

Utilization of Engine Exhaust Waste Heat for Refrigeration Application

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Abstract: *In modern automotive systems, a large portion of energy from internal combustion engines is wasted as heat through exhaust gases and cooling systems, reducing overall efficiency. This project, titled “Utilization of Engine Exhaust Waste Heat for Refrigeration Application,” aims to recover this waste heat using thermoelectric technology. The system employs Peltier (TEC1-12706) modules based on the Seebeck effect to convert exhaust heat into electrical energy. The generated power is stored in a 12V, 8Ah battery and later used to operate another set of Peltier modules for cooling. A thermally insulated box (250 mm × 250 mm) serves as the refrigeration chamber, maintaining temperatures between 5°C and 10°C. The setup includes the engine, silencer, heat sinks, fans, and battery mounted on a portable mild steel frame. This system provides cooling for medicines, beverages, and perishable items during travel or field operations. It eliminates the use of external electricity and harmful refrigerants, making it eco-friendly and energy-efficient. Overall, the project demonstrates a sustainable and innovative method of converting waste heat into useful refrigeration power.*

Keywords: Supporting frame, Ic engine, Thermoelectric Module, Battery, Refrigeration Chamber

I. INTRODUCTION

In today’s world, a large portion of energy produced by internal combustion (IC) engines is lost in the form of waste heat through the exhaust system and cooling system. Studies show that nearly 60–70% of the total fuel energy in an engine is dissipated as waste heat instead of being converted into useful mechanical work. This unused energy represents a significant loss in overall efficiency and contributes to higher fuel consumption and emissions. Therefore, recovering and utilizing this waste heat has become an essential area of research to improve energy efficiency and sustainability automotive systems.

This project, titled “Utilization of Engine Exhaust Waste Heat for Refrigeration Application,” focuses on harnessing the thermal energy from the exhaust gases of a bike engine and converting it into usable electrical power through thermoelectric generation. The concept is based on the Seebeck effect, where a temperature difference across a thermoelectric (Peltier) module generates an electric voltage. By placing Peltier modules on the surface of the hot exhaust silencer and maintaining a cooler side using a heat sink and DC fan, a small but useful amount of electrical energy can be produced.

The importance of this project lies in its energy recovery and reuse principle, which directly contributes to improving the overall efficiency of IC engines. It also supports sustainable energy practices by reducing dependency on conventional electric power sources for small cooling applications. Furthermore, the system is eco-friendly, as it eliminates the need for conventional refrigerants and compressors, which often have adverse environmental impacts.

- To design a system that converts engine exhaust heat into electrical energy using Peltier modules.
- To store the generated electrical power in a 12V lead-acid battery for later use.
- To utilize the stored energy to operate a thermoelectric cooling unit efficiently.
- To construct a portable and durable frame for mounting the engine and cooling components.
- To achieve effective cooling inside an insulated thermocol box using Peltier modules and fans.



To reduce dependency on external electrical sources for small-scale refrigeration.

To promote energy recovery, sustainability, and eco-friendly technology in automotive systems.

II. HISTORY/ BACKGROUND

Early developments in waste-heat utilization began in the 1940s–1960s, when industries experimented with using exhaust heat to generate steam or power auxiliary equipment. However, applying waste heat for refrigeration became prominent later when engineers recognized the high temperature of exhaust gases (300–600°C) as a suitable energy source for absorption refrigeration systems.

During the 1970s oil crisis, global interest in energy conservation increased. This led to research on ammonia–water (NH₃–H₂O) and lithium bromide–water (LiBr–H₂O) absorption cycles driven by low-grade heat sources such as engine exhausts, solar energy, and industrial waste heat. By the late 1980s and 1990s, several automotive researchers began testing exhaust-heat–driven cooling for vehicle air conditioning, aiming to reduce the load on the vehicle engine caused by conventional compressor-based AC systems.

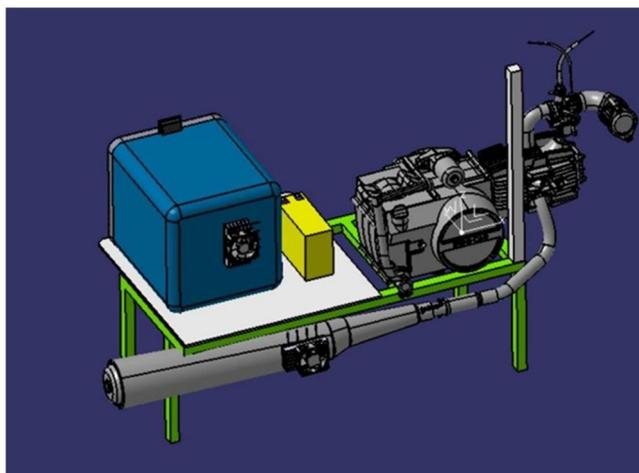
In the 2000s, advancements in heat exchanger design, computational simulations, and environmentally friendly refrigerants encouraged more practical applications. Researchers demonstrated that engine exhaust heat could successfully drive small-scale refrigeration units for trucks, buses, and stationary engines, resulting in reduced fuel consumption and improved thermal management.

More recently, developments in thermoelectric generators (TEGs) and ejector refrigeration systems opened new possibilities for compact and maintenance-free cooling powered purely by waste heat. This makes waste-heat-driven refrigeration an important research area for improving energy efficiency, reducing emissions, and promoting sustainable engineering practices.

Today, the utilization of engine exhaust waste heat for refrigeration represents a promising solution in automotive, transportation, and industrial sectors, with ongoing studies aimed at enhancing system performance, cost-effectiveness, and real-world applicability

III. CONSTRUCTION & WORKING

CONSTRUCTION:



The mild steel frame serves as the main supporting structure for mounting the engine, transmission components, and other mechanical parts of the system. The frame is fabricated using 1-inch square mild steel tubes with a 1.2 mm wall thickness, cut precisely to the required lengths and joined by arc welding to form a rigid rectangular base measuring 745 mm in length, 300 mm in width, and 256 mm in height. Engine-support brackets are welded at predetermined positions



to hold the engine securely and to distribute the load uniformly over the frame surface. When the system operates, the total estimated weight of around 25 kg (including the engine, accessories, and mounting fixtures) acts on the frame. The load from the engine and components is transferred through the brackets into the frame members, where the mild steel tubes primarily experience bending and shear stresses. The square tubular construction provides high rigidity with minimal deflection under operating loads. During operation, vibrations and dynamic forces generated by the running engine are absorbed and distributed evenly through the frame, minimizing local stresses and preventing deformation. The welded joints ensure that no relative movement occurs between members, maintaining structural integrity. Internal components and helps in proper ventilation around the engine. Overall, the frame provides a strong, lightweight, and vibration-resistant foundation that ensures safe operation and stability of the entire system under static as well as dynamic loading condition

WORKING

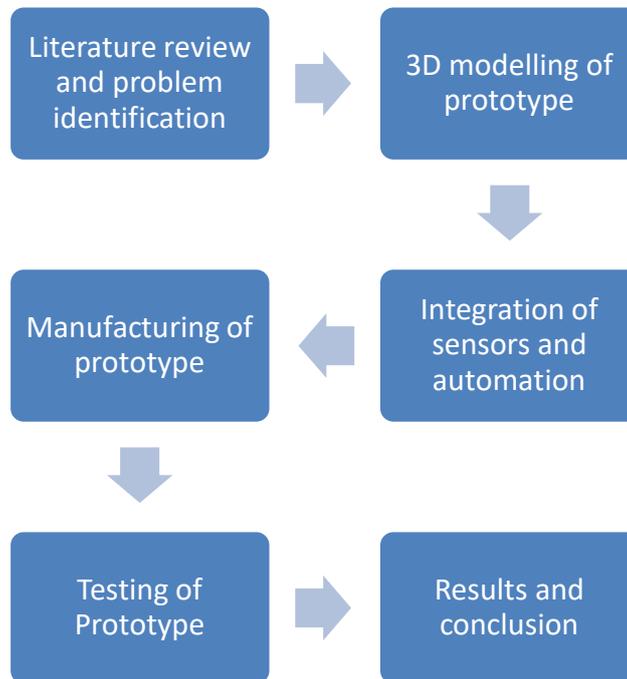
The hot exhaust gases pass through a heat exchanger attached to one side of the thermoelectric modules, while the other side is connected to a cooling chamber. Due to the temperature difference, the thermoelectric effect generates a heat transfer from the cold side, producing a cooling effect inside the chamber. A small fan or heat sink helps maintain proper heat dissipation and temperature balance. Thus, engine waste heat is efficiently utilized to produce refrigeration without any external power input or harmful refrigerants. safe operation.

The system works by first converting engine exhaust waste heat into electrical energy using a Thermoelectric Generator (TEG). The hot exhaust gases flow over one side of the TEG while the opposite side is cooled using fins or a cooling jacket. This temperature difference creates a voltage through the Seebeck effect, generating DC electrical power without any moving parts. The greater the temperature difference between the hot and cold sides, the more electricity the TEG produces, allowing efficient utilization of otherwise wasted exhaust heat.

This electricity is then supplied directly to a Peltier (thermoelectric) cooling module, which operates based on the Peltier effect. When DC current flows through the module, one side becomes cold and absorbs heat from the cooling chamber, while the other side becomes hot and releases heat to the surroundings. By maintaining this current flow using the power generated from the exhaust heat, the system produces a continuous refrigeration effect without needing a compressor, refrigerant, or additional engine load. This creates a compact, efficient, and eco-friendly refrigeration solution powered entirely by waste heat.



IV. METHODOLOGY



V. ADVANTAGES, DISADVANTAGES AND APPLICATIONS

ADVANTAGES

1. Converts waste heat from the engine into useful electrical energy.
2. Reduces energy losses and improves overall engine efficiency.
3. Operates without moving parts, reducing maintenance needs.
4. Provides an eco-friendly refrigeration system without harmful refrigerants.
5. Compact, low-cost, and suitable for small-scale energy recovery applications.

DISADVANTAGES

1. Limited power generation efficiency due to small temperature difference.
2. Peltier modules are sensitive to excessive heat and require proper cooling.
3. Initial setup requires precise thermal insulation and contact.
4. Cooling performance depends on ambient temperature and battery charge.
5. Not suitable for large-scale or heavy-duty applications

APPLICATIONS:

1. Can be used in motorcycles and small vehicles for power recovery.
2. Suitable for portable refrigeration and cooling units.
3. Useful in remote areas where electrical power is not easily available.
4. Applicable in research for thermoelectric energy recovery studies.
5. Can be integrated into hybrid and green vehicle systems.



VI. CONCLUSION

The project successfully demonstrates the utilization of engine exhaust waste heat for refrigeration applications using thermoelectric modules. The system effectively converts heat energy into electricity and reuses it for cooling, achieving dual energy recovery and conservation. The design is compact, eco-friendly, and cost-effective for small-scale use. This project highlights the potential of thermoelectric technology in sustainable automotive applications. Future improvements can include higher-efficiency modules, better thermal management, and real-time performance monitoring to enhance output and reliability.

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