Rahul et al. 2021. *Int. J. Vehicle Structures & Systems*, 13(1), 14-18
ISSN: 0975-3060 (Print), 0975-3540 (Online)
doi: 10.4273/ijvss.13.1.04

International Journal of Vehicle Structures & Systems
Available online at www.maftree.org/eja

Performance and Emission Characteristics of SI Engine with Standard and Modified Piston with Turmeric Leaf Oil as Biofuel

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ABSTRACT:

Turmeric leaves are waste products after removing turmeric rhizome. In the present work, the oil was extracted from the leaves of curcuma longa by hydro distillation method. The extracted oil was studied for preliminary physicochemical and phytochemical tests. The phytochemical evaluation of the turmeric leaf oil indicates the presence of terpenes which was used to run two stroke and four stroke engines. Engine emits less harmful product with turmeric oil as compared to petrol. Hence, it has been concluded that the turmeric leaf oil can be used as an alternative biofuel for petrol. Theoretically, turmeric leaf oil properties are similar to that of petrol. By performing practical experiments on this oil using different types of piston head shapes and varying parameters, we came to know that this will fulfil all capabilities as a biofuel in IC engines. In the second part, the characteristics fuel properties of turmeric leaf oil and their blends with petrol in the proportion of 40:60 (B40) have been studied. In the third part, engine tests have been conducted on turmeric leaf oil blends with petrol oil and brake thermal efficiency, engine gas temperature and air fuel ratio were evaluated. The next part consists of exhaust emission tests such as CO and HC emission measurement with a five gas analyser.

KEYWORDS:

Turmeric leaf oil; Biofuel; Air fuel ratio; Emissions; Engine performance

CITATION:

R.P. Tardale, S. Suresh and K. Ramesh. 2021. Performance and Emission Characteristics of SI Engine with Standard and Modified Piston with Turmeric Leaf Oil as Biofuel, *Int. J. Vehicle Structures & Systems*, 13(1), 14-18. doi:10.4273/ijvss.13.1.04.

1. Introduction

Nowadays petrol is most popularly used for transportation, agricultural and industrial purpose due to which it is consumed a lot. The petroleum products were imported from foreign countries, foreign exchange sources and the demand for petroleum products are growing day to day and this situation can become worst in future. Petrol engines emit more carbon dioxide (CO_2), carbon monoxide (CO) and un-burnt hydrocarbon (UBHC) emissions [1]. It will affect atmosphere and human life that further leads to global warming and greenhouse effect. Proper use of natural sources is one of the basic requirements for any country. Many researchers have been studying on the alternative fuel for energy crisis as fossil fuel is very rapidly becoming self-sufficient [4]. There are more than 300 types of trees in India which contains oil. India has more potential to produce rich biofuels in the world. Biofuels can be produced from edible and non-edible sources such as jatropha, turmeric, turmeric leaf, caster, kasum, mahua etc [2]. Now by using turmeric leaf oil we are assessing the performance and combustion characteristics of S.I engine with standard and modified piston by varying its compression ratio and injection timing.

In order to decrease the exhaust emissions and increase the fuel economy, automotive engineers have attempted several modifications like changing the shape of the inlet system, the shape of the combustion chamber geometry etc. In S.I. engines burning is incomplete due to several reasons like combustion space, availability of air, improper mixing of air and fuel etc [5]. Some of them are not possible to change but some of them may be corrected up to certain extent. By introducing specific profiled grooves upon the piston crowns, the turbulence of the charge can be created which lead to vigorous mix of the fuel with air so that it can burn the fuel completely by which it saves nearly 50% of the fuel cost [7].

Our aim was to conduct the performance and emission characteristics of S.I engine with standard and modified piston with turmeric leaf oil fuel as biofuel. We studied and compared the properties of turmeric leaf oil with petrol. We started with a typical petrol engine using a blend of turmeric leaf oil and studied their performance in regard to Brake Power (BP), Brake Thermal Efficiency (BTE), Engine Gas Temperature (EGT), Air Fuel Ratio (AFR) and emissions such as UBHC and CO for comparisons [6]. The same properties were to be determined for engine operation with conventional petrol oil also. We blended turmeric leaf oil in different proportions with petrol and carried out various tests.

This will give double benefits of reducing the viscosity of these esters and achieving alternative source in the place of petrol. As we know the transportation sector is mostly depending on petroleum for fuel needs, over dependence on petroleum products by our nation increases the emission levels and results in environment pollution. The cost had made natural energy sources more attractive nowadays [8].

Fossil fuels are non-conventional types and have some disadvantages such as cost of fossil fuel in India, emission of CO_2 in fossil fuels and Government is totally dependent on gulf countries for importing fossil fuels makes it difficult to use it as an alternative fuel. The quantity of CO and UBHC emitted after using petrol oil as fuel was 7.6% and 1880 ppm respectively where as in same engine the quantity of CO and HC emitted after using turmeric leaf oil as fuel was 8.9% and 2000 ppm respectively [9]. This shows that turmeric leaf oil produces more pollution as compared to petrol as fuel. By using B40 oil, CO and HC emission is around 7.7% and 1895ppm respectively. Hence by using turmeric leaf oil B40 as biofuel the emission of CO and HC can be similar to petrol [3].

The present work relates to modification of SI engine piston head design for enhancing turbulence by squish and tumble flows to improve the combustibility of the mixture. The modification includes making different geometrical shaped groove of specified dimensions upon the piston crown. The engine is fuelled with turmeric leaf oil and pure petrol oil. The effect of piston modification on performance and emission characteristics is studied. Through this work we can check if there are any significant improvements due to geometrical shaped groove modification of piston crown. The effects of various blending percentage of turmeric leaf oil with petrol are analysed. Table 1 shows the percentage composition of turmeric oil. Table 2 lists the physical properties of turmeric leaf oil and petrol.

Table 1: Fatty acid composition (%) of turmeric oil

Component	% by vol.	Component	% by vol.
Caproic acid	10.27%	Oleic acid	1.76%
Caprillic acid	Nil	Linoleic acid	0.85%
Capric acid	0.62%	Linolenic acid	5.85%
Lauric acid	Nil	Arachiodonic acid	5.84%
Myristic acid	Nil	Behenic acid	Nil
Palmitic acid	1.46%	Erucic acid	Nil
Stearic acid	0.83%	Lignoceric acid	Nil

Table 2: Physical properties of turmeric oil and petrol oil

Property	Units	Turmeric leaf oil	Petrol oil
Viscosity at 40°C	cst	6.55	0.88
Density	kg/m^3	955	770
Flash point	°C	59	37.8
Fire point	°C	61	40
Calorific value	MJ/kg	38.46	47.3

2. Experimental setup

The computerised four stroke single cylinder air cooled SI engine with high speed data acquisition system, eddy current dynamometer, piezoelectric transducer, five gas exhaust emission is employed for the present study. The experimental setup of the engine is shown in Fig. 1. Fig. 2 shows the exhaust gas analyser used in our experiment. The engine is started by hand cranking with the help of lever and the load is applied on the system using eddy current dynamometer. The load on the engine was changed by controlling the current given to the electromagnet. The performance and emission test were carried out on SI engine using various blends of biofuel with petrol oil as fuels. The performance and emission tests were carried out on CI engine using various blends of biodiesel with diesel and methanol as fuel. The test was conducted at a constant speed of 3000 rpm with varying load and BMEP. The experimental data generated was documented and stored in the system and analysed using appropriate graphs. The thermal performance on the engine was conducted to determine various parameters such as BP, brake specific fuel consumption (BSFC), BTE, mechanical efficiency and AFR with respect to applied load. The emission parameters such as CO, UBHC and NO_x were measured using calorimeter with respect to applied load.

Fig. 1: Petrol engine test rig

Fig. 2: Exhaust gas analyser

3. Performance characteristics

Fig. 3 shows the effects of BP on BTE when SI engine was run on turmeric leaf oil with flat piston head shape (TOF), turmeric leaf oil with two grooved piston head shape (TTG), turmeric leaf oil with four grooved piston head shape (TFG) and petrol oil. It shows that with increase in power, BTE also increases. Minimum BTE (4.7%) was obtained for TOF at 0.44BP, which is 80.85% lower than petrol for a flat shaped piston head with same power due to its lower calorific value and octane number. Maximum BTE (15.7%) was obtained for TFG at 2.2 kW BP which is 3.18% lower than petrol for flat shaped piston head at same power. BTE of TOF is lower for TTG and TFG which is at 0.44BP. At 2.21kW BP, the BTE for TFG is higher than TOF and TTG. The same exercise is repeated for turmeric leaf oil B40 blend (40% turmeric oil and 60% petrol) with

different piston head shapes. Fig. 4 shows that the lowest BTE (4.8%) was obtained for TOF (B40) at 0.44kW BP which is 77.08% lower than petrol oil. The higher BTE (15.8%) was obtained for TFG (B40) at 2.21 kW BP which was 2.53% lower than petrol oil at same load. B40 has higher BTE than B100 due to lower calorific value and octane number.

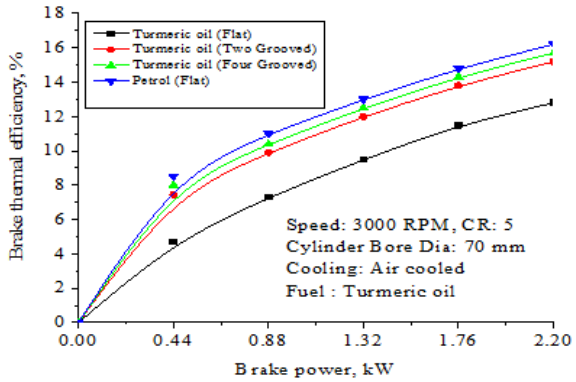

Fig. 3: Effects of BP on BTE – Turmeric oil

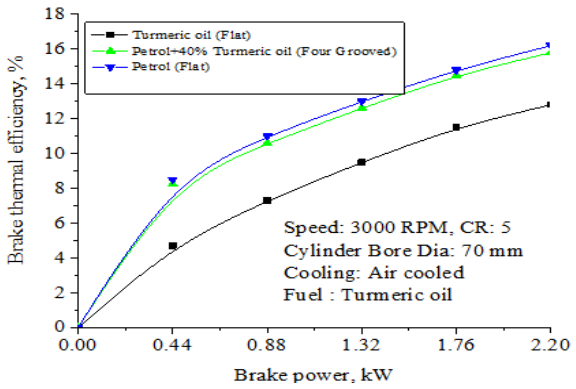

Fig. 4: Effects of BP on BTE – Turmeric oil B40 blend

Fig. 5 shows the effects of BP on EGT when SI engine was run on TOF, TTG, TFG and petrol oil. Minimum EGT 140°C was obtained for TFG at 0.0 BP, which is 7.69% higher than petrol flat shaped piston head at same power due to excess heat supplied to engine cylinder. Maximum EGT 600°C was obtained for TOF at 2.2 kW BP which was 15.38% higher than petrol flat shaped piston head at same power. EGT of TOF is higher than TTG and TFG at 0.0kW BP. EGT of TFG is lower than TOF and TTG at 2.21kW BP. Fig. 6 shows the lowest EGT of 135°C which was obtained for TFG (B40) at 0.0 kW BP. It is 3.84% higher than petrol oil. The higher EGT of 600°C was obtained for TOF (B40) at 2.21kW BP. Here EGT is 15.38% higher than petrol oil with same power whereas B40 has lower EGT than B100 oil. EGT refers to excess heat supplied to engine cylinder. The incomplete combustion due to improper air fuel mixture could be responsible for this trend and is very much evident from BTE. However EGT was lowered with improved performance of the turmeric oil when suitable combustion chamber shapes (two and four grooved pistons) were adopted. The improved combustion with respective combustion chamber could be responsible for this observed trend.

Fig. 7 shows the effects of BP on AFR when the SI engine was run on TOF, TTG, TFG and petrol oil. Minimum AFR of 12 was obtained for TOF at 0.0kW BP, which is 33.33% lower than petrol flat shaped piston head at same power. Maximum AFR (19.5) was obtained for TFG at 2.21kW BP which is 3.58% lower than petrol flat shaped piston head at same power. AFR of TOF is lower than TTG and TFG at 0.0kW BP. AFR of TFG is higher than TOF and TTG at 2.21kW BP.

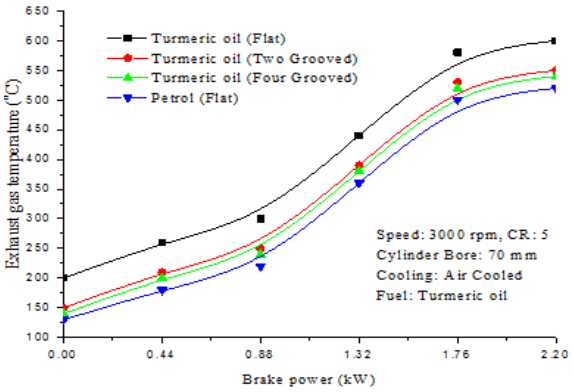

Fig. 5: Effects of BP on EGT – Turmeric oil

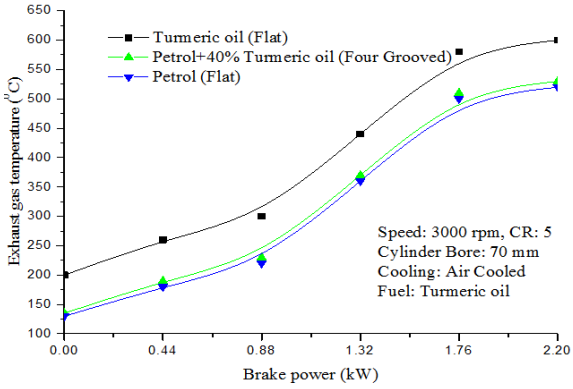

Fig. 6: Effects of BP on EGT – Turmeric oil B40 blend

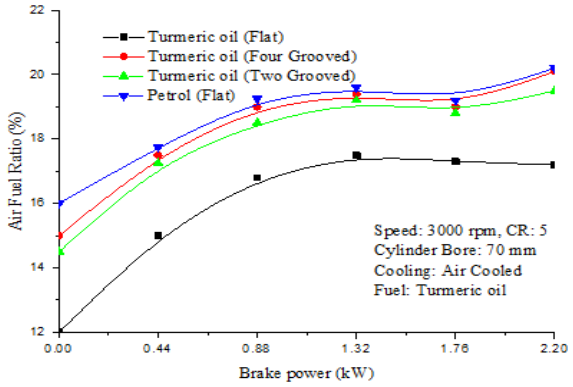

Fig. 7: Effects of BP on air fuel ratio – Turmeric oil

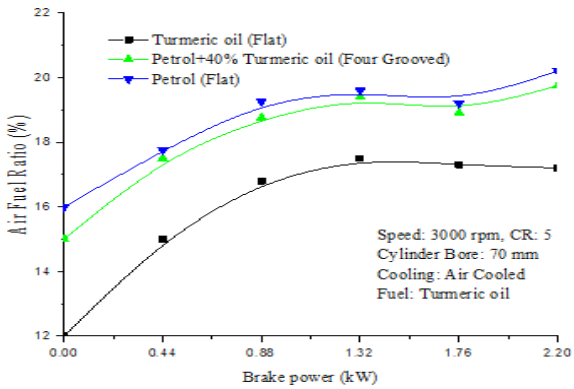

Fig. 8: Effects of BP on air fuel ratio – Turmeric oil B40 blend

Fig. 8 shows that the lowest AFR of 12% was obtained for TOF (B40) 0.0kW BP which was 33.33% lower than petrol oil. The higher AFR (19.75) was obtained for TFG with B40 blend at 2.21kW BP. AFR is 2.27% lower than petrol oil for same load. B40 oil has higher AFR than B100.

4. Emission characteristics

Fig. 9 shows the effects of BP on CO emission when SI engine was run on TOF, TTG, TFG and petrol oil. It shows that with increase in power, CO emission decreases. Minimum CO emission of 0.05% was obtained for TFG at 2.2 kW BP, which is 60% higher than petrol flat shaped piston head at same power due to the presence of maximum oxygen contents in turmeric leaf oil. Maximum CO emission of 9% was obtained for TOF at 0.0kW BP which is 18.42% higher than petrol flat shaped piston head at same power. CO emission of TOF is higher than TTG and TFG at 0.0kW BP. CO emission of TFG is lower than TOF and TTG at 2.21kW BP. Fig. 10 shows the CO emission percentage for turmeric leaf oil with different piston head shapes and B40 blend. The lowest CO emission of 0.03% was obtained for TFG (B40) at 2.21 kW BP which is 50% higher than petrol oil. The higher CO emission of 9% was obtained for TOF (B40) at 0.0kW BP, which is 18.42% higher than petrol oil at same load. B40 has lower CO emission than B100.

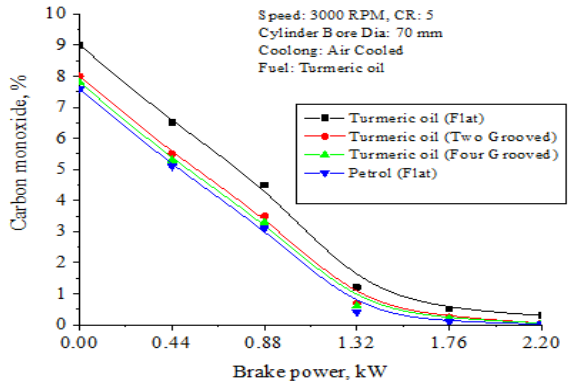

Fig. 9: Effects of BP on CO emission – Turmeric oil

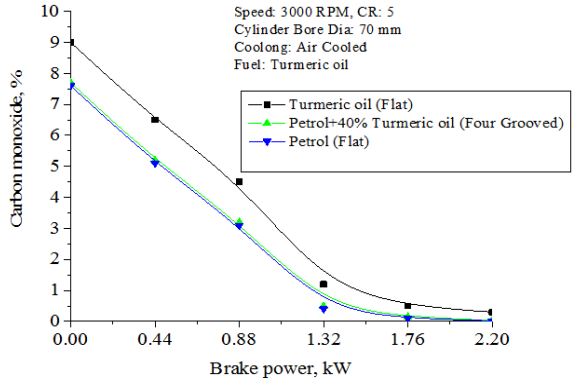

Fig. 10: Effects of BP on CO emission – Turmeric oil B40 blend

Fig. 11 shows the effects of BP on HC emission when SI engine was run on TOF, TTG, TFG and petrol oil. It shows that with increase in power, HC emission decreases. Minimum HC emission (900ppm) was obtained for TFG at 1.76 kW BP, which is 2.27% higher than petrol flat shaped piston head at same power due to presence of maximum oxygen contents in turmeric leaf oil. Maximum HC emission (2000ppm) was obtained for TOF at 0.0 kW BP which is 6.382% higher than petrol flat shaped piston head at same power. HC emission of TOF is higher than TTG and TFG at 0.0kW BP. HC emission of TFG is lower than TOF and TTG at 1.76 kW BP. Fig. 12 shows that the lowest HC emission (890ppm) was obtained for TFG (B40) at 1.76 kW BP which is 1.136% higher than petrol oil. The higher HC emission (2000 ppm) was obtained for TOF (B40) at 0.0 kW BP, which is 6.38% higher than petrol oil at same load. B40 has lower HC emission than B100.

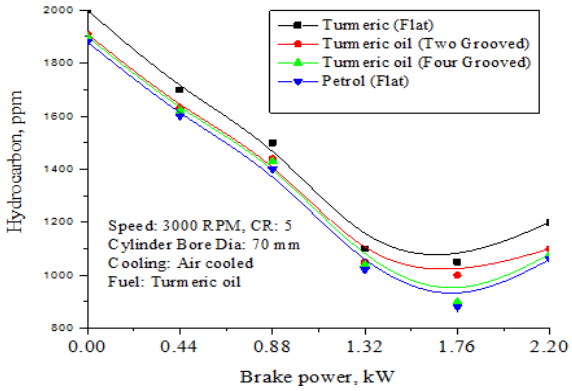

Fig. 11: Effects of BP on UBHC emission – Turmeric oil

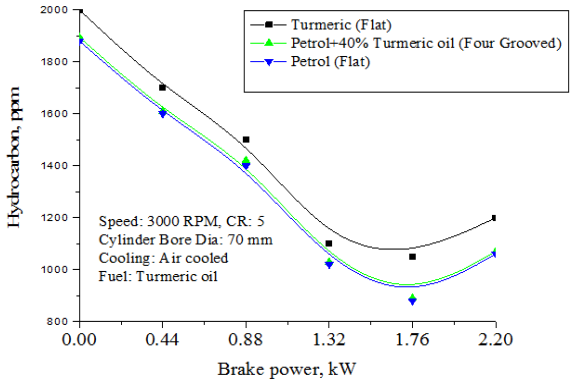

Fig. 12: Effects of BP on HC emission – Turmeric oil B40 blend

5. Conclusion

The biofuel production of turmeric leaf oil is very cost efficient and it is produced from waste turmeric leaves. The turmeric leaf oil is less flammable and volatile. It can be stored in atmospheric temperature. Thus turmeric leaf oil can be used in place of petrol oil. Most effort and research is needed to increase the yield of oil. The turmeric leaf oil gives same engine performance when compared with petrol oil and it will burn completely like petrol oil. The spark plug got the carbon deposition on faces many times which has been reduced by using turmeric oil. The above is based upon the experiment carried out in this study.

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