lighting in public places and power supply for various purposes around the actual plan of the speed breaker. It can also be directly used as a trigger to certain devices like calling bells, security and surveillance alarms etc.

1) Calling Bells:

At door steps of every house the mechanism can be arranged. When a person steps on the door step the weight of the person drives the mechanism and initiates a trigger signal which closes the circuit that finishes an alarm. When he steps the second time, the circuit can be arranged to trigger the second signal as stop signal for alarm. The same application can be used to develop power through steps on stair cases.

2) Surveillance Alarm:

With small changes to the above application the device can be used as a surveillance alarm. When the person steps on the device, the alarm turns on. It can be stopped only by any

personnel switching off the switch of the alarm at the security room

G. Advantages

1. Never decreasing vehicular frequency
2. Power generation at the place of consumption , leading to fewer transmission losses
3. Prevention of jerk generated due to speed breaker, to certain extent as the mechanism absorbs the energy.
4. No fuel input required
5. Non – conventional energy source

6. Low initial and maintenance cost

IV. CONCLUSION

In this paper power was generated at speed breakers by using rack and pinion mechanism. This type of power generation is identified to be cheaper than many other alternatives and the model has less number of parts and the assembly would cost very less with all the components being available regularly and no model specific parts are to be manufactured.

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