Appendix II

Review Related Studies

Some noted investigators have authored various literature reviews which comprise of a collection of works conducted by various investigators around the globe. Such literature reviews are briefly explained in this appendix.

A.S. Ramadhas et al. [100] reviewed the studies conducted by many investigators from various countries using vegetable oils as I.C. engine fuel substitutes. The review includes papers from 1981 to 2002. The review indicates that vegetable oils posed some problems when subjected to prolonged usage in compression ignition engines because of their high viscosity and low volatility. The common problems were poor atomization, carbon deposits, ring sticking, fuel pump failure, etc. hence it was suggested to convert them into their blends with diesel or esters(known as biodiesels) to minimize these problems. The results showed that thermal efficiency was comparable to that of diesel engines with small amount of power loss while using vegetable oils. The particulate emissions of vegetable oils are higher than that of diesel fuel with a reduction in NO_X. Vegetable oil methyl esters gave performance and emission characteristics comparable to that of Diesel oil. Hence, they may be considered as diesel fuel substitutes. Raw vegetable oil can be used as fuel in diesel engines with some minor modifications. The use of vegetable oils as I.C. engine fuels can play a vital role in helping the developed world to reduce the environmental impact of fossil fuel.

E. Shahid and Y. Jamal [101] reviewed the use of biodiesels for compression ignition engines based on the study of reports of about 50 investigators who published their results between 1900 and 2005. These investigators used different types of raw and refined oils. It was reported that the use of raw vegetable oil as fuel did not show satisfactory results and caused problems of injector coking and piston ring sticking. However, transesterified biodiesel fuels brought down the properties like density, viscosity and flash point as compared to raw biofuels and comparable to that of Diesel oils. The transesterified fuels were blended with Diesel oils in different proportions. Blends above 20% showed maintenance problems & resulted in engine wear when used for long term applications. Some authors reported success in using vegetable oils as diesel fuel extenders in blends of more than 20% even in long term studies. It was reported that there was a slight decrease in brake power and a slight increase in fuel consumption with biodiesel applications. Lubricating properties of biodiesels are better than diesel which can help to increase the engine life and were found to be environment friendly with much less produce of NO_x and HC emissions, absolutely no SO_x and with CO_2 level maintained almost a constant. It was concluded in the review that vegetable oils in refined, degummed, dewaxed & transestrified form can replace Diesel oil. Particularly rapeseed and palm oil are most suitable as diesel fuel extenders. Unmodified vegetable oils can be used only for small engines for a short term period. For long term use for heavy engines either biodiesels or their blends with diesels are recommended. They observed that Indirect fuel injection systems are more successful with vegetable oil applications as compared to direct injection systems. They report that the engine is to be started with Diesel oil alone and after warming up could be shifted to biodiesel-diesel blends. More care, regularity in maintenance and periodic services of the engine is required. Biodiesel generates much less pollutant gases as compared to diesel. Hence it would be better to use B100 in the urban area applications in particular. Studies on cottonseed, rapeseed, soybean, palm, peanut oils and other miscellaneous studies of vegetable oils in dual fuel mode conducted by various investigators are taken for comparison.

Y.C. Sharma et al. [102] concluded from his review that biodiesel studies are mainly from edible and non edible oils. The review consists of studies from 1978 to 2008. The main advantage in the usage of biodiesels is attributed to lesser exhaust emissions in terms of carbon monoxide, hydrocarbons, particulate matter, polycyclic aromatic hydrocarbon compounds and Nitrited polycyclic aromatic hydrocarbon compounds. Transesterification is the process successfully employed at present to reduce the viscosity of biodiesel and improve other characteristics. Methanol being cheaper is the commonly used alcohol during transesterification reaction. Among the catalysts, homogeneous catalysts such as sulphuric acid, sodium hydroxide, potassium hydroxide are commonly used at industrial level production of biodiesel. Heterogeneous catalysts such as calcium oxide, magnesium oxide and others are also being tried to decrease the catalyst amount and production cost of biodiesel. Transesterification reaction can be completed even without catalyst by using supercritical methanol but it will increase the production cost of biodiesel as it is energy intensive. The molar ratio of alcohol to oil required is 3:1 by stoichiometry, but excess molar ratio has been used for biodiesel production & for better yield in lesser time. The molar ratio employed during acid esterification is between 6:1 and 18:1 whereas the molar ratio used in alkaline transesterification ranges between 5:1 and 12:1 after reducing the acid value to less than 2.0% approximately. The temperature ranges between 318 and 338 K as the boiling point of methanol is 337.7 K and heating beyond this temperature would burn methanol. However, higher temperature is employed while using supercritical methanol (473–573 K). Depending on the feedstock taken; amount & type of alcohol and catalyst; temperature employed; mode and rate of stirring; there is difference in the yield of biodiesel which varies from 80 to 100%.

Another added advantage of biodiesel is that it is biodegradable in nature. When used as blend along with diesel fuel, it shows positive synergic effect of biodegradation by means of co- metabolism. Major disadvantage of biodiesel is the inverse relationship of oxidation stability of biodiesel with its low temperature properties which includes cloud point and pour point. Higher composition of saturated fatty acids in feedstock will increase the oxidation stability of biodiesel but will lower its cloud and pour points. Whereas, higher composition of unsaturated fatty acids will enhance the cloud point and pour point of biodiesel but will have poor oxidation stability. Hence, a balance has to be maintained between the ratio of saturates and unsaturates, for the oil to be used as a feedstock for biodiesel production.

From Indian perspective, they observed that as India is rich in plant biodiversity, there are many plant species whose seeds remain unutilized and underutilized. They are being tried for biodiesel production. These species have shown promises and fulfil the requirements & meet various biodiesel standards. However, they also state that there still is paucity in terms of all the standards which should be fulfilled for their large commercial application and acceptance from public and governing bodies.

A.Murugesan et al. [103] presented a review of the prospects and opportunities of introducing vegetable oils and their derivatives i.e., bio-diesel as fuels in diesel engines. The review is done for researches conducted from 1981 to 2007. It was highlighted in this review that vegetable oils are very promising as alternative fuels in diesels engines because their properties are comparable with those required to operate diesel engines. Optimization of alkali based transesterification of Pongamia Pinnata oil for the production of bio-diesel was discussed. They observed that bio-diesel could bring down the emissions to a safer level. The suitability of injection timing indicated that it should be retarded. A review of performance of bio-diesel blends indicated that the

BSFC is about 8% to 10% higher than that of Diesel oil because of a decrease in the calorific value of fuel with an increase in bio-diesel percentage in the blends. From the review, they concluded that bio-diesels blended with diesel is a suitable strategy for saving of fossil fuel consumption and B20 is best alternative fuel for diesel in conformity with performance and emission with base line data of diesel.

S. Basha and K. RajaGopal [104] authored a literature review which was based on biodiesel production, combustion, performance and emissions. This study was based on the reports of about 130 scientists who published their results between 1980 and 2008. It was concluded in the review that biodiesel is one of the best available sources to fulfil the energy demand of the world. Though more than 350 oil bearing crops were identified ,but among them only few like sunflower, rapeseed, palm and jatropha were considered as potential alternative fuels for diesel engines according to this review. Many of the investigators mentioned that short term engine test using vegetable oils are promising but long term test showed long carbon build up, lubricating oil contamination resulting in engine failure. Hence blending with diesel or chemically altering the oil into esters (bio-diesel) was carried out. Running in this manner on a CI engine provides engine power output comparable to that of base line data which is obtained using diesel as fuel. It was reported that the combustion characteristics of biodiesel are similar as diesel and blends were found to have shorter ignition delay, higher ignition temperature, higher injection pressure and peak heat release. The engine power output was found to be equivalent to that of diesel fuel. In addition, it was observed that the base catalysts are more effective than acid catalysts and enzymes. The tests with refined oil blends indicated considerable improvement in performance. The emission of unburnt hydrocarbon from the engine was found to be more on the all the fuel blends as compared to diesel. The emission of oxides of nitrogen from the engine were found to be higher on all fuel blends as compared to Diesel oil.

H. C. Ong et al. [105] reviewed and compared the performance and emissions of Jatropha, Palm and Penaga Laut biodiesels. The review is conducted for studies carried out between the years 1954-2010. Penaga Laut is also known as Callophyllum Inophyllum and is found in Malaysia, India, Myanmar etc. In India it is popularly known as Polanga. From the review, it was observed that most of the research work conducted on biodiesels by various investigators showed combustion characteristics of biodiesels are same as diesel and biodiesel blends can reduce hydrocarbons, smoke opacity, particulate matters, carbon dioxide and carbon monoxide emissions but slightly higher NO_x emissions. The exhaust emissions of NO_x can be controlled by adopting techniques such as changing the composition of biodiesels in the blend, improve cetane number of biodiesel, retardation of injection timing and exhaust gas recirculation. The high viscosity and low volatility of vegetable oils cause poor combustion in diesel engines. Several ways to reduce the viscosity of vegetable oils have been discovered by various investigators. They are preheating of oil, micro emulsion with solvents, dilution, blending with diesel, thermal cracking and transesterification. Thermal cracking is also called as pyrolysis. Palm is widely produced in Malaysia hence it is economically viable to use palm oil in that part of the world. Palm is one of the most oil bearing crops in terms of land utilisation, efficiency and productivity. But, when compared with non edible oils, edible oils cannot be preferred as they are the sources of food. This shifts the attention to nonedible oils like Jatropha and Polanga which are grown in tropical and subtropical climatic region countries. Among the non edible oils the most preferred one is Jatropha oil as it is a drought resistant plant and can be cultivated success fully in wastelands. Polanga can also be considered as a as a potential biodiesel fuel and could be transesterified. However, compared to Palm and Jatropha biodiesel industry, production of polanga biodiesel is still at a nascent stage.

The different review related studies conducted on biodiesels are shown in a chronological order in Table II.1. Almost all studies reveal that biodiesels blended with diesel in a definite proportion can be used in existing diesel engines. But the disadvantage of using biodiesel is that it gives higher percentage of NO_x emissions compared to diesel, however the other harmful emissions are less with biodiesels. Even though NO_x emissions are higher with biodiesels they are not appreciably higher compared to diesel. The reviews also validate the fact that transesterification is the most accepted and widely used method for production of biodiesels as it yields biodiesel whose properties are closer to that of conventional diesel. The yield percent of biodiesel is more using transesterification method.

Table II.1 Summary of Review Related Studies Carried Out On Biodiesels

Sr. No	Investigators	Year	Observation made from the review
1	A.S. Ramadhas et al.	2004	The review showed that vegetable oils posed some problems when subjected to prolonged usage in compression ignition engines because of their high viscosity and low volatility.
2	E. Shahid and Y. Jamal	2007	The review showed that indirect fuel injection systems are more successful with vegetable oil applications as compared to direct injection systems. It was also reported that the engine is to be started with diesel alone and after warming up could be shifted to biodiesel-diesel blends.
3	Y.C. Sharma et al.	2008	Transesterification is the process successfully employed at present to reduce the viscosity of biodiesel and improve other characteristics.
4	A.Murugesan et al.	2009	A review of performance of bio-diesel blends indicated that the BSFC is about 8% to 10% higher than that of diesel because of a decrease in the calorific value of fuel with an increase in bio-diesel percentage in the blends.
5	S. Basha and K. Raja Gopal	2009	The engine power output was found to be equivalent to that of diesel fuel. In addition, it was observed that the base catalysts are more effective than acid catalysts and enzymes
6	H. C. Ong et al.	2011	The exhaust emissions of NO_x can be controlled by adopting techniques such as changing the composition of biodiesels in the blend, improve cetane number of biodiesel, retardation of injection timing and exhaust gas recirculation.