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Research Paper

Harvester Wheel Energy (type1)

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Abstract-
In our rapidly changing world, renewable sources of energy, in particular electricity obtained from fresh source s, are being developed each day.The purpose of this paper is to examine how energy harvester architectures can be used to harvest wheel motion energy by electromagnetic. Based on this principle, Basically, the design involves a magnetic surrounded by copper coil windings. In accordance with Faraday's Law, an electrical current flow in the coil when the magnet rotates and moves within the cage. During experiments, the output voltagesof electromagnetic were measured and calculated.
Keywords- *energy harvesting, electromagnetic, Rotational magnet movement.*

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I. INTRODUCTION

In the future the development of long-lasting power solutions will be important. We will need more and more innovative solutions for generating power which can be achieved through energy harvesting sources.Recent years have seen an increase in research on energy harvesting, as well as many popular articles about it. Energy harvesting has been around for quite a while, in the form of wind energy (windmills), water energy(turbines) and solarpower from the sun. In addition to the previous sources the current trend is towards clean energy to eliminate fuel consumption and preserve the environment, so other sources are necessary to organize and classify, even they are few.For example, piezoelectric devices, mechanical vibration devices, thermo-electric and electromagnetic generators and…. etc.
This paper will demonstrate a source using electromagnetic energyhowever, wehave to figure out the concept of electromagnetism.

II. ELECTROMAGNETIC ENERGY HARVESTING

Electromagnetic induction, discovered by Faraday in 1831, involves the creation of an electric current in a conductor when it is surrounded by a magnetic field. A coil serves as a conductor, and electrical energy is generated by altering the magnetic field or repositioning the magnet in relation to the coil. The quantity of energy relies on a magnetic field, speed of movement, and number of the coil. Electromagnetism can be classified[i]as follows:
1- Moving coil/fixed magnet: the coil movement accomplished as:
- Mechanical spring.
- Rotation or displacement.
- Vibrating structure.

2- Moving magnet/fixed coil: it is possible to move magnates by:
- Mechanical spring.
- Magnetic spring.
- Without spring / move as free (unreservedly).

3-Magnetostriction:
Several ferromagnets exhibit magnetostriction which permit to convert magnetic energy into kinetic energy like Galfenol and Terfenol-D. It represents the relationship between the magnetic field and the applied stress.
4- Ferrofluid:
It is a fluid possessing ferromagnetic characteristics and the most studied ferrofluids are water based ferrofluid (MSG W11) and hydrocarbon oil ferrofluids (EFH1).

Researchers tried to use and explain electromagnetismbased on classification in several ways like MA. Halim,[ii] in 2018 they have designed, optimized, and characterized an electro-magnetic energy harvesting device based on a sprung eccentric motor to harvest power from pseudo-walking signals.

Also, LB. Zhang, [iii]in 2019 demonstrated and present an energy harvesting method from ambient vibrations resulted from mechanical motions and body movements that uses a rolling magnet to cut coils that produces a higher magnetic flux rate than a sliding magnet and the electric power source with a working voltage of 1.1 V can be operated for up to two minutes with the energy harvested from a minute of hand shaking.

Prior to this, scientist researchers attempted and concerned of this type in 2021 as Jin, X.,[iv] demonstrates TENG displays a cost-effective and unconventional technique for harvesting magnetic energy. Herein, magnetic energy is harvested from transmission lines by using a TENG based on magnetic balls rotating around a core. Under the alternating magnetic field generated by the transmission line, the magnetic ball rolls in a spherical shell. As a result, the output power of a single TENG unit equal 1.5Kv, 6.67 mW. Also Z. wang, W. wang [v] propose to install an energy-monitoring system on the bogie frames to measure the electromagnetic energy of the rotor.The coils and magnetic field move relative to each other when a counterweight acts as a friction pendulum and this arrangement simplifies the process of mounting the device to the wheelset. The output under train which speed between (420-820) rpm about 1982 W. m^{-3}.

By utilizing the second principle of electromagnetism, it is possible to make a rotating magnet that is powered by the rotation of the wheel and the coils that are mounted in its lower section, so that the energy can be obtained from it.

III. THE CHARACTERIZATION OF HWE

Taking a look at the following table&Figur1one must first become familiar with the type of wheel which Goodyear manufactures and identify its technical characteristics according to its specifications.

Diameter	25″
Width	7.7″
Rim Range	5.5- 7″
Max Load	1356 lbs
Max PSI	51 psi
Speed	149 mph
REVS/Mile	831

Figure 1. characteristic of Goodyear wheal196/65R15''

Coil and magnet are the basic components of electromagnetic energy harvesters.The coil, which has resistance Rc, is secured with a rod to half of the bottom of the wheel, as shown in figure 2, while the magnet, which is driven by wheel rotation, is fixed to the edge of the rim.

Figure 2. simple drawing about placement of magnetic and coil

Drawing the schematic diagram of the wheel is necessary to begin modeling and calculating the motion of the magnet as refer that in figure 3a & 3b. When start the wheel rotating the magnet also start rotate with swing angle ($\boldsymbol{\theta}$)as respect to time (t). the speed of wheel defined:

$$v = R.\theta^{\cdot}$$

v : is the speed of the wheel center.
$\theta^{\cdot}$: is the wheel rotation speed.

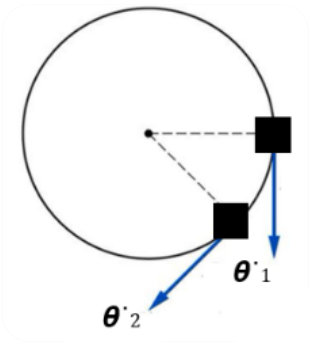


Figure 3a

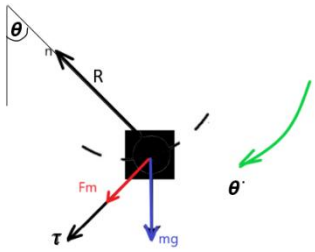


Figure 3b

Based on the second Newton law, the following can be written:

$$m.\mathrm{a} = \sum_{i=1}^{n} F_{\mathrm{i}}$$

$$m.\mathrm{R}.\theta^{\cdot\cdot} + \mathrm{K}\boldsymbol{\nu}.\mathrm{R}.\theta^{\cdot} = F + m.g.\sin\theta(1)$$

M: mass of magnetic(kg).
$\boldsymbol{\theta}^{\cdot\cdot}$: accelerationrotate wheel (m. s^{-2})
K$\boldsymbol{\nu}$: dumping constant(N.s.m^{-1})
F: electromagnetic force (N).
g: gravitational acceleration (m. s^{-2}).

The electromagnetic force (F) that is generated by an integrated coil length within a magnetic field is given by Lorentz's principle, as follows:

$$\mathrm{F} = \mathrm{I}\int dL\,\mathrm{X}\,\mathrm{B} = \mathrm{ILBex} \quad (2)$$

The magnetic field is calculated on center of wheel and gives as the following equation:

$$B = \frac{\mu\,\mathrm{I}}{4\pi\mathrm{R}^2}\int_0^{\pi r} dl = \frac{\mu\,\mathrm{I}}{4\mathrm{R}} \quad (3)$$

Also, the magnetic field for half arc of wheel gives as:

$$B = \frac{\mu\,\mathrm{I}}{4\pi\mathrm{R}^2}\int_0^{\pi r} dl = \frac{\mu\,\mathrm{I}}{4\mathrm{R}}.\frac{\theta}{\pi} \quad (4)$$

By substituting equation (4) into equation (2):

$$\mathrm{F} = \frac{\mu\,\mathrm{L}\,\theta\,\mathrm{I}^2}{4\,\pi\,\mathrm{R}} = \mathrm{K}.\theta\,.\mathrm{i}^2 \quad (5)$$

Putting equation(5) in equation (1):

$$\mathrm{m}.\mathrm{R}.\theta^{\cdot\cdot} + \mathrm{K}\boldsymbol{\nu}.\mathrm{R}.\theta^{\cdot} = \mathrm{K}\,.\theta\,.\mathrm{i}^2 + \mathrm{m}.\mathrm{g}.\sin\theta$$

$$\theta^{\cdot\cdot} + \frac{\mathrm{K}\boldsymbol{\nu}}{\mathrm{m}}\,\theta^{\cdot} = \frac{\mathrm{K}}{\mathrm{m}.\mathrm{R}}.\theta.\mathrm{i}^2 + \frac{g}{\mathrm{R}}.\sin\theta$$

$$\theta^{\cdot\cdot} + \frac{K\upsilon}{m}\,\theta^{\cdot} - \frac{K}{m.R}\,\theta.i^2 - \frac{g}{R}.\sin\theta = 0$$

$$\theta^{\cdot\cdot} + K_1\,\theta^{\cdot} - K_2\,\theta.i^2 - K_3\sin\theta = 0$$

The simulation for the magnet(m=0.01 kg) andcoil(L=10 m) can be designed by Simulink and it is shown in figure 4 also defining constants requires these steps:

- $K_1 = \frac{K\upsilon}{m}$

In the researcher's study JA Calvo. [vi], he provided a value$K\upsilon$ for comfortable car between 0.20-0.25. Furthermore, the magnetic mass equal (10 g).

$$K_1 = \frac{0.225}{0.01} = 22.5$$

- $K_2 = \frac{K}{m.R} = \frac{\mu_o L}{4\pi m R^2} = \frac{4\pi.10^{-7}.10}{4\pi.\ 0.01\ .\ (0.1905)^2}$

$$= 2{,}755.\ 10^{-7}\ (N/A)$$

- $K_3 = \frac{g}{R} = \frac{9.81}{0.1905} = 51.49\ (sec^{-2})$

Following figure (4) are the components of the system:

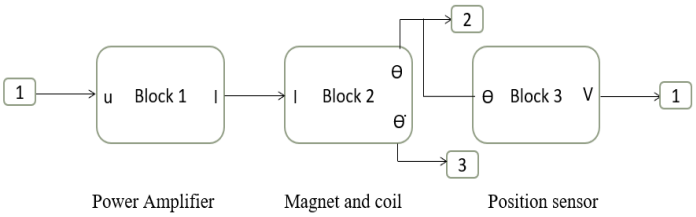


Figure 4

According to MATLAB Simulink, it can be drawn as figure (5):

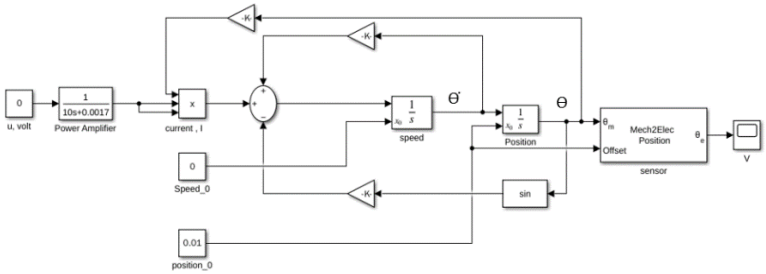


Figure 5

The block (2) explains about the magnet and the coil relation and it shown in Simulink as figure (6):

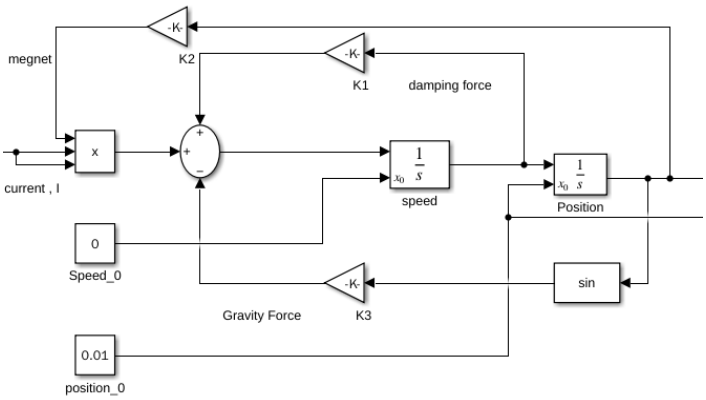
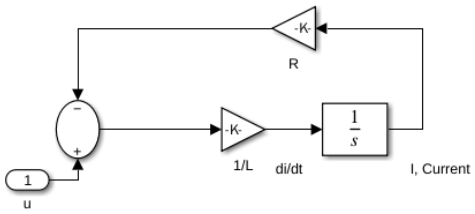


Figure 6

The block(1) explains in drawing (7) relation between (I & u) in Amplifier which have resistance and inductance, this relationgives in following equation:

$$\frac{I}{U} = \frac{L}{S + \frac{R}{L}}$$

L: represents coil inductance and here it equal 10(H).
Rc: Copper coil Resistance and it equal 0.17(Ω).



Drawing 7

The response of system according to time and as($\theta = 0.01 \& \dot{\theta} = 0$) can be found in figure (8-1):

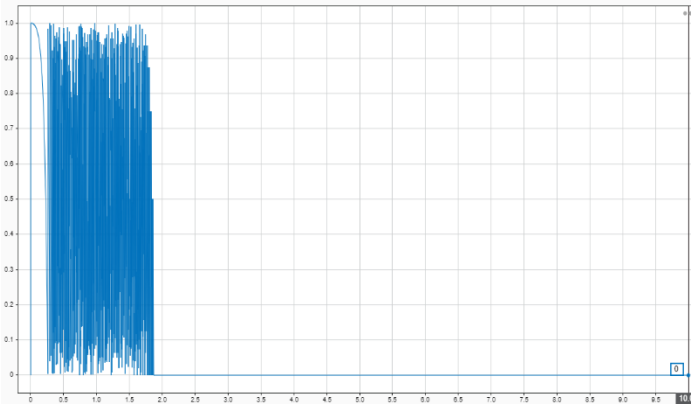


Figure 8-1

IV. RESULTS

The chart of response time to figure (8-2) indicates that the extracted voltage (output) is approximately 1.05 volts and that the electric power is 6.48 watts. In addition, the maximum number of revolutions per mile is about 831 for our Goodyear wheel, and it can determine the total output power.

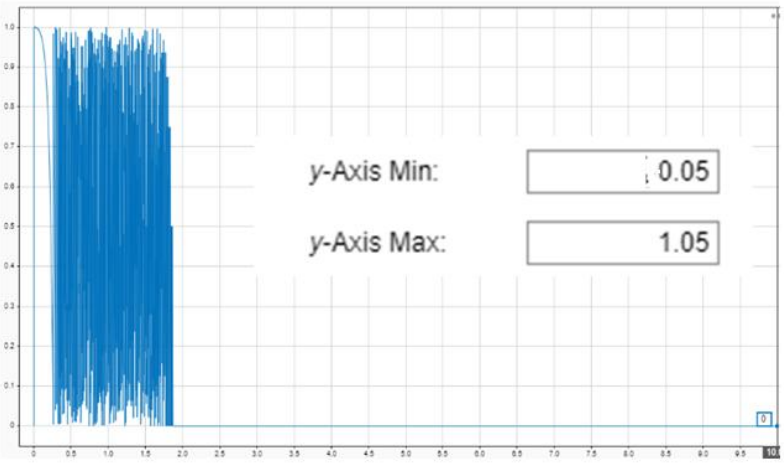


Figure 8-2

V. CONCLUSION

By studying the previous design, we observed that it is possible to generate energy from the movement of the magnet, which is caused by the movement of the wheel,inside the fixed coil by a rod. The model was created in Simulink-MATLAB, so the simulation also includes the output voltage, which was calculated depending on Faraday's law and a magnetic field equation. In the future this model may be improved, used and controlled due to the current trend of using clean energy sources in cars instead of fossil fuels.

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