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Dynamic Testing for Compatibility Assessment of Non-Metal Automotive Components with Biodiesel Fuel: A Concept Study

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ABSTRACT. Over the years, concern on the compatibility issue of the blended biodiesel fuel with non-metal material components in diesel engine vehicles had received many attentions. Assessing the compatibility of non-metal material components like elastomer and plastics usually rely on the measurement of mechanical and physical properties such as tensile strength, elongation, hardness, surface morphology, weight and volume changes. These properties are typically measured after the static immersion test is done accordingly to the ASTM D471. However, data and results given from the static immersion test is only applicable when the samples are in a static condition and not in a dynamic situation. Thus, this paper attempts to review some common issues related to the biodiesel fuel and non-metal components and introducing the dynamic testing approach that can be applied when assessing the compatibility study of biodiesel fuel with some potential problems that might be encountered.

Keywords: *Biodiesel fuel, Compatibility, Dynamic test rig, Non-metal automotive components;*

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1. INTRODUCTION

Due to the lessen of fossil fuel resources, alternative or renewable fuel is not a new topic and received many interests in Malaysia. Blended biodiesel fuel derived from palm oil, for example, is widely used as transportation fuels in Malaysia and other countries. It is widely acknowledged that pure biodiesel or higher blended biodiesel fuel will be used for the increment of the energy sources for transportation in the near future.

Theoretically, biodiesel is referred as methyl ester of a fatty acid (or shortly known as FAME) which have to fulfill the ASTM D6751 specifications for use in diesel engines. Previous studies show that biodiesel helps to reduce carbon dioxide and other pollutants emission from engines [1]. Another advantage of biodiesel is, it does not require extensive engine modification in the diesel engine and can performs better due to the high cetane number [2]. It is also one of the most promising alternative fuels for diesel engines since there will be no underwater plantation, drilling and refinery. In other words, biodiesel would make an area become independent of its need for energy as it can be produce locally depending on the feed stock available in that area.

Blended biodiesel fuel is where pure biodiesel fuel (B100) is blended with diesel fuel and signified as "BXX" (e.g., B5, B10, B20), where "XX" is denoted as the volume percentage of the biodiesel content in the diesel fuel [3,4]. The implementation of blended biodiesel fuel is due to rapid growth of the studies on the production of blended biodiesel fuel from various feedstock either edible or non-edible and on the fuels efficiency in the diesel engine vehicles. In order to ensure that the blended biodiesel fuel can be used in diesel engine vehicles, the fuel properties must be corresponded to the standard provided, the ASTM D7467 [5] that covers fuel blended with the grades of 6 to 20 volume percent (%) biodiesel.

Any fluids can cause chemical degradation, swelling, cracking and extraction of additives of elastomers or rubber and plastics. The absorption of fluid into the polymer network of the elastomer can caused swelling. A general rule is that polar substances dissolves better in polar liquids and non-polar substances dissolves better in non-polar liquids [6]. As noted, the chemical structure of biodiesel is chemically different than diesel and contains more polar esters. Therefore swelling of polar elastomers is greater in biodiesel than in diesel. Swelling is observed when more liquid is absorbed than soluble components are being extracted from the rubber. Opposing, the volume decreases might be due to soluble components being replaced by less dense solvent molecules or that the extraction of additives is greater than the absorption of solvent [6]. Volume change is increased at higher temperatures [7].

The difference of chemical composition in biodiesel fuel shows an important reason for why the compatibility of non-metals material in diesel engines should be further studied. Nevertheless, the compatibility of biodiesel with non-metals components that includes elastomers and plastic that are widely used in diesel engines has not been fully explored, and to date, few papers discussing this issue have been published.

2. NON-METALS COMPATIBILITY.

The effect of biodiesel or blended biodiesel fuel on engine performances and emissions had been undertaken in a gradually trend and gives several good examples. However, little or not much information is known about the effect of biodiesel fuel on the non-metal automotive components like elastomer or rubber compound and plastic that usually applied as fuel transportation or sealing elements and fuel tank in the diesel engine vehicles. Fig. 1 shows some of the non-metal automotive components found in the fuel system of diesel engine.

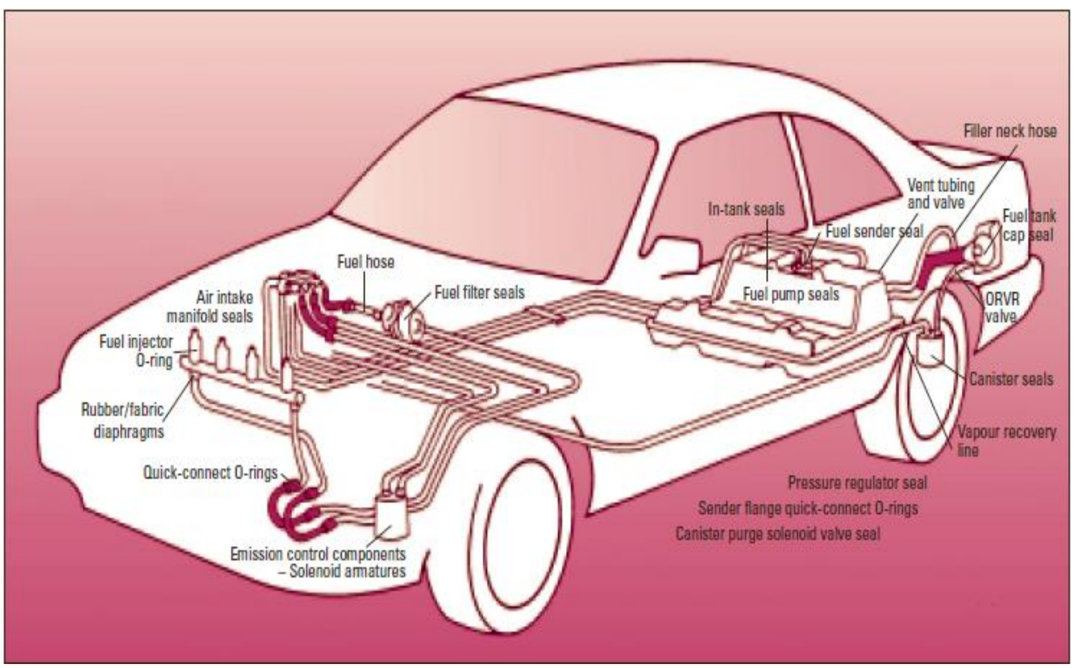

Fig. 1 Non-metal automotive components in fuel system [8]

The resistance of some non-metal automotive components like elastomer or rubber compounds are thoroughly analyzed because of the importance of these compounds in fuel system components of diesel engine as hoses, seals, and tubes. For example, nitrile butadiene rubber (NBR) is used widely to fabricate vehicular hoses and gaskets, and these components come into constant contact with fuels when the engine is running [9].

Several studies had listed out the common issue observed on engine components with the used of biodiesel fuel. Terry et. al had identified that usually there will be a possibility of the fuel injector blockage and excessive fuel injector wear corrosion on the fuel injection equipment components and significantly resulted on the elastomer and rubber seal failures [10].

Concern arises from the fact that diesel fuel and biodiesel fuel have different chemical structures and consequent different effects on the non-metal automotive components. It is because there must be a reaction occurred between the alternative fuel and the non-metal automotive components in the fuel system of diesel engine vehicles. Relatively the presence of alcohol and fatty acid methyl ester in the biodiesel fuel, potentially can deteriorates the element and may affect the material on the components of the fuel system in the diesel engine vehicle. Besides that, blended biodiesel fuels might be aggressive towards the components in the fuel system of diesel engine due to the difference of chemical composition in biodiesel fuel. Even the biodiesel fuel is mixed with the diesel fuel in small amounts, material compatibility is still one of the important issue whenever the fuel composition is changed in the fuel system [11]. This is because many components in the fuel system of diesel engine vehicles are specifically designed to run on diesel fuel which are known by the automotive industry. Moreover, biodiesel fuels are prone to oxidation upon exposure to air and storage conditions which can increase the total acidity and risk of degradation of automotive parts and components made from materials like copper and nitrile rubber [12] in the fuel system of diesel engine vehicles [13]. Previous review [14] identified that most automotive rubbers tend to swell, deteriorates and degrade when being exposed to the blended biodiesel fuel.

3. STATIC IMMERSION TEST.

Assessing the compatibility of blended biodiesel fuel with non-metal material components is challenging and needs a lot of data and information. Since the duration of usage of the non-metal components are typically some years, thus it is not realistic to perform tests for such a long time. To estimate how well a material will perform during its life time, accelerated tests are used, where there is a standard used in the industry on how to perform these tests. Usually, static immersion test are done by completely soaking the test pieces in different reference tested fuels samples at specified time and temperature upon the fuel system of diesel engine vehicle condition. The effect of fuels on the non-metal compounds are evaluated by measuring certain mechanical properties like mass change, volume change, surface morphology, hardness and tensile-stress properties [15-17]. ASTM D471 [18] provides test methods and guideline procedure on exposing the specimens to the influence of liquids or fuels for a duration of times and temperature. However there are drawbacks of this immersion test. The disadvantages of this test is that the experimental conditions are differ from the real service conditions in the fuel system of diesel engine vehicles and hence the results can be clashed. Furthermore, literatures search on the fundamental durability and resistance study of non-metal components in biodiesel fuel in dynamic condition also has shown the scarcity of publications in this field. Therefore, there is a need to study the degradation and durability of non-metal components in biodiesel fuels and to provide comparative data on the dynamic condition.

Micallef, G. [19] have compared standard laboratory testing (according to standard ASTM D2240 hardness, ASTM D412 stress-strain and ASTM D471 fluid immersion) with testing under service conditions for different fluoroelastomers in different fuels. Under service conditions, water contamination is expected, especially in biodiesel since water is more soluble in biodiesel than in diesel. The water contaminated fuel gave a large deterioration of some of the elastomers compared to standard laboratory tests and it is suggested that the water causes hydrolysis of esters in biodiesel which open up for other chemical reactions than in fuel without water. This is one of the issue of how real service conditions can give differences in properties of the non-metal automotive components.

4. DYNAMIC TEST RIG.

Fig. 2 shows the design of preliminary test rig developed for the dynamic test. This test rig is developed to undertake the compatibility of non-metal automotive component with biodiesel fuel and design based on the existance fuel system of diesel engine. The experimental test rig is also suitable to conduct various test runs under different working conditions in comparison with that of a diesel operated engine. It can be seen that the proposed test rig is a closed loop test and consist of the fuel storage tank, measuring equipments and of course the test piece of non-metal automotive components.

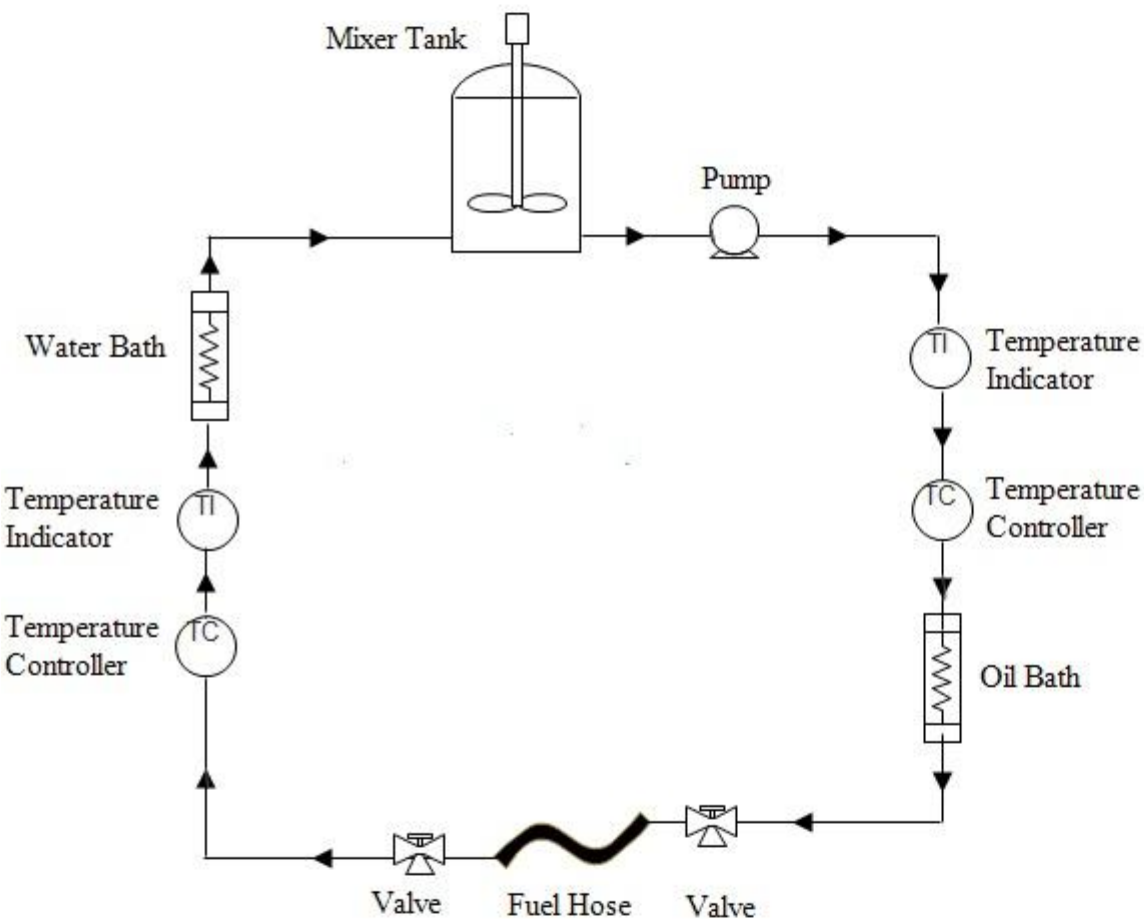

Fig. 2 Experimental dynamic test rig

This test was done dynamically in many cycles and certain period of times for different type of fuels. The fuel from the tank will be transporting and pass through the test piece of non-metal automotive components that is connected to the stainless steel tubing and then the fuel will be returning back to the storage dynamically for a period of time. A filter is located before the tank to minimize the contamination of the fuels. During this test, the samples of non-metal automotive components was maintained at specific temperature or at ambient temperature (25 ^{o}C) depending on the application. The variable parameter like pressure and flow rate were adjusted accordingly by pressure gauge and flow meter. The sampling points were located before and after the tested piece for fuel properties determination and results comparison purposes.

As in the static test, before the test started, the mass, volume, inner diameter and cross-section diameter of the fuel hose were measured as the initial data. After certain period of time and cycles, the samples were picked up and dried by air. Then, immediately after the test piece is removed from the tested fuel, the mass, volume, inner diameter and cross-section diameter of it were measured and several analysis and mechanical properties were performed for comparison purposes.

5. SUMMARY

This paper managed to highlight the common issues regarding to the compatibility of non-metal components in diesel engine with biodiesel fuel. As mention previously, non-metal automotive components presence in the fuel system of diesel engine vehicles are not in a static condition. Thus, with the dynamic test rig approach that considering different parameters such as temperature, pressure, fuel composition and time exposed, we can simulate as far as possible the actual and real operational condition before carrying out in the field trials. This attempt will simplify some of the confusion surrounding dynamic testing on the non-metal automotive components in the fuel system. Moreover, data from the dynamic condition would give quantitative information to the diesel engine vehicles users. However, a systematic and deep investigation on the proposed dynamic test rig needs to be done with extra data and empirical work to check the accuracy and that would give valuable information and better understanding of the compatibility asessment of non-metal components with biodiesel fuel.

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