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Development of Prototyping Regenerative Power Braking

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Abstract

Regenerative braking system is a promising energy recovery mechanism to achieve energy saving in mostly Electric and Hybrid Vehicle. This system enables the recovery of kinetic energy that is dissipated during vehicle braking maneuvers, which would otherwise be wasted as heat or lost energy. With the aims of maximizing energy recovery efficiency, optimal system design and integration play a crucial role. This research paper focus investing the amount of energy can be produced by a Dynamo Hub by conducting an actual experiment to analyse the amount of voltage can be generate with different parameters and also to analyze the effficiency of eletrical energy generate from braking. This experiment would be conducted on a Yamaha LC135 motorcycle with the regenerative braking system installed on the rear wheel that was supported by dynamo frame, the data collected were obtained with help of Arduino UNO that to capture the energy that produced. One experiment focus on how to increase 1% of charging within a fix route and the other one was generating a different output voltage with variable speeds. The outcome came with as approaching higher speed, the voltage and energy produced by the system also increase. However, if the braking time was short, a higher voltage alone may not necessarily mean more energy recovery as time play a crucial role in regenerative braking. Essentially, this system experience a significant energy lost of 99%, despite the loss, some energy still produced underscores the validility of the regenerative braking system concept. This study proposes the harnessing of waste energy in daily life activities, with the aim of transforming it into electrical energy to the greatest extent possible.

1. Introduction

Regenerative braking is a technology commonly used in electric and hybrid vehicles that enables the recovery and reuse of energy that is typically lost during the braking process. When a vehicle that was equip with regenerative braking system slows down or comes to a stop, instead of dissipating the kinetic energy as heat through traditional braking systems, the energy was converted into electrical energy and stored for later use. A few of the regenerative braking-related themes that have been the focus of countless studies and research publications include the effectiveness of energy recovery, braking performance, system optimization, control methods, and environmental concerns. Especially to those electric vehicles that are using regenerative braking system. These vehicles have become highly popular in recent years due to their significant fuel economy and minimum vehicle emissions. Studies have shown that approximately one-third of the energy produced by a vehicle during urban driving is consumed by braking [1], [2]. While research in this specific area was limited, this study aims to explore the potential benefits and challenges associated with regenerative braking on motorcycles.

The problem at hand was the significant energy waste occurring across various sectors and processes, leading to unnecessary resource depletion, increased greenhouse gas emissions, and inefficiency in energy utilization [3]. Due to ineffective energy conversion mechanisms, frequent regenerative braking might cause energy loss. Control algorithms, motor/generator performance, and power electronics efficiency were a few examples of the elements that affect how well kinetic energy was converted into electrical energy. When braking occurs quickly and often, the regenerative braking system might not have enough time to maximize energy conversion, resulting in subpar energy recovery and loss. However, by maximizing energy efficiency in transportation, regenerative braking helps to reduce energy consumption and promotes the sustainable use of resources, contributing to SDG 7's target of increasing energy efficiency. Increase the integration and application of regenerative braking technology.

The comprehensive study to these technologies on a single at the same time was rarely paid attention to [4]. Implementing regenerative braking systems can initially be more expensive than traditional braking systems, which could be a deterrent for some vehicle manufacturers, especially in lower-cost vehicle segments. In this study we are aiming on energy recovery which was regenerative braking technology, this system has the potential to recover and convert the kinetic energy of a moving vehicle into electrical energy, thereby improving energy efficiency. With the use of electromagnetic, piezoelectric, or electrostatic processes, this energy can be transformed into electrical energy.[5] Certain electric and hybrid cars employ a regenerative braking to retain some of the kinetic energy during braking rather than losing it as heat energy [6]. Regenerative braking was how to optimize the efficiency and effectiveness of this technology while balancing the trade-offs between regenerative braking and traditional friction braking. It is important to understand the basic of braking system was essential to improve energy efficiency. This study begins with designing and implementing a regenerative braking system on motorcycle to analyze the significant of research on this project.

Regenerative braking is a type of stopping that transforms the mechanical and kinetic energy of the motor into electrical energy, which is then utilized to replenish the battery. When the automobile is in regenerative braking mode, the engine slows down when going uphill. The car slows down and the motor begins to rotate in the opposite direction when the brake pedal was firmly applied [7]. Rotational energy, kinetic energy, potential energy is considered as mechanical form of energies which often find in energy conversions. The conversion of mechanical energy to electrical energy can be done using the principle of faraday's laws of the electromagnetism [8]. Induction as the rotor spins inside the magnetic field of the stator, the magnetic field induces an electric current in the coil of wire. The amount of electrical energy produced by the generator was then determined by the strength of the magnetic field, the speed of the rotor, and the number of turns in the coil of wire [9]. Regenerative braking is a key feature in that enhances energy efficiency, there are a few parameters that should be consider such as SOC (battery state of charge), vehicle speed, Brake pedal input, and braking time as they play a crucial roll in this regenerative system.

2.0 Methodology

This chapter reviewed the detail and the flow of the research planning, research method, and the parameter study toward the regenerative braking system. A Yamaha LC135 was used as the primary equipment in studying kinetic energy, followed by a dynamo, Arduino to capture the energy and convert it into electric energy. The specification of the motorcycle was shown in Table 2. A regenerative braking model would be developed with the help of previous researcher on motorcycle regenerative braking. The experiment parameter was included the voltage that obtained over different time and also distance. Then, with the different variable an analysis of charging rate over different parameter. Next, a validation study of kinetic energy and energy efficiency would be conducted to compare motorcycle performance with and without regenerative braking system. First of all, a prototype was created by using an old wheel barrow along with an unused dynamo. The function of this prototype was to test the preliminary result before going to an actual experiment. The prototype can be shown in Figure 1. By applying the brake force to engage the surface contact with on the dynamo. This kinetic energy then was converted to electrical energy by cutting the magnetic flux in the dynamo. AC current that produces by the dynamo would be converted by AC to DC converter, then the current would be stabilize with the help of converter. The experiment equipment was shown in Table 1 along with the properties of each component. The electrical circuit was done in Figure 3 before applying into the actual model. Before charging directly to the battery, it was controlled by a battery charging module to protect from overvoltage or short circuit, thus the lithium battery can charge with securely. In order to hold the dynamo at the rear wheel, a dynamo frame was invented as a place for the dynamo hub to stand still. The actual model of the regenerative braking system can be shown in Figure 2. It was design with two wings with a hole then it could be tightened on the swing arm with a bolt. This frame comes with a supported spring that was connected with the rear braking system so that when brake was pressed, the spring that pull the dynamo the tires surface. To determine the voltage generated from the dynamo, the circuit was connected with an Arduino to read the possible voltage produce per milli-second. To proceed with experiment, there were a few parameters that have to be consider. Setting experiment parameters involves defining and selecting the variables and conditions that would be manipulated and measured during the experiment.

Table 1 *Experiment Equipment*

Components	Properties
Dynamo Hub	6V, 2.4W
XPJ-01D	5V, 2A
Arduino Type	UNO
Battery Charger PCB Power Module (18650)	5V,2.1A
Lithium Battery (18650)	3.7V 1200mAH
Dynamo Frame	Metal Rod

Table 2 *Yamaha LC135 Specification*

Components	Characteristic
Engine	4-Stroke
Weight	105kg
Displacement	134CC
No of Cylinders	1-Cylinder
Compression ratio	10:9:1
Bore x Stroke	54.0 X 58.77mm

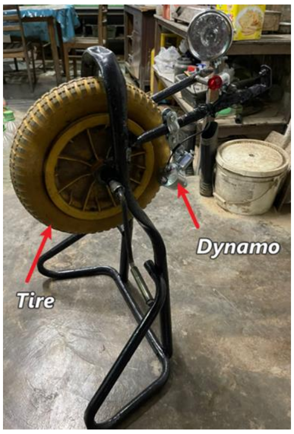

Fig. 1 *Prototype*

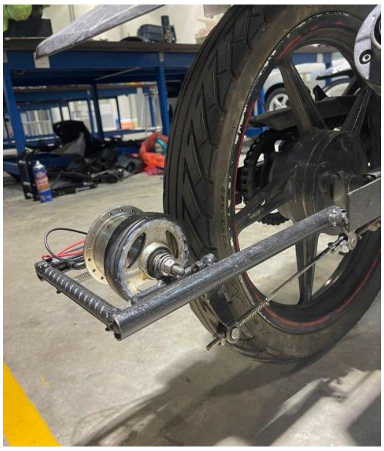

Fig. 2 *Actual*

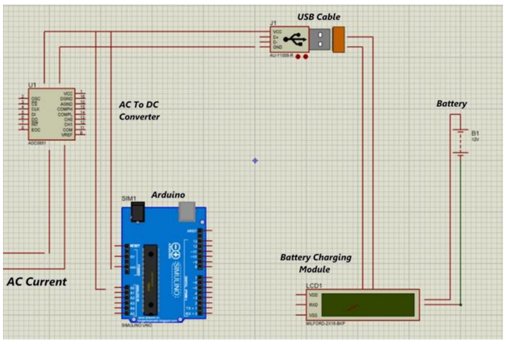

Fig 3 *Electrical Circuit*

3.0 Result and Discussion

In this study, four basic parameter was preliminary selected to study and examine the performance and the efficiency of the regenerative braking system. This experiment was separate into 2, the first one was to increase 1% of charging and the second one was voltage and energy produce with different speeds.

As presented in Figure 4, the data generated was presented in bar chart method, while Table 3 presented the data generated in a tabulation method. The first experiment was carried out for time taken in order to increase 1% in the regenerative system. There were a lot of possibility that different time was taken due to the different output that produced by the dynamo to charge the battery. Since different voltage was generated from the dynamo in a delay of 100 milliseconds between each iteration of the loop to slow down the readings. An average voltage was calculated by using the sum of voltage produced divided by the per unit voltage produced as presented in the table 1. The produce voltage was ranged between 2.6 to 3.0 volt as the input of braking were different from time to time. There were several reasons why regenerative braking systems exhibit output fluctuations. The quantity of energy regenerated was strongly influenced by the driver's actions when braking, which results in varying output levels. As mentioned before, this experiment was mainly focus on the 5 data to increase 1% charging of lithium charging with average voltage was calculated during braking. The unit voltage generated throughout the entire route consistently fell within the range of 5000 to 5600 units, exhibiting a fluctuation between the highest value of 5 V and the lowest value of 0.01 V. The generated electrical energy is used to charge the lithium battery at the capacity 1200mAh, since our battery was 3.7 V, regenerative braking charging started at the state of voltage produced above 3.7 V and discharge at 3.7 V below. The results confirm that regenerative braking systems on bikes were technically feasible, despite variations in average output, distance traveled, and braking duration between the datasets. As presented in Figure 4, the selected parameter of time taken against different taken was presented in the form of bar method. In the bar chart, each of the data displayed the time required to fully charge of 100%.

Table 3 *5 different data collected to increase 1% battery capacity*

	Average Voltage	Braking Time (Min)	Voltage (unit)	Total Voltage (v)	Distance (km)	Number of Braking
Data 1	2.875	15	5258	15118	8.72	59
Data 2	2.911	14	5031	14649	8.99	56
Data 3	2.77	16	5531	15360	10.37	68
Data 4	2.729	16	5331	14551	9.42	61
Data 5	3.008	15	5021	15103	8.39	51

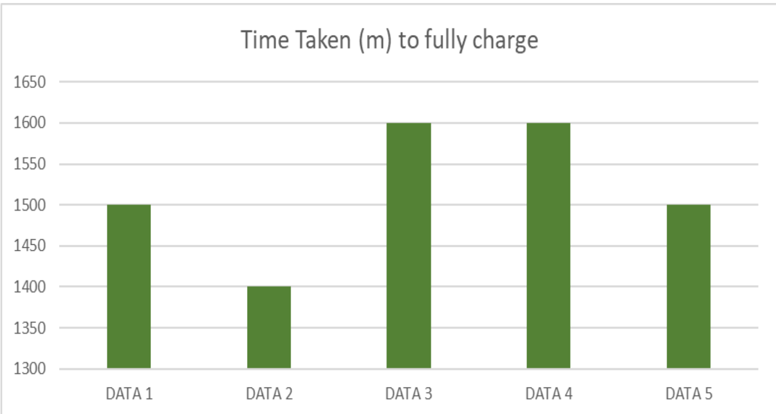

Fig. 4 *Bar Chart for 5 data taken to fully charge*

Based on the result obtained from the experiment 2, brake system was expected to control the vehicle speed under all conditions. 4 different speed was tested on the regenerative system can result in varying levels of the voltage generate. The amount of energy can be recovered through regenerative braking depends on the vehicle kinetic energy. The value of kinetic energy changes as the vehicle speed changes. At higher speeds, a vehicle has more kinetic energy, and regenerative braking system required rotation from the wheel to capture and to capture more of this energy to convert into electrical energy. At lower speeds, the kinetic energy was lower compare to high speed, thus the regenerative braking system produce a lower voltage. According to the graph, the average voltage that produced by the speed 40 km/h was much lower compare to other speed due to the reduced kinetic energy available for conversion. For data 1 of 40 km/h the result obtained was the lowest, followed by second, third and the last data was very close to 50 km/h. It was proof that the time taken of braking does play a big role in determining the voltage output. The average voltage produced by the speed of 70 km/h was consider the maximum voltage of 3.47 Volt which was the highest among the other speed. Even though at a certain time, the regenerative produced various value of voltage, however the value generated 3.7 V above was valid in charging the lithium and discharge again at 3.7 V below. As the dynamo contact with the wheel at higher speed of the motorcycle, the rotation in dynamo cut the magnetic flux at high speed where it allows the dynamo to produce higher voltage. This also proof that at higher speed the rotation of the dynamo to cut the magnetic flux increasing thus more voltage and energy was produced.

Table 4 Energy and average voltage from 40 km/h and 50 km/h

40 km/h			50 km/h		
	Average Voltage (V_a)	Energy (J)		Average Voltage (V_a)	Energy (J)
DATA 1	2.83	0.155	**DATA 1**	3.13	0.2079
DATA 2	2.98	0.172	**DATA 2**	3.15	0.191
DATA 3	2.95	0.168	**DATA 3**	3.18	0.2335
DATA 4	3.00	0.191	**DATA 4**	3.18	0.2336
DATA 5	3.18	0.234	**DATA 5**	3.19	0.2356

Table 5 Energy and average voltage from 60 km/h and 70 km/h

60 km/h			70 km/h		
	Average Voltage (V_a)	Energy (J)		Average Voltage (V_a)	Energy (J)
DATA 1	3.20	0.2364	**DATA 1**	3.19	0.2159
DATA 2	3.21	0.2388	**DATA 2**	3.27	0.2272
DATA 3	3.23	0.2412	**DATA 3**	3.32	0.2550
DATA 4	3.24	0.2436	**DATA 4**	3.32	0.2556
DATA 5	3.26	0.2673	**DATA 5**	3.47	0.3247

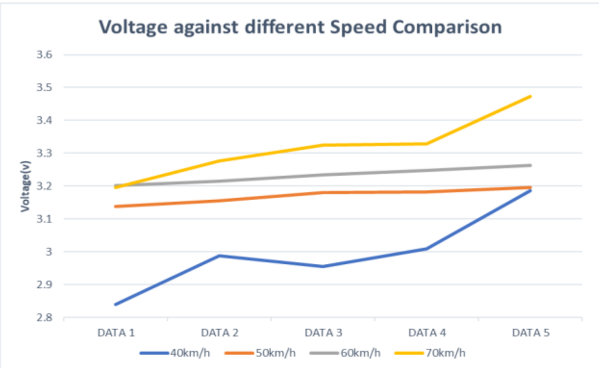

Fig. 5 Voltage produced against different speed

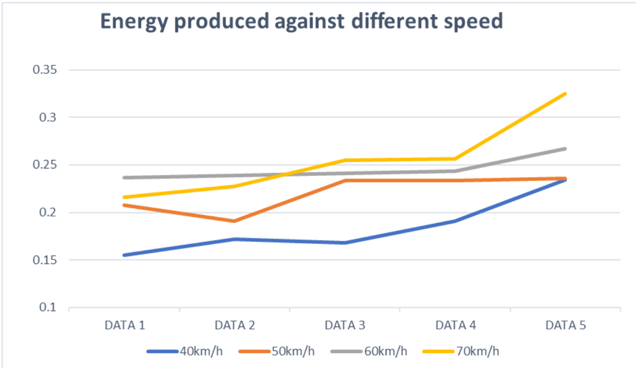

Fig. 6 Energy produced against different speed

The discussion revolves around a regenerative braking system for a motorcycle, as reflected in table 3 and 4. Higher speeds, especially at 70 km/h, show increased energy production during regenerative braking. The relationship between power, braking time, and energy recovery was emphasized, with longer braking times contributing to more significant energy generation. The text notes that a higher voltage doesn't guarantee more energy recovery, especially if the braking time was short. Conversely, a lower voltage combined with a longer braking time can result in substantial energy recovery. The result was proof in Table 4 and 5 with generated average and energy output based on different speed. Energy efficiency was highlighted, with the system demonstrating efficiency close to 100%, indicating effective energy recovery despite inevitable losses due to factors like heat, drag force, and friction. The experiment's limitations were acknowledged, specifically the constrained input (5V, 2A) leading to relatively small energy generation. Figure 5 and 6 show the graphical method between the data collected to make analysis. This graph shown a linear graph as the speed increases. Despite this, the primary goal was to understand and validate regenerative braking principles on a motorcycle. The discussion concludes by emphasizing the growing importance of energy recovery in vehicles for environmental sustainability, reducing reliance on fossil fuels, and moving towards a more sustainable transportation future.

Conclusion

This paper offers valuable insights into implementing a regenerative braking system for motorcycles, emphasizing a holistic approach to vehicle energy recovery. The study involves a generator installed on the rear wheel, activated by braking to convert kinetic energy into electricity for charging a 3.7V lithium battery. Despite voltage challenges, the paper underscores the importance of carefully designing the energy storage system for efficiency. The experiment reveals varied output voltages at different speeds, suggesting a feasible 1% increase in charging through regenerative braking under specific conditions. The study recognizes the impact of individual braking behaviors on results. Despite a considerable 99% energy loss but was not 100% completely due to converter limitations, the research affirms the legitimacy of the regenerative braking concept. To sum up, the study proposes the practical application of regenerative braking to capture and repurpose waste energy during braking, transforming it into electrical energy. The paper envisions the technology's potential in diverse contexts and suggests it could serve as an innovative means of utilizing energy typically lost during braking. The research anticipates regenerative braking systems becoming alternative energy sources in the future.

References

[1] Y. Gao, L. Chen, M. Ehsani, and C. Mesa, "Investigation of the Effectiveness of Regenerative Braking for EV and HEV Reprinted From: Electric and Hybrid Electric Vehicles and Fuel Cell Technology (SP-1466) Future Transportation Technology Conference and Exposition," 1999.

[2] A. Öz, H. Gürbüz, A. K. Yakut, and S. Sağiroğlu, "Braking performance and noise in excessive worn brake discs coated with HVOF thermal spray process," Journal of Mechanical Science and Technology, vol. 31, no. 2, pp. 535–543, Feb. 2017, doi: 10.1007/s12206-017-0106-4.

[3] E. R. Aswathi, P. K. Prathibha, and J. R. Nair, "Regenerative Braking of BLDC Motor using Fuzzy Control for Electric Vehicles," in *Proceedings of the International Conference on Inventive Communication and Computational Technologies, ICICCT 2018*, Institute of Electrical and Electronics Engineers Inc., Sep. 2018, pp. 1661–1665. doi: 10.1109/ICICCT.2018.8473242.

[4] N. A. Q. Muzir, M. R. H. Mojumder, M. Hasanuzzaman, and J. Selvaraj, "Challenges of Electric Vehicles and Their Prospects in Malaysia: A Comprehensive Review," *Sustainability (Switzerland)*, vol. 14, no. 14. MDPI, Jul. 01, 2022. doi: 10.3390/su14148320.

[5] D. Zhu and S. Beeby, "Kinetic energy harvesting," in Energy Harvesting Systems: Principles, Modeling and Applications, Springer New York, 2011, pp. 1–77. doi: 10.1007/978-1-4419-7566-9_1.

[6] Z. Pusztai, P. Kőrös, F. Szauter, and F. Friedler, "Implementation of Optimized Regenerative Braking in Energy Efficient Driving Strategies," Energies (Basel), vol. 16, no. 6, Mar. 2023, doi: 10.3390/en16062682.

[7] H. Kılıç, B. Güney, and H. Kiliç, "Research on Regenerative Braking Systems: A Review Licensed Under Creative Commons Attribution CC BY Research on Regenerative Braking Systems: A Review," *Article in International Journal of Science and Research*, 2020, doi: 10.21275/SR20902143703.

[8] A. H. Balayeva, "Use of mechanical braking energy in vehicles as electricity and hydrogen energy," *Int J Hydrogen Energy*, vol. 48, no. 80, pp. 31023–31039, Sep. 2023, doi: 10.1016/J.IJHYDENE.2022.11.341.

[9] "Electric Motor & Electric Generator | Science Class 10." Accessed: Jun. 14, 2023. [Online]. Available: https://edurev.in/t/187389/Electric-Motor-Electric-Generator