Experimental Research on Utilization of Motorcycle Exhaust Heat Using Thermoelectric Generator (TEG) For Mobile Phone Chargers

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***Abstract*—In most vehicles with a combustion engine, about 65% of the remaining combustion energy dissipating as heat. Heat is a form of energy release from the combustion process in the combustion chamber channeled through a motorized vehicle's exhaust. The exhaust heat has the potential to be reused as a source of heat energy that can be transformed into electrical energy using a thermoelectric generator (TEG) attached to a motorized vehicle exhaust system. The application of TEG in motorcycle exhaust is an effort to increase the fuel efficiency of motor vehicles. This research aims to create and develop prototypes that apply TEG to motorcycle exhausts, convert motorcycle exhaust heat into electrical energy, and make prototype designs for cell phone chargers. Several steps have been conducted, including the design process with Autodesk Fusion 360 Student Edition application, while prototyping is done by manually assembling all the components used. The measuring instruments used during the prototype testing are the k-type thermocouple and DC voltage sensor connected to the data logger and laptop. The engine speed at the time of testing was 4000 RPM. In the test using a heat pipe, it was obtained ΔT 115°C on the cold side of TEG at a voltage of 4.47 V when the motorbike was stopped or idle, which was relatively better than the TEG test using a heatsink as a cooling system.**

***Keywords*—motorcycle, exhaust-heat, thermoelectric-generator, mobile-phone, charger**

I. INTRODUCTION

Motorbikes and four-wheeled vehicles powered by internal combustion engines are still in demand and are increasingly flooding the roads. In the meantime, internal combustion engines' maximum efficiencies still have to deal with the thermodynamic limitation [1]. To this day, severe environmental contamination, entropy rise, and greenhouse effect show an increasing trend when almost 60 – 70% of waste heat becomes the leading contributor to the energy inefficiency out of the internal combustion system [2–4]. Factually, diesel engine thermal brake efficiency tends to grow 10% from the 1960s to 44% in the early 2000s. A few years later, in 2004, the value decreased to 42% (due to cooled EGR to meet the 2004 emissions) and increased slightly back to 43% throughout 2004–2010 despite additional strict emissions guidelines. SCR engines' thermal efficiency recovery shows a more prominent behavior due to their extra sophisticated fuel injection timing. In recent years, there were investigations on car exhaust heat recovery to convert the thermal energy to electrical, intensifying Internal Combustion engines' efficiency and simultaneously reducing CO2 emissions. Research has shown that converting 10% of this waste heat into electricity may increase fuel efficiency by around 20% - 30% [5,6].

Recent studies are indicating that the utilization of TEG technology to harvest waste heat is increasing. They range from low-temperature grade heat internal combustion engine (i.e., portable generator, motorbike, car, household waste heat) to a relatively higher temperature such as conventional power plant, yet there is still some room for continual improvement [3,7–9]. Other research came with a particular focus on the characteristics of the output voltage from the thermoelectric generator utilizing waste heat of the motorcycle with heat pipe sink [10]. Even though thermoelectric efficiency still needs a lot more work to increase thermoelectric systems' efficiency [11], there are many possibilities to provide new renewable technology as the market demand. TEG works based on Seebeck's effect and generally generates electrical power out of "dissipated" thermal energy. TEGs have provided several advantages covering design simplicity, solid-state, prolonged lifetime, maintenance less, and relatively ecologically saver [11]. The materials used to develop TEG modules can interconvert thermal and electrical energies and capture waste heat and temperature control devices[12]. Understanding that the heat waste from engine exhaust is gainable, this study develops an approach to produce a prototype of small-scale mobile phone chargers powered by a single thermoelectric generator. This study should provide an in-ride mobile phone charger during travel without sacrificing the principal battery life nor additional load to the engine.

II. METHODS

The experiment was conducted using two different cooling mechanisms with air as the medium. TEG is cooled with a help heatsink in the first model, while the second one is utilizing a heat pipe. The idea of using these two different cooling methods was also to understand the stability of voltage development. The basic concept of research is shown in Fig. 1.

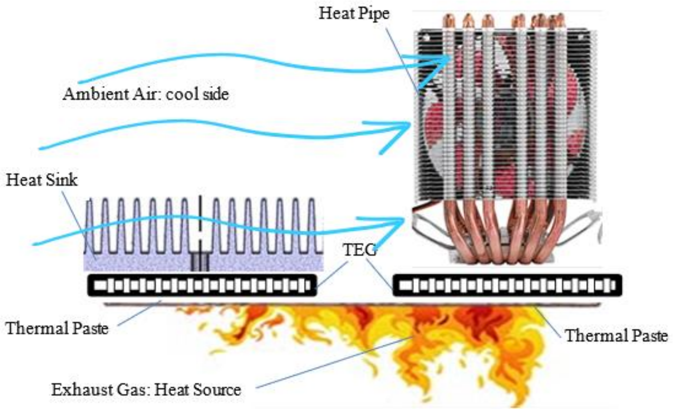


Fig. 1. Basic concept.

The concept mentioned above promotes a development process of an actual instrument attached to a motorcycle exhaust, as shown in Fig. 2. The heat harvested from the exhaust gas by the TEG device turns into electricity. The voltage is then stepped up with a converter made of an Arduino circuit and directly used to charge the mobile phone.

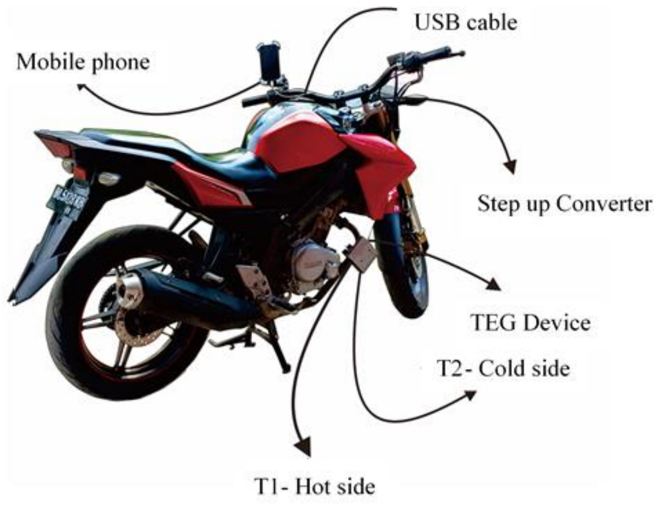


Fig. 2. The mounting place of the device during the test.

As for the test scheme, Fig. 3 explains the setup of data acquisition methods during the research. The temperature is measured using a K-type thermocouple installed at two points, and the voltage is measured using a voltage sensor connected to the data acquisition devices (DAQ). The laptop downloads the data then interpolated them as temperature and voltage.

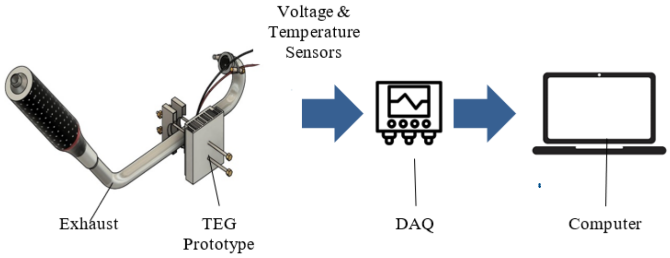


Fig. 3. Testing scheme.

A. Testing Procedures

Several test steps have been prepared for the safety testing procedure, and the data recorded to be valid, as briefly shown in Fig. 4. Some of the steps referred to include the preparation of relevant devices and components, installation of a prototype thermoelectric generator module on the motor exhaust, installation of measurement equipment (i.e., thermocouple and voltage sensor) at each point to be measured, connecting the measurement equipment with a data recording device (data logger) and data reading interface on a laptop. Before the measurement process begins, a calibration is carried out. Then the test is carried out by starting the motorbike with various RPMs. Thus, the data logger record all the variables that are then downloaded via software installed on the computer.

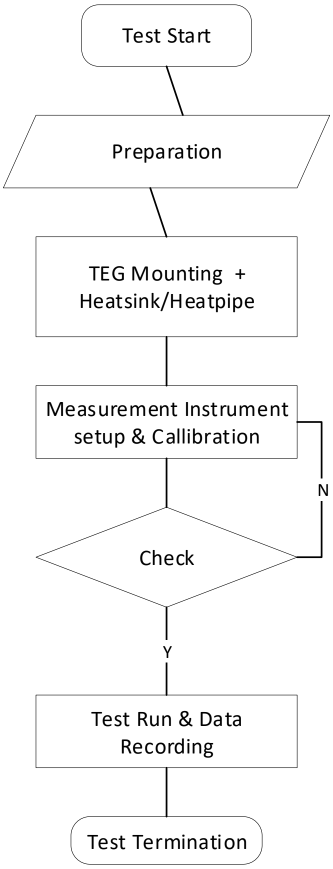


Fig. 4. Schematics of the testing procedure.

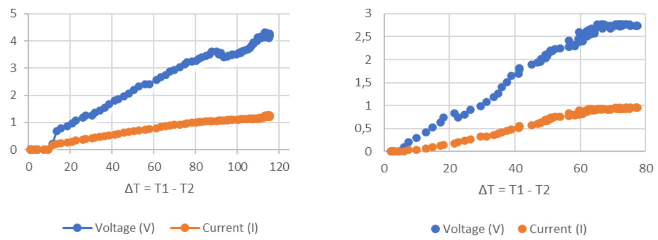
III. Results and Discussions

Tests were carried out on the exhaust of a 150 cc Yamaha Vixion motorcycle as a heat source, using a thermoelectric generator equipped with two cooling systems, namely a heatsink and a heat pipe. Consequently, testing was conducted in two types of test variations.

The temperature test point using the k-type thermocouple is that T1 is located on the thermoelectric generator's hot side, while T2 is on the TEG's cold side. Meanwhile, the voltage sensor used is directly connected to the thermoelectric generator output cable. The study was carried out with two variations of heat transfer media, namely a heatsink and a heat pipe, which was tested at 4000 RPM engine speed, and each variation was tested twice, namely when the condition of the motorbike was idle and running.

A. *Testing Using Heatsink (TEG-Heatsink)*

In this test, temperature build-up and reach a higher temperature. The voltage and current show a trend to increase with the temperature. Nevertheless, the temperature while running seems to drop due to the airflow through the heatsink. Therefore the temperature difference is lower compared to the test during idle. Figures 5 (a) and 5 (b) portray the voltage and current build-up regarding the device's temperature difference and temperature drop during idle and running motorcycle.

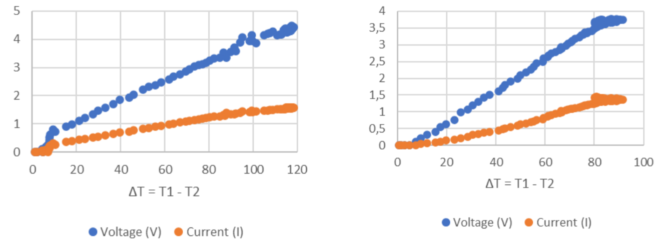


(a) (b)

Fig. 5. (a) The effect of temperature on voltage and current during idle, (b) The effect of temperature on voltage and current during riding.

B. *TEG Testing Using Heat Pipes (TEG-Heatpipe)*

This test also seems to depict the same phenomenon as the test in the device with the heatsink. The voltage and current are build up as the temperature is rising. The higher the temperature differences, the voltage and the current developed by the device is increased. The exciting thing is that the voltage and the current drop while the motorcycle is on the run are not significant as the other test where the TEG device uses a heatsink. Figures 6(a) and 6(b) depict the temperature build-up during motorcycle idle and running, respectively.



(a) (b)

Fig. 6. (a) The effect of temperature on voltage and current during idle, (b) The effect of temperature on voltage and current during running.

IV. Conclusion

The research has been conducted for the TEG-Heatsink and TEG-Heatpipe, respectively, at engine speed around 4000 rpm for 5 minutes. The maximum ΔT reached in the TEG-Heatsink test is 115.4 C, and the maximum voltage generated is 4.26 volts during idle, while during running, the maximum ΔT is 65.3 C, and the maximum voltage generated is 2.77 volts. In the same test parameter for a TEG prototype equipped with a heat pipe, the maximum ΔT reach is 117.5 oC, and the maximum voltage release is about 4.47 volts. Meanwhile, while running the motorbike, the maximum ΔT is 89°C, and the maximum voltage generated is 3.76 volts. The research shows that the device can work in both conditions, idle and running. Nevertheless, more advanced research still needs to be conducted to ensure that the device could continue to work in a more challenging environment.

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