A study of performance of a diesel engine fueled with emulsified biofuel and its blends

M.F.Hamid¹, M.K. Abdullah²*, M.Y. Idroas¹, Z.A. Zainal Alauddin¹, C.M. Sharzali¹, M.A.M. Naser², and S.R. Khimi²

¹School of Mechanical Engineering, Universiti Sains Malaysia, Engineering Campus, Penang, Malaysia
²School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia, Engineering Campus, Penang, Malaysia

Email: mkhalil@usm.my

Abstract. Diesel and natural gas are most popular fuels application in the natural aspirated (NA) compression ignition (CI) engine. However, burning fossil fuel results in serious environmental changes i.e. global warming. The direct use of liquid biofuel to the engine can harm the engine system, engine performance, and emission. To mitigate this problem, it is necessary to change biofuel’s properties. Emulsification techniques are one of the possibility to obtain the emulsified biofuel (EB). However, EB has an undesirable higher viscosity, larger and heavier molecules which lead to lower atomization and less mixing with fuel-air mixing. Therefore, a proper mixture of surfactant and co-surfactant is focused on this study. The combination of two different types of surfactant possible to reduce surface tension and improved atomization during injection. The 2% of surfactant agent mixture containing 60% of span-80 and 40% of Tween-80 is the best formulation. EB 5% shows the stable solution and produced the closest result to fossil diesel curve performance.

Keywords: Compression ignition (CI) engine, Biofuel, Emulsified biofuel, Emulsifier, Diesel engine

1. Introduction

Compression Ignition (CI) engines are become most popular power generation basis and widely used in both heavy and light duty transportations [1]. They are most reliable and powerful in term of fuel efficiency. Contrasting with spark-ignition (SI) or known as a gasoline engine, diesel engine technology used high compression ratios and combust via elevated temperature of the air in the cylinder due to mechanical compression (adiabatic compression) [2]. However, great achievement of diesel engine power generation are overshadowed by its emission poison like PM (particulate matters), Soot, THC (total hydrocarbons), NOx, SOx, and CO. These emissions effect have contribute to the adverse health and environmental issues [3]. Moreover, strict regulations imposed by many European countries have restricted many application in various field and reduce the potential of this engine to be used in a near
future power generation. The extensive efforts have been made by engine manufacturers, researchers, and scientists to control emission emitted by this CI engine such as external devices and chemical, but only a few to a certain extent [4]. To mitigate this matter, exploring a new renewable energy source to replace fossil fuel are substantially being conducted globally. The used of biofuel, particularly made from palm oil is among the popular fuels to be discover on their potentials.

Burning the biofuel to the engine has improved emission indirectly due to the high oxygen content of biofuel [5]. However, straight application biofuel to the engine are strictly prohibited since it will harmful the engine such as carbon deposit, injector clogging, and incomplete combustion. This problem can be tackled fundamentally either need to improve via engine hardware system or improved the chemical properties of biofuel [6]. Improved the chemical properties of biofuel is seen feasible techniques and no modification required on the engine [7]. The most popular techniques is emulsification techniques which considering water in the fuel system [8]. Water present in the fuel system will reduce the emission of NOx, reduce the temperature in the combustion chamber and improve combustion as well via micro-explosion effect [9]. Introducing water in fuel system as such as thrust boosters or power supplements for fuel system. Azahari et al. [10] have studied the effect of water in diesel (W/O) emulsion with combination of surfactant type of Span 80 and Tween 80. They found that the 15% of water content will reduce almost 71% of reduction in PM emission. It is because of micro-explosion effect aids in faster fuel breakdown, allowing them for secondary atomization due to different boiling point of each fuel and improved injection penetration because of different fuels density.

To obtain an economic and environment-friendly engine fuel from biofuel, it is necessary to modify the biofuel chemical properties such as viscosity, surface tension, phospholipids, free fatty acids, sterols and moisture content [11]. Nevertheless, the high surface tension and viscosity of biofuel is the main obstacle confronted before any emulsification approach will be introduced [12]. Emulsification system consists of two immiscible and miscible fluids and form together to be a stable solution [13]. To stabilize emulsification in biofuel system, the combination of two types of surfactant agent has been refocused. A surfactant molecule has two parts of affinity; affinity for water and affinity for oil [14]. The concentration of surfactant and water quantity in the emulsion play a major role as well as the suitable combination of dual surfactants [15]. The combination of dual surfactants will specify the suitable value of HLB number. In this paper, the effect of formulation of surfactant agents on palm oil biofuel and its effect on the engine performance running with using emulsified biofuel as a primary fuel in diesel engine has been investigated.

2. Experimental study

2.1 Materials

The palm oil used in the present study for emulsified biofuel were collected from School of Mechanical Engineering, Universiti Sains Malaysia, and surfactant agents were purchase from CSI Labshop Malaysia. Two types of surfactant agents used were Tween 80 and Span 80.

2.2 Experiment engine setup

The setup as shown in Figure 1 consist of one cylinder, four-stroke Yanmar L70AE diesel engine connected to eddy current type dynamometer for loading (15kW). Provision is also made for interfacing airflow, fuel flow, temperatures and load measurements. Exhaust was assembled with ventilation system and the water cooling system was turned on. For initially, the fossil diesel was run, the torque data was collected and compared with standard manual performance given by manufacturer to validated 0purposed. The pure biofuel and EB was run then and the data was collected.
3. Results and discussion

3.1 Physiochemical characteristic of emulsified biofuel

Emulsified biofuel (EB) properties is a basic study to determine the liquid characteristics. The properties of EB is a vital stage to experiment. The testing was based on the American Society of Testing and Materials (ASTM). It was observed that, the increased of water percentage will increase the viscosity. It will benefit during injection due to different boiling point of auto ignitions [16].

Table 1. Physiochemical properties of EB

| EB/Test | Specific weight (ASTM D854) | Kinematic Viscosity (at 40°C) (ASTM D445) | Calorific value (ASTM 2382) | Poor Point (ASTM D97) | Flash Point (ASTM D93) |
|---------|-----------------------------|------------------------------------------|-----------------------------|-----------------------|------------------------|
| Neat Biofuel | 8.83 | 31.7 | 41.3 | 16 | 310 |
| 1% of EB  | 8.87 | 32 | 40.3 | 16.5 | 313 |
| 2% of EB  | 8.88 | 33.0 | 39.8 | 17 | 315 |
| 3% of EB  | 8.89 | 33.5 | 39.4 | 18.5 | 319 |
| 4% of EB  | 8.90 | 34.5 | 39.2 | 19 | 325 |
| 5% of EB  | 8.91 | 35 | 39 | 19.5 | 332 |
3.2 Engine torque

Figure 2 shows that diesel fuel produced higher torque performance curve compared to that of other biofuels. The higher torque was generated via diesel due to its lower viscosity and more complete combustion. Higher engine torque can be initially observed and it consequently decrease due to friction losses (negative torque). EB5 produced almost near to diesel and pure biofuel generated lower torque. EB produced a micro-explosion phenomenon and it’s depend on the water droplet size or water volume. EB5 is closer to diesel performance is because it consist of bigger water dispersed phase size and providing additional energy from water explosion.

![Engine Torque against engine speed](image)

**Figure 2.** Engine Torque against engine speed

3.3 Brake power

The brake power produced by the engine using pure diesel, pure biofuel, and EB is presented in this section under variable conditions and speeds. Figure 3 shows that the brake power gradually increases with the increase of engine speed. Diesel fuel produced the maximum speed compared to EB. It was found that EB5 is much closer to diesel performance curve. This is because of the influence of the composition water volume in biofuel consequently improve combustion efficiency, improve the retardation of flame propagation, prolong the ignition delay and lower the rate of pressure in combustion.
4. Conclusion

The experiment investigation fueled with diesel, pure biofuel and EB has been conducted. The results of EB were compared with diesel and pure biofuel in order to validate and enhance the understanding of performance characteristic, influence of water disperse phase, water volume, and air-fuel mixing process of EB. EB is a mixture of two immiscible liquids. In order to ensure the mixture between them is homogeneous, surfactant agent is used to weakening the surface tension. 2% of surfactant agent mixture containing of 60% of span-80 and 40% of Tween 80 is the best formulation. EB5 is a more reliable solution and produced closest result to diesel curve performance, with an approximately 15% total difference in overall. This was effect from micro-explosion phenomenon and the water sized gave influence of results during combustion.

5. Acknowledgement

This study was funded by Research University Grant Scheme (Project code of 1001/PBAHAN/8014006).

References

[1] Hamid, M. F., Idroas, M. Y., Basha, M. H., Sa’Ad, S., Mat, S. C., Abdullah, M. K., & Zainal Alauddin, Z. A. 2016 MATEC Web of Conferences 90
[2] Heywood, J. B. 1988 Internal Combustion Engine Fundamentals. McGrawHill series in mechanical engineering 21
[3] Chen, S. M., & He, L. Y. 2014 China Economic Review 31 106
[4] Tartakovsky, L., Baibikov, V., Czerwinski, J., Gutman, M., Kasper, M., Popescu, D., Zvirin, Y. 2013 Atmospheric Environment 64 320
[5] Hamid, M. F., Idroas, M. Y., Ishak, M. Z., Zainal Alauddin, Z. A., Miskam, M. A., & Abdullah, M. K. 2016 BioMed Research International 2016
[6] Vallinayagam, R., Vedharaj, S., Yang, W. M., Lee, P. S., Chua, K. J. E., & Chou, S. K. 2014 Applied Energy 130 466
[7] Wong, K. I., Vong, C. M., Wong, P. K., & Luo, J. 2015 Neurocomputing (Part A) 397
[8] Mrad, N., Varuvel, E. G., Tazerout, M., & Aloui, F. 2012 Energy 44 955
[9] Demirbas, A. 2008 *Energy Conversion and Management* 49 2106
[10] Azahari, S. R., Salahuddin, B. B., Noh, N. A. M., Nizah, R., & Rashid, S. A. 2016 *Biofuels* 7 337
[11] Kannan, T. K., & Marappan, R. 2011 *Journal of Applied Sciences* 11 2961
[12] Koc, A. B., & Abdullah, M. 2013 *Fuel Processing Technology* 109 70
[13] Debnath, B. K., Sahoo, N., & Saha, U. K. 2013 *Energy Conversion and Management* 69 191
[14] Lin, Y. S., & Lin, H. P. 2011 *Renewable Energy* 36 3507
[15] Nadeem, M., Rangkuti, C., Anuar, K., Haq, M. R. U., Tan, I. B., & Shah, S. S. 2006 *Fuel* 85 2111
[16] Hamid, M. F., Idroas, M. Y., Sa’ad, S., Saiful Bahri, A. J., Sharzali, C. M., Abdullah, M. K., & Zainal, Z. A. 2018 *Renewable Energy* 127 84