*Journal of Mechanical Engineering* *Vol SI 7 (1), 103-110, 2018*

# Fuel Consumption Reduction by Increasing Thermal Efficiency through Heating of Fuel

*Edmund Hilary Nicholas*
*School of Engineering,*
*KDU Penang University College,*
*10400 Georgetown, Penang, Malaysia*

*Kumaresan Magaswaran**
*Vikneswary Jayapal*
*School of Engineering,*
*Faculty of Computing, Engineering and Technology,*
*Asia Pacific University,*
*Technology Park Bukit Jalil, 57000,*
*Kuala Lumpur, Malaysia*
**kumaresan.m@staffemail.apu.edu.my*

## ABSTRACT

*The drive to produce a more efficient and low fuel consuming internal combustion engine has been ongoing ever since the birth of the internal combustion engine. This drive is ever so more important with the current stringent emission regulations all around the world. A complete burned fuel in an internal combustion engine produces lots of heat as a by-product. To convert this by-product into useful heat to increase efficiency is beneficial. This paper will investigate the potential of harvesting heat from the exhaust to preheat the fuel to improve fuel consumption. A heat exchanger is designed to heat up fuel followed by the experimentation on an internal combustion engine using various combinations of fuel temperature. Performance parameters such as thermal efficiency, exhaust gas, power, fuel consumption and output power are being discussed. The study shows that the fuel consumption is lowest at 34°C where else the maximum power was produced at 30°C.*

**Keywords:** *Fuel consumption, fuel heating, thermal efficiency, heat exchanger, IC engine.*

---

ISSN 1823- 5514, eISSN 2550-164X

Received for review: 2017-10-11
Accepted for publication: 2018-07-16
Published: 2018-11-30

## Introduction

Transportation is one of the biggest sector worldwide that demands the highest share of fossil fuel usage. In the year 2009 in view of rising concerns on road transport being the major contributor to greenhouse gases, The European Parliament came up with regulations to reduce carbon dioxide emission ($CO_2$) of new passenger cars to 130 grams of $CO_2$ per kilometre. In view of the emission control legislation and the demand from consumers for fuel economy, automotive manufacturers were challenged to look into ways to increase the efficiency of the internal combustion engine. It is estimated that that only 25% on the energy generated from the combustion is used to propel a vehicle and up to 35% of energy is lost as exhaust heat and with another 30% of the energy is lost in the engine cooling system. [1] Therefore if this wasted energy is routed back into the fuel thus the efficiency of the combustion engine could be increased. [2]

The research of harvesting heat of the exhaust and heating the fuel has been on-going.[2,3,4] The Rankine cycle can be utilized to harvest heat from the exhaust gas. This is could be done in such a way that an expander is used to extract mechanical energy and used directly to drive the powertrain. Another option would convert this mechanical energy to electrical energy by simply attaching a generator to the expander. [5]. The performance of these heat energy harvesters can be improved using alumina and copper oxide nano-fluid provided a constant thermal condition and a laminar flow is maintained.[6] The most commonly used heat exchanger is the helically coiled tube heat exchangers (HCTHEs). The application of HCTHEs ranges from electrical power generation, nuclear technologies, HVAC system, piping systems, chemical reactors, refrigeration systems and much more. This wide application mostly due to the high thermal efficiency and the relatively smaller size of the HCTHEs. The HCTHE owes it high efficiency to the construction of the curving helical tube which increases the surface area for the heat transfer process and also the production of a secondary flow.[7] Another design of the heat exchanger is the Micro-channel heat exchanger (MHE). This design uses a multi-fluid filled channel at reduced scales to maximize heat transfer by taking advantage of the dynamic boundary layers produce in this system. The MHE is optimized by carefully analyzing the fluid dynamics and reducing its thermal resistance. This is done using a two-phase flow and high thermal conductivity materials. [8] Significant improvements in efficiency can be done through homogenous charge compression ignition by the elimination of the pumping loss caused by intake throttling and the acceleration of the heat release process[9]. The heating energy can be taken from the high-temperature exhaust gas thus eliminating the parasitic load of the heating element [10]. The heating process by introducing more energy to the fuel causes the viscosity and density of fuel decrease thus leading to a favourable effect on fuel atomization and combustion characteristics [11].

The aim of this paper is to introduce heat into the fuel line of an internal combustion engine to investigate its potential benefits in terms of fuel consumption, power and thermal efficiency. This is done by designing a heat exchanger capable of heating the fuel. Then the heat exchanger is fabricated and fitted to an IC engine fuel line. Subsequently, the various test was carried out which the results were used to deduce the effect of the heating the fuel on the performance parameters of the internal combustion engine.

## Materials and Methods

The experiment will be done on a TD200 small test engine manufactured by TecQuipment Ltd with the specifications shown in Table 1. Figure 1 shows the designed and fabricated heat exchanger. This heat exchanger will be placed in a stainless steel container containing water which is heated using an electrical heater as shown in Figure 2. The fuel will be run through the heat exchanger as shown in Figure 3. The heat exchanger is then connected to the carburettor as shown in Figure 4. The fuel will be tested at room temperature which is 24°C and then the test is repeated with the fuel heated to 28°C till 36°C with incremental steps of 2°C. The engine will be run at 2500 rpm, 3000 rpm and 3500 rpm. Data on exhaust gas temperature, power, fuel consumption, volumetric efficiency and thermal efficiency will be obtained.

Table 1 Engine Specifications

| Item | Specification |
|---|---|
| Engine dimension with base | W 500mm x H 430mm x D 400mm |
| Fuel type | Unleaded Petrol (Ron 95) |
| Ignition system | Electric |
| Net power | 145 W at 3600 rev/min<br>102 W at 1800 rev/min |
| Bore | 70mm |
| Stroke/crank radius | 54 mm / 27 mm |
| Engine capacity | 208 cc |
| Compression ratio | 8:5:1 |
| Room Temperature | 24°C |

Figure 1: Heat exchanger

Figure 2:Electrical heater

Figure 3: Fuel run through the heat exchanger heated using the electrical heater

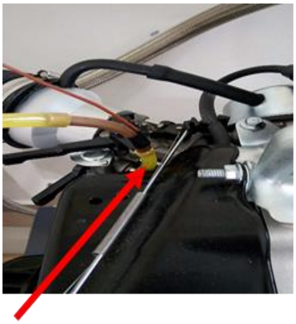

Figure 4:Heat exchanger connected carburettor

## Results and Discussions

Figure 5 shows the graph of fuel consumption against speed at different fuel temperature. The fuel at 34°C registered the lowest fuel consumption compared to the rest which is 6.9 ml/min at 2500 rpm, 7.6ml/min at 3000rpm and 10.4 ml/min at 3500 rpm. When the temperature of the fuel is at 36°C, fuel consumption is the highest which is at 2500 rpm is registered at 8.1 ml/min while consumption at 3500 rpm is at 12 ml/min. The difference between 34 °C and 36 °C is at an average of 13%. The fuel that enters the combustion chamber at room temperature registered 7.2 ml/min, 8.6 ml/min and 11.5 ml/min for the speed of 2500 rpm, 3000 rpm and 3500 rpm respectively. These values compared to when the fuel heated to 34°C shows that fuel consumption improved by a maximum of 11.5% when heated.

Figure 6 shows the exhaust gas temperature when the engine is operated at various speed. Generally, the exhaust temperature increases as the engine speed increases. The fuel at room temperature for 2000 rpm, the exhaust gas temperature is 382°C and peaks at 632°C at 3500 rpm which is the lowest compared to the heated fuels. The difference between the lowest and highest temperature is in the range of 39%. The highest exhaust temperature was produced by fuel heated to 32°C which is 495°C at 2000 rpm rising to 715°C at 3500 rpm Common assumption of the exhaust gas temperature is that the temperature reflects the air and fuel mixture. This means that if the exhaust gas temperature is high then the combustion in the chamber is lean and vice versa. The temperature measured is usually at the specific area of the exhaust where the sensing unit is installed. The temperature registered at the sensing point is not as critical as the temperature of the burning gas in the combustion chamber. However, this does not mean it is less important because it is not practical or possible to measure the temperature inside the combustion chamber. Therefore this temperature is a representative measurement of the burning gas as it exits from the combustion chamber. The registered exhaust gas temperature does not reflect the actual combustion temperature in the combustion chamber rather the temperature at a location away from the combustion chamber.

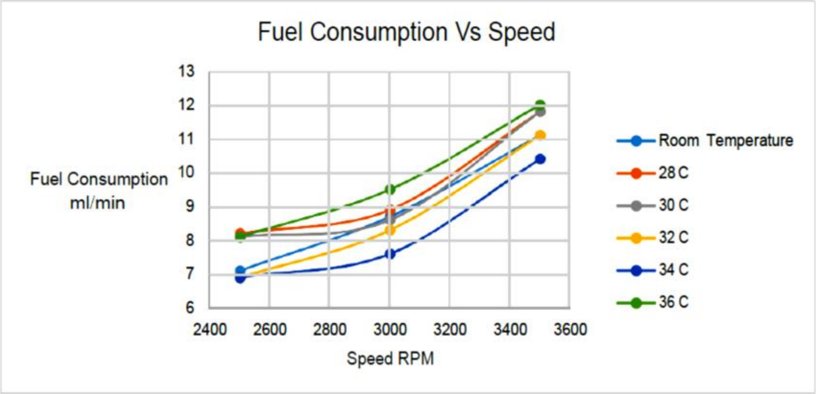

Figure 5: Fuel consumption and speed for various fuel temperature

Figure 7 shows the power against speed produced by the fuel when heated to the various mentioned temperatures. From the graph, it can be seen clearly that all test shows a gradual and steady increase in power as the engine speed increase. From the graph, the fuel temperature of 32 °C produces the least power during the experiment, registering 33 Watts at 2500 rpm and reaching a peak of 85 Watts at 3500 rpm. Based on figure 6 the fuel at 32°C showed the highest exhaust temperature. This observation enforces that the lean burning of fuel would produce low power. Meanwhile, when the fuel temperature is at 30 °C, power produced is at the highest which stands at 154 Watts compared to the rest of the fuel at other temperature.

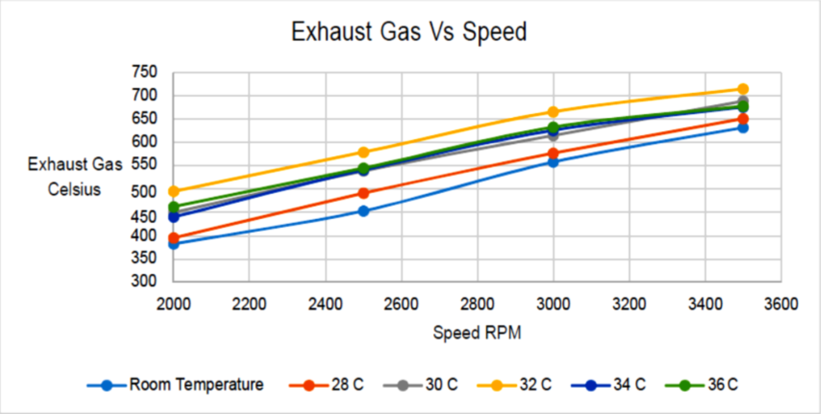

Figure 6: Exhaust gas temperature and speed for various fuel temperature

Figure 7: Power and speed for various fuel temperature

Figure 8 shows the graph of thermal efficiency against speed. From the graph, at the speed above 2500 rpm, the lowest thermal efficiency is at 16 per cent for fuel at 32 °C. Experiment on fuel at a temperature of 30 °C reveals that the thermal efficiency is the highest among the rest with data showing 28, 3.1 and 2.7 per cent for 2500, 3000 and 3500 rpm respectively. The fuel heated to 30°C is also the fuel that produced the highest power. Therefore it could be said that a high thermal efficiency would yield high power in the internal combustion engine. The vice versa can also be said to be true based on the lowest thermal efficiency of the fuel heated to 32°C at 2000 rpm but at 3000 rpm and 3500 rpm, the lowest thermal efficiency is from the fuel heat to 34°C. Note that the fuel heated to 34°C is the fuel that showed the lowest fuel consumption based on Figure 5. This is because thermal efficiency is calculated based on the percentage ratio of the heat energy input to the internal combustion engine and the work output from the internal combustion engine. Therefore when the heated fuel gave a high input of heat energy into the engine resulting in low fuel consumption, the power produced was also low leading to a low thermal efficiency.

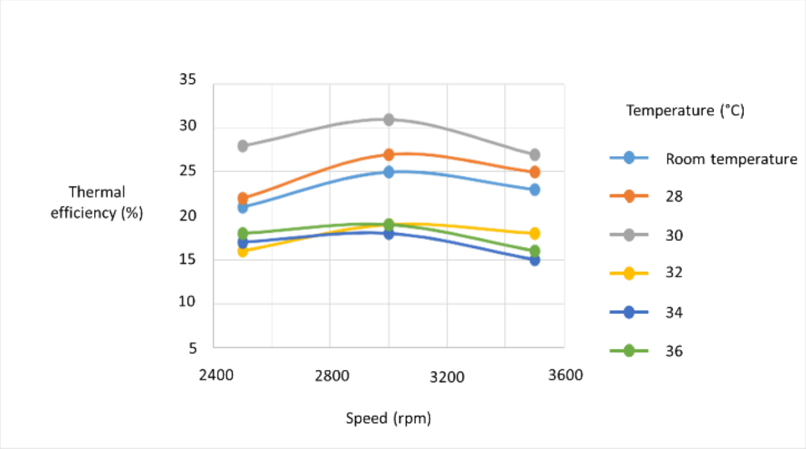

Figure 8: Thermal efficiency and speed for various fuel temperature

## Conclusion

The heating of fuel has been proven to improve on fuel consumption while compromising on the power output and the thermal efficiency of the internal combustion engine. The results also have shown that the high exhaust temperature indicated low power where else the high thermal efficiency related to high power output from the internal combustion engine. An economical way for the implementation of the proposed method would be by heating the fuel using the heat waste through the exhaust gas or the cooling fluid which cools the engine. This coupled with the existing eco-mode function available in the modern car has the potential to further optimize the driving experience in terms of power or fuel economy.

## References

[1] T. L. Bergman, A. S. Avine., D. P. Dewitt, F. P. Incropera,. Fundamentals of Heat and Mass Transfer. 2007.

[2] B. Orr, A. Akbarzadeh, M. Mochizuki, and R. Singh, “A review of car waste heat recovery systems utilising thermoelectric generators and heat pipes,” Applied. Thermal. Engineering., 2015.

[3] M. Hatami, D. D. Ganji, and M. Gorji-Bandpy, “A review of different heat exchangers designs for increasing the diesel exhaust waste heat recovery,” Renewable and Sustainable Energy Review., (37), 168–181 (2014).

[4] [4] S. Nadaf and P. Gangavati, “A review on waste heat recovery and utilization from diesel engines,” International Journal of Advanced Engineering. Technology., (5), 31–39, (2014).

[5] K. Choi, K. Kim, and K. Lee, “Effect of the heat exchanger in the waste heat recovery system on a gasoline engine performance,” Proceedings of the Institution of Mechanical Engineers. Part D Journal of Automobile. Engineering, ( 229), 506–517 (2015).

[6] H. R. Allahyar, F. Hormozi, and B. Zarenezhad, “Experimental investigation on the thermal performance of a coiled heat exchanger using a new hybrid nanofluid,” Experimental Thermal and Fluid Science ( 76), 324–329 (2016).

[7] Huminic, Gabriela, and Angel Huminic. "Heat transfer characteristics in double tube helical heat exchangers using nanofluids." International Journal of Heat and Mass Transfer. (54), 4280-4287 (2011).

[8] E. Borquist, S. Thapa, and L. Weiss, “Experimental and lattice Boltzmann simulated operation of a copper micro-channel heat exchanger,” Energy Conversion and Management.,(117), 171–184 (2016).

[9] Z. Wang, J.-X. Wang, S.-J. Shuai, G.-H. Tian, X. An, and Q.-J. Ma, “Study of the Effect of Spark-Ignition on Gasoline HCCI Combustion,” Proc. Inst. Mech. Eng. Part D J. Automobile. Engineering., (220), 817–825 (2006).

[10] Y. Huang and G. Hong, “Investigation of the effect of heated ethanol fuel on combustion and emissions of an ethanol direct injection plus gasoline port injection (EDI+GPI) engine,” Energy Conversion and Management., (123), 338–347 (2016).

[11] M. Karabektas, G. Ergen, and M. Hosoz, “The effects of preheated cottonseed oil methyl ester on the performance and exhaust emissions of a diesel engine,” Applied. Thermal. Engineering., (28), 2136–2143 (2008).