



THERMOELECTRIC POWER FROM MOTORCYCLE EXHAUST GAS WITH TiO₂ NANOFLUID COOLING

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Abstract : This paper presents the design and analysis of a thermoelectric power generation system utilizing motorcycle exhaust heat, enhanced with TiO₂ nanofluid cooling. The study integrates theoretical analysis with practical experimentation to optimize thermal efficiency. The methodology involves designing a thermoelectric generator (TEG) system, integrating TiO₂ nanofluid cooling, and evaluating its performance through experimental testing. Results indicate a significant improvement in heat dissipation and power output, demonstrating the feasibility of nanofluid-based cooling in thermoelectric applications. This work contributes to sustainable energy solutions by optimizing waste heat recovery in small-scale automotive applications.

Key Words - Thermoelectric Generator, Exhaust Heat Recovery, TiO₂ Nanofluid, Energy Efficiency, Waste Heat Utilization

I. INTRODUCTION

The increasing demand for sustainable energy solutions necessitates innovative approaches to harness waste heat from internal combustion engines. This study investigates the use of thermoelectric generators (TEGs) to convert exhaust heat into electrical power, with enhanced cooling using TiO₂ nanofluid. Conventional methods of heat recovery suffer from efficiency limitations due to ineffective cooling and heat dissipation. This paper aims to bridge this gap by optimizing the cooling mechanism and improving the overall performance of the thermoelectric system. Thermoelectric generators (TEGs) present a promising solution for converting waste heat into electrical energy. TEGs operate on the principle of the Seebeck effect, wherein temperature differences across a thermoelectric material generate electrical power. However, one of the main challenges with TEGs is their limited efficiency, typically around 5%. To overcome this, enhancing the heat transfer on the TEG's cold side becomes crucial, as it increases the temperature differential and subsequently improves power output. This project focuses on optimizing TEG performance by utilizing titanium oxide (TiO₂) nanofluid as a cooling medium in vehicle exhaust systems. Nanofluids, particularly those based on metal oxides like TiO₂, exhibit higher thermal conductivity compared to conventional coolants. By incorporating TiO₂ nanofluid, the system aims to improve TEG power output and efficiency across different engine speeds. This report presents a detailed investigation of the experimental setup, methodology, results, and the potential of TiO₂ nanofluid to boost TEG efficiency in waste heat recovery applications.

2. METHODOLOGY

The project employs a structured methodology involving:

2.1 Design of TEG Module:

Placement of thermoelectric modules on the motorcycle exhaust pipe to harness waste heat. The TEG are placed in between two Aluminium fins for proper conduction of heat from exhaust.

3.2. Integration of TiO₂ Nanofluid Cooling System:

Circulating TiO₂ nanofluid to improve heat dissipation and maintain optimal temperature differences across the TEG. TiO₂ nanofluids enhance heat transfer efficiency in cooling systems.

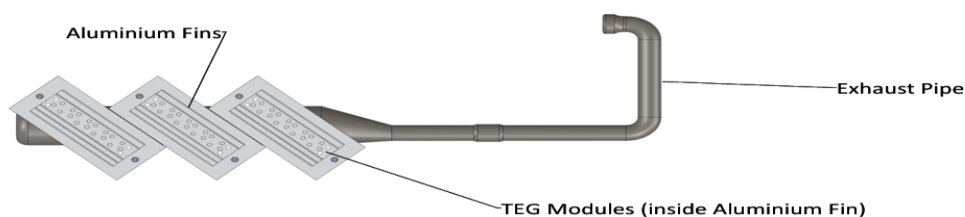


Fig no: 1 Design of Exhaust pipe with TEG and cooling systwm integration

2.3. Experimental Setup:

Testing the system under real time motorcycle operating conditions evaluate power output and efficiency. This involves the starting of motorcycle and evaluate the readings of temperature, voltage and current for proper calculation.



Fig no:2 Testing setup

3. RESULTS AND DISCUSSIONS:

The experimental results demonstrate a clear enhancement in thermoelectric power generation when TiO₂ nanofluid is used as a coolant compared to water and no coolant conditions. Without any coolant, the power output remained minimal, with a peak of 1.3 mW, indicating inefficient heat dissipation. Water cooling significantly improved the performance, reaching 8 mW at a 2.6°C temperature difference, proving that active cooling enhances thermoelectric efficiency. However, the most notable improvement

was observed with TiO₂ nanofluid, where the highest recorded power output was 88 mW, nearly 10 times higher than water cooling, due to the superior thermal conductivity of TiO₂ nanoparticles.

The effectiveness of TiO₂ nanofluid can be attributed to its enhanced convective heat transfer properties, which help maintain a lower temperature on the cold side of the thermoelectric generator (TEG). The relationship between temperature difference and power output was evident, as the highest temperature gradient (2.6°C) coincided with the maximum power generation. This confirms that better cooling results in a higher temperature difference across the TEG, leading to improved conversion efficiency. Additionally, the dispersion of TiO₂ nanoparticles in the fluid aids in heat dissipation, ensuring stable and consistent performance throughout the testing process.

Although the study confirms the benefits of TiO₂ nanofluid cooling, certain aspects require further investigation. The long-term stability and potential agglomeration of nanoparticles in the coolant must be analyzed to ensure sustained efficiency.

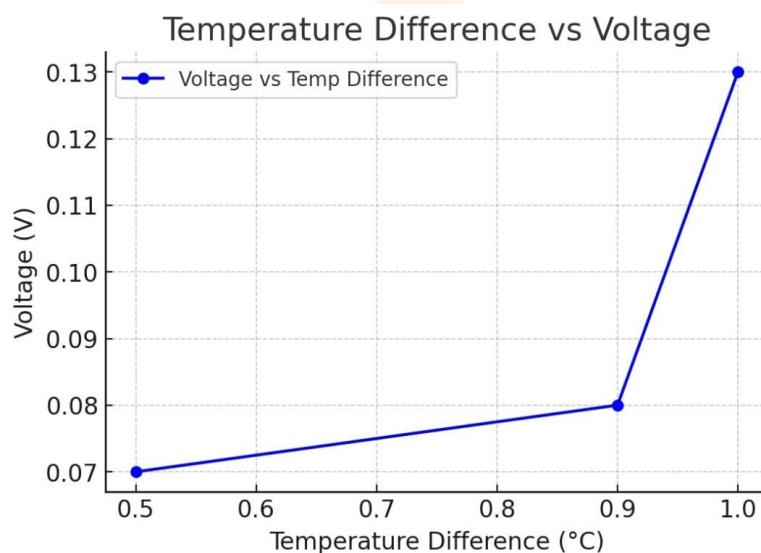
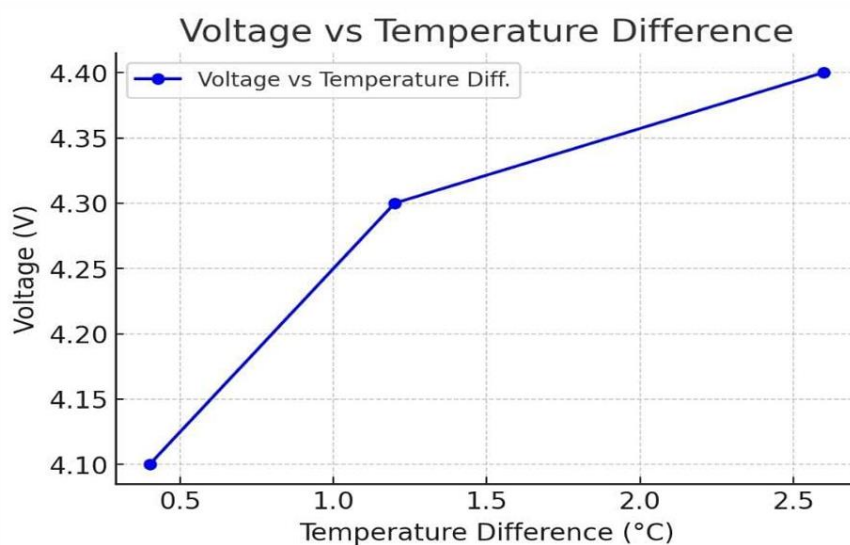


Fig no:3 Results-without coolant

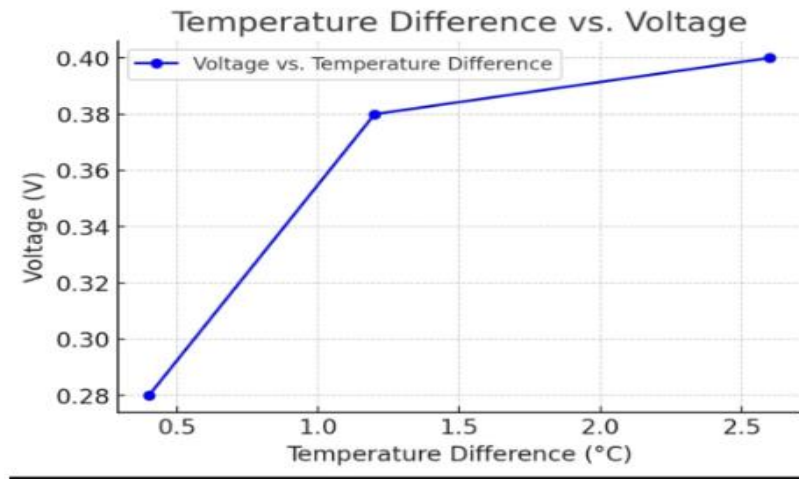


Fig no:4 Results-with water

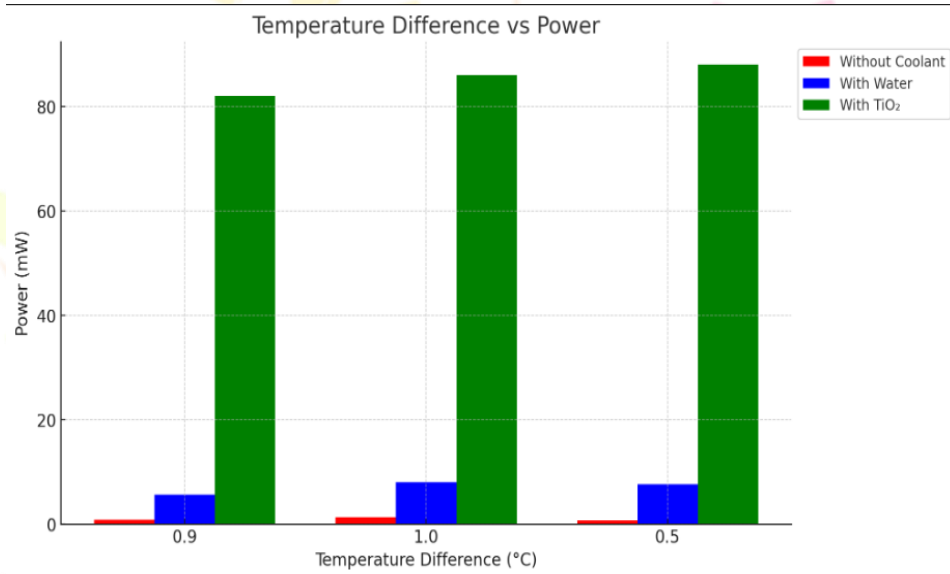
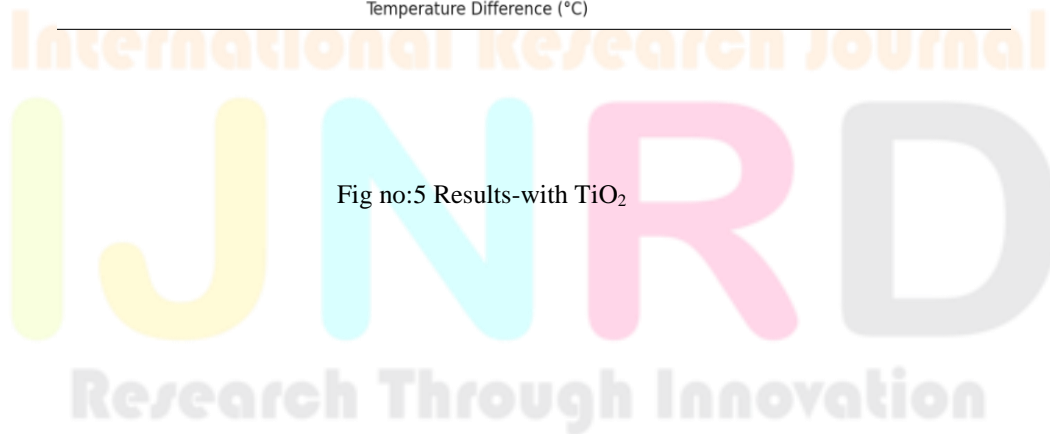


Fig no:5 Results-with TiO₂



4. Conclusion and Future Work:

This study successfully developed a thermoelectric power generation system utilizing motorcycle exhaust heat, demonstrating enhanced performance through TiO₂ nanofluid cooling. Future research should explore long-term durability, optimization of nanofluid concentration, and real-world implementation in commercial motorcycle models to maximize energy recovery. Integrating TEGs with nanofluid cooling into electric and hybrid vehicles could support the energy needs of auxiliary systems, reduce alternator load, and enhance battery performance.

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