Fabrication of Energy Harvesting Using Piezo-Electric Material in Slider Crank Mechanism

G.Anil[1], P.Harsha Teja Santosh[2], P.Taraka Dharma Rao[3], M.Shashank[4] ,B. Naga Sudha Rani[5]
[1,2,3,4,] *UG students, Department of Mechanical Engineering, NRI Institute of Technology,Pothavarappadu, Eluru (Dist), AP, India - 521212*
[5]*Associate professor, Department of Mechanical Engineering, NRI Institute of Technology, Pothavarappadu, Eluru (Dist), AP, India – 521212*

Abstract: **Energy harvesting (EH) is the most upcoming technology which is defined as a process where the environmental energy sources such as load, mechanical vibrations, temperature changes, light energy, wind energy etc. are captured and transformed to acquire quite small levels of power within the of range of Nano Watts - Milliwatts. This method is used to power an installed system by accumulating energy from ambient sources such as solar, wind, thermal and radio frequency waves. It is also called Energy Scavenging. The purpose of energy harvesting is to power electronic devices where there are no conventional power sources. The energy harvesting device has design goals and the three main elements are energy Source, Energy harvesting IC, Energy storage. In particular the energy harvesting used in charging of rechargeable batteries on site, low power electronic devices like traditional and super capacitors. Common energy harvesting systems include a lot of applications in many remote locations, distant locations, undersea where batteries and conventional power are not in used practically. In this project primarily we observe the vibrations occur in slider Crank mechanism and control. This voltage is harvested by a micro energy harvester and stored by suitable circuitry. Also, this paper presents a systematic design of proposed circuit that allows us to harvest energy under both ideal and realistic constraints.**

Keywords: Slider-crank mechanism, micro energy Harvester, circuit Diagram.

I.INTRODUCTION

1.1 INTRODUCTION:

Energy harvesting is approaching an interesting technological juncture wherein the power requirements for electronic devices have been reduced while at the same time the efficiency of energy harvesting devices has increased. Out of various possible energy harvesting technologies, piezoelectric vibration energy harvesting has emerged as a method of choice for powering meso-to-micro scale devices.1,2,3,4 Piezoelectric materials and transducers can be designed to handle a wide range of input frequencies and forces allowing for energy harvesting to occur.

Working principle of piezoelectric materials:

In piezoelectricity the term" piezo" stands for pressure or stress. Thus piezoelectricity is defined as "Electricity generated by application of mechanical stress or tension" and the materials that exhibit this property comes under the category of piezo-electric materials

A piezoelectric crystal is placed between two metal plates. At this point the material is in perfect balance and does not conduct an electric current.

Mechanical pressure is then applied to the material by the metal plates, which forces the electric charges within the crystal out of balance.

Piezoelectric effect is extensively used to convert the electric energy into mechanical energy and vice-versa i.e. the piezoelectric substances are used as electromechanical transducers as shown in figure.1.

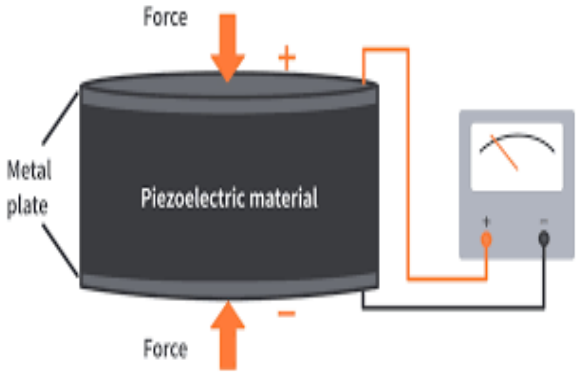


Fig.1: Working of piezo electric material

II.LITERATURE REVIEW

A. Arbie et.al [1] proposed in this journal their work is mainly based on increasing the voltage is based on increase the number of piezo electric plats. Furthermore, when compared with the configuration of the first (28 pieces), second (70 pieces), and third (98 pieces) piezoelectric configuration numbers, there was an increase in the average voltage, current, power, and electrical energy by 18.12 and 69.85%, 49.17 and 73.03%, 76.19 and 193.89%, and 39.51 and 188.47%, respectively. Abdul Aabid et.al[2] say's Then a summary of previous studies based on PEH's other applications is listed, considering the technical aspects and methodologies. The piezoelectric materials have shown key characteristics for engineering applications, such as in sensors and actuators for industrial use. As a result, this review can provide a guideline for the scholars who want to use PEH's for their research. In addition, the fundamental idea about piezoelectric materials, along with their modelling for various applications, are detailed systematically. In this review article, a detailed study focused on the piezoelectric energy harvesters (PEH's) is reported. Because of their excellent mechanical-to-electrical and vice versa energy conversion properties, piezoelectric materials with high piezoelectric charge and voltage coefficient have been tested in renewable energy applications. A discussion has been provided as a critical review of current challenges in this field. Shreyanil Kar et.al [3] discussed The energy generated here is very less and hence, may be used in the modern environment like baffle gates. Here, to obtain energy from this process and use it with batteries for vehicles, it is crucial to cover as much of a tire's inner surface area as possible with PZT benders. This brings us to piezoelectric materials, which have the property to generate electricity once mechanical stress has been applied on them. Benders made of PZT (lead zirconate titanate) attached to a tire have also been used but only to supply energy to pressure sensors in a tire that function sporadically. The output power that is generated from the stress applied on the material is thus sufficient to contribute to motion of the vehicle because of its high-power generation. Nilimamayee Samalet. al [4] say's For managing the soaring power demand, various types of Energy Harvesting Systems (EHS) have been developed. The Piezo-electric energy harvesting system works on the phenomena of direct piezo-electric effect; i.e. the transducer generates electric energy when it is exposed to mechanical stress/pressure/vibration. The goal of this paper is to review the PEH (Piezo-electric Energy Harvesting) systems developed in last decade to harness energy required for small electronics. The energy harvesting from unutilized natural renewable sources using piezoelectric transducers is one of them. The suitability of piezo-electric transducer for different applications depends upon the piezo-electric materials, their shapes and configurations. In this article the different piezoelectric materials and the transducer configurations have been discussed. Kavya Ameta et.al [5] proposed Producing a decisive amount of electricity from a bicycle or converting the energy into electricity while travelling protracted distances, has always been a myth. In this context, we are putting forward a novel idea of generating electricity using a hybrid bicycle. Also, this paper presents a systematic design of proposed circuit that allows us to harness energy under both ideal and realistic constraints. This voltage is harvested by a micro energy harvester and stored by suitable circuitry. This paper aims at developing a piezoelectric generator which harvests energy through pedalling; a piezoelectric transducer is an electro-mechanical converter which converts mechanical vibrations into pulsating. Corina Covaci et.al [6] proposed The goal of this paper is to review current methods of energy harvesting, while focusing on piezoelectric energy harvesting. The piezoelectric energy harvesting technique is based on the materials' property of generating an electric field when a mechanical force is applied. This phenomenon is known as the direct piezoelectric effect. Piezoelectric transducers can be of different shapes and materials, making them suitable for a multitude of applications. Melodi Sila Bozkaya et.al [7] say's In this project low current and voltage producing piezoelectric crystals were connected in a parallel circuit which contained a capacitor. In it's paper discuss about the producing electricity in the in-sound waves with help of piezo-electric crystals. Due to the existence of the capacitor the values for the current and the voltage have increased. The primary goal of producing usable energy from ambient noise has been achieved and enough energy to charge a phone that works with 1 ampere and 5 volt has been produced .E.L.Pradeesh et.al [8] discussed This by numbers, electronic deep line for moving parts in a machine, electronic necessary things has been got mixed

together into to do with man beings as a part of their body. In a far away, widely different area such as tree-covered lands and hill areas, common putting payment through ways of doing of electric units by wire is not possible. supplying power through wires is hard. To over-come this, an able to keep going answer is power for a given time getting together. The renewable starting points for power for a given time getting together are light, heat, wind, regularly changing, motion, and vibration. persons making observations have more interest in getting together power for a given time through machine-like quick motion because of, in relation to its more than enough able to use. This paper papers the work about piezoelectric become glass-like and their part in power for a given time getting together, simulation software used, power for a given time getting together journeys round and place for storing apparatuses. Nabeel Ahmad et.al[9] proposed It can also be utilized for uninterruptedly powering up a soldier's wearables electronics gadgets in military operations. Our design feasibility will be proved by the positive results obtained from the experimental prototype. This paper demonstrates the method of harvesting energy from human walk. Harvesting mechanical energy from human movement is an appropriate approach for acquiring environment-friendly electrical energy. It can also be used to track any soldier's location in remote areas. Our design will demonstrate the feasibility of harvesting electrical energy from piezoelectric to low power wearable devices. Generated electric energy can be used to power mobile phones, emergency flashlights, etc. After receiving desired outcomes, this energy source can become a direct current (DC) power supply with a support from power management. Sanjay Sharma et.al [10] say's A short discussion of the approach is also included, as well as a thorough review of the rotating parts technique. This study paper also addressed the area of research carried out on the rotor system's dynamic and analysis techniques. In the small equipment which can be used in the machine, household works, as well as cooking accessories, sometimes rotating parts are used. In a different application of the technology used in the world, rotating machinery is generally used, i.e. There are so many devices in today's ever-growing world that have rotating parts, but rotating parts have the primary concern of regulating and managing the vibration. A summary of the research work conducted in the actual real-time balance and vibration regulation of rotating machinery in this article. N.Ramkumar et.al [11] discussed The following study explains how a pneumatically driven slider mechanism for demonstration and experimentation in a classroom is developed, manufactured and tested. During operation, transductions attached to the mechanism record movie and dynamic force data which can be comparable with analytical results. The location, speed and shaking forces generated during operation by a slider wardrobe mechanism can be analytically determined. In analytical calculations, certain factors are often ignored that cause differences in results from experimental data. The slider-crank framework is a special 4-bar link configuration, which displays both linear and rotational motion at the same time. In a balanced and unbalanced way, the system can measure the severity of the forces of shaking. This method is frequently used for studying computer kinematics and the related dynamic forces in undergraduate engineering courses. This is achieved by changing the mechanism of the screwdriver. The resulting "closed curved" movement can be used to construct useful work. The motor was produced successfully and works as planned. Chunhua Sunet.al [12] proposed The technology is then summarized and the direction of future development and efforts is further pointed out. Based on the different human motions, the existing technology gy of piezoelectric energy harvester (PEH) is firstly classified, including PEHs through heel-strike, knee-joint, arm motion, centre of mass. with the rapid development of low-power communication technology and microelectronics technology, wearable and portable embedded health monitoring devices, micro-sensors, and human body network positioning devices have begun to appear. For seeking reliable energy sources to replace battery on these devices, it is of great significance for developing low power products to explore the research of piezoelectric effect in conversion of human motion into electricity. Jiangyun Miao et.al [13] say's This study discusses the application of piezo electric material in microfluid drive technology. It is fast responding and high-speed precision. Here piezoelectric materials are applied in the microfluidic drive technology due to their excellent dielectric, piezoelectric and optical properties, where the piezoelectric ceramic is chosen in theoretical and experimental research. The piezoelectric ceramic has the advantages of high piezoelectricity and dielectric

constant, and can be processed into any shape. The microfluidic drive device with the piezoelectric material and its working principle are introduced. The researching results show that at the voltage of 150V, the elongation length of the piezoelectric ceramic is 18.556μm, the maximum displacement of the driven fluid is 4.761mm, and the driven volume of fluid is 0.714μl. The work here can promote the application of piezoelectric materials in microfluidic technology. Hao Wanga et.al [14] proposed In this paper dicuss about the piezo electric material in applied in the roads and bridges to produce the electricity while applied moving the vehicles. Energy harvesting technologies provide promising ways to generate clean and regenerative energy for different applications. The new technologies that have emerged within this field rely on two sources of energy; namely thermal energy (from sun or earth) and mechanical energy (from vehicle loading or wind). The preferred energy harvesting technology may vary depending on the working principle and application focus. Samin Akbaria et.al [15] proposed This paper examined the various connect rod lengths utilised in the slider crank mechanism. Then, two control plans are suggested for the suppression of electrodynamic vibration of the flexible connecting rod and ensuring that the crank rotates at a constant angle. Both the first and second schemes are based on a feedback linearization technique. Two layers of piezoelectric film are adhered to the top and bottom surfaces of the connecting rod, and an electric motor at the crank ground joint applies the input signals. Both controllers are successful in reducing the elastic linkage's vibrations. Yao Fenglin et.al [16] say's energy harvester. This paper uses ANSYS to analyze the single piezoelectric cantilever in static analysis, model analysis, harmonic response analysis and mechanical-electrical coupling analysis. With the application of wireless sensor networks become widespread, supply energy for these wireless sensors proves to be a significant issue. It analyses the natural frequency and voltage effect from four aspects which are length to thickness ratio, length to width ratio, the substrate thickness to piezoelectric thickness ratio and seismic mass. Madan Mohan Behera et.al [17] proposed In this paper, a technique of application of piezoelectric material for harnessing energy i.e. along the circumference of the inner lining of the tyre and rough calculations has been made to project the probable energy tapped and its usage. The current work describes a sample arrangement of crystal and various new arrangements based on maximum power output can be made. With the increase of popularity of non-conventional energy sources among the researchers all over the world, the possibilities of energy harvesting by the use of piezoelectric materials paves its way towards major green technology designs. X.D. Xie et.al [18] discussed This paper represents For energy harvesting from ambient vibrations of a vehicle suspension system subjected to the roughness of road surfaces, a dual-mass piezoelectric bar harvester is designed. The harvester is composed of two masses: a sprung mass (the body mass) and an unsprung mass (the wheel mass), which are joined by a piezoelectric bar transducer, which can be equivalently represented mathematically as a suspension spring and a damper. In order to produce an electric charge, the dual mass piezoelectric bar harvester is effectively developed in a vehicle suspension system on wheels. Renato Caliò et.al [19] say's This paper papers the state of the art in piezoelectric power for a given time getting together. It presents the basics of piezoelectricity and has a discussion about materials selection. The workplaces making a point of on material operating forms and apparatus forms, from resonant to non-resonant apparatuses and also to rotational answers. The gone over again written works is made a comparison of based on power measure of space between parts and bandwidth. lastly, the question of power make into different sort is worked out by going over again different way taken by electric current answers. Tao Li et.al [20] proposed This paper is an insight on the current research and development status of piezoelectric materials community. After decades of research and development, piezoelectric materials have been applied in a wide range of applications, ranging from household appliances to industrial equipment's. In the paper "Electromechanical and dynamic characterization of in-house-fabricated amplified piezo actuator" a diamond-shaped amplified piezo actuator was fabricated and tested. In the paper "Modelling hysteresis with inertial-dependent Prandtl-Ishlinskii model in wide-band frequency-operated piezoelectric actuator," the hysteresis and nonlinear effect of a piezoelectric actuator was modelled and characterized. This literature review gives the more information about the piezo electric materials.it some complication is there to use the piezo electric materials in the different application in the society.

III. METHODOLOGY

Slider crank mechanism: slider-crank mechanism, arrangement of mechanical parts designed to convert straight- line motion to rotary motion, as in a reciprocating piston engine, or to convert rotary motion to straight-line motion, as in a reciprocating piston pump.

Using multimeter: Vibration analysis is a process that monitors vibration levels and investigates the patterns in vibration signals. It is commonly conducted both on the time waveforms of the vibration signal directly, as well as on the frequency spectrum, which is obtained by applying Fourier Transform on the time waveform.

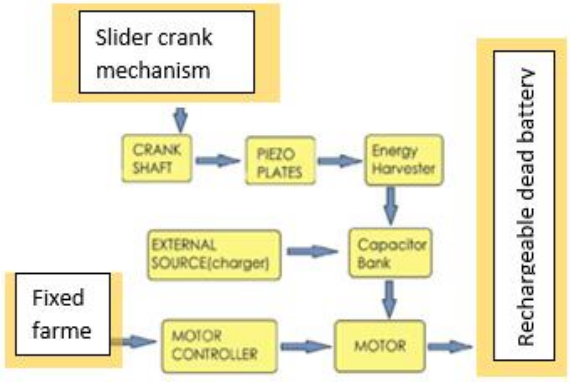
Conversion of vibrations: Conversion of vibration in electricity with help of piezo electric material. Based on vibration of is increase the voltage will also increase.

Harvesting the voltage: Harvesting the voltage it means to store the voltage in the Battery. With the help of lithium battery in 3.7V. Based on the output of voltage of the piezo electric material.

Boost up Voltage: Boost up the voltage with the help of boost converter. Its help to improve the voltage in more than 3times.

Electric devices: Stored the power used in light devices. Example: Charge the mobile.

Circuit Diagram:



Construction:

1.To prepare a slider crank mechanism with a compact disc (CD) and injection.

2.Connect the compact disk in 12v motor. Connect the seeped regulator in motor to control motor speed.

3.Fix the slider crank mechanism with the help of screws.

4.On the top and bottom (fig-3.1 and fig-3.2) of the wood, place the piezoelectric discs. and connect the piezoelectric plates in series with the help of soldering.

5.Power on the switch to observe the vibration on the slider crank mechanism.

6.Connect the multimeter to the piezoelectric material at two points with wires. It is to measure the voltage output. save the output voltage in battery use the mobile charging fig-3.3

Fig.3.1: Top of wood

Fig .3.2: Bottom of wood

Fig.3.3: Final project

IV.RESULT AND DISCUSSIONS

Modal 1

Using multiple no.of piezo electric plates :

Based on input voltage will increase output voltage is represent the table-4.1.

Table-4.1: Output voltage

Input voltage (v)	Out put voltage (v)	Time (Min)
3.91	0.62	3
5.15	1.11	3.03
7.3	1.2	3.32
11.12	1.9	1.38
14.12	2.52	5.2
19.04	3.98	2.35
19.57	4.2	1.45
25	5.08	2.43

Modal 2

Based on the few plates using applying manual load produce electricity table -4.2.

Table-4.2 : Based on 3 plates

	10 plates	20 plates
Voltage (V)	Time (Min)	TIME (Min)
0.37	0	0
0.38	51.2	25.3
0.39	108.3	70.3
0.4	200.02	180.09
0.41	305	270.02
0.42	420.3	350.1

Modal 3

Based on couple of plates store the power in 3.7 voltes battery in using slider crank mechanism table-4.3

Table-4.3: Based on 10 plates

Voltage (V)	Time (Min)
0.37	0
0.38	51.2
0.39	108.3
0.4	200.02
0.41	305.0
0.42	420.3

Modal 4

Based on multiple no. of plates used to produce the voltage to store the power in 3.7V battery table-4.4.

Table-4.4: Based on 20 plate

VOLTAGE (V)	TIME (Mn)
0.25	0
0.26	2.5
0.27	5.2
0.28	7.2
0.29	10.5
0.3	15

Modal 5

Take different time readings using few and multiple plates table-4.5.

VOLTAGE (V)	TIME (Min)
1.99	0
2	25.3
2.01	70.3
2.02	180.09
2.03	270.02
2.04	350.1

Table-4.5: Different time readings

Modal 6

Take table-4.6. different time readings using few and multiple plates

Voltage (V)	Time (Min)	Boost the voltage (V)
3	7200	11.5
4.03	14400	15.3

Table-4.6: Boost up the 3v battery

4.2 RESULTS

4.2.1 Graph for model 1:

Based on motor input voltage vs piezo electric material. The output voltage is represented by the Y-axis, while the X-axis is based on the motor input voltage as shown in fig-4.7. As the input voltage rises, the output voltage rises along with it, causing the vibrations to rise.

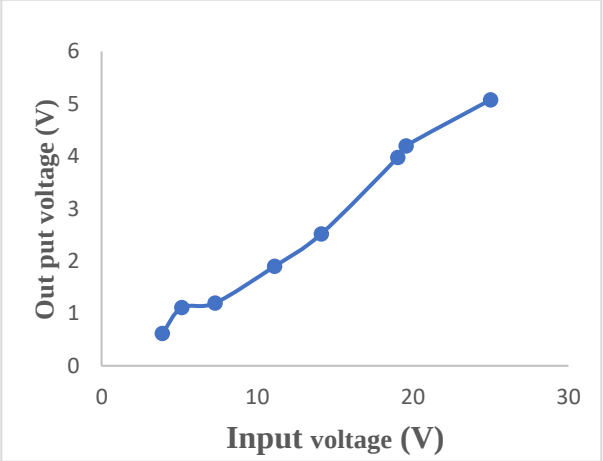


Fig-4.7: Variation of input voltage to output voltage

4.2.2. Graph for modal 2:

The X-axis represents voltage(V), and the Y-axis is based on time (Min) as shown in fig-4.8. The pressure is manually applied to the plates, and in the time it takes to charge the battery, the pressure is transformed into power. It will not give higher voltage, but it will give some voltage.

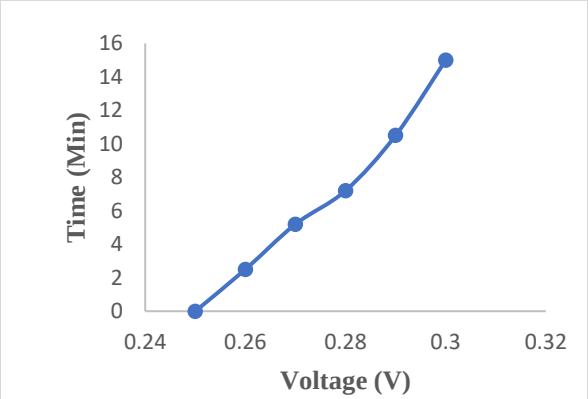


Fig-4.8: Based on few plates graph

4.2.3. Graph for modal 3:

The X-axis represents voltage(V), and the Y-axis is based on time (Min) as shown in fig-4.9. The battery is charged according to the 10 plates that were utilised by the mechanism over the course of time.

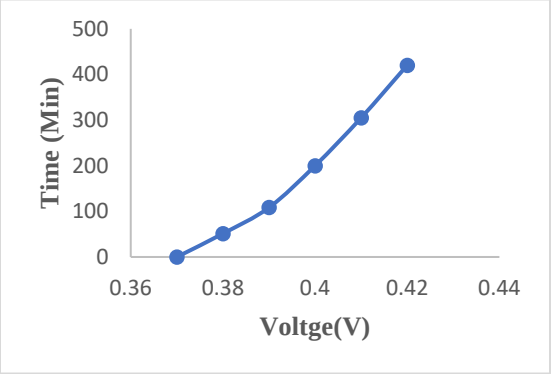


Fig-4.9: Based on few plates graph

4.2.4 Graph for modal 4:

The X-axis represents voltage (V), and the Y-axis is based on time (Min) as shown in fig-4.10. The 3.7-volt battery is charged in accordance with the few plates used by the mechanism over time.

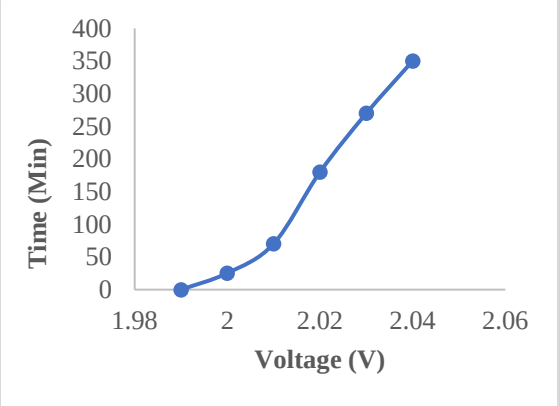


Fig-4.10: Based on multiple no. of plates graph

5.2.5 Graph for modal 5:

Different time readings:

The X-axis represents voltage (V), and the Y-axis is based on time (Min) as shown in fig-4.11. Take a different time 3.7 volts. reading based on the very few and multiple plates used to charge the battery at 3.7V. The number of plates has been increased while the charging time has been reduced. The blue colour line appears on ten plates, while the red colour line appears on multiple plates.

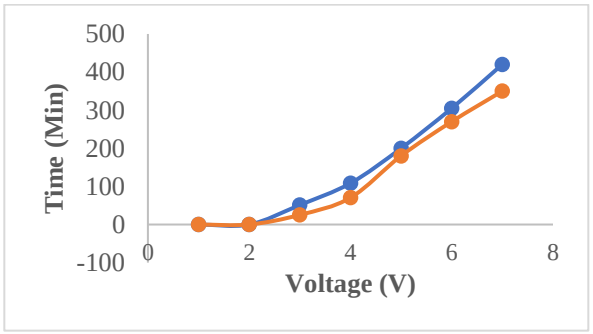


Fig-4.11: Different time readings

4.2.6 Graph for modal 6:

Boost up the 3v battery.

The X-axis represents voltage (V), and the Y-axis is based on time (Min) as shown in fig-4.12. This graph depicts the boost-up of the 3.7V battery up to 15V, as well as the time required to charge the 3.7V battery. The blue colour line appears on normal voltage, while the red colour line appears on boost up the voltage.

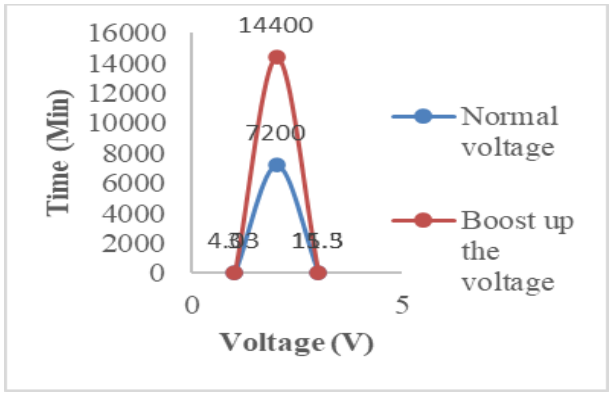


Fig-4.12: Boost up the voltage

V.CONCLUSION

In this mini project, fabrication of slider crank mechanism was done and connected to the designed circuit. There is no such technology in the current age that can harness electricity through slider crank mechanism, and through this idea, this could be

achieved. To maximize electricity production, we need to rotate at a constant speed. If the crank rotates non- linearly, the frequency of the current produced would be altered. This material proposed above is simple yet can revolutionaries the prevailing clean energy sources. This power, which is harvested from mechanism, will compensate for the loss of energy arising while the mechanism is in running.

ACKNOWLEDGMENT

We take immense pleasure in expressing my deep sense of gratitude to our guide for his encouragement all the way during the investigation of the project. His annotations and criticisms are the key behind for successful completion of the project work and our Head of Department, for his able guidance and for the freedom of thought and action, we had enjoyed during the entire course of our project work. We were privileged to experience a sustained enthusiastic and involved interest from his side. We express a special gratitude to our Parents for their great encouragement to complete the project in all the ways.

REFERENCE

[1] A. Arbie ,Z. A. Hasan, and A. W. Nuay "Piezoelectric Configuration for Generating Electricity Using Waves Power" Journal of energy, Hindawi Volume 2021 ,page no :1-9, December 2021.

[2] Abdul Aabid, Md Abdul Raheman, Yasser E. Ibrahim, Asraar Anjum, Meftah Hrairi, Bisma Parveez , Nagma Parveen and Jalal Mohammed Zayan "A Systematic review of piezoelectric material and energy harvestets for industrial applications" sensors, MDPI, pg.no: 1-27, June 2021.

[3] Shreyanil Kar, Kaustubh Samanth,K. Raghunandana "Cost effectiveness of piezo electric energy harvesting" Materials Today: Proceedings, Esliver, pg.no :101-104, January 2021.

[4] Nilimamayee Samal and O. Jeba Shiney "Energy harvesting using piezoelectric transuducers : a review" Journal of Scientific Research Volume 65, Issue 3, 2021, DOI:10.37398/JSR.2021.650320 pg.no :163-176, 2021.

[5] Kavya Ameta, Rajkumar Soni, Prasun Chakrabarti , Hung Bui, Sandeep Poddar "Piezo based electric bike" Materials Today: Proceedings, Esliver Pg.no : 1-9, November 2020

[6] Corina Covaci and Aurel Gontean Sensor "piezoelectric energy harvesting solution: a review" DOI:10.3390/s20123512 page no :1-37, June 2020.

[7] Melodi Sila Bozkaya, , Hesna Elif Erim, Berksan Gumus "energy harvesting from sound waves using piezoelectric crystals" Global scientic journal (GSJ), Volume 8, Issue 3, ISSN 2320-9186, pg.no : 973-978, March 2020.

[8] E.L.Pradeesh,,S.Udhayakumar,.G.Vasundhara, V.Vadivel Vivek "vibration based piezoelectric energy harvesting - a review" IOP Conference Series: Materials Science and Engineering, IOP,DOI:10.1088/1757-899X/995/1/01200 page no :1-11, 2020.

[9] Nabeel Ahmad, Muhammad Talha Rafique and Rabia Jamshaid "Design of piezoelectricity harvester using footwear" IEEE International Conference on Engineering Technologies and Applied Sciences (ICETAS), June 2019.

[10] Sanjay Sharma "Vibration control of rotating machine through balancing" Journal of Emerging Technologies and Innovative Research (JETIR) , Volume 6, Issue 4, ISSN-2349-5162, pg.no :810-813 , April 2019.

[11] N.Ramkumar, Raghavendra Rao P S "A brief review on slider-crank mechanism" Journal of Emerging Technologies and Innovative Research (JETIR) Volume 6, Issue 1, ISSN-2349-5162, pg.no :129-133, January 2019.

[12] Chunhua Sun, Guangqing Shang, Hongbing Wang "On piezoelectric energy harvesting from human motion" Journal of Power and Energy Engineering , DOI: 10.4236/jpee.2019.71008 , pg.no: 155-164, January 2019.

[13] Jiangyun Miao, Jing Wan, Feng Sun, Mingxian Guo, Zhaosong Wang "Piezoelectric material and their applications in the microfluidic drive technology" IOP Conference Series: Materials Science and Engineering (IOP) (2018), DOI:10.1088/1757-899X/490/2/022042, Page no :1-5, 2019.

[14] Hao Wanga, Abbas Jasim , Xiaodan Chen "Energy harvesting technology in roadway and bridge for different applications-a comprehensive review" Applied energy, Elsevier, (2017). Page no :1083-1094, December 2017.

[15] Samin Akbaria, Fatemeh Fallahi, Tohid Pirbodaghi

"Dynamic analysis and controller design for a slider-crank mechanism with piezoelectric actuators" Journal of computational design and engineering, Elsevier, DOI:http://dx.doi.org/ 10.1016/j.jcde. 2016.05.002 pg.no 1-20, May 2016.

[16] Yao Fenglin, Meng Wengjun, Zhao Jie, and Yin Hang "Cantilever beam based piezoelectric energy harvester" INTERNATIONAL JOURNAL ON SMART SENSING AND INTELLIGENT SYSTEMS, VOL. 8, NO. 4, pg.no: 2018-2041, DECEMBER 2015.

[17] Madan Mohan Behera "Piezoelectric energy harvesting from vehicle wheels" International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue, ISSN: 2278-0181, pg.no: 1-4, May-2015.

[18] X.D. Xie, Q. Wang Energy "Energy harvesting from a vehicle suspension system", Energy, Elsevier, pg.no: 1-8, March 2015.

[19] Renato Caliò, Udaya Bhaskar Rongala, Domenico Camboni, Mario Milazzo , Cesare Stefanini, Gianluca de Petris and Calogero Maria Oddo "Piezoelectric energy harvesting solutions" MDPI,sensors,ISSN:1424-8220, DOI:10.3390/140304755,pg.no:4755-4790,March 2014

[20] Tao Li, Jan Ma, Mohammed Es-Souni, and Peter Woias "Advance piezoelectrics: materials, devices, and their applications" Smart Materials Research, Hindawi Volume 2012, DOI:10.1155/ 2012/259275 pg.no: 1-2, March 2012.