Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2020, 7(1):125-139

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Experimental Review and Analysis of an Improved Energy Generation by Using Speed Humps

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Abstract The world with economic crisis today needs to develop non-traditional ways for their energy generation. Today continuous reduction in the conventional energy sources is happening. Source which should be eco-friendly and require less developing effort, speed humps in this study contains the improved development of the effective energy generation mechanism. By mentioning all the constraints, a review with relationships will be drawn by varying the inputs and power outputs will be exhibited accordingly. Finally, a conclusion having comparison with the previous mechanisms will be extracted for sustainable design and solutions of effective power generation.

Keywords Meshed gear, Humps, Load analysis, Model Efficiency

1. Introduction

Energy crisis and global warming are considered as two severe problems worldwide and researchers are trying their best for substituting fossil energies for a long time [1]. Energy in the form of electrical or mechanical can play a vital role for the cause [2]. Energy saving is indeed an essential ingredient for economic development and prosperity of a country [3]. Conventionally power plants have been large, centralized units, a new trend is developing towards distributed energy generation which means the conversion units are situated close to the consumers [4].

Renewable energy is becoming a prosperous industry with numerous researchers focusing and exploring new and effective ways to harness the power from available sources. This paper presents a new mechanism for energy generation from vehicles passing over ramps, energy will be wasted if not harvested [5]. In particular, small-scale and community-based renewable energy projects can assist the under developed countries [6]. The benefits of promoting the renewable energy sources are regularly claimed with energy security, climate change mitigation and job creation [7]. Price profiles for each non-combustion renewable energy technology show high capital intensity and low running costs [8]. Iran as one of the major oil producing country has increasingly paid attention to the non-fossil energy resources, in particular to renewable energy resources for its longer term energy plans [9]. Electrical energy can also be generated by using coal, biomass, solar and chemical processes but they may cause different pollutions and CO emissions and are harmful to the environment and society, it was also a necessity to produce electricity by renewable sources which are eco-friendly [10].

Over speeding one of the most common contributing factor in vehicle crashes [11] can to be reduced heavily by introducing humps. The use of speed humps as an effective measure to reduce the rate of traffic accidents. Speed bump energy harvester is a novel technique of harvesting energy from the passing vehicles on the streets and the road [12]. Pressure has large opportunities and stronger range of force recovery on the road. Therefore, this project utilizes force created from vehicle hump as an alternative and new renewable energy source [13].

Among all the energy related human activities, traffic is one of the most energy-expensive ones, and, furthermore, it is characterized by great waste. Only 30% of the fuel potential is used to transfer kinetic energy to the vehicle and the largest part of this energy is dissipated in decelerating phases by brakes and gases [14] in the normal operation of the vehicle, the said force is in no way capable of causing any vertical return displacement .The energy is lost as trapped energy [15] so alternative way to utilize this energy is approached.

The current trends of producing energy from fossil fuels may increase ambient temperatures substantially. Energy harvesting through road speed breakers poses no environment threat with additional advantage of its non- dependence on seasons [16].

Energy conversion can be done from one form to the other, for example, potential energy conversion into kinetic energy and vice versa. In the same way, mechanical power is converted into electrical power. The vehicles produce kinetic energy while moving. A number of vehicles on the road show a significant increase day by day which is a good thing to generate electricity by passing these vehicles over speed humps. A large amount of kinetic energy is wasted in the form of friction and heat when they pass over the hump and it can be converted into electrical energy in different ways. The potential and kinetic energy can be converted into electrical energy by the vertical displacement of the hump [17].

In this system, electricity is generated with the help of mechanical and electrical components. When the vehicles move on the speed hump, the hump moves down due to the force applied. This force moves the rack down and the pinion attached to the rack rotates [18]. The pinion is mounted on a primary shaft on which a large gear is also mounted. In order to get the unidirectional motion of the pinion, a ratchet type bearing is used. The large gear meshes to the small gear of the secondary shaft. These gears are used to transmit power from one shaft to the other shaft. A flywheel is used for continuous motion of mechanism by storing the rotational energy. The secondary shaft is connected to the generator shaft with the help of gears. The generator produces power which is stored in the battery [19].

This mechanism has advantages over other mechanisms which are using chain and sprocket, roller mechanism, hydraulic method, flip plate, and crank mechanism etc. The efficiency of chain and sprocket is less than the gear mechanism because more power is transmitted by gears. Noise is produced by chain and sprocket mechanism. In the flip plate mechanism, the flywheel is attached to flip plates directly so modified velocity cannot be achieved [20]. The rusting and wear and tear are produced in case of energy generation by the fluid mechanism [21]. This mechanism is eco-friendly because by using this method a little bit noise is produced which is negligible as compared to the power output. The maximum power transmission ratio is achieved by gear meshing. This mechanism is compact in size. The speed bumps equipped with steel casing are suitable for use as part of system components in producing electrical energy [22].

In coming days, this will be an effective way to save a lot of electricity of power plants that gets wasted in illuminating the street lights [23]. The results of experimenting and prototyping revealed that the designed system produced sufficient rotation of the armature to generate enough current to charge a standard 12V battery [24]. The electricity produced by the speed breaker can be utilized for the lightening of the bus stops, streets, roads, signboards and signals on the road. It can also be used in check post and highways [25].

Literature Review

Numerous energy generation techniques and mechanisms have been developed previously. G. Del Castillo et al. presented an elemental hydraulic TEHD which comprises piston, cylinder, pipes and a hydraulic turbine. That system was based on Bernoulli´s principle, the compressed fluid inside the piston goes into the external pipes decreasing its pressure but increasing its velocity, due to a cross-section reduction. A hydraulic turbine transforms the fluid speed into mechanical energy and then into electricity [26]. Like other progressive countries, application of solar energy have been appreciated by the government of Pakistan and common people in recent times as reliable and useful energy source [27] but it has more limitations regarding running costs and handling. The energy from ocean waves is the most conspicuous form of ocean energy. The waves are produced by wind action and are therefore an indirect form of solar energy [28].

Hiba *et al* presented a technical simulation based system to support the concept of generating energy from road traffic using piezoelectric materials [29]. A speed bump energy harvester based on a piezoelectric cantilever translates kinetic energy generated by a passing over vehicle into electrical energy. Upon detection of the voltage generated by the piezoelectric cantilever, the proposed circuit had the converter and extracts maximum power from the piezoelectric cantilever through impedance matching [30]. Another work has developed an energy harvesting system which uses vibrations from railroads [31]. [20] deals with energy resources and energy crisis to state economy. These energy crises can be reduced by using road power generation from speed humps.
Patel *et al* presented RPG through Chain and Sprocket Mechanism in which chain and sprocket are used to transmit power and motion from one shaft to the other shaft. Chain and sprocket are useful when the distance between shafts is relatively large as compared to the desired size of the gearing [21]. Rao *et al* presented RPG by Flip Plate Mechanism in which the rack and pinion are moved with the help of plates on the road surface. The pinion is fixed on the shaft which rests inside the frame with the help of bearings. Frame which is under the road surface, there is a primary shaft having the flywheel with a gear and this gear meshes with the gear of secondary shaft which is then coupled to a 12V DC generator to provide rotations to it [2]. Pandey & Rafiq presented RPG by moving Plates on Roads in which moving plates are installed on the road, during the motion of vehicles small movement occurs on the road surface. This movement of vehicles runs the flywheel system. In this mechanism, one flywheel is driven by other when a specific velocity of the first flywheel is achieved. This flywheel system is very useful to utilize a large amount of energy in relatively small space [25].

Problem Formulation

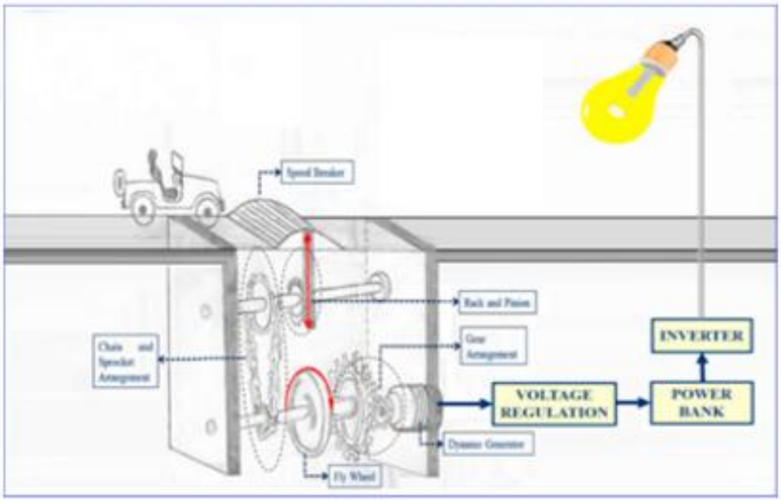

Figure 1: Chain and Sprocket Mechanism [32]

The figure above reveals the idea of s road power generation from speed breaker with rack and pinion, interconnected with chain and sprocket. Rack and pinion are used to convert the reciprocating motion of rack attached to the hump into the rotary motion of pinion of the primary shaft. The mechanism has a secondary shaft attached horizontally with the primary shaft. Both of the primary upper and secondary lower shafts are chained together with the help of chain and sprocket mechanism. The rotational power of upper shaft is transferred to the lower shaft by rotations of chain and sprocket [32].
This work shows that the chain and sprockets are being replaced by gear meshing, making a gear train which provides a larger capability with increasing rotations. Similar to the mechanism as discussed, rack and pinion is used to convert the reciprocating motion of the hump to rotary motion of the pinion which will eventually yield higher efficiency and maintainability. The mechanism has two shafts, the upper shaft has pinion and a larger diameter gear attached to it which is connected to the lower shaft of the mechanism, the lower shaft has another larger diameter gear which is meshed with the generator shaft gear and hence runs the 12V DC generator. The details will be elaborated further in next sections.

Methodology

A 3D Model of desired mechanism to be constructed was made on AutoCAD as shown in figures below

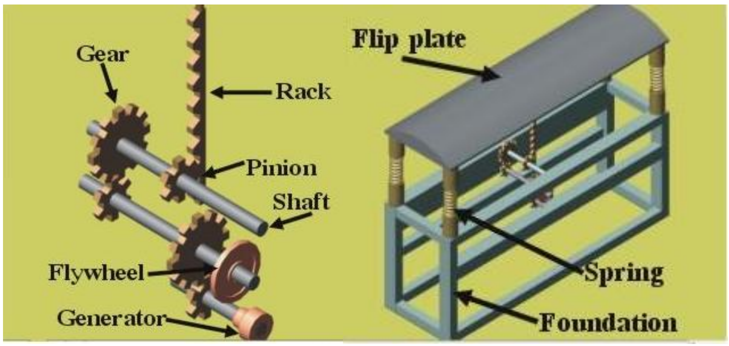

Figure 2: 3D gear model

Construction Methodology

This mechanism needed a sequence of assembly of parts. The methodology of this work is below

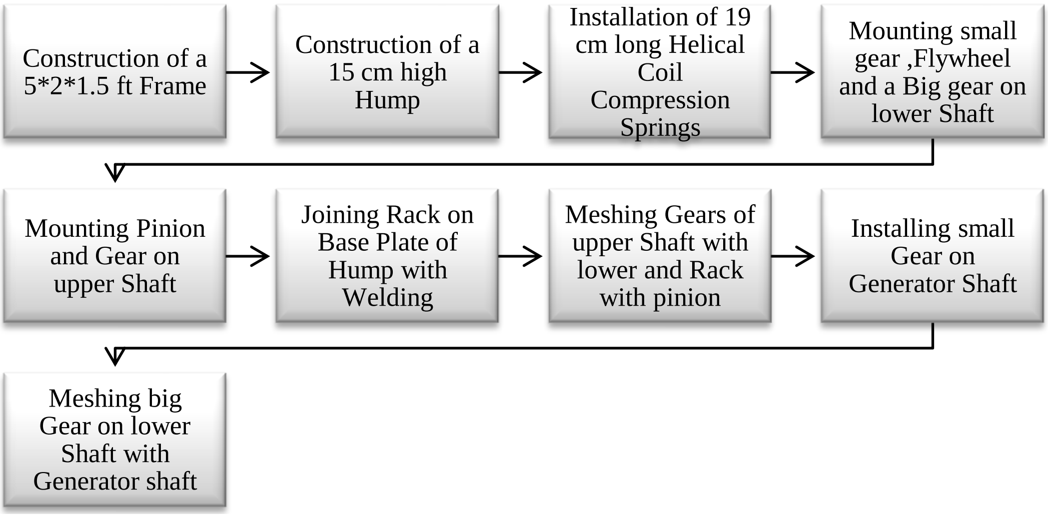

Figure 3: Construction Methodology

Frame

A frame is made with the same load bearing capacity of "Suzuki Mehran" genre of Pakistani automobile. The frame consists of square cross-section tubes and rectangular tubes for supporting the mechanism.

Table 1: Frame technical specifications

length	152.4 cm
width	45.72 cm
height	60.96 cm
Gauge of the rectangular tube	18
Square tube cross section area	4.95*4.95=24.50 cm^2
Material	Cast iron

Figure 4: Iron frame

Hump

Mild steel plate was selected for making hump whose thickness is 4 mm and load is 30kg. Bending of the plate was done with the help of hydraulic press machine. Three pieces of mild steel were fastened together by arc welding for the support foundation of springs and rack & pinion with a hump.

Table 2: Humptechnical specifications

Sheet gauge	11
Support gauge	4
length	152.4 cm
width	45.72 cm
height	12 cm
Load (kg)	30
Material	Mild steel

Figure 5: Hump

Compression Springs

These springs are attached for the instant vertical feedback. In RPG mechanism, requirement for hump plate to bounce back rapidly is achieved by carefully considering spring stiffness which will eventually fulfill the maximum energy storing purpose.

Other advantages for springs for the said cause are resisting the movement of other components, providing consistent pressure and useful for Impact loading.

Figure 6: Springs

Table 3: Spring technical specifications

Wire diameter	0.92 cm
Mean coil diameter	6.9 cm
Length	19 cm
Maximum deflection	15 cm

Helical Gears

Helical gears are adjoined in this design. Some advantages of obtaining better transmission efficiency, helical gears are preferred over spur gears. Also torque capacity of helical gear is higher than the spur gears. Spur gears are weaker because loads are transmitted over fewer teeth. The teeth of helical gears are angled, hardened and ground, which is complex but necessary to achieve higher gear mesh. Gear technical Specification and its designing is illustrated in tables below.

Figure 7: Helical Gear

Table 4: Gear Design calculations

Number of teeth (n)	79
*outside diameter (d_o)	184
*pitch circle diameter (d)	$\frac{Do}{(1+2n)} = \frac{184}{1+2/79} = 179.45$
module	$\frac{D}{n} = \frac{179.45}{79} = 2.27$
pressure angle of gear (ϕ)	20^o
*diametral pitch (p)	$\frac{N}{d} = \frac{79}{179.45} = 0.45$
*addendum (a)	$\frac{1}{p} = \frac{1}{0.45} = 2.25$
*deddendum (b)	$\frac{1.157}{0.45} = 2.57$
*tooth thickness	$\frac{1.5708}{p} = \frac{1.5708}{0.45} = 3.49$
*whole depth	$\frac{2.157}{p} = \frac{2.157}{0.45} = 4.79$
*clearance	$\frac{0.157}{p} = \frac{0.157}{0.45} = 0.35$
* center distance	$\frac{(n1+n2)}{2p} = \frac{79+19}{2(0.45)} = 108.88$
*working depth	$\frac{2}{p} = \frac{2}{0.45} = 4.45$
*addendum circle diameter	D – 2(m) = 184 – 2(3) = 178
*deddendum circle diameter	D – 2.5(m) = 184 – 2.5(3) = 176.50

*dimensions are in mm

Table 5: Gears technical specifications

*length of the rack	450
No. of teeth on the rack	40 teeth
*effective length	150
*diameter of pinion	73
No. of teeth on the pinion	30 teeth
*diameter of the large gear	184
No. of pinion	1
*addendum (a)	2.25
*deddendum (b)	2.57
*module	3
*clearance	0.35
*tooth thickness	3.49
*diametral pitch (p)	0.45
No. of teeth of the driver gear	79
*pitch diameter	179.45
No. of small gear	2
*diameter of the small gear	50
No. of teeth of the driven gear	19
*addendum	2.38

*deddendum	2.75
Module	3
*clearance	0.37
*diametral pitch	0.42
*tooth thickness	3.74
*working depth	4.76
*whole depth	5.137
No. of small gears	2
Material	Cast iron

*dimensions are in mm

Design of Rack and Pinion

Rack and pinion mechanisms are the easier and compact way to convert linear motion into rotary motion. Being a cheaper mechanism, it gives reliable control over the system. Maintenance is quite easy. It has less backlash. It can be power assisted. It has greater feedback [33].

Figure 8: Pinion with Rack

Table 6: Rack and Pinion design calculations

No. of teeth	30 teeth
*pitch circle diameter	67.5
Module	$\frac{\text{Pitch circle diameter}}{\text{number of teeth}} = 2.25$
*pitch circle diameter	$\frac{D}{2} = 36$ mm
*addendum circle diameter	$R + \text{addendum} = 38.25$
Pressure angle of pinion (ϕ)	14.5 involute
*length of the path of contact	18.83
*length of the arc of contact	$\frac{\text{Length of the path of contact}}{\cos \emptyset} = \frac{18.83}{\cos 20} = 20.04$
Minimum no. of teeth contact	$\frac{\text{Length of an arc of contact}}{\text{circular pitch}} = 3.18$
	4 teeth of pinion contacts with the pinion
*circumference of gears	$2 * \pi * r$ = 2*3.14*38.5 = 226
*length of rack	226+224 = 450

*dimensions are in mm

Flywheel

The flywheel which makes shaft rotation consistent and it helps the 12V DC generator shaft to maintain its RPM for a long time. Consider a constant torque with the help of input power source and is applied on the flywheel, which rotates the shaft from initial angular velocity ω_1 to final angular velocityω_2.the radius of the flywheel is denoted as r and ΔE is the energy stored in the flywheel[34]. The equation for finding the mass of flywheel is given as

$$\Delta E = mR^2\omega^2 C_s \quad (1)$$

Coefficient of speed of fluctuation = Cs = 0.020

Radius selected = 150mm = 0.150m

Here, ω is the nominal angular velocity of the flywheel.

$$\boldsymbol{\omega} = \frac{\boldsymbol{\omega_1} + \boldsymbol{\omega_2}}{\mathbf{2}} \quad (2)$$

For $\omega_1 = \frac{35.9 rad}{s}$, $\omega_2 = 15.7 rad/s$, it yields $\omega = 25.05\ rad/s$

The energy stored in the flywheel is given by,

$$E_1 = \frac{1}{2}\omega_1{}^2; \quad E_2 = \frac{1}{2}\omega_2{}^2 \quad (3)$$

Putting the values in [1], m is found out to be 17.24kg

Other specification of the design is as follows

Table 7: Technical Specifications of Flywheel

Material	Cast iron
Load	17.24 kg
diameter	148 mm
thickness	24 mm

Figure 9: Flywheel

Ratchet Bearing

Ratchet type bearing is used here to fulfill the requirement of unidirectional motion of the shaft with no interruption hence has achieved purpose of constant motion of the shaft.

Figure 10: Ratchet Bearing [35]

Shaft

A shaft made of cast iron is shown below. It was chosen due tocost effectiveness. It was fixed inside the bearing After the selection of gears and shafts, the gears were mounted on a shaft .Rack and pinion were attached at the mid of the hump with help of arc welding. Pinion mounted on the shaft and fully fixed by key. A large gear also mounted on this shaft and joined with the shaft permanently by using arc welding. This shaft moves freely due to ratchet type bearing used between the pinions. The large gear meshed with small gear which is mounted on the second shaft. A flywheel is attached at second shaft which stores the energy and gives linear motion.

Table 8: Technical Specifications of Shaft

Length	1.9
Diameter	42
Material	Cast iron

*dimensions are in cm


Figure 11: Cylindrical Shaft

Generator

A 12V DC generator is used to convert the mechanical power to electrical power [21]. Specialized generators for low RPM projects are very difficult to get and costs too much because of job shop production.

Table 9: Technical Specifications of Generator

Voltage	12 V
Type	DC
Current	40 A
Battery	Lead acid

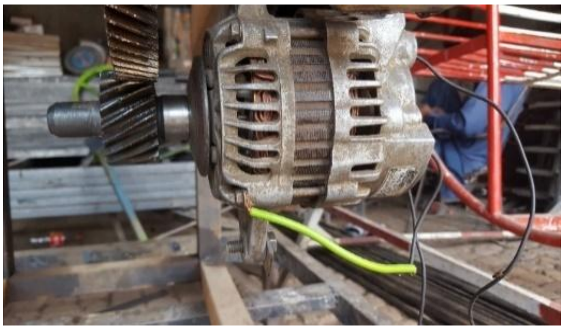
Figure 12: DC Generator

Battery

A Battery is used to store DC output from DC generator [36]. The battery used have following specifications.

Table 10: Technical Specifications of Battery

Battery amp hour	50
Discharge Capacity	5 A/h
Voltages	12 V
Type	6 cells lead acid

Fabrication and assembly

Fabrication of the designed mechanism was done by making a metallic frame of cast iron rectangular tubes joined with Electric Arc Welding. The inside assembly was made by mounting helical gears and flywheel on shaft according to design and then it was meshed and assembled inside the mechanism. Shafts were hold inside the thrust load bearings. For upper assembly of hump, the springs were mounted on the top four corners of frame with the help of metallic cups and same for base of hump plate. The hump plate was made of 11 SMG mild steel sheet which was bended according to the length and width of design calculations. Both the upper assembly and lower frame assembly were connected with springs. For output shaft which emerged out of frame was connected with a 12V DC Generator supported with frame with the help of cast iron strips. The Driven gear of generator shaft was welded on it and meshed with the output driver gear of Mechanism in order to run the generator.

Working and Results

Theoretical Calculations

Table 11: Theoretical Calculations [39]

Parameters	**Value**	**formula**
The height of the flip plate	12 cm	Assumption [37]
Watts of street light	55 watt each	$P = v * i$ [38]
Total required output watts for 4 lights to be lit up 8 hours	1760 watts	No. of lights*watts for each light*turn ON hours
Mass of vehicle	200 kg approximately	Approximation and Compared
force on hump	1962N	M*g
Work for one pushing force	1962*0.12 0= 235.4 J	F*d
Output power for one push	235.4/60 = 3.92 watt	$\frac{\text{Work}}{\text{time}}$
for one hour	235.4 watts	3.92*60
for 8 hours per day	1883 watts	235.4*8
The diameter of 4th gear	24 cm	Measured
Rev. of pinion attached with rack	47.7 RPM	$\frac{N_1}{N_2} = \frac{N_2}{N_3} = \frac{N_4}{N_5}$
Velocity of rack	14.9 cm/sec	$v = r * \omega$
Time taken by rack for downward motion	0.8 sec	d = 12 cm

According to the width of the hump if a car passes over it then the distance covered will be 47.25 cm if the velocity of a car remain between 2 km/h to 5 km/h, choosing the velocity to be 2 km/h and time 0.85 sec. Other necessary calculations were done as follows

Force present on rack = 200*9.8 = 1960 N

Work = W = 1960*0.15 = 294 J

Power = $\frac{work}{time} = \frac{294}{0.85}$ = 345.88 W

Revolution of pinion for 0.85 sec = 0.6

As no of teeth of pinion is 30 and no. of teeth of rack is 18

For 60 seconds, RPM gain will be 42.35 RPM

$$\text{Torque} = \frac{p(60)}{2 * \pi * n} = \frac{345.8 * 60}{2 * 3.1416 * 42.35}$$

T = 77.99 Nm

Angular velocity = 4.43 rad/s

As the gear ratio is 4 so the RPM at second shaft will be 169.4 RPM

Torque for the second shaft will be 19.93 Nm

Angular velocity = 17.73 rad/s

RPM on the generator shaft will become (169.4)*(4) =679.6 RPM

When no load then torque = 4.855 N.m.

Angular velocity = 67.96 rad/s

When load on then torque = 10 N.m.

RPM find by tachometer = 320

Angular velocity = 32 rad/s

Mechanical power = 10*32 = 320 w

Electrical power = V * I = 11.25*12 = 135w

Actual/ experimental calculations

Experiments was carried out for different loads by observing after intervals and it was noted for analyzing further.

Table 12: Experimental Readings for RPM

No of pushes	Load applied (kg)	Rpm measured	Time duration
1	60	248	3.8 s
2	60	395	6.31 s
4	60	485	11.3 s
1	130	325	5.24 s
2	130	420	13.52 s
4	130	534	15.24 s

Table 13: Experimental Readings for Power output

No of pushes	Load Applied (kg)	RPM Measured	Volts V	Amperes A	Output Power Watts
2	60	73	12	0.4	4.8
4	60	95	12	0.8	9.6
2	130	205	12	0.9	10.8
4	130	328	12	1.9	22.8
2	220	412	12	1.5	18
4	220	548	12	2.2	26.4

Table 14: Comparison of Actual and Theoretical values

Output	Theoretical values	Actual values
Output Power for 2 push	7.86 W	6.00 W
Output Shaft Angular speed	750 RPM	534 RPM
Spring Deflection	12 cm	15cm

Graphical Representations

Graphs are vital feature to exhibit systems' trend for a relatively larger approximated values. Different dependent and independent relations are formed and explained further.

Load Variation Effect on Output Watt

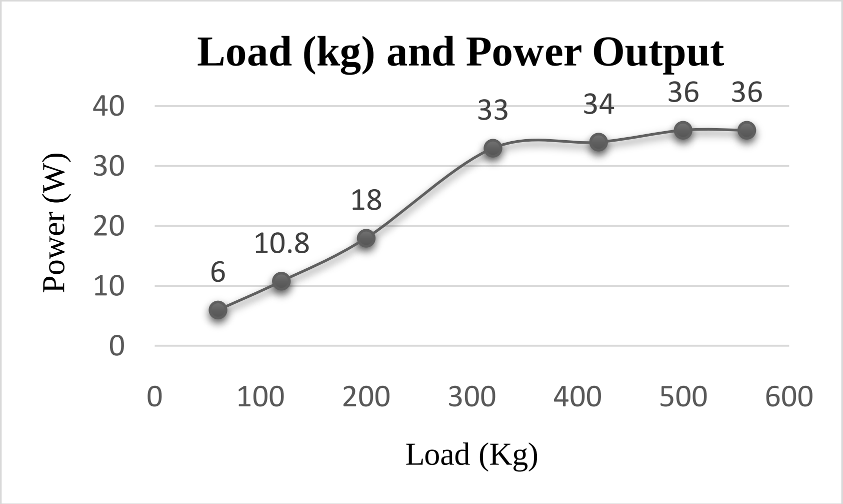

Figure 13: Load Power Response

Values obtained are for 2 pushes. The graph trends shows that the output power increases linearly by increasing load [40] but this increment is up to the specific value of the revolutions of the shaft.

Effect of No. of Pushes on RPM

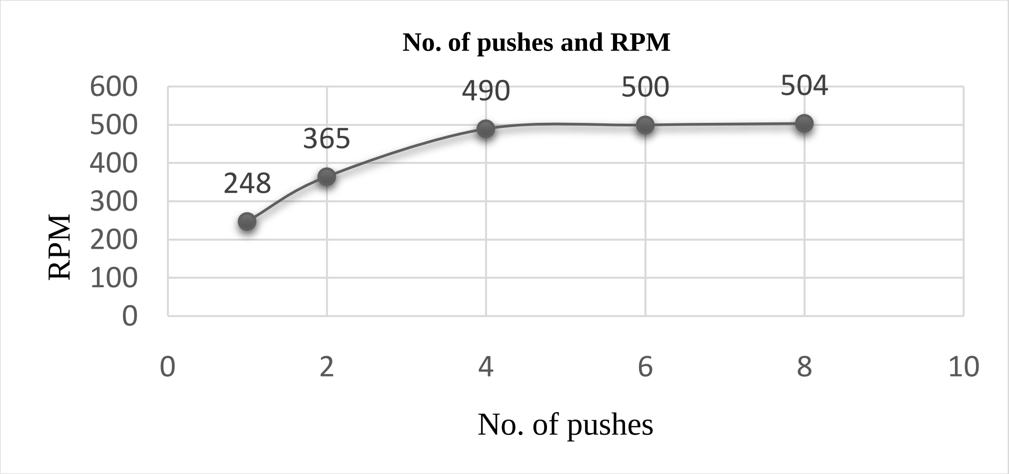

Figure 14: RPMs

Results shown exhibits that if its have more number of pushes, the more will be RPMs, but this increment will be up to a specific limit of pushes and will vary according to dimensional constraints.

Rpm Obtained on 12V DC Generator Shaft and Load Applied

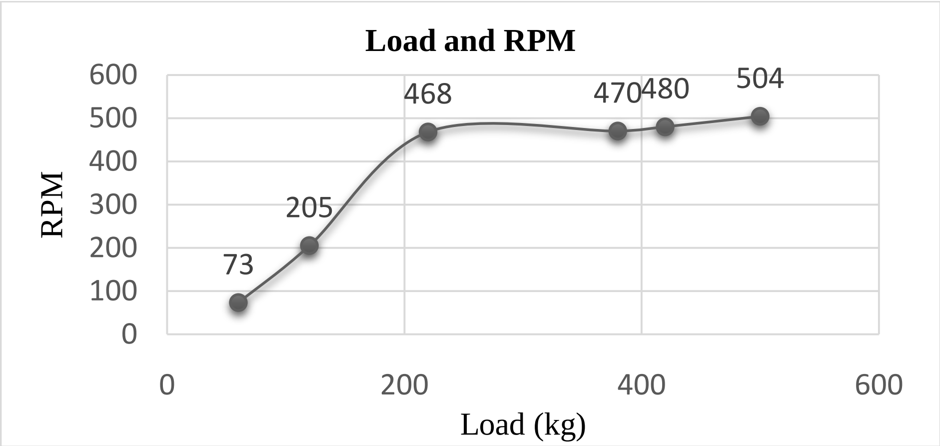

Figure 15: load vs RPMs

The load applied on hump has a direct relation with RPM of shaft. By increasing the load, we can increase no of revolutions of shaft. Comparing the results of road power generation with rack and pinion the help of chain and sprocket [32] and same rack and pinion mechanism but connected with gears.

To establish some conclusions, it was necessary to extract the useful information regarding the input and output power which are calculated as

The input and output watts are calculated by following formulas

Input mechanical power = $\frac{Mass\ of\ object\ \times 9.8 \times Displacement\ \ of\ rack}{Time\ taken\ to\ deliver}$

Output electrical power = V × I [38]

Table 15: Comparative study results

Existing work				Our work			
Mass (kg)	**Input power (watts)**	**Output power (watts)**	**Efficiency**	**Mass (kg)**	**Input power (watts)**	**Output power (watts)**	**Efficiency**
50	21.87	7.02	32 %	60	12	4.80	40.0 %
75	37.96	11.88	31 %	130	26	10.8	41.5 %
110	68.75	17.22	25 %	220	44	18	40.9 %
Rpm per push on generator shaft (75) kg load 10.28				Rpm per push on the generator shaft (75kg load) 45.622			

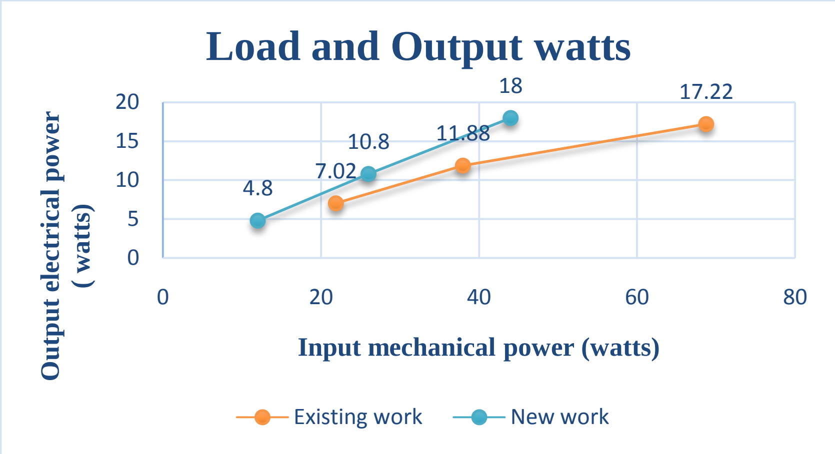

Figure 16: Comparative Graph of Power generation

The graph trend clearly shows that the output watts are increasing linearly by increasing input power in form of mechanical energy i.e. the more will be input energy more will be output watts, while in case of previous work output watts increase up to a specific limit and then remains constant approximately.

Efficiencies are found in table 15 which summarizes the trend graph below

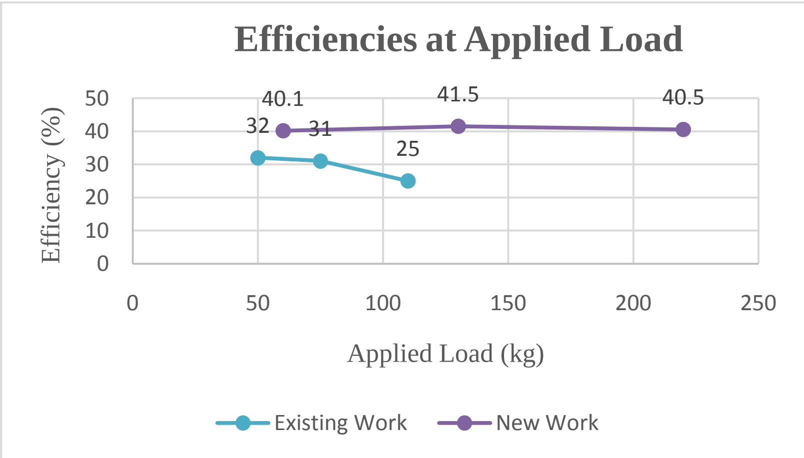

Figure 17: Efficiency Comparison

By comparing the values from the graph shown above, at 60 kg of the load for both of the designs, the efficiency of gear meshed design is 10% more than the chain and sprocket design and also with 110 kg load, the value of new work is 15% more than existing work. Also the efficiency of the previous related work is decreasing up to provided values while the efficiency of new work remains constant comparatively.

Conclusions

This work explains complete design and analysis of speed hump power generation. As Battery charging can be done with a continuous supply. This work reveals that one car can give 30 watts approximately. This mechanism can be easily implemented for streets with smart lightening system to save maximum energy. Comparative study of this design is done with[32]. It has concluded that by using the gear train instead of chain and sprocket mechanism for interconnecting two shafts of the mechanism can increase the rotations almost four times and output watts are also higher at same input watts. Moreover the efficiency of designed mechanism increases with increasing loads as compared to the mechanism already designed whose efficiency decreases with increment of load [32]. Also Constant efficiency concludes that the proposed design has maintainability and reliability for increased loads.

References

[1]. Y. H. Zheng *et al.*, "Biomass energy utilization in rural areas may contribute to alleviating energy crisis and global warming: A case study in a typical agro-village of Shandong , China," vol. 14, pp. 3132–3139, 2010.

[2]. A. P. Rao, A. K. Kumar, and S. Suresh, "Power Generation from Speed Breaker by Rack and Ratchet Mechanism," *Int. J. Curr. Eng. Technol.*, no. 2, pp. 549–552, 2014.

[3]. J. Khan and M. H. Arsalan, "Solar power technologies for sustainable electricity generation - A review," *Renew. Sustain. Energy Rev.*, vol. 55, pp. 414–425, 2016.

[4]. K. Alanne and A. Saari, "Distributed energy generation and sustainable development," *Renew. Sustain. Energy Rev.*, vol. 10, no. 6, pp. 539–558, 2006.

[5]. U. A. Khan, S. Khan, and A. W. Azman, "Energy harvesting for back-up power supply using speed humps," in *Proceedings - 5th International Conference on Computer and Communication Engineering: Emerging Technologies via Comp-Unication Convergence, ICCCE 2014*, 2015, pp. 24–27.

[6]. J. Terrapon-Pfaff, C. Dienst, J. König, and W. Ortiz, "A cross-sectional review: Impacts and sustainability of small-scale renewable energy projects in developing countries," *Renewable and Sustainable Energy Reviews*, vol. 40. Elsevier Ltd, pp. 1–10, 2014.

[7]. P. Silva and R. Jasmine, "The challenges of determining the employment effects of renewable energy," *Renew. Sustain. Energy Rev.*, vol. 16, pp. 4667–4674, 2012.

[8]. A. Evans, V. Strezov, and T. J. Evans, "Assessment of sustainability indicators for renewable energy technologies," vol. 13, pp. 1082–1088, 2009.

[9]. M. Bahrami and P. Abbaszadeh, "An overview of renewable energies in Iran," *Renew. Sustain. Energy Rev.*, vol. 24, no. April, pp. 198–208, 2013.

[10]. S. Islam, S. K. Rahman, and J. Jyoti, "Generation of Electricity Using Road Transport Pressure," vol. 2, no. 3, pp. 520–525, 2013.

[11]. F. K. Afukaar, "Speed control in developing countries: issues, challenges and opportunities in reducing road traffic injuries.," *Inj. Control Saf. Promot.*, vol. 10, no. 1–2, pp. 77–81, 2003.

[12]. G. Motors and W. Europe, "No 主観的健康感を中心とした在宅高齢者における健康関連指標に関する共分散構造分析Title," no. June, 2016.

[13]. H. C. M. Haris, M. A. N. M. Nor, M. H. F. Rahiman, and N. F. A. A. Rahman, "Development of energy harvesting using speed breaker," in *Proceedings - 2016 IEEE Conference on Systems, Process and Control, ICSPC 2016*, 2017, pp. 53–57.

[14]. A. Pirisi, F. Grimaccia, M. Mussetta, and R. E. Zich, "Novel speed bumps design and optimization for vehicles' energy recovery in smart cities," *Energies*, vol. 5, no. 11, pp. 4624–4642, 2012.

[15]. Asim K. Sen, "Generation of Electricty Using Gravitational Energy," no. 19, 2006.

[16]. T. Aized, T. Ilahi, A. M. Qureshi, and A. A. Bhatti, "Potential analysis of kinetic energy harvesting system from national highways of Pakistan," *Pakistan J. Eng. Appl. Sci.*, vol. 21, pp. 1–7, 2017.

[17]. I. Journal, O. F. Advanced, and C. Systems, "Design and Fabrication of Power Generator By Using Flip-Plate," pp. 270–277, 2017.

[18]. A. Azam and S. Ali, "Speed Breaker Power Generator," no. November 2016, 2017.

[19]. M. Sailaja, M. Raja Roy, and S. P. Kumar, "Design of Rack and Pinion Mechanism for Power Generation at Speed Breakers," *Int. J. Eng. Trends Technol.*, vol. 22, no. 8, pp. 356–362, 2015.

[20]. P. V. Ashtankar *et al.*, "Road Power Generation (RPG) by Flip plate Mechanism," *Int. J. Sci. Eng. Technol. Res.*, vol. 3, no. 3, pp. 560–562, 2014.

[21]. H. Patel, H. K. Patel, S. K. Dutta, P. Sahu, and K. Das, "Production of Electricity by the Method of Road Power Generation," *Int. J. Res.*, vol. 2, no. 5, pp. 636–640, 2015.

[22]. S. N. Kane, A. Mishra, and A. K. Dutta, "Preface: International Conference on Recent Trends in Physics (ICRTP 2016)," *J. Phys. Conf. Ser.*, vol. 755, no. 1, 2016.

[23]. P. Vishnoi and P. Agrawal, "Power Generation by Kinetic Energy of Speed Breaker," *MIT Int. J.*

Electr. Instrum. Eng., vol. 4, no. 2, pp. 90–93, 2014.
[24]. R. Saneifard, R. Dana, and A. Sianati, “Design and implementation of an electromechanical system utilizing speed bumps to generate electric power,” *J. Eng. Technol.*, vol. 26, no. 2, pp. 16–23, 2009.
[25]. A. Pandey and J. Rafiq, “Road Power Generation by Flip Plate Mechanism,” vol. 3, no. 2, pp. 240–242, 2015.
[26]. G. Del Castillo-García, E. Blanco-Fernandez, P. Pascual-Muñoz, and D. Castro-Fresno, “Energy harvesting from vehicular traffic over speed bumps: A review,” *Proc. Inst. Civ. Eng. Energy*, vol. 171, no. 2, pp. 58–69, 2018.
[27]. S. K. Sahoo, “Renewable and sustainable energy reviews solar photovoltaic energy progress in India: A review,” *Renewable and Sustainable Energy Reviews*, vol. 59. Elsevier Ltd, pp. 927–939, 01-Jun-2016.
[28]. A. Falcao, “Wave energy utilization : A review of the technologies,” no. April 2010, 2018.
[29]. H. Najini and S. A. Muthukumaraswamy, “Piezoelectric Energy Generation from Vehicle Traffic with Technoeconomic Analysis,” *J. Renew. Energy*, vol. 2017, pp. 1–16, 2017.
[30]. J. H. Hyun, N. Chen, and D. S. Ha, “Energy harvesting circuit for road speed bumps using a piezoelectric cantilever,” in *Proceedings: IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society*, 2018, pp. 4219–4223.
[31]. X. Zhang, Z. Zhang, H. Pan, W. Salman, Y. Yuan, and Y. Liu, “A portable high-efficiency electromagnetic energy harvesting system using supercapacitors for renewable energy applications in railroads,” *Energy Convers. Manag.*, vol. 118, no. June, pp. 287–294, 2016.
[32]. T. Younas, M. Saadat, I. Hussain, and Z. Rashied, “Energy Recovery Using Ratchet Mechanism: An Experimental Study,” *Energy Procedia*, vol. 118, pp. 104–109, 2017.
[33]. “Green Mechanic: Advantages and Disadvantages of Different Types of Gears.” [Online]. Available: https://www.green-mechanic.com/2014/05/advantages-and-disadvantages-of_7.html. [Accessed: 21-Oct-2018].
[34]. R. Baxter, N. Hastings, A. Law, and E. J. . Glass, *[Shigley_Mechanical engineering Design]*, vol. 39, no. 5. 2008.
[35]. “China Customized One Way Bearing Ratchet - China One Way Ratchet Bearing, Ratchet Wheel.” [Online]. Available: https://cnqd007.en.made-in-china.com/product/wKznJmZLXScl/China-Customized-One-Way-Bearing-Ratchet.html. [Accessed: 18-Oct-2018].
[36]. C. K. Das, S. M. Hossain, and M. S. Hossan, “Unit for Minor Needs,” 2013.
[37]. “The law on speed breakers and speed humps in India - Lawgic.” [Online]. Available: https://lawgic.info/law-speed-breakers-speed-humps-in-india/. [Accessed: 20-Oct-2018].
[38]. “What is Electrical Power | Watts | Electronics Notes.” [Online]. Available: https://www.electronics-notes.com/articles/basic_concepts/power/what-is-electrical-power-basics-tutorial.php. [Accessed: 20-Oct-2018].
[39]. P. K. Ghule, “Electricity Generation By Speed Breaker Using Rack and Pinion Mechanism,” no. 6, pp. 2395–4396, 2016.
[40]. M. Ramadan, M. Khaled, and H. El Hage, “Using Speed Bump for Power Generation-Experimental Study,” *Energy Procedia*, vol. 75, pp. 867–872, 2015.