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Studies on a Four Stroke Spark Ignition Engine Under Additive Reformulated Lubricants

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***Abstract*— In this project, an attempt is made to utilize three vegetable oils, such as Pongamia, Neem and Coconut oils as bio lubricant base oils for the engine lubrication. Reformulation of additive process is used in this work for formulating vegetable oil bases bio lubricant base oils. The additive, Zinc dialkyldithio phosphate (ZDDP), is blended to the three vegetable oils, referred as formulated oils. Experiments are carried out on a vertical single cylinder air cooled four stroke gasoline Honda engine developing 1.3 kW at 4200 rpm, under three formulated bio lubricants. The engine is coupled to an electric generator for varying the load. The performance values like specific fuel consumption, power and engine efficiency are measured. Also, the emission values such as Carbon monoxide and Hydrocarbon are measured using a gas analyzer. The obtained results from these experiments are compared with the results under mineral oil lubrication. The results reveal that, the engine consumes almost similar amount of fuel under all modes of lubrication. Thermal efficiency of the engine under all bio lubricants is at par with mineral oil lubrication. However, a slight increase in efficiency is seen under Neem blended with 2 % ZDDP lubrication mode, compared to mineral oil. Engine emits lower carbon monoxide and unburnt hydrocarbon, operated under all bio lubricants, compared to mineral oil mode of lubrication. Lowest carbon monoxide and hydrocarbon are observed when engine is operated under Coconut oil blended with 2 % ZDDP mode of lubrication compared to mineral oil mode. Based on experimental results, formulated Coconut oil is found to be the best lubricant base oil in all respects compared to other oils.**

Keywords— Vegetable oils, Base oils, Engine lubrication, Additive, Efficiency, Experiments, Emission

INTRODUCTION

The environmental impact of petroleum based oils is often negative because of its toxic content and that in turn can affect all forms of life and sources. However alternate methods such as usage of synthetic lubricants, solid lubricants and vegetable oil based lubricants have made their way through to overcome the negative effects.

Vegetable oils are promising candidates as base fluids for eco-friendly lubricants because of their excellent lubricity, biodegradability, viscosity- temperature characteristics and low volatility, environmentally friendly and oxygenated fuel and it produces lower emissions while using in engine [1]. Vegetable oils consist of primarily of triglycerides, which are glycerol molecules with three long chain fatty acids attached at the hydroxyl groups via ester linkages [2]. Vegetable oils are of two types, Edible and Non edible. Edible oil; A liquid fat that is accomplished of being eaten as a food or food access, like Coconut, Olive, Soyabean, Sunflower, Palm, Peanut, Rapeseed, Corn etc. Non edible; as a substitute non edible vegetable oil can prove to be valuable like Neem, castor, Mahua, rice bran, karanja, Jatropha, and linseed oils [3]. Fox and Stachowiak [4] reviewed that long, polar fatty acid chains provide high strength lubricant films that interact strongly with metallic surfaces, reducing both friction and wear. The strong intermolecular interactions are also resistant to changes in temperature providing a more stable viscosity, or high viscosity coefficient. The entire base oil is also a potential source of fatty acids.

Oxidation stability of vegetable oil is one of the problems in formulating bio-lubricants using vegetable oils [5]. The high content of unsaturated fatty acids in vegetable oils produces the oil less cooperative in stabilizing the oxidation. The modification of the vegetable oil or addition of antioxidant additives could help in stabilizing the oxidation process [6]. The degradation of lubricant oil can be decreased by the addition of ZDDP into the base parent oil as the effective antiwear and antioxidant additive [7]. Their long and polar fatty acid chains can provide high strength lubricant films that interact strongly with metallic surfaces [8].

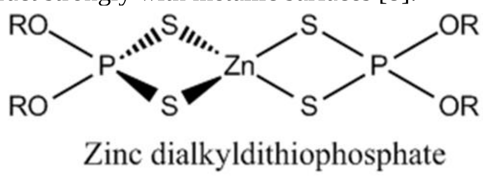

Figure-1. The structure of zinc dithiophosphate. The R group describes whether it is an alky- or aryldithiophosphate [9].

Additives are widely used to improve the lubricant performance of base oil. Without additives, even the best base fluids are deficient in some features. The performance of a lubricant depends collectively on the base oil, additives and formulation. Phosphorus,sulphur, zinc dialkyldithiophosphates (ZDDP) are examples of some of the widely used additives. Sulphur-containing additives are probably the earliest known additive compounds in lubricants. In recent decades, it had attracted a considerable amount of research efforts to further explore their potential as effective anti-wear (AW) and extreme pressure (EP) additive (10,11). Fatty acids, alcohols, amines and esters are some of the AW additives used to produce a molecular film adhering to the surfaces by physical or chemical adsorption (12). The lubricant films are built up of orderly and closely packed arrays of molecular layers, with the polar head of the additive molecule anchored on the worn surface (13). Sulphur-, chlorine- and phosphorus-containing compounds are commonly used as EP additives to provide protection in EP condition (14). These additives would form layers of iron compounds such as sulphides, chlorides and phosphates, respectively, through tribochemical reactions (15). The mechanism of lubrication which is influenced by these additive elements involves some chemical changes on the surface to form a surface protection film. This film is called boundary lubricating film or a tribofilm. The tribofilm plays a major role in determining the friction and wear of the tribological interaction. The morphology, integrity and mechanical properties of the tribofilms may vary depending on the properties of rubbing material as well as the type of lubricant additives used (16,17). ZDDP was initially used as an antioxidant, but their excellent AW properties were quickly recognised and had been investigated intensively by many researchers. The AW function of ZDDP was attributed to its decomposed products that led to the formation of sacrificial reaction layers on the rubbing surfaces [18].

This work deals with use of Pongama, Neem, Coconut oils as bio lubricant base oils for operating a four stroke SI engine. The additive, Zinc dialkyldithio phosphate (ZDDP), is added to the oils to improve their lubrication characteristics. Performance and emission characteristics of the engine are determined under these oils of lubrication. The results are compared with those obtained under mineral oil operation.

RESULTS AND DISCUSSIONS

The discussions are based on two aspects such as engine performance and emissions of the engine. The results from three bio lubricants such as Pongamia blended with ZDDP (2%), Neem blended ZDDP (2%) and Coconut oil blended with ZDDP (2%) are compared with the results obtained under mineral oil lubrication of operation of the engine.

FUEL CONSUMPTION

Fig 2 shows variation of specific fuel consumption and brake power for various lubricants. It is seen that the specific fuel consumption (SFC) is increased in bio lubricants mode compared to mineral oil lubricant mode. However, when engine is operated under mineral oil lubricant mode, the engine shows a moderate drop in specific fuel consumption (SFC). But when engine operated at bio lubricant mode of operation there is slight increase in specific fuel consumption. At the low load operation, the fuel consumption is above 30 % under Neem mode of operation compared to mineral oil and about 25 % increase in fuel consumption is noticed under Pongamia is due to poor atomization of the fuel[19]. About 17% increase in fuel consumption is noticed under Coconut oil due to the high density and high viscosity [20, 21].

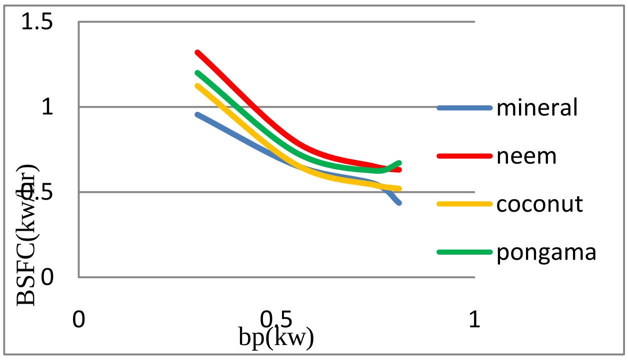

Fig 2 Variation of specific fuel consumption with brake power

BRAKE THERMAL EFFICIENCY

Fig 3 depicts variation of brake thermal efficiency with brake power for various lubricant modes. It is seen from fig 3 that, at full load operation, about 10 % of the brake thermal efficiency of the engine is increased under Coconut oil compared with mineral oil. However, about 5 % and about 9 % of brake thermal efficiency of the engine is decreased under pongama and neem respectively compared to mineral oil lubrication mode is due to the poor atomization of blends due to their higher viscosity [19].

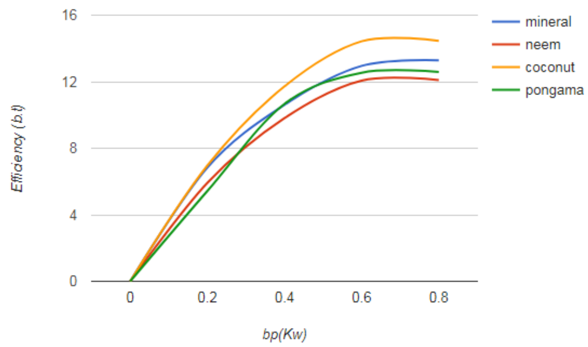

Fig 3 Variation of brake thermal efficiency with brake power

MECHANICAL EFFICIENCY

Fig 4 shows variation of mechanical efficiency with brake power for various lubricants. At full load operation, it is observed that the mechanical efficiency of the engine under Coconut oil is increased 2%, compared to mineral oil lubricant mode. However, about 10% and about 13% mechanical efficiency of the engine is decreased under pongama and neem respectively compared to mineral oil lubricant mode.

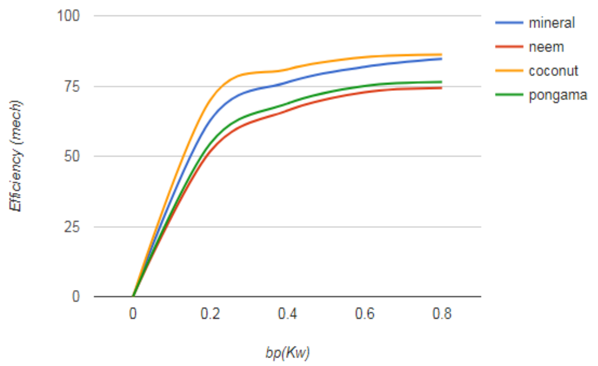

Fig 4 Variation of Mechanical Efficiency with brake power

EMISSION STUDY

Carbon Monoxide

Fig. 5 shows variation of carbon monoxide with brake power. At low load operations, the engine emits about 27% decrease in carbon monoxide (CO) under Pongama and also about 44% lower in carbon monoxide under both Neem and Coconut oil compared to mineral oil lubrication mode of engine operation. At part load operations, the engine emits about 5%, 4% and 19% decrease in carbon monoxide emission under pongama, Neem, and coconut oil respectively compare to mineral oil lubrication mode of engine operation. At full load operation the engine emits about 22%, 19%, and 25% decreased in carbon monoxide (CO) under pongama, neem and coconut oil compared to mineral oil lubrication mode of engine operation. It may be due to better combustion of fuel under bio lubricants compared to mineral oil lubrication of the engine [22].

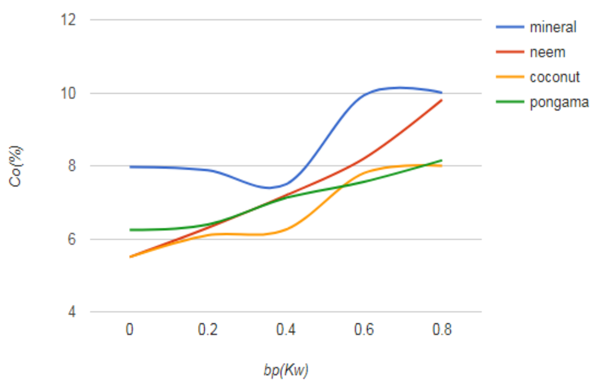

Fig 5 Variation of Carbon Monoxide with brake power

HYDROCARBON

Fig 6 shows variation of unburnt hydrocarbon with brake power. It is observed that the engine emits lower unburnt hydrocarbon for all the loads of operation under bio lubricant mode of lubrication compared to mineral oil mode.

At part load operations, about 34 % decrease in Hydrocarbon under both neem and Coconut oil respectively. And also, about 27% decrease in hydrocarbon under pongama compared to mineral oil lubrication. Further, at full load operations of the engine, it emits 43 %, 44 % and 47 % decrease in hydrocarbon under pongama, neem and coconut oil respectively compared to mineral oil mode of lubrication of the engine. It may be due to better combustion of fuel under bio lubricants compared to mineral oil lubrication [22].

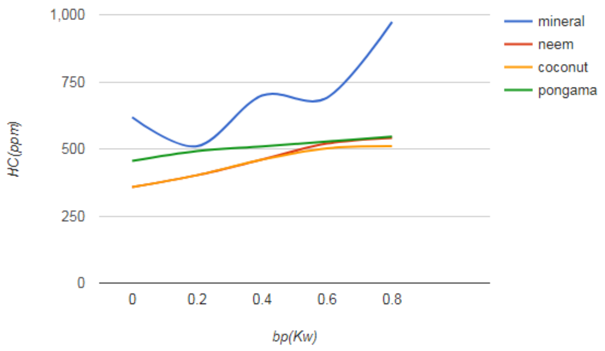

Fig 6 Variation of unburnt hydrocarbon with brake power

CONCLUSIONS

- A slight increase in fuel consumption under all bio lubricants mode of lubrication is noticed compared to mineral oil mode. However, similar fuel consumption pattern is observed under both formulated Coconut blended with 2 % Zinc dialkyldithio phosphate (ZDDP) and mineral oils mode of lubrication of the engine.
- Thermal efficiency of the engine under formulated Coconut blended with 2 % Zinc dialkyldithio phosphate (ZDDP) is marginally increased compared to mineral oil mode of lubrication. However, moderate escalation of efficiency is noticed compared to other two formulated oil modes of lubrication.
- Engine emits low Carbon Monoxide (CO) and unburnt hydrocarbon (UBHC) under all bio lubricant mode of lubrication. Significant drop of CO and UBHC are seen under formulated Coconut blended with 2 % Zinc dialkyldithio phosphate (ZDDP) compared to mineral oil mode of lubrication.
- Based on experimental results, formulated Coconut oil blended with 2 % Zinc dialkyldithio phosphate (ZDDP) is found to be the best lubricant base oil in all respects compared to other oils.

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