Design and Performance of a Power Generating Manual Treadmill

Ammar A.M. Al-Talib
Department of Mechanical and Mechatronics, Faculty of Engineering, Technology and Built Environment, UCSI University, 56000 Kuala Lumpur, Malaysia

Sarah 'Atifah Saruchi
Faculty of Manufacturing and Mechatronic Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26600 Pekan, Pahang, Malaysia

Cik Suhana Hassan
Department of Mechanical and Mechatronics, Faculty of Engineering, Technology and Built Environment, UCSI University, 56000 Kuala Lumpur, Malaysia

Nor Fazilah Binti Abdullah
Department of Mechanical and Mechatronics, Faculty of Engineering, Technology and Built Environment, UCSI University, 56000 Kuala Lumpur, Malaysia

Ain Atiqa Mustapha
Department of Mechanical and Mechatronics, Faculty of Engineering, Technology and Built Environment, UCSI University, 56000 Kuala Lumpur, Malaysia

Ahmad Jelban
Department of Mechanical and Mechatronics, Faculty of Engineering, Technology and Built Environment, UCSI University, 56000 Kuala Lumpur, Malaysia

E-mail: ammart@ucsiuniversity.edu.my, sarahatifah@umpsa.edu.my, suhana@ucsiuniversity.edu.my, , norfa@ucsiuniversity.edu.my, ainatiqa@ucsiuniversity.edu.my

Abstract

Treadmills are one of the most popular training equipment in the gym and at home. The working principle of treadmills is by moving the belt with the human knee bending, which creates mechanical energy to turn the belt. A gear or pulley and belt system connects to the generator along the axel line of the rolling bars. The power generated by the DC generator is stored in a battery pack and could be used to charge phones or other equipment. It has been found that treadmills can provide an efficiency of 95% when the DC motor is used and 92% when the AC motor is used. The main objective of this study is to design and fabricate a powder-generating manual treadmill and to analyze the performance of the system under different operation conditions.

Keywords: Manual Treadmills, Gym Renewable Energy

1. Introduction

In 2015, the United Nations General Assembly established the Sustainable Development Goals (SDGs), which consist of 17 objectives to be accomplished by 2030. SDG 7 aims to provide affordable, reliable, sustainable, and modern energy for all [1] This goal is especially relevant during the COVID-19 pandemic, as measures such as movement control orders (MCO) have significantly increased residential energy consumption while commercial and business energy consumption has decreased [2]. Impact of the MCO on electricity consumption has shown a sharp increase in residential electricity consumption [3]. To address this issue, the treadmill, which has become a popular fitness equipment for both home and gym use, can be modified to generate electricity. Originally the treadmill consumed energy to operate [4]. The treadmill consists of a wide belt driven by a variable-speed motor. However, by connecting it to a generator or an inverter, the kinetic energy generated by a person walking or running on the belt can be converted into electrical energy. This energy can then be used to power various devices or fed back into the power grid, making the treadmill a potential solution to the increased energy consumption during the pandemic [5].

2. Methodology and Experimental Setup

As shown in Fig. 1, this experiment is set up with a 36 V DC generator that is driven by a pulley linked by a belt, with the main motion generated by the user walking or running on the treadmill belt [6]. The generator is connected to a charging control that regulates the voltage and current supplied to a 12 V, 7.2 Ah battery. The battery then supplies a 200 W inverter, which converts DC to AC power that can be used to charge devices such as phones and laptops. A Watt meter is connected between the generator and the charging controller to measure the current and voltage produced by the generator.

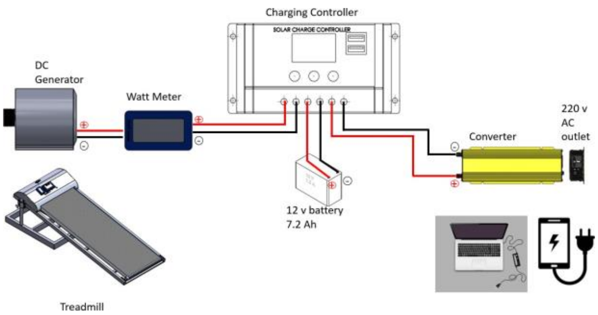

Fig. 1 Connection Illustration of The Setup

2.1. Design and Modifications

As the treadmill was already made, modifications are required to convert the regular treadmill to manual one that is able to generate electricity. The modifications can be summarized as an assembly of a jack to have an incline, support for the side, generator base, motor pulley and treadmill roller. Fig. 2 shows the treadmill before modifications.

Fig. 2 Treadmill Before the Modifications

Fig. 3 shows the modified treadmill at its charging status.

Fig. 3 Charging Laptop from The Treadmill Battery

3. Results and Discussion

In this section, Table 1 shows the average results of 3 different people who tested the prototype. The results are the readings from the watt meter for the voltage and current while the average speed is from the speedometer after 5 minutes of walking on the treadmill. As stated, before the treadmill is not motorized, therefore the speed is not constant, and the only way to maintain a constant speed is dependent on the person himself. However, the adjustment of pace was constant to maintain a relatively constant speed.

Table 1. Average Speed for The Three Testers

	Person 1	Person2	Person 3
Speed (km/hr)	2.24	3.12	5.05
Current (A)	0.56	0.86	1.19
Voltage (v)	12.18	12.53	13.24
Power (W)	6.81	10.63	15.43

3.1. *Discussion*

Fig. 4 shows the average result for the three-persons. The results are combined in one graph, in terms of speed (km/hr), current (A), Voltage, and power (W).

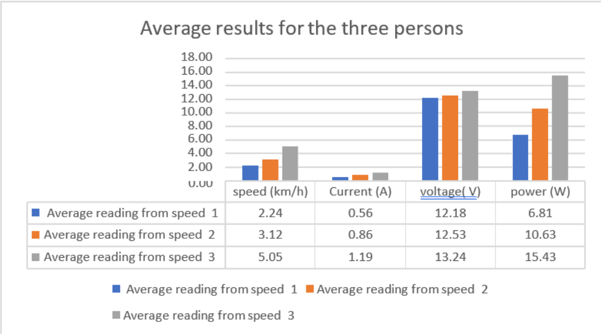

Fig. 4. Average Results for The Three Persons

From Fig. 4, it can be noticed that the higher the speed the higher the voltage and current, and accordingly the power generated. The data represents the average speed that has been achieved by each user. The voltage and current generated by the lowest speed of 2.24 km/h are 12.18 v and 0.56A respectively. This speed can be achieved by anyone as it is within the normal walking speed. Speed 2 of 3.2 km/h induced a voltage of 12.53 v and a current of 0.86 A. The results are the average of the 3 trials by each person. And lastly, speed 3 which is the average of the highest speed that can be achieved at 5.05 km/h induced a voltage of 13.24 v and current of 1.19 A. Taking into consideration that the maximum current to charge the battery as recommended by the manufacturer is 0.1 to 0.25 of the battery capacity. The current achieved falls within these values. Based on the results, it is evident that there is a direct relationship between the speed, voltage, current, and power output of the manual Treadmill. When the speed of the person increases, the voltage and current generated also increase, resulting in higher power output.

3.2. *Theoretical Current*

From the generator specifications the RPM rating is 3400, while the current is 9.5 A for the 36 v. the generator efficiency is stated to be 78%. Eq. (1) is used to calculate the current produced by 1 RPM.

$$Current = \frac{I}{RPM} \tag{1}$$

The treadmill belt is connected to the roller pulley with a ratio of 1:20 which is measured experimentally. The ratio between the roller pulley and the generator pulley can be calculated using Eq. (2) to Eq. (5):

$$\frac{D_r}{D_m} = \frac{95}{35} = 2.7 \tag{2}$$

$$\text{Roller Pulley RPM} = \frac{\text{speed(m/s)}}{\pi D} \tag{3}$$

$$\text{For Motor RPM} = \text{Roller Pulley RPM} \times 2.7 \tag{4}$$

$$\text{For Current generated current} = \text{current}\ \left(\frac{A}{RPM}\right) \times \text{Motor RPM} \tag{5}$$

From Eq. (1) for each rotation of the generator, a current of 0.0029 A will be produced. The motor efficiency is 78% as stated by the manufacturer, which will be considered when calculating the current. The average speed in Table 2 will be considered for these calculations.

Table 2. Average Speed Current Calculation

	Speed 1	Speed 2	Speed 3
Speed (km/hr)	2.24	3.12	5.05
Speed (m/s)	37.28	52.0	84.11
Roller (RPM)	125.0	174.14	282.0
Motor (RPM)	337.41	470.16	761.31
Current (A)	0.91	1.27	2.06
Current with 78% efficiency	0.71	0.99	1.61

Eq. (6) is used to calculate the efficiency for actual current and theoretical current.

$$\textit{current efficiency} = \left(1 - \frac{\textit{theoretical current} - \textit{actual current}}{\textit{theoretical current}}\right) \times 100 \tag{6}$$

Table 3. Actual Current and Theoretical Current Efficiency

Actual Current (A)	0.56	0.87	1.19
Current with efficiency	0.71	0.99	1.61
Efficiency	78.88%	87.88%	73.91%

From Table 3, it can be noticed that the produced current is less than the theoretical current and that is due to the losses due to friction during the experiments.

4. Conclusion

In conclusion, the prototype of the manual treadmill is able to operate and generate electricity of different values depending on the walking/ running speed of the user as it is directly connected. The results have shown that the faster the walking on the treadmill, the higher the current generated which is required to charge a battery for later use. The average 3 speeds are 2.24 km/h, 3.12 km/h, and

5.05 km/h which have generated a current of 0.56A, 0.86A, and 1.19 A respectively. While the voltage for the 3 speeds is 12.18 v 12.53 v and 13.24 v. For the application of the manual treadmill, 3 devices with different battery capacities have been tested. The devices are a smartphone, a smartwatch, and a laptop, with batteries capacities of 4200 mAh, 455 mAh, and 56 Wh respectively. After testing using USB and a normal charger it has been found that the 7.2 Ah battery can charge the smartform 4.8 times, the smartwatch 44.6 times, and the laptop 1.5 times. However, it is important to note that the manual treadmill is designed to be an affordable and accessible option for exercise beside being successful in generating electrical power. The findings of this research align with target 13.2 of the SDG's, which emphasizes the integration of climate change measures into policies and planning.

Acknowledgements

The authors would like to express their gratitude towards the Faculty of Engineering, Technology and Built Environment at UCSI University, for the labs and facilities provided during the research.

References

1. M. Yu, J. Kubiczek, K. Ding, A. Jahanzeb, and N. Iqbal, "Revisiting SDG-7 under energy efficiency vision 2050: the role of new economic models and mass digitalization in OECD," Energy Effic, vol. 15, no. 1, p. 2, Jan. 2022, doi: 10.1007/s12053-021-10010-z.
2. S. I. Mustapa, R. Rasiah, A. H. Jaaffar, A. Abu Bakar, and Z. K. Kaman, "Implications of COVID- 19 pandemic for energy-use and energy saving household electrical appliances consumption behaviour in Malaysia," Energy Strategy Reviews, vol. 38, p. 100765, Nov. 2021, doi: 10.1016/j.esr.2021.100765
3. Md. T. Ullah, Md. A. Bin Karim, M. H. Uddin, and G. M. Tauseef, "Harvesting green energy from wastage energy of human activities using gymnasium bicycle at Chittagong city," in 2015 3rd International Conference on Green Energy and Technology (ICGET), IEEE, Sep. 2015, pp. 1–4. doi: 10.1109/ICGET.2015.7315085.
4. S. Kolgiri, "'Design & Fabrication of Treadmill Bicycle' Synopsis for B.E. (Mechanical Engineering) Project Analysis Ergonomics aspects of Powerloom Industry View project STATIC AND DYNAMIC ANALYSIS FOR ROTOR SHAFT OF ELECTRIC MOTOR " View project." [Online]. Available: https://www.researchgate.net/publication/331950519
5. Sahil, P. K. Sharma, N. Hari, N. Kumar, and D. Shahi, "An innovative technique of electricity generation and washing machine application using treadmill," in 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), IEEE, Jul. 2016, pp. 1–5. doi: 10.1109/ICPEICES.2016.7853524.
6. R.Harsha, "DESIGN AND FABRICATION OF TREADMILL BICYCLE," Chennai, T.Nagar, 2018. [Online]. Available: www.jetir.org
7. Mustapa, S. I., Rasiah, R., Jaaffar, A. H., Abu Bakar, A., & Kaman, Z. K. (2021). Implications of COVID-19 pandemic for energy-use and energy saving household electrical appliances consumption behaviour in Malaysia. Energy Strategy Reviews, 38, 100765. https://doi.org/10.1016/j.esr.2021.100765

Authors Introduction

Ammar Abdulaziz Al Talib

He received his B.Sc and M.Sc degrees in Mechanical Engineering from the University of Mosul Iraq.
He has finished his Ph.D degree from UPM University, Malaysia. Member of the Institute of Mechanical Engineers UK. (CEng. MIMechE). He has developed all the Postgraduate Programs at the Faculty of Engineering at UCSI University / Malaysia and worked as the Head of Postgraduate and Research department at the same faculty for the years 2010-2018.

Sarah 'Atifah Saruchi

She received her B.Eng. in Mechanical and Aerospace Engineering from Nagoya University, Japan She received her Master and Doctoral degrees from Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia. Currently, she is working at Universiti Malaysia Pahang Al-Sultan Abdullah, Pahang, Malaysia. Her research interests include mechatronics and artificial intelligence.

Cik Suhana Hassan

She received her bachelor's and master's degrees in 2009 and 2011, respectively, from Universiti Teknologi PETRONAS, and her PhD in 2019 from Universiti Putra Malaysia. She is an Assistant Professor at the Department of Mechanical and Mechatronics Engineering of UCSI University. Her research interests include the investigation of bio-composites for use in automotive applications. She is also an active member of the materials community, having been recognized as a Professional Member of the Institutes of Materials Malaysia and a Professional Technologist of the Malaysian Board of Technologists in the Material Science Technology field .

Nor Fazilah Abdullah

She received her Bachelor's degree in aerospace engineering (Hons) from IIUM, Gombak in 2010 and her Master's degree in Mechanical Engineering from UKM, Bangi in 2015. Currently she is pursuing Doctoral of Philosophy programme at UCSI University, Kuala Lumpur. Her research interest in bio-based nanoparticles materials.

Ain Atiqa Mustapha

She received her Master's degree from the Faculty of Electronic & Computer Engineering, Universiti Teknikal Malaysia Melaka, Malaysia in 2017. She is currently a Tutor under Department of Mechanical and Mechatronics Engineering, UCSI University, Kuala Lumpur. Her field of research is renewable energy and artificial intelligence.

Ahmad Abu Jelban

He graduated from the Mechanical Engineering Department at UCSI University in 2022, and currently is working as an Engineer.