Application of Green Technologies for UTHM in Realizing the Green Campus Concept

Mohd Faisal Hushim[1,*], Ahmad Jais Alimin[1], Md Nor Anuar Mohammad[1], Rais Hanizam Madon[2], Shahrul Azmir Osman[1], Shahrin Hisham Aminordin[1], Hamidon Salleh[2], and Mohd Faizal Mohideen Batcha[2]

[1]Automotive Research Group (ARG)
[2]Energy Technologies Research Group (EnRG)
Department of Plant and Automotive Engineering
Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia (UTHM)
Parit Raja, Batu Pahat, 86400 Johor
Malaysia

*mdfaisal@uthm.edu.my

Abstract:
Greenhouse gas (GHG) emissions are of increasing concern due to their impacts on the global warming. Many ongoing researches in this area are focusing on investigating solutions to reduce GHG emissions and their detrimental impacts to human and environment. This paper discusses the strategies proposed by Automotive Research Group and Energy Technologies Research Group under the faculty to promote the sustainability and green campus concept in Universiti Tun Hussein Onn Malaysia. Steps being proposed include the application of conventional and innovative technologies such as: fuel-injection retrofitting-kit, mono-gas retrofitting-kit, waste heat recovery system and usage of biodiesel for diesel fuelled vehicles. With these strategies, the groups expected that reduction in emission footprint can be achieved, while at the same time, promoting green technologies and green campus concept to the university.

1. Introduction

Greenhouse gas (GHG) emissions are of increasing concern due to their impacts on the global warming. The seven main GHG are: Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulfur Hexafluoride (SF_6) and Carbon Monoxide (CO).

In tackling the GHG emissions, Automotive Research Group (ARG) and Energy Technologies Research Group (EnRG) under the Department of Plant & Automotive Engineering, Faculty of Mechanical & Manufacturing Engineering (FMME) are actively promoting 'green campus' and sustainable energy for implementation in the university. Both groups are acting as Sustainable Campus Transportation System Task Force (CSTS) under Sustainable Campus Unit (SCU), Universiti Tun Hussein Onn Malaysia.

ARG and EnRG have put forth strategic efforts to understand these important environmental issues and find effective and innovative solutions, as well as looking forward for the future. While steady progress has been made, some innovative technologies have been initiated. Improved fuelling system, exhausts after treatment systems, catalyst technologies are under development, with alternative fuels playing important roles.

Due to the increasing number of vehicle users among students and staffs annually, fuel efficiency and exhaust emissions are two main concerns that must be addressed. Fuel-injection retrofitting-kit and mono-gas retrofitting-kit are among the novel fuelling management system-kit that can easily be retrofitted to any vehicle with minor modifications that can promote fuel economy and environmental friendly. In addition, alternative propulsion vehicles, such as electric vehicle & hybrid also can reduce emission footprint in the campus.

Shifting to alternative fuels can also bring significant reductions in GHG emissions and oil used. There are many potential alternative fuels including natural gas and biodiesel.

2. Fuel-injection retrofitting-kit

Motorcycles are the main option as a medium of transportation among students and staffs. The motorcycle is a very popular vehicle for transportation due to its mobility, convenience, economy, and door-to-door functions. One advantage of motorcycles is their high power to weight ratio gives them good fuel economy.

Traditionally, small capacity engines employed the use of carburettors to control the amount of air and fuel that entered the combustion chambers.

The demand for small capacity engines with high power to weight ratio and low emissions is well known [1-2]. Fuel injection system can substantially lower consumption and emissions when compared to conventional vehicles, no matter what fuel they use [2].

There are three ways to reduce emissions form spark-ignition engines which are; changes in engine design, combustion conditions, and catalytic after-treatment. Some of the variables of the engines and combustions that affect emissions are the air-fuel ratio, ignition timing, and turbulence in combustion chamber. Among these variables, air-fuel ratio is the most importance variable that needs to be focused on. Air-fuel ratios for the internal combustion engine are controlled by fuelling system which is either by using carburetor system or fuel injection system.

For small gasoline-fuelled engines (below 250cc), a carburetor system is still favourable. It is proven for many years that such system is cheap and easy to maintain. However, Komuro et al. [3] and Latey et al. [4] have shown that there are much improvement can be made by converting the carburetor system to a fuel injection (FI) system alone. The fuel economy may be improved as much as 6% [3]. Moreover, hydrocarbon (HC) and CO emissions may be reduced up to 26% and 70% respectively [4].

Fig. 1 shows that the prototype of port-fuel injection retrofit-kit that have been developed by ARG's team.

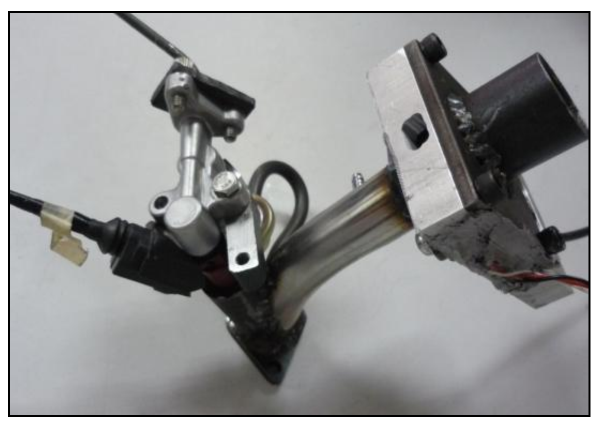

Fig. 1: Port-fuel injection retrofit-kit prototype.

3. Dedicated mono-gas Fuelling System

Natural gas (NG), or commonly known as compressed natural gas (CNG), which is primarily composed of methane, is regarded as a promising alternative to replace the use of gasoline and diesel fuels for internal combustion engines. CNG offers various advantageous; among others, higher hydrogen to carbon ratio (H/C) and research octane number. CNG octane number is in the range of 120 to 130, compares to 93 to 97 for gasoline. Additionally, CNG fuel cost is lower and it produces lower exhaust gas emissions. Current researches in the usage of CNG are divided into three main concepts: dual-fuel (mixing of primary and secondary fuels), bi-fuel (alternate usage) and mono-fuel (totally using CNG). The mono-fuel study uses a specialised or dedicated engine, which needs to be designed and optimised to operate using CNG as the sole fuel source. This enables the characteristic of natural gas to be fully exploited, but accurate modifications of the engine are important. Until now, most of the CNG engines are simply conversions from either petrol or diesel, which far from the optimum design [5].

Since fuel cost is a major portion of total operating costs for heavy duty market especially for vehicle fleet of logistic and haulage companies as well as city transit fleets, any increase in costs here are not readily accepted [6]. Therefore, individual or companies who use the diesel engines for their applications expect the natural gas replacement engine to have similar reliability and durability equivalence performance [6]. The main problem with dual-fuel operation in CNG engine was the drop in efficiency and power output with respect to engine fuelled using diesel only, due to loses in volumetric efficiency, flame speed and drop in compression ratio [6-10].

Due to interest on CNG, ARG has initiated a mono-gas fuelling system for retrofitting a diesel fuelled engine using compressed natural gas (CNG). It is proven that the gas fuelled spark ignition (SI) engines and compression ignition (CI) engines are very ecological drive for the motor vehicles [7].More important is emission reduction where gas fuelled engines having reduction of more than 10 times compared to CI and SI engines [7].

Moreover, CNG itself also offers various advantageous; fuel cost is much lower and it produces lower exhaust gas emission compared to both conventional fuels. The operational cost of a vehicle using CNG is one third of using petrol as fuel [11]. Additionally, total engine efficiency using CNG as a fuel also increased approximately up to 12% [9].

4. Waste Heat Recovery System

Waste heat recovery system (WHRS) is considered to be an important method among renewable energy processes because of its capability to generate power from the available waste heat and natural heat sources, such as solar radiation, ocean thermal sources, geothermal sources, biomass, and waste heat from engine combustion or industrial processes [12-17]. The production of the waste heat from industrial and combustion processes happen due to the limitation of the present technology to utilize all the heat energy generated as useful energy, and the present technology designs were not considered to cater such waste heat condition.

Beginning with the WHRS for automotive application, a research under the ARG’s group has been initiated to recover the heat released from internal combustion engines. Besides the main research objective to improve the thermal efficiency of automotive engines, the clear benefits from the application of WHRS include: reduction in fuel consumption and cost of fuel [18-20], and reduction in pollution emitted to the environment (i.e. thermal and air pollution) [20]. It has been highlighted that even modern automotive engines, approximately 40% of the maximum thermal efficiency can be achieved, and at least 60% of the total combustion energy is lost via exhaust and engine coolant [14]. Therefore, the application of WHRS into automotive particularly into the exhaust and cooling system will be the important approach to reduce the energy lost from the automotive engine.

There are three research stages to be tackled: study on preliminary model and simulation, development of experimental rig, and onboard prototype. The WHRS applied in the research is based on a thermodynamic Rankine cycle, and schematic diagram of its model is shown in Fig. 2 which comprises boiler (1), expander (2), condenser (3), working fluid tank (4), pump (5) and working fluid (not shown in the figure).

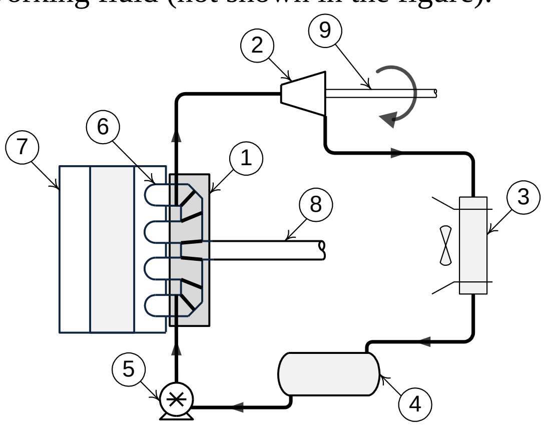

Fig. 2: Schematic diagram of WHRS model.

The WHRS operation begin with pump (5) deliver the working fluid from tank (4) to evaporator (1) to recover the waste heat released by the engine (7) through exhaust manifold (6) and pipe (8). Inside evaporator, the working fluid temperature and pressure increased due to high temperature exhaust heat and then change its state from liquid to superheated vapor. This superheated vapor is converted into rotation power when it expands in the expander (2). The output power of WHRS is measured through expander shaft (9). Low-pressure vapor leaving the expander (2) is then condensed at the condenser (3) before it is returned to the tank (4) to complete a cycle of WHRS operation. The system will continuously circulate the working fluid through the entire cycle for the next cycle operation.

In order to meet the regulation of GHGs reduction [21], a new type of refrigerant called HFO-1234yf (2,3,3,3-tetrafluoropropene) will be introduced as working fluid for the WHRS in this research. This refrigerant exhibits more desirable properties than the present refrigerants. Spatz and Minor [22] reported that HFO-1234yf has excellent environmental properties such as a low global warming potential (GWP), zero ozone depletion potential (ODP), and a favourable life cycle climate performance (LCCP). The feasibility of the fluid to be a working for WHRS is currently being investigated by ARG's group.

5. Biodiesel

Biodiesel is an alternative diesel fuel that is biodegradable and nontoxic, derived from the transesterification of vegetable oils, animal fats, or waste frying oils with alcohols to give the corresponding fatty acid either methyl or ethyl esters [23]. Due to the increasing price of petroleum fuel, many countries has shown their interest to use and doing research in this area [24].

Biodiesel can be used as blended fuel or in its pure form, in compression ignition engine; either with minor or without modification to the engine [23, 25]. With these potentials, UTHM under the FMME is currently in the process of commissioning biodiesel fuel production capability for use by in-campus diesel vehicles and equipment. With this developed biodiesel power plant, it serves as a basis for large scale and commercial utilization.

As transport sector is a main source of GHG and other air pollutant emissions, it is imperative to apply biodiesel that are produced from our own production plant in all UTHM's transport sector.

Usage of biofuels, specifically biodiesel, will reduce the total carbon footprint with regards to energy used for transportation.

Summary

By adapting all the proposed technologies, the research group expect they will reduce the amount of total carbon footprint with regards to energy usage for transportation. At the same time it will improve the quality of life for the campus community. Green campus concept can also be a marketing tool for attracting new students by promoting the campus as 'green' which is fast becoming a buzz-word among the collegiate community.

References:

[1. Hayakawa, K., et al., *125cc Small Engine Fuel Injection System with Low Emissions Solutions.* SAE Technical Paper, No. 2004-32-0094, 2004.

2. Mohd Faisal Bin Hushim, et al., *A Review and Investigation on Port-fuel Injection for Small 4-stroke Single Cylinder Engine*, in *Postgraduate Seminar 2010 (PGS2010)*. 2010: Universiti Tun Hussein Onn Malaysia (UTHM).

3. Komuro, K., et al., *Fuel Injection System of Air-cooled Engines for Small Displacement Motorcycles.* SAE Technical Paper, No. 2005-32-0035, 2005.

4. Latey, A.A., et al., *Gasoline Fuel Injection Investigations on Single Cylinder SI Engine.* SAE Technical Paper, No. 2005-26-012, 2005.

5. Semin, A. Idris, and R.A. Bakar, *An Overview of Compressed Natural Gas as an Alternative Fuel and Malaysian Scenario.* European Journal of Scientific Research, 2009. **34**(1): p. 6-15.

6. D.S.Shin, et al. *Development of a Natural Gas Fueled Daewoo 11.1L Engine*. in *FISITA World Automotive Congress*. 2000. Seoul, Korea.

7. Beroun, S. and J. Martins, *The Development of Gas (CNG, LPG and H2) Engines for Buses and Trucks and their Emission and Cycle Variability Characteristics.* Society of Automotive Engineers, 2001. **21**: p. 0144.

8. Cho, H.M. and B.-Q. He, *Spark ignition natural gas engines—A review.* Energy Conversion and Management, 2007. **48**: p. 608–618.

9. Korakianitis, T., A.M. Namasivayam, and R.J. Crookes, *Natural-gas fueled spark-ignition (SI) and compression-ignition (CI) engine performance and emissions.* Progress in Energy and Combustion Science, 2011. **37**(1): p. 89-112.

10. Zeng, K., et al., *Combustion characteristics of a direct-injection natural gas engine under various fuel injection timings.* Applied Thermal Engineering, 2006. **26**: p. 806–813.

11. Rosli, A.B., A.S. Mardani, and W.H. Mun. *Towards the implementation of CNG engine: A literature review approach to problems and solution*. in *BSME-ASME International Conference on Thermal Engineering*. 2002. Dhaka.

12. Saitoh, T., N. Yamada, and S.-I. Wakashima, *Solar Rankine cycle system using scroll expander.* Journal of Energy and Engineering, 2007. **2**(4): p. 708-719.

13. Teng, H., *Improving fuel economy for HD diesel engines with WHR Rankine cycle driven by EGR cooler*

heat rejection. SAE Technical Paper No. 2009-01-2913, 2009.
14. Ringler, J., et al., *Rankine Cycle for Waste Heat Recovery of IC Engines.* SAE Technical Paper No. 2009-01-0174, 2009.
15. Yamada, N., A. Hoshi, and Y. Ikegami, *Performance simulation of solar-boosted ocean thermal energy conversion plant.* Renewable Energy, 2009. **34**(7): p. 1752-1758.
16. Tchanche, B.F., et al., *Fluid selection for a low-temperature solar organic Rankine cycle.* Applied Thermal Engineering, 2009. **29**(11-12): p. 2468-2476.
17. Kosmadakis, G., D. Manolakos, and G. Papadakis, *Parametric theoretical study of a two-stage solar organic Rankine cycle for RO desalination.* Renewable Energy, 2010. **35**(5): p. 989-996.
18. Zhang, L. and T. Akiyama, *How to recuperate industrial waste heat beyond time and space.* International Journal of Exergy, 2009. **6**(2): p. 214-227.
19. *Tapping Industrial Waste Heat Could Reduce Fossil Fuel Demands*. 2009 4 April 2009 [cited 2011 10 March 2011]; ScienceDaily:[Available from: http://www.sciencedaily.com/releases/2009/04/090401102235.htm.
20. Chiriac, R. and G. Descombes, *Fuel consumption and pollutant emissions reduction for diesel engines by recovery of wasted energy.* Environmental Engineering and Management Journal, 2010. **9**(10): p. 1335-1340.
21. Takizawa, K., K. Tokuhashi, and S. Kondo, *Flammability assessment of $CH_2=CFCF_3$: Comparison with fluoroalkenes and fluoroalkanes.* Journal of Hazardous Materials, 2009. **172**(2-3): p. 1329-1338.
22. Spatz, M. and B. Minor. *HFO-1234yf low GWP refrigerant: A global sustainable solution for mobile air conditioning, Honeywell/ DuPont Join Collaboration*. in *SAE 2008 Alternate Refrigerant Systems Symposium*. 2008. Scottsdale, Arizona, USA: SAE.
23. Lin, Y.-f., Y.-p.G. Wu, and C.-T. Chang, *Combustion characteristics of waste-oil produced biodiesel/diesel fuel blends.* Fuel, 2007. **86**(12-13): p. 1772-1780.
24. Bozbas, K., *Biodiesel as an alternative motor fuel: Production and policies in the European Union.* Renewable and Sustainable Energy Reviews, 2008. **12**(2): p. 542-552.
25. Tesfa, B., et al., *Prediction models for density and viscosity of biodiesel and their effects on fuel supply system in CI engines.* Renewable Energy, 2010. **35**(12): p. 2752-2760.