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WASTE HEAT RECOVERY USING TEG AND SIGNIFICANCE OF PCM

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ABSTRACT

All This paper provides a detailed overview of a waste heat recovery system that produces useful energy from waste heat from a four-stroke internal combustion engine's exhaust manifold using a thermoelectric generator (TEG). The TEG output is thenboosted by a Joule Thief converter to power auxiliary automobile devices or charge a battery. The viability of an expanded paraffin wax phase changematerial (PCM) heat exchanger as a heat storage system for an instant air sourceis also explored. The experimental data is used to analyse the energy efficiency and heat transfer rate of the heat discharging process. The PCM heat exchanger offers high energy storage density and even temperature during the storage process, making it an alternative way to retain thermal energy. Overall, this paper presents a cost-effective and environmentally friendly solution for wasteheat recovery and thermal energy storage. from the exhaust manifold of a four- stroke internal combustion engine into usable electricity. The TEG output is thenboosted by a Joule Thief converter to power auxiliary automobile devices or charge a battery. The viability of an expanded paraffin wax phase change material (PCM) heat exchanger as a heat storage system for an instant air sourceis also explored. The experimental data is used to analyse the energy efficiency and heat transfer rate of the heat discharging process. The PCM heat exchanger offers high energy storage density and even temperature during the storage process, making it an alternative way to retain thermal energy. Overall, this paper presents a cost-effective and environmentally friendly solution for wasteheat recovery and thermal energy storage

Keywords:
Phase Change Material, Seebeck Effect, Thermo Electric Generator, Waste Heat Recovery.

INTRODUCTION

The demand for the vehicles specially for passenger vehicles has increasing. Owning a vehicle is now become important considering the busy lifestyle and conditions of public transport in India . because of this the automobile industry has grown tremendously in the last 20 years resulting in the high amount of energy consumption and green house emission. Along with that the internal combustion engine have been highly inefficient . Producing the efficiency of only 41 percent of total efficiency . The 65% has been given to atmosphere in the form of exhaust and engine coolant . This in the long term leads us in severe energy crisis and environmental damages (In the form of air pollution). considering these factors. There has been urgent need to trap this unused heat and convert it into usable energy (Functional energy). Thermo- electric technology has been evident and proved its significance in creating the electricity from the waste heat. The Seebeck principle can be said as major working principle . Thermo - electric generator are

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said to be the solid-state devices that can trap the emitted heat and convert it into the electrical energy .The temperature of the exhaust of the heavy vehicles ranges from 600-800 degrees Fahrenheit. This system can be used on the exhaust gas-pipeline for an engine . This in turn will improve the efficiency and help the system to perform smoothly . This section of the thermal engineering has been neglected from the long time and need more research and analysis for improving efficiency and cost - economical section of the thermo - electric generators.

In This paper, we will study about the feasibility and efficiency of the thermo - electric generators . Performing the experiments in different operating conditions and varying the factors such as Temperature gradient , current flow. Also using different PCM materials . Testing and experimenting under these conditions will give us the most efficient and economical combination of PCM and temperature grading. Our primary aim is to compare the environmental effects of using Thermo - electric generator with other waste heat recovery systems. As said in the above issues , we are hoping to provide brief understanding of capability of thermo - electric generator in reducing and reducing the waste heat for energy conservation . This will help reduce the green houses gases and reduce the pollution as well.

PROBLEM STATEMENT

The utilization of fossil fuels has been causing a significant amount of environmental pollution and energy wastage. The high temperature exhaust gases from various industrial processes and internal combustion engines are a source of wasted heat energy. The recovery and conversion of this wasted heatenergy into electricity is essential for sustainable energy generation. Due primarily to the constraints of the material employed and the high working temperatures necessary, the present techniques for utilizing waste heat energy, such as thermoelectric generators (TEG), operate with poor efficiency. As a result, waste heat energy is not used to its full potential, and energy conversion rates are reduced. Additionally, the TEG system's flexibility and usefulness are constrained by the need for an external heat source. Phase change materials (PCM) have the potential to significantly improve the effectiveness of TEG systems. During the melting process, PCM has the ability to absorb and store thermal energy, which causes the temperature to drop and the temperature gradient across the TEG to rise. As a result, the TEG system becomes more efficient and can convert energy at higher rates. However, further study is required to improve the design and functionality of the TEG-PCM system since integrating PCM into the TEG system is difficult.

Therefore, the principal objective of the research is to design and build a TEG-PCM system that can efficiently collect and convert waste heat energy to electricity. The purpose of this study is to investigate how different PCMs and TEG materials may be used to enhance the functionality of the TEG-PCM arrangement. The integration of PCM into the TEG system and its impact on energy conversion rates, system effectiveness, and longevity will be examined in the proposed research. The results of this study will help create an effective and useful TEG-PCM system that can be applied in a variety of transportation and industrial settings to cut down on energy use and pollution

OBJECTIVE

To study and compare the existing technologies and improvising the existing technology regarding the waste heat and Thermo - electric generator (TEG) . Waste heat recovery plays an important role in increasing the efficiency of the system and making it more sustainable . It has been a proven technology for waste heat to be converted into electricity as in the form of usable energy

The second objective is the development of a TEG system that can capture waste heat energy from multiple sources and transform it into electricity is another goal of this study. Phase change materials (PCM) will be utilised in the setup to boost heat recovery effectiveness and system performance as a whole. The objective is to maximise the use of waste

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heat energy and ensure uniform charging of portable batteries and other small appliances by optimising the heat transfer process from the warm region to the cold region of the TEG system.

The third objective of this research paper is to evaluate the effectiveness and efficiency of the TEG setup with PCM in recovering waste heat energy and generating electricity through experimental testing and analysis. The setup will be tested with different waste heat sources, including vehicle radiators, industrial boilers, and human body locomotion, to determine the feasibility of using the TEG setup in various industrial scenarios, including small and large- scale units.

The fourth objective is the design and development of a control mechanism for the TEG setup, which comprises regulator circuits, microcontrollers, and relays to assure the system's appropriate operation, serves as the fourth purpose of this research work. In order to maintain the ideal temperature differential between the cold and hot sides of the TEG setup and to guarantee the consistent charging of portable batteries and other small appliances, the control mechanism will be essential..

The fifth objective is the analysis of the environmental advantages of adopting the TEG configuration in lowering global warming, minimizing power shortages, and load shedding is the sixth goal of this study article. The TEG setup with PCM can significantly reducethe carbon footprint of industrial processes and increase the overall energy efficiency of the system. This research paper will investigate the environmentalimpact of waste heat recovery and TEG with PCM and provide recommendationsfor improving the environmental benefits of the technology.

The final objective of this research paper is to explore the possibility of transferring the portable TEG setup to different locations for efficient utilizationof waste heat energy. This could include using the setup for emergency power supply, off-grid power generation, and in remote areas with limited access to electricity. By achieving these objectives, this research paper aims to contributeto the development of sustainable and efficient energy systems that can meet the increasing energy demands of the growing population while mitigating the adverse effects of energy production on the environment

LITERATURE SURVEY

Q. Cao et.al. - "Performance enhancement of heat pipe assisted thermoelectricgenerator for automobile exhaust heat recovery"

They had conducted an experiment employing a thermoelectric generator with heat pipes to collect waste heat from a car. The heat pipe is frequently used to expel waste heat due to its low thermal resistance. When fins are used in the gas flow channel, heat pipes will bring the TEM surface temperature closer to the exhaust temperature. For the recovery of waste heat from automotive exhaust, a thermoelectric generator with 36 TEMs is suggested. Before being used in the building of the HP-TEG system, several aspects of the heat pipe application were examined. Analysis was done on a comparative evaluation of the TEG with and without heat pipes. It was discovered that there was an increase in power-generating efficiency when exhaust temperatures rise.

At a mass flow rate of 80 kg/h and an exhaust temperature of 300 °C, the highest power production efficiency of 2.58% was achieved. Because the pressure drop was less than the permitted pressure dips of engine exhaust, it was acceptable for HP-TEG to be utilized in automobiles without impairing the engine's regular performance are considered.

Estimated number of modules has also been taken for available space constraint from this paper. Insulation parameters regarding the concentration of heat at a single space is also found.The temperature gradient should be high enough so that maximum voltage could be producedand this is possible using fins which will improve the heat transfer rate.

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D. Patilet.al. - "Thermoelectric materials and heat exchangers for power generation.

In this paper the attempt was made by the authors regarding the materials which are efficient for the thermoelectric generation & heat exchanger with internal structures

The paper gave us the learning about the different resources like silicon germanium, lead telluride, and bismuth telluride that are used in the TEGS according to their temperature capacity

The result can be calculated upon the difference between the temperature of heat sink, heat source , physical properties of working fluid

The conversion efficiency depends on the shape, material , type of heat exchanger with reference to this paper . we got to know about the specified temperature in which bismuth telluride is available in commercial nodule form that temp is 250 degrees Celsius . The lowest for bismuth telluride is -50. From this we can specify the working temperature would be in these numbers only.

Hlghoolet.al. - "Report on Design, Modelling, and Fabrication of thermoelectricgenerator for waste heat recovery in automobile industry"

This paper discusses the principles and theories of thermoelectric generators (TEGs) and their significance in waste heat energy applications. It elaborates onthe impact of materials on the conversion efficiency of TEG devices and the importance of heat sinks in enhancing their performance. The paper provides a classification of heat sinks and their applications in TEGs, emphasizing the importance of careful selection and design. Passive and phase change heat sinks are found to be the most efficient approaches. Micro-channel heat sinks can improve heat flow but are costly to fabricate. The paper also highlights the need to take advantage of waste heat or cooling sources to cool TEGs without extra energy consumption. The Figure-of-merit (ZT) is crucial for TEGs, and electricalconductivity is the variable parameter that can maximize it. A good TEG shouldhave a ZT value of more than 4, and it is suitable for medium and high- temperature sources of waste heat.

Ngendahayoet.al. - "A review on heat sink for thermoelectric power generation.

The paper states that the thermoelectric effect is the process by which electrical potential is created by the presence of a temperature difference and vice versa, and that the material qualities of thermocouples as well as their size, including their areas and lengths, affect this outcome, The materials for thermos elements have been created using high manganese silica (HMS). The findings are encouraging and demonstrate that as temperature differences increase, output also increases. The electrical power generated changes as a result and can therefore be conditioned and supplied to electronics devices or used for other purposes to boost plant productivity. This suggests that the manufacturing and production sectors should use or adopt this system in order to protect the environment. It is necessary to conduct the experiments on the figure-of-merit(ZT), Physically to improve the performance.

EXPERIMNETAL SETUP &MODEL

While considering the design of the model . We must consider different parameters such as temperature , strength, etc. The frame on which the entire set-up is mounted on is made up of mild -steel . considering the parameters such as High impact strength ,good ductility and weldability. We have used shallow aluminum rectangular box for holding the PCM material . The temperature of the PCM material and the set-up will be as high as 95-96 degrees and this require the metal having High thermal conductivity. Also, the metal used can be easily welded, machined, and can be easily casted . The

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metal should be corrosion resistive in nature .Water tank is kept behind the mid-frame . A metal frame or a section is made on which the temperature sensor is mounted and multi-meter is also mounted.

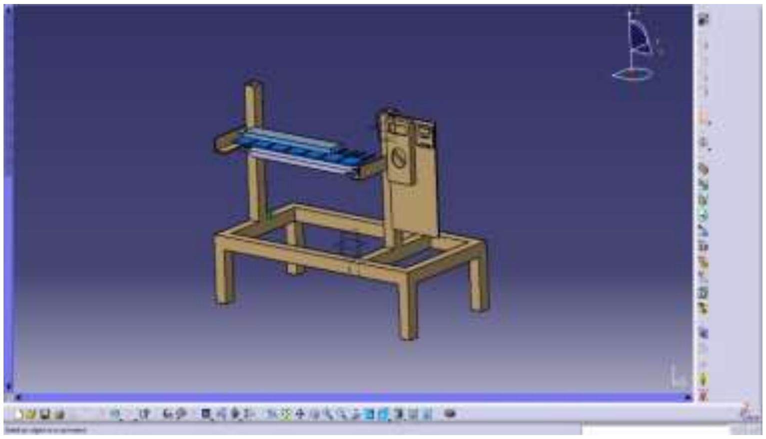

Fig. 1: CAD Model of Setup

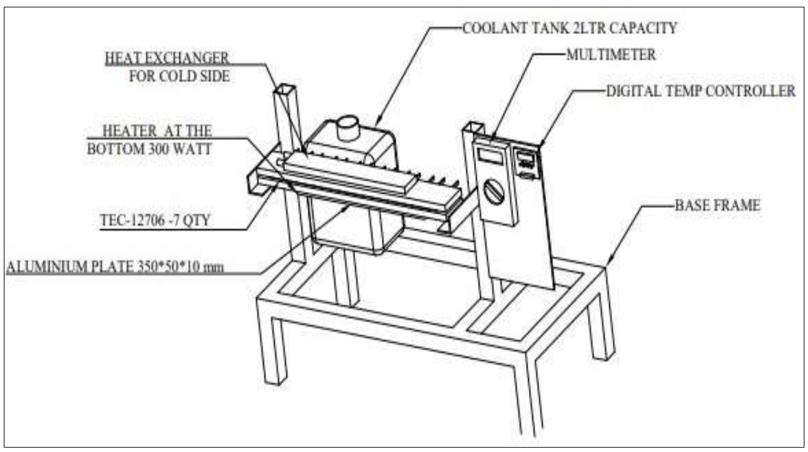

Fig. 2: Schematic Diagram of Model

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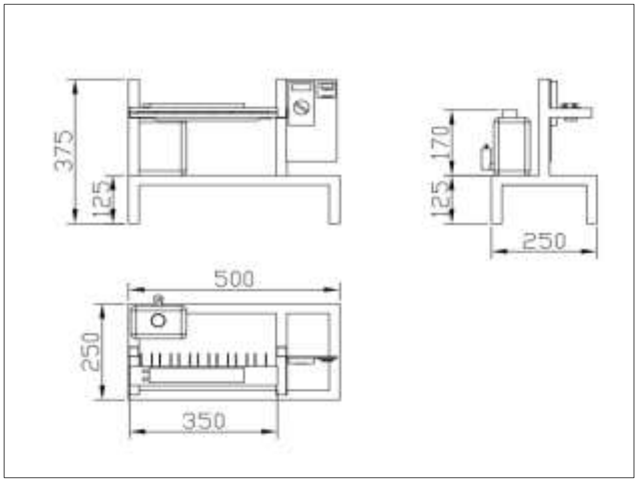

Fig. 2: Drafted model of setup

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TESTING & RESULTS

TABLE 1: READINGS WITH PARAFFIN WAX

SR.NO	TEMPERATURE			VOLTAGE	TIME
	HOT (°C)	COLD (°C)	ΔT (°C)	(VOLT)	(MIN)
1.	31	31	0	0	0
2.	41	33	8	2.63	0.50
3.	51	34.5	16.5	4.42	1.51
4.	61	36.3	24.7	6.35	2.46
5.	71	38.4	32.6	8.09	4.07
6.	81	41	40	10.17	5.39
7.	91	43.2	47.8	12.36	7.46
8.	101	46.5	54.5	14.24	8.33

GRAPH 1: VOLTAGE & TEMPERATURE DIFFERENCE GRAPH

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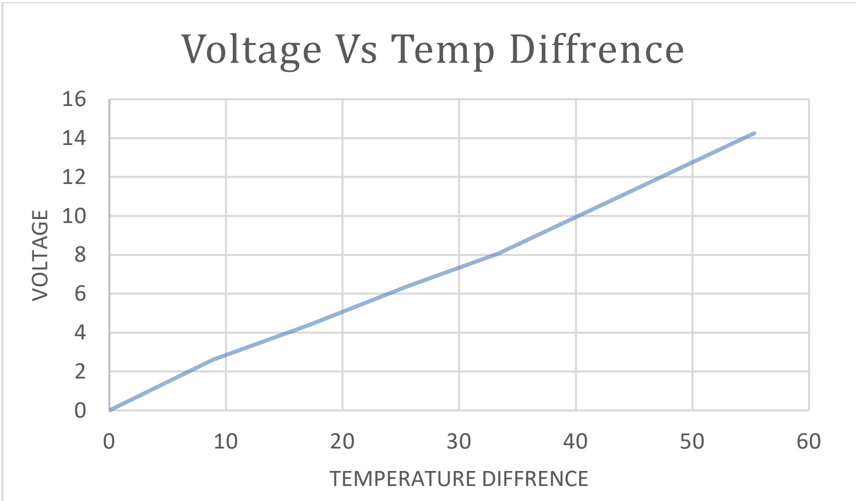

EXPERIMENTAL WORK & PROCESS

After the completion of research and analysis of design we tend forward for the actual experimental work or begin the experiments and trail to get desired output and compare them with the estimated outcomes

Preliminarily, we ensured that all the electronic parts are working. For the first experiment we used the paraffin wax as the phase change material . We heated and melted the paraffin wax to be placed in the hollow aluminium rectangular frame. This frame relates to the both Heated (heater is placed below the rectangular frame) and cooling side (The heat exchanger is placed above the rectangular plate). after ensuring all the electric connection are done properly. We switched on the setup and wait for the reading to appear on both multi-meter and temperature sensor. While taking the reading we had to frequently change the water . As this water is connected to the heat exchanger . The heat is dissipated to the water in the water tank. We also observed that the temperature of the water was changing as the time goes . During the mid-Experiment . The water was lukewarm and thus we had to change the water frequently . we also observed that more cold the water more the voltage was recorded in the Multimeter. For the demonstration purpose we used the small 4 volt led bulb. During our entire process we had produced enough voltage to lit this led bulb . As soon as the temperature reached to 40 degrees the Paraffin wax started melting . For this experimental setup-up we used Two plate heaters for the heating purposes.

As you can see in the above table . The readings were taken by using Paraffin Wax as mentioned earlier . This is completely clear from the above readings that as the temperature increase the voltage at the other end also increase. Cold water adds the advantage to this process . As the efficiency of the TEG (thermo Electric generator) increases when the cold end is more cold and hot end is hotter. Seebeck effect works on the principle of temperature difference . This difference determines the voltage produced .

Now after heating the experimental set-up . We switched off the connection to the heater . we will now be using the heat that is trapped in the PCM material or the heat that is trapped in the rectangular hollow box containing the PCM material. This trapped heat will now be providing thermal energy or heat energy to one end of the TEG . This serves the purpose that once the heat is provided to the certain metal or heat rejecting object with the help of PCM. After the connection is cut down or the system emitting the heat is cooled . Still

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there is lot more thermal energy is left. In our experimental set-up when the temperature reached to around 95 degrees. we switched off the heaters providing the thermal energy to the set-up . Even after switching of the set-up. The experimental set-up was giving the voltage for a long time. When the temperature started decreasing. The voltage was gradually decreasing as the temperature began reduced to 90 degrees the voltage was 7.79. By these figures we can demonstrate that the PCM material has the property to hold the thermal energy for a particular period of time even after discontinuing the heat supply .

Trapping this thermal energy and using this thermal energy for other purposes was the wholesome idea of this experimental setup and highlighting the significance of PCM as well

FUTURE SCOPE

The Applications for personal electronics will frequently involve thermoelectric devices. They include biomedical applications as well as wearables like watchesand clothing. uses include medicine delivery and vital sign monitoring. Devices for microelectronics uses, including cooling integrated circuits, are now possible thanks to technology. However, in order to fully utilize these applications, a low-cost mass production technique must be devised, and performance must be improved. Generally speaking, the use of these devices will expand to numerous industrial applications as a result of mass production. Following more scope for future work listed.

I. Developing more efficient TEGs: While TEGs have been shown to be effective atconverting waste heat into electricity, their efficiency can still be improved. Research could focus on developing new materials for TEGs that can generate higher voltages or improve the conversion rate of heat into electricity.

II. Optimizing the use of PCMs: The use of PCMs to store waste heat and release itat a later time can help increase the efficiency of waste heat recovery systems. Future research could explore ways to optimize the use of PCMs, such asidentifying the ideal type of PCM to use for a given application or developing new materials with better thermal conductivity.

III. Integration with renewable energy systems: TEGs and PCMs might be used for waste heat recovery when integrating alongside renewable energy systems like wind turbine and solar panel. These devices might become even more effective and offer a more dependable source of renewable energy by converting waste heat into power.

IV. Applications in industry: Applications for waste heat recovery employing TEGs and PCMs include steel mills, cement plants, and chemical plants, among other industrial settings. Future studies may concentrate on determining the ideal uses for these technologies and creating systems that are suited to the requirements of particular sectors.

V. Economic feasibility: While waste heat recovery using TEGs and PCMs has the potential to save energy and reduce greenhouse gas emissions, it is important to determine whether it is economically feasible. Future research could explorethe economic viability of these technologies, taking into account factors such asinitial investment costs, maintenance costs, and potential savings in energy costs

CONCLUSION

In conclusion, waste heat recovery is a promising technology for improving energy efficiency and reducing carbon emissions. The use of thermoelectric generators (TEGs) has been shown to be an effective method for converting waste heat into useful electricity, TEGs have the potential to become even more effective with the use of phase change materials (PCMs). The experimental findings provided in this study show that it is feasible to use a TEG-PCM system for waste heat recovery in a variety of processes, including industrial ones and those used in automobiles.

Through this research, It was shown that by reducing thermal resistance and enhancing differences in temperature

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inside the TEG, introducing PCMs to the TEG system can improve the TEG's efficiency. This ultimately leads to higher power output and improved efficiency. The TEG-PCM system may also be made more affordable and ecologically responsible by using inexpensive, eco-friendly PCMs like paraffin wax or fatty acids.

Overall, the findings of this research suggest that the use of TEG-PCM systems for waste heat recovery has great potential for widespread adoption in various industries and applications. Future research could focus on enhancing the TEG-PCM system design even more, looking into the system's long-term dependability and stability, and studying new and cutting-edge PCMs that may boost the system's effectiveness and performance. The creation and usage of TEG-PCM waste heat recovery systems can ultimately significantly reduce energy use and greenhouse gas emissions while also offering a sustainable source of electricity.

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