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Research Article

Energy Harvesting from Industrial Exhaust: Electricity Generation Using Thermoelectric Generators (TEGs)

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ABSTRACT

This research investigates the generation of electricity by using factory exhaust with the help of Thermoelectric Generator (TEG) technology. TEGs harness waste heat from exhaust gases and convert it into electrical energy through the Seebeck effect, offering a sustainable approach to energy recovery. The study focuses on designing a TEG based system optimized for industrial applications, evaluating its efficiency, and assessing its potential to use waste heat and lower carbon emissions. Results demonstrate that TEG technology can effectively enhance energy efficiency in manufacturing processes, contributing to sustainable industrial energy management and aiding in the reduction of global warming by minimizing greenhouse gas emissions.

1 Introduction

The industrial sector is a significant contributor to global energy consumption and greenhouse gas emissions. As the demand for sustainable and energy-efficient solutions intensifies, innovative technologies that can harness and repurpose waste energy are gaining prominence. One such promising technology is the Thermoelectric Generator (TEG), which utilizes the Seebeck effect to convert waste heat from industrial exhaust into electrical energy.

Thermoelectric Generators (TEGs) offer a unique advantage in energy recovery by converting thermal energy directly into electricity without moving parts, resulting in a reliable and low-maintenance solution. This research aims to investigate the feasibility and efficiency of using TEG technology to capture waste heat from factory exhausts and convert it into usable electrical power. By doing so, it addresses the dual challenge of improving energy efficiency in industrial processes and reducing carbon emissions.

The primary focus of this study is to reduce air pollution by designing a TEG-based system optimized for industrial applications, evaluating its performance in real-world conditions, and assessing its potential to mitigate environmental impacts. The integration of TEGs into industrial settings not only enhances energy efficiency but also contributes to sustainable energy management practices. By capturing and utilizing waste heat, TEG technology presents a viable solution to reduce dependency on conventional energy sources and decrease the carbon footprint of manufacturing operations.

This research endeavors to provide comprehensive insights into the application of TEGs in industrial environments, highlighting their role in promoting sustainability and combating global warming. The findings are expected to demonstrate that TEG technology can effectively harness waste heat, thereby enhancing energy efficiency, reducing greenhouse gas emissions, and contributing to the overarching goal of sustainable industrial energy management.

2 Experimental Setup

To evaluate the feasibility and efficiency of Thermoelectric Generators (TEGs) for energy harvesting by using industrial exhaust greenhouse gas, a comprehensive experimental setup was designed. The setup includes the following key components and procedures:

2.1 Dome

- A chamber for trapping gas inside, which is opaque to heat. This means it allows heat to enter but does not allow it to escape.
- The dome is designed to maximize the heat retention from industrial exhaust gases, creating an optimal environment for TEG operation.

2.2 *TEG Platter*

- A specialized platform equipped with Thermoelectric Generator modules to generate electricity by sensing the heat inside the dome.

- The TEG platter is designed to maximize contact with the trapped heat, ensuring efficient energy conversion.

2.3 *Heat Sink*

- A component used to provide a temperature difference between the two surfaces of the TEG platter.

- The heat sink is crucial for maintaining the temperature gradient required for optimal TEG performance, as it helps dissipate heat from the cold side of the TEG modules.

2.4 *Voltmeter*

- An instrument used to measure the potential difference developed between the two wires of the TEG platter.

- The voltmeter is connected to the electrical circuit of the TEG system to monitor the voltage output and assess the efficiency of the energy conversion process.

2.5 *Carbon Dioxide (CO_2)*

- Artificially prepared CO_2gas is used to observe the increased efficiency of the TEG platter.

- The reaction used to produce CO_2gas involves acetic acid and sodium bicarbonate.

- This setup allows to evaluate the impact of CO_2on the efficiency of TEGs in capturing and converting waste heat.

This experimental setup aims to harness waste heat from industrial exhaust gases as well as heat trapped inside due to sunlight and greenhouse effect, converting it into electrical energy through the Seebeck effect facilitated by TEG technology. By effectively capturing and utilizing this heat, the study seeks to improve energy efficiency in industrial processes, reduce greenhouse gas emissions, and lower air pollution, contributing to a more sustainable and environmentally-friendly approach to industrial energy management.

3 Measurement Procedure

Measurement Procedure

All readings were taken in the morning at an environmental temperature of 28O C. The measurement procedure involved three distinct steps to evaluate the performance of the TEG system under different conditions:

1. Sunlight Exposure

- The TEG platter device is first exposed to direct sunlight.

- Measurements of voltage output are taken using the voltmeter to establish the baseline performance of the TEG modules when exposed to natural sunlight.

- This step helps in understanding the initial efficiency of the TEG system under solar heating conditions.

2. Dome Placement

- Next, the TEG platter is placed inside the dome designed to trap heat.

- The dome allows heat to enter but prevents it from escaping, thus creating a controlled environment for the TEGs.

- Measurements of voltage output are taken again using the voltmeter.

- This step aims to assess the performance of the TEG system when operating in a heat-retained environment.

3. Carbon Dioxide Introduction

- Finally, artificially prepared carbon dioxide (CO_2) gas is introduced into the dome.

- The CO_2gas is produced by reacting acetic acid with sodium bicarbonate.

- The TEG platter remains inside the dome with the CO_2gas, and measurements of voltage output are taken once more.

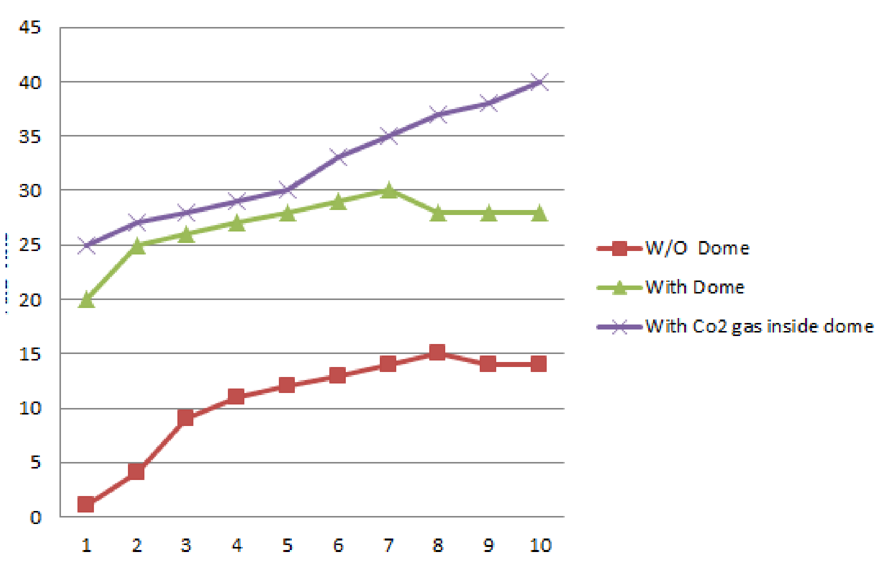
- This step evaluates the impact of CO_2on the efficiency of the TEGs in capturing and converting waste heat.

This measurement procedure ensures a comprehensive analysis of the TEG system's performance under different conditions, providing valuable insights into its feasibility and efficiency for energy harvesting from industrial exhaust gases and heat trapped due to the greenhouse effect.

4 Experimental Data

Voltage (m V) Time(minute)	TEG is directly exposed to the sunlight.	TEG inside the Dome	TEG inside the dome with CO2.
1	1	20	31
2	4	25	33
3	9	26	34
4	11	27	35
5	14	28	37
6	15	29	40
7	17	30	43
8	19	28	46
9	15	28	44
10	15	28	44

5 Results



Time (min.)

6 Conclusion

The research demonstrates that the efficiency of the TEG chip significantly increases when placed within a dome structure, with further enhancement observed upon the introduction of CO_2 gas. This suggests the potential to utilize exhaust gases to trap more heat, thereby generating greater amounts of electricity.

Additionally, the particulate matter settling within the dome could serve as a valuable resource for construction applications. Post-usage, the exhaust gases can be filtered through catalytic converters to mitigate the emission of harmful pollutants, thereby reducing air pollution. Moreover, CO_2 gas can be isolated using chemical processes for various commercial applications, adding another dimension of utility to this approach.

While these findings highlight the promise of this method in harnessing heat and minimizing environmental damage, further experimentation and development are required to enable practical implementation.

In conclusion, this innovative approach offers a dual benefit of energy generation and environmental preservation, paving the way for sustainable technological solutions.

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