Electric Powered Food Container by Energy Harvesting from Suspension System

Jilong Shi*

Department of Mechanical Engineering, University of New South Wales, Sydney, NSW 2052, Australia

*Corresponding author: z5277246@ad.unsw.edu.au

Abstract. According to the ratings of delivery applications, the most common question raised by customers is poor food quality. Hence, the research paper on an energy harvesting system to help improve food delivery quality without consuming additional energy is being carried out. The detailed demonstration of a completed energy harvesting system shows that renewable energy can be collected from the commercial vehicle and converted into extra electrical power, which can be stored and used properly. This conceptual design is raised and tested by others, which is listed in the references, but the application after energy harvesting is not mentioned. Therefore, a meaningful idea to improve food delivery services is coming up due to food delivery becoming more and more common in daily life. Basically, the electricity is converted from the suspension's kinematic energy, which can be achieved by wrapping coils around the spring and inserting a magnetic inside shock absorber to generate electrical power. The electricity is stored in a lithium-ion battery and used to charge the food container named food blazer.

Keywords: Energy harvesting; food container; renewable energy; suspension system.

1. Introduction

Environmental issues, especially carbon dioxide emission, which is the main factor causing global warming, increase rapidly and beyond the estimation every year. Fig. 1 shows the growth of carbon dioxide emissions from 1940 to 2020 [1]. Therefore, energy harvesting from vehicles can help to reduce emissions in order to achieve a carbon-free century. Before it goes further, the energy production method needs to be clear and emission-free. This means that it cannot result in further emissions or energy consumption. Therefore, energy harvesting from suspension systems emerges as a new technology to reduce emissions for both the industry and customers [2]. Additionally, the definition of energy harvesting is that the energy captured from a system environment is transferred into electric power. It can make electrons move when the conventional power source is not functioning properly, avoiding the need for complicated wiring and battery replacements.

The basis of energy conservation states that the total energy of an isolated system remains constant. It cannot be created or destroyed but can only be transformed or transferred from one form to another [3]. Therefore, the energy flow cycle involves the transfer of electric energy from kinetic energy and its use to provide heat energy. The assumption is that neglecting the energy loss during the system operation is because of the study purpose and simplifying further calculations.

The collected power can be divided into three sections: usage, storage, and accumulation. The derivation of these three sections is related to the entire system design. To be more specific, the energy comes from the motion of the suspension, as the suspension is always working during the vehicle's operation, especially on bumpy roads. Because the suspension is working vertically, the principle of creating current is cutting magnetic lines of flux. Afterward, the energy needs to be stored in a Lithium-ion battery pack for consistent usage in the further stage [4]. The battery pack is considered a consumable part, but due to the technology limitations, the most balanced battery tech used to store energy inside a vehicle is Lithium-ion. Then, the use of the energy is taken more care of by the delivery person, which is an electrically powered food heater installed on the vehicle. The detailed information about each section is introduced in the following paragraphs. The CAD model of the entire system is shown below (Fig. 2).

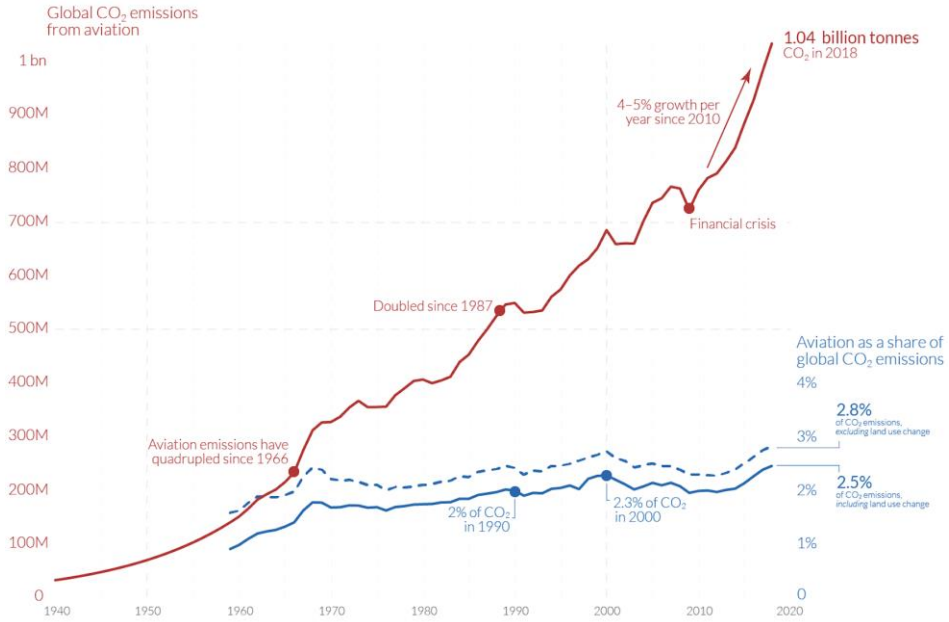


Fig. 1 The growth of carbon dioxide emission [1].

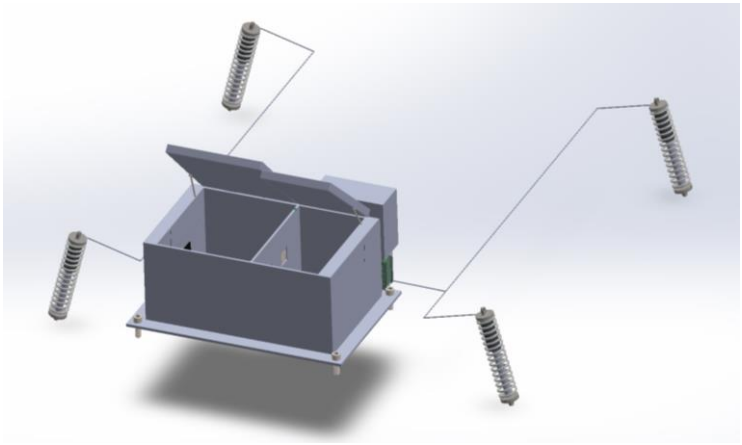


Fig. 2 CAD model of the entire energy collection system (Photo/Picture credit: Original)

2. Energy Harvesting System Design

2.1. How to Gain Power from Vehicle – Accumulation Module

The accumulation module can convert the kinetic energy from the moving suspension system into the electric energy, which is then used to be stored in the storage module. The main principle behind the design of the accumulation module is Lenz's Law, which is basically the generation of voltage due to the change of magnetic flux. Hence, the main components of this module are solenoids with neodymium magnets and high gauge copper wire coils (Fig. 3).

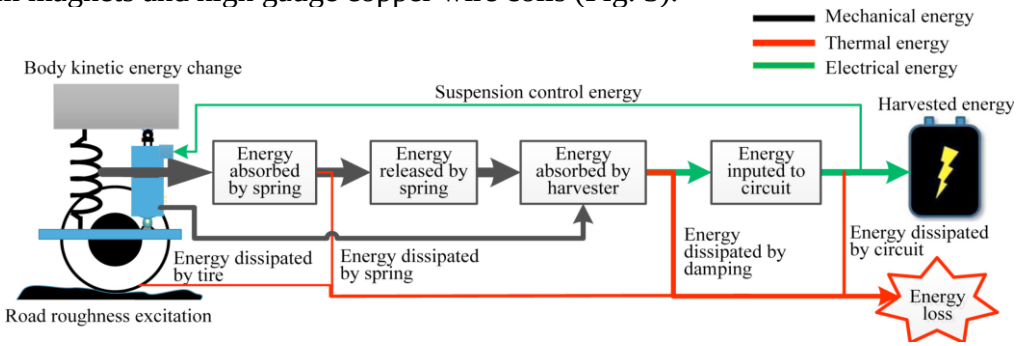


Fig. 3 Explanation of energy transportation through each component of vehicle [4]

According to the research, Audi has a complicated linkage system that can generate electricity up to 613 Watts on bumpy roads, whereas some basic linear generators can only output in the range of 214 Watts to 586 Watts [5,6]. The method used in the accumulation module is to set up a permanent magnet inside the suspension and copper wires wrapped along with the springs outside the suspension shock. Hence, as long as the springs are compressed, the copper wires would cut through the magnetic field lines, causing induced current to be generated, which can then be transported and stored in the storage module. The section view of the suspension with energy collection is shown in Fig. 4.

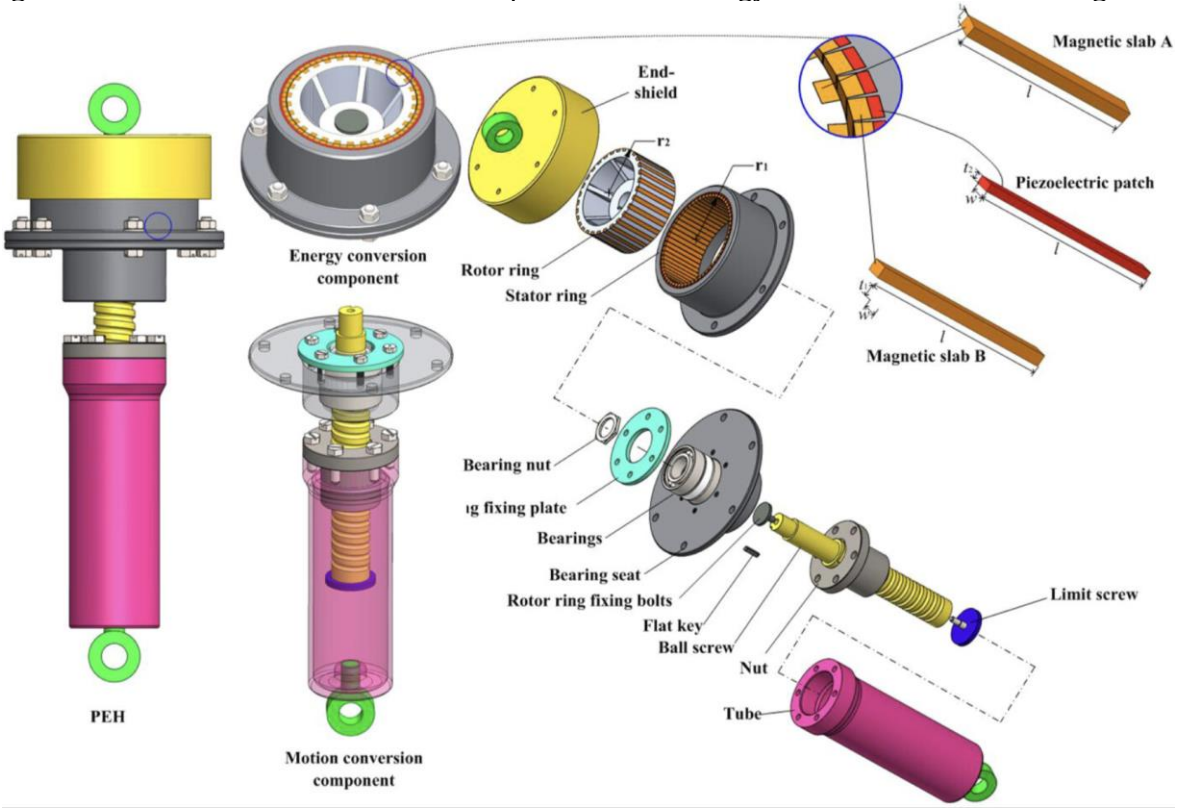


Fig. 4 Section view and labeled components of collective suspension system [7]

Practically, a normal commercial magnet rated 1.2 Tesla is used to participate in the following calculations to roughly show how much power can be generated under ideal assumptions [8]. Besides, the 10 Meters of 3-mm thick copper coils are chosen to be wrapped outside the shock, which is decided based on the average shock and spring lengths. The average frequency of spring vibration when the vehicle is running on a comfortable road is 1.8 Hz [9]. Based on the average moving velocity of the shock, 0.13 m/s, and according to the EMF equation:

$$\mathrm{EMF} = \mathrm{BLV} \tag{1}$$

Where B is the magnet power, L is the wire length, and V is the velocity of the coils moving. The calculation of the maximum voltage generated can be estimated as 12.9 Volts after substituting all parameters into the equation [10]. Combined with the resistance of 0.022 Ω of 10 Meters of copper wire, the maximum power output of four shocks by the method is around 490 Watts.

2.2. How to Save the Collected Power–Storage Module

Lithium-ion batteries can be used for storage of the electric power collected and converted from mechanical power because they have higher energy density and safety levels than other batteries. To satisfy all the requirements of input and output, the 18650 battery pack with BMS can be connected in series to form a cell (Fig. 5). Then, 15 cells are connected in parallel to output at 1200 Watt-Hour under ideal assumption (maximum output without temperature affecting it).

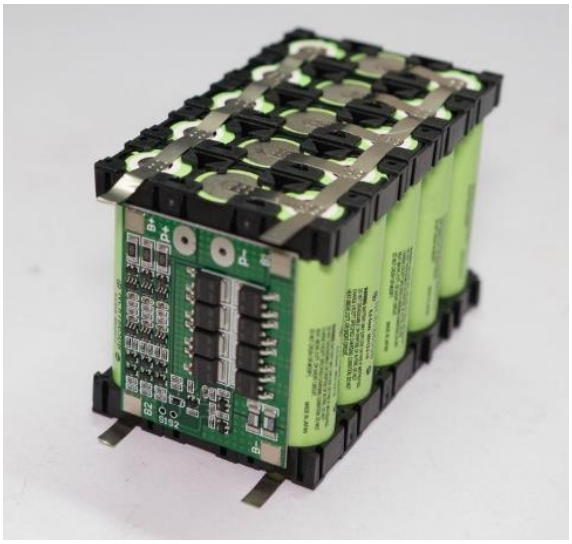


Fig. 5 DIY 18650 battery pack [11]

Another factor that needs to be considered when choosing a battery is whether its labeled output power can keep the usage module operating at a decent level. Additionally, it cannot be taken too many places as the target customers always have higher volumetric requirements than other drivers. Furthermore, the sustainability of the design is important for the environment and battery development, given the increasingly severe environmental problems. Lithium-ion batteries have better performance than lead-acid batteries as they have higher energy density, allowing them to store the same amount of energy with less volume, thereby reducing material consumption.

2.3. How to Use the Stored Power–Usage Module

The usage module stands for the disposal of collected energy, which is decided to heat a food container in the vehicle. In order to ensure the Food Blazer operates with the goal of maintaining temperature and reducing the risk and labor of the user, below is a brief list of each component used to construct the container: thermal electric pad, camel fur insulation and stainless steel sheet metals. The thermal electric pad performs heating and cooling of the interior of the container to make the temperature controllable. It is a double-sided temperature controller, which means it can have one side heating up and the other side cooling down. The principle behind this is that it is made of a solid-state semi-transistor, which can transfer heat from a hot area to a cold area. The key component that achieves the goal is called a thermoelectric couple. The section view and working principle is visible in Figs. 6 and 7.

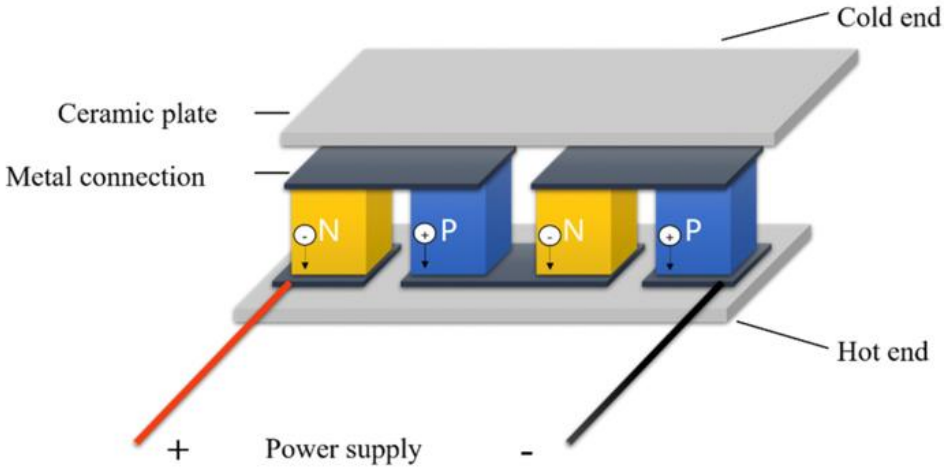


Fig. 6 Thermoelectric couple section view [12].

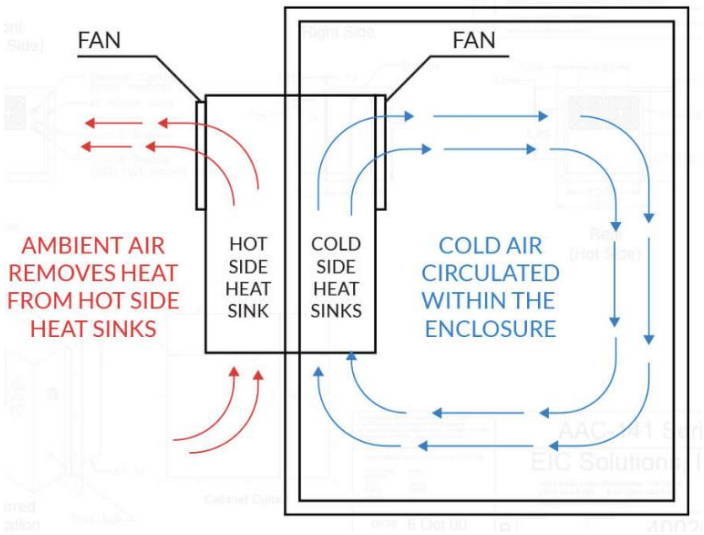


Fig. 7 Thermoelectric couple working principle [12].

Camel fur is stuck on the outside of the container to provide stronger insulation, further reducing energy consumption. This insulation material is completely natural and environmentally friendly, requiring no manufacturing and avoiding polymer insulation, which is not sustainable for future use. Furthermore, camel fur has better insulation capability, which means less energy consumption during operation. A stainless steel sheet is a food-safe material that satisfies safety requirements. Also, its radiation emissivity is 0.15, which is lower than other food-safe materials, indicating that it can maintain a specific temperature with less heat loss [13].

3. Discussion and Improvements

3.1. Accumulation Module Improvement

The accumulation module can be further improved by modifying the hydraulic tube inside the suspension shock as the shock absorber is moving vertically to reduce and dampen the vibration in order to provide a better sitting feeling for the driver and passengers. Hence, a certain amount of heat should be generated by friction inside the tube. By replacing the metal hydraulic tube with the thermoelectric generator, it can generate current based on temperature differences. Therefore, the efficiency of the power generation system can be further improved.

3.2. Storage Module Improvement

A nickel-iron battery can replace the lithium-ion battery as it has better durability. Or costly, it can be replaced by a cheaper lead acid battery. Based on some research, the advancement of lithium-ion battery technology is limited. This means that in the future, other battery technologies may surpass lithium-ion, but lithium-ion is still the most balanced option for now.

3.3. Usage Module Improvement

Some tasteful features can be installed on the usage module, such as an electrically powered lid opener [14]. It can maximize the user experience, especially after picking up the food inside the container. It can automatically close, giving it the feel of an automatic boot. It can be used hands-free, saving users' time. The CAD model of the lid opener is shown in Fig. 8.

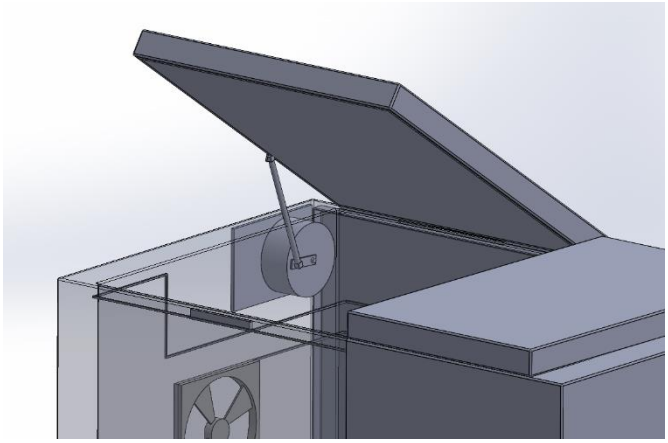


Fig. 8 Electric lid opener CAD model (Photo/Picture credit: Original)

4. Conclusion

In general, the lost energy collection from the vehicle suspension system is achieved by using a permanent magnet wrapped with copper coils. The energy can be stored in a Lithium-ion battery pack and used to heat and cool the container called Food Blazer. Theoretically, the Food Blazer can be replaced by other applications such as fans, etc. But, as introduced before, a food heater container should be important and popular among delivery people.

Besides, some modifications can be applied to the system to increase total efficiency further. To be more specific, the heat energy released inside the shock tube can also be collected and then charged to the battery pack. The lithium-ion battery pack can be replaced by a nickel-ion battery based on durability or a lead-acid battery based on cost. An electric lid opener can be installed to provide extra convenience for users.

Due to the lack of enough practical data, all the information and technology provided in the previous paragraphs are taken under the ideal scenario. Whether it is worth promoting this technology to the public is still under consideration. However, every innovation must go through several iterations to become developed. Hence, further development should focus on improving the total efficiency of the system. Furthermore, durability and feasibility are also considered as the key criteria of a successful design. On the other hand, due to climate change and emission limitations, energy harvesting is a popular trend that can be further improved to prevent severe environmental problems.

References

[1] Ritchie Hannah. Climate change and flying: what share of global CO2 emissions come from aviation? October 22, 2020. Retrieved on August 15, 2023. Retrieved from: https://ourworldindata.org/co2-emissions-from-aviation

[2] Abdelkareem Mohamed AA., Xu Lin, Mohamed Kamal Ahmed Ali, et al. Vibration energy harvesting in automotive suspension system: A detailed review. Applied Energy, 2018, 229: 672-699.

[3] Wikipedia. Conservation of energy. August 24, 2023. Retrieved on September 1, 2023. Retrieved from: https://en.wikipedia.org/wiki/Conservation_of_energy

[4] Zhang Yuxin, Guo Konghui, Wang Dai, et al. Energy conversion mechanism and regenerative potential of vehicle suspensions. Energy, 2017, 119: 961-970.

[5] Viknesh Vijayenthiran, Audi unveils suspension-energy regeneration technology. August 10, 2016. Retrieved on September 4, 2023. Retrieved from: https://www.motorauthority.com/news/1092944_audi-unveils-suspension-energy-regeneration-technology

[6] Kim Ji Hye, Shin Yu Jeong, Chun Yon Do, et al. Design of 100W regenerative vehicle suspension to harvest energy from road surfaces. International Journal of Precision Engineering and Manufacturing, 2018, 19: 1089-1096.

[7] Zhao Zhen, Zhang Baifu, Li Yongxin, et al. A novel piezoelectric energy harvester of noncontact magnetic force for a vehicle suspension system. Energy Science & Engineering, 2023, 11(3): 1133-1147.

[8] Wikipedia. Neodymium magnet. July 14, 2023. Retrieved on September 3, 2023. Retrieved from: Neodymium Magnet Grades. https://en.wikipedia.org/wiki/Neodymium_magnet

[9] Alan. Standard Shock Absorber Specifications You Should Know. December 9, 2019. Retrieved on September 5, 2023. Retrieved from: https://mzwmotor.com/shock-absorber-specifications/

[10] QA1 Tech. How Much Shock Travel Do I Need? September 28, 2022. Retrieved on September 5, 2023. Retrieved from: https://www.qa1.net/tech-center/tech-articles/how-much-shock-travel-do-i-need

[11] Opengreenenergy. DIY Professional 18650 Battery Pack. 2017. Retrieved on September 3, 2023. Retrieved from: https://www.instructables.com/DIY-Professional-18650-Battery-Pack/

[12] Energy.gov. Thermoelectric Coolers. Retrieved on September 8, 2023. Retrieved from: https://www.energy.gov/energysaver/thermoelectric-coolers

[13] The Engineering ToolBox. Emissivity Coefficient Materials. Retrieved on September 10, 2023. Retrieved from: https://www.engineeringtoolbox.com/emissivity-coefficients-d_447.html

[14] Frightprops. Electric Lid Opener. Retrieved on September 14, 2023. Retrieved from: https://www.frightprops.com/electric-lid-opener.html.