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Potential utilization of biodiesel as alternative fuel for compression ignition engine in Malaysia

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Abstract. Biodiesel is a type of fuel which is derived from various sources of vegetable plants and waste fuels. Today, numerous biodiesels have been engineered to be at par or even better in term of performance in comparison to pure diesel. Therefore, biodiesel has shown a promising sign as one of the best candidate in overcoming total dependency on pure diesel. This paper gives review on various tests and experiments conducted on biodiesel in order to highlight the potentials given by this particular fuel. In addition, providing the supporting evidences to further endorse for a mass usage of biodiesel in Malaysia – simultaneously, driving the country to become a potential global biodiesel producer in the near future. The reviewed studies were obtained mainly via indexed journals and online libraries. Conclusively, every test and study for every blend of biodiesel had shown consistent positive results in regards to performance and in overcoming emission related issues. Thus, providing the evidence that biodiesel is highly reliable. Malaysia as a semi-agricultural nation could take the advantage in becoming one of the leading global biodiesel producers. Nevertheless, this will requires total cooperation of every concerned government bodies and authorities.

1. Introduction

Global energy crisis along on both socioeconomic and environmental aspects on continuous use of petroleum derived fuels had given rise on demands for alternative fuels [1-3]. This is proven by the European Union (EU) promotion on the use of biodiesel fuels for transportation in 2003. This particular promotion has given an increment from 2%-5.75% from the year 2005-2010 [2-4]. Biodiesel is a fuel derived from natural, renewable sources, such as from new and used vegetable oils, animal fats, and recycled restaurant grease [5, 6]. This is achieved via the transesterification process to bring the viscosity and density level of the produced biodiesel fuels to be close to that of diesel [7-9]. In order to be called biodiesel, the fuel must meet the strict quality specifications of ASTM D 6751 [7]. Additionally, biodiesel is found to be diesel engine friendly [8, 3]. The aim of this study is to give review on the unique advantages in utilizing biodiesel as an alternative source of fuel and also to highlight on the extraordinary potentials of biodiesel for mass application in Malaysia in the near future.

2. Literature Review

2.1. Performance of pure biodiesel and biodiesel blends

Literature has discussed on various positive outcomes with the use of biodiesel. The advantages of biodiesel fuels are summarized as follow [1, 8, 26]:

a) Biodiesel fuels show excellent lubricity characteristics, though, most are sulphur free. These fuels were found by Alam et al. [10] and Chuepeng et al. [11] to have the capability to increase the overall engine performance and reduce particulate matter emissions.
b) Biodiesel fuels are safe to be stored and handled since they have a flash and fire point higher than 150^0C.
c) High oxygen percentage (10%) in biodiesel fuels "significantly contributes" to complete fuel combustion.
d) The cetane number (CN) for biodiesel fuels is almost similar or higher than that of diesel, though still dependent on the source. Higher CN would lead to lower ignition delay [12].

Biodiesel could be utilized either as a pure form (100% biodiesel) or blended with petroleum-based diesel fuel (biodiesel blend) "designated BXX, where XX represents the volume percentage of biodiesel fuel in the blend" (biodiesel.org). The commonly tested types of biodiesel are the 10% (B10), 20% (B20) and 100% (B100). The summary of the tests from the previous studies is presented as in Table 1 [4, 10, 11, 13-20, 30].

Table 1. Summary of tests conducted on biodiesel.

Test	Result	Percentage
Particulate matters (PM)	Significance decrement in percentage of emission	0.25±0.13%
Carbon monoxides (CO)		0.277±0.041%
Hydrocarbon (HC)		0.49±0.05%
Smoke emissions		-
Nitrogen oxides (NOx)	Increment in percentage of emission	0.186±0.022% for every 1% of biodiesel in the blend
Specific fuel consumption	Increment	0.116±0.009% (95% confidence interval) for every 1% of biodiesel
Engine relative energy conversion efficiency	Increment	Approximately 3-5% of the petrodiesel fraction

As a result, from the existence of several blends of biodiesel; Suryanarayanan et al. [21] had conducted a study to seek for the optimum blend of biodiesel "for which the best performance and/or lowest emissions are obtained". They concluded that the selection of blend must be made dependent on the goal or objective concerning the aforementioned parameters (SFC, NOx, and HC emission), as well as other factors such as cost. The summary of the comparison test from previous studies [1, 4, 8, 12-14, 19, 31, 32] among pure biodiesel (B100) and other blends of biodiesel is as shown in Table 2.

In order to totally exploit the true potential of biodiesel, the CI engine has to be specifically calibrated. Kim et al. [22] reported that "there exists optimum fuel injection pressure that has minimum droplet size when the ambient gas pressure is constant". Basavaraja et al. [3] concluded that the optimum injection pressure for operation of biodiesel is at 20 MPa. At 20 MPa calibration, exhaust temperature was reduced, maximum brake thermal efficiency obtained and combustion emissions being smoke, CO, HC, NOx and UBHC were lowered. For this operating calibration, they also recommended the usage of a B20 biodiesel (off vegetable oil ester) since the study regarded that particular blend to be the best blend in term of overall performance as oppose to other blends.

Table 2. Summary of comparison test of B100 and B20 biodiesel blends with other biodiesel blends and diesel.

Biodiesel Blends	Results summary
B100	The use of pure biodiesel (B100) in comparison to other biodiesel blends is not recommended due to having a lower brake thermal efficiency, mainly as a result from having a high viscosity level and inferior peak power of as oppose to diesel. B100 also shows a higher level of smoke, CO, HC and combustion duration, yet, relatively lower peak power NO emission and heat release rate (decrease of 9%-12%) in the maximum value of BMEP (brake mean effective pressure) and a minimal increase of fuel conversion efficiency were observed. This suggested that a pure biodiesel is not the best fuel to be used for compression ignition engines.
B20	B20 shows higher exhaust temperature due to higher mixing and diffusion of controlled combustion fractions. Also, the specific fuel consumption is higher resulting from a lower heating value and the high percentage of oxygen atom leads to late burning of heavier components of biodiesel in the expansion stroke, thus, leading to the increment of the mass average temperature and the lowering the emission of HC (by 9% lower), CO (by 3% lower), PM and smoke (by 10% lower) at 95% level of confidence. Soluable organic fraction (SOF) and sulphates were observed to have been reduced with the use of B20. Maximum engine power and torque of B20 was also observed to be at par with pure diesel blends which do not really give much disadvantages in regards to engine power, fuel consumption and NOx emission (at low injection pressure), although, minimal drop in power is almost negligible (approximately 3% and 8%).

Verhaeven et al. [4] specifically highlighted on the advantages of low blends biodiesel fuel over pure biodiesel and mineral diesel fuel. Firstly, there is no need for engine adjustments (also noted by Malhotra et al. [1], Basavaraja et al. [3], Bushnoor et al. [15] in regards to biodiesel in general). Secondly is there is no effect on fuel consumption and vehicle power and potential of emission reduction. Next is that there is better lubrication of the fuel injection system and a comparable or somewhat higher energy efficiency. Finally, there is improvement of the biodegradability of the fuel [4]. Patterson et al. [9] showed that different sources of biodiesel could give different outcome of combustion output. However, Malhotra et al. [1] specifically concluded that various biodiesels (but with B20 blends) were able to meet the diesel BIS specification. Hence, this indicated that the B20 is the most optimum blend of biodiesel which could be incorporated at a much larger scale. Though Patterson et al. [9] had carried out a study in comparing three different biodiesel fuels (rape, soy and waste oil) this study suggested for a higher variant of biodiesel fuels to be tested simultaneously in the future.

2.2. Issues with NOx emission: impact on human and the environment

Although, biodiesel have shown such a promising characteristic for a substitute from total dependent on diesel, it should be noted that almost all aforementioned studies had highlighted on the increase of NOx emission as a result from biodiesel fuel combustion. This however, will give negative impact to human and the environment.

From the observation made by this study, the main trade-off in controlling smoke emission is the increase of NOx emission [4, 10, 11, 13-20] and excessive emission of NOx that could bring catastrophic impact to both human as well as to the environment such as chronic bronchitis and pulmonary edema [24, 27, 28]. Nevertheless, continuous studies – for example, Zhang et al. [12] and Patterson et al. [9] have suggested that a specific paper that discussed on reviewing past and current studies in achieving both the control of NOx and smoke should be presented in the near future since it is a wide topic.

3. Malaysia as potential user and global producer of biodiesel

Malaysia as a semi-agricultural country has both the high potential for mass utilization of biodiesel fuel and as global producer of the fuel. Southeast Asia has a variety of sources for biofuel for instances, palm oil and coconut oil, and Malaysia is already the world's leading producer for palm oil [26]. Verhaeven et al. [4] had outlined several "conditions" which need to be considered prior to introducing biodiesel for public usage and "a number of these are already being looked into on a European level":

1. There has to be guarantee of product quality, that is, the produced biodiesel should have fulfilled certain product specifications, hence, being safe for usage.
2. The availability of raw materials either naturally or through imports
3. Industrial and government support and co-operation

Hence, it is clear that the "conditions" denoted by Verhaeven et al. [4] require the involvement of every level of individuals in the country to make full introduction and application of biodiesel fuel in the country. A report released by USDA suggests that the consumption of B10 will reach by 770 million litters in 2017 and by 2020, a 15% blend in expected for a roll-out. Hence, over the next few years, the higher blending rates combined with the increasing size of the biodiesel pool, will result in the expansion of biodiesel usage [29]. This paper truly believes that Malaysia could definitely do so, given the time and opportunity.

4. Conclusions

Conclusively, every test and study had shown consistent positive results for every blend of biodiesel in regards to performance and in overcoming emission related issues. Thus, providing the evidence that biodiesel is highly reliable. Malaysia as a semi-agricultural nation could take the advantage in becoming one of the leading countries in the world's supplier of biofuel. Nevertheless, this will require total cooperation of every concerned government bodies and authorities.

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