Biodiesel as alternative fuel for marine diesel engine applications: A review

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\begin{abstract}
Transportation and shipping activities are major contributor to air pollution at sea where most of it occurs as a result of exhaust emissions from ships. Stringent emission limitations enforced by the International Maritime Organization have hastened the need to find a new alternative fuel for marine diesel engines. Thus, biodiesel fuel was chosen as one of the environmentally friendly alternative energy that can reduce ship toxic gas emissions and at the same time reduces dependence on petroleum-based fuels. Therefore, the purpose of this paper is to provide a comprehensive review of biodiesel as an alternative fuel for marine diesel engine applications. This review covers the biodiesel fuel background, engine performance, history, recent progress, engine warranty, issues, challenges, and possible solutions on using biodiesel for marine applications. A significant number of literatures from indexed journals were cited accordingly. The results of previous studies had shown that the use of biodiesel would mostly increase the amount of brake specific fuel consumption and nitrogen oxide gas while conversely reducing other toxic gas emissions. Although a number of issues and challenges arise, most marine engine manufacturers give conditional warranty against the use of biodiesel in the engines. The study concluded that biodiesel and its blends have a bright future in the marine sector, provided some of the highlighted issues can be solved.
\end{abstract}

1. Introduction

Marine transportation activities are mostly driven by marine diesel engines due to their efficiency compared to gasoline engine. Exhaust gases from marine engines can be considered as one of the major causes of air pollution at sea \cite{1,2}. The most crucial seaborne emission released from the combustion of marine fuels consists of nitrogen oxides (NO\textsubscript{X}), sulphur oxides (SO\textsubscript{X}), carbon monoxide (CO), carbon dioxides (CO\textsubscript{2}), and particulate matter (PM). The presence of these gases will adversely affect the environment and human health with lung cancer, cardiopulmonary deaths, bronchitis, pneumonia and global warming \cite{3}. International Maritime Organization (IMO) reported that the annual shipboard CO\textsubscript{2} emissions in 2012 were 938 million tons, which constituted about 2.6% of global human-made emissions of the same substance. This scenario is expected to rise three folds by 2050 if no action is taken. Meanwhile the emissions of NO\textsubscript{X} and SO\textsubscript{X} were 15% (19 million tons) and 13% (10.2 million tons) respectively, from their global emissions \cite{4}. In order to cope with this issue, a more stringent regulation is necessary. The latest Marine Pollution (MARPOL) in Annex VI revision recommends limiting the sulphur level from the current 3.50% to 0.50%, effective January 1, 2020. For NO\textsubscript{X} emissions, it was reduced to Tier II and Tier III for global and North American Emission Control Areas, respectively since January 2016.

On the other hand, the shortage and rising cost of fossil fuels has made renewable energy more popular \cite{5}. In addition, the petroleum-based fuel resources are limited to certain countries \cite{6}. Therefore, there is a need to look for new alternative fuels to cater to the existing market. Based on previous findings, biodiesel was identified as one of the potential resources that fulfill the world's energy demand and can be a prominent candidate as alternative to petroleum-based fuels \cite{7,8}. Nowadays biodiesel, biofuel and biogas are a form of alternative energy which is rapidly gaining interest among consumers. It is an environmentally friendly energy, non-toxic and has properties similar to diesel fuel \cite{9-11}. Biodiesel can be applied in diesel engines without requiring any changes to the engine systems as their combustion characteristics are almost similar to the conventional diesel. Biodiesel fuel was discovered by Rudolf Diesel in 1912 and concluded that the use of vegetable oil would be preferred in the future \cite{12}. Biodiesel can be processed from multiple feedstocks. In Europe and the United States, rapeseed and soybean oil are typically used for the production of biodiesel. Tropical countries including Malaysia, Thailand, Indonesia, Nigeria and Colombia extract biodiesel from palm oil. Palm biodiesel that

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