INVESTIGATING PERFORMANCE AND EMISSION CHARACTERSTICS OF CI ENGINE WITH CASTOR BASED BIODIESEL WHILE ADDING NANO METAL OXIDES OF ALUMINIUM AND COPPER

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Abstract

Growth in demand for fuels in day to day life and its depletion has become a serious problem for everyone all around the world. Increase in fuel cost, an increase in greenhouse gases emissions and decrease in fuel supply are the main reasons for promoting the development of Alternative fuels nowadays. Diesel is one of the main fuels used for the transportation sector, agricultural sector and power sectors in India. Biodiesel is a most commonly used alternative fuel because it is renewable and it can either be used as a fuel with different blends directly in common diesel engines without any modifications to it. Biodiesel can be easily produced from the oil of different seeds which are abundantly available in nature. The properties like higher density, high fuel consumption, lesser heating value, and emission, etc. can be reduced with the addition of fuel additives to the biodiesel without affecting its initial properties and performance. Metal-based additives or metal oxide-based additives, antioxidant additives, cetane number additives, and oxygenated additives are the most widely used additives which help in improving the combustion, fuel economy and reducing the emissions. This work is based on the preparation of biodiesel by using pumpkin and castor oil with nano metal oxide additives of copper and aluminium separately and checking its combustion, performance, and emission characteristics. Finally, the blends were made, consisting of pure diesel, B15A50C and B15C50C.

Keywords: methyl ester pumpkin, castor oil, metal oxide based nano additives, Aluminium oxide nano particles, Copper oxide nano particles.

Nomenclature:

Al2O3 – Aluminium oxide (Alumina)

CuO – Copper oxide

B15- 15% Bio fuel and 85% pure Diesel

B15A50C-15% Castor oil-based biodiesel with aluminium oxide nano additives.

B15C50C-15% Castor oil-based biodiesel with Copper oxide nano additives.

1.Introduction

As the population all around the world is increasing rapidly day by day, fuel consumption is also increasing which leads to depletion in fossil fuel resources, increase in the cost of the fuel and also there is increase in emissions from harmful gases like unburnt Hydrocarbons, nitrogen oxides and oxides of carbon which lead to formation of carbon dioxide and monoxide . The increase in number of these gases which are greenhouse gases also, results in causing global warming which includes rise in temperature, improper and irregular rainfall and melting of glaciers, resulting in rise in sea-level. In the process to overcome or reduce these problems, the development of alternative fuels has been promoted. There are many types of alternative fuels mainly Ethanol, Natural gas, Hydrogen, and biodiesel. The alternative fuels are not produced through the finite fossil fuels and they can be helpful in many ways like reducing emissions, less contributing to smog and reducing global warming. Out of these, most commonly used alternative fuel is biodiesel. It refers to the fuel generated from vegetable oil based, recycled cooking oil-based or animal fat-based oil instead of fossil fuels. Based on the nature of the soil and climatic conditions biodiesel can be prepared with different types of vegetable oils or non-edible oils in different countries. Some of the oils used for preparation of biodiesel are Coconut, Mustard, Soybean, Sesame, Rapeseed, Palm, Castor seed, Pumpkin seed, Mahua, Karanja, Jatropha. Transesterification process is used most widely for producing biodiesel. In this process, oil is reacted with alcohols such as ethanol or methanol with a catalyst of acid or base catalyst. After the reaction that occurs, it forms biodiesel and glycerol as a byproduct which can be separated from it. Mainly ethanol is used rather than methanol as it can be derived from agriculture waste which is renewable source and also it is non-harmful. Transesterification process is shown in Fig. 1.

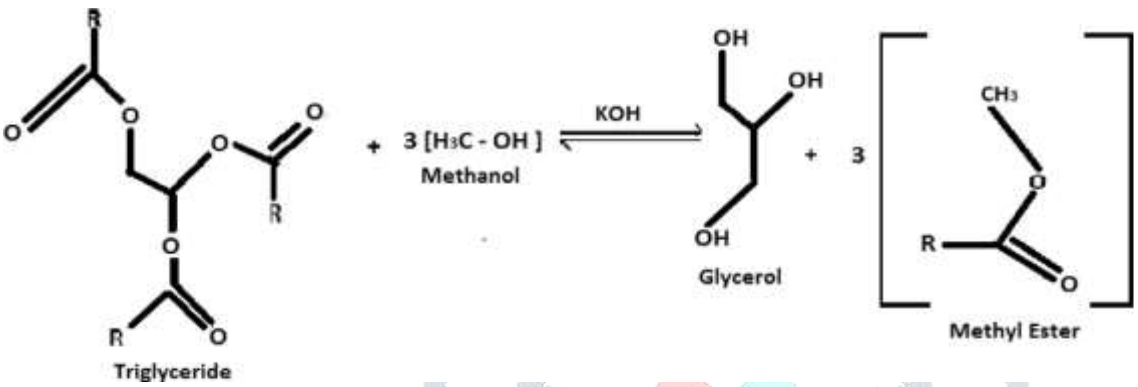

Fig.1 Transesterification reaction

Methyl esters produced during this reaction propose lower emissions of CO and unburnt hydrocarbons, but the major disadvantage is higher NOx emissions and also, they won't absorb the fuel emissions generated while growing the crops and preparing biodiesel. So, some kind of additives are required to be added which can act as catalyst and actually help it to produce lesser emissions with better thermal efficiency by increasing the heat release rate and improving the fuel quality. Nano particles are metal additives or their oxides that are mostly used as nano-sized particles of different sizes in ppm or percentage like Aluminium (Al), Iron (Fe), Copper (Cu), Cerium oxide ($Ce0_2$), Copper oxide (CuO), Aluminium oxide (Al_2O_3) etc. They help in reducing pollutants in emissions, proper combustion of fuel, short ignition delay periods and flash point.

P.Schinas [1] investigated the production of biodiesel using pumpkin oil through base catalyzed transesterification process. The pumpkin seed oil has a high fatty acid value which lead to increase in brake thermal efficiency, decrease in brake specific fuel consumption due to better combustion, decrease in exhaust gas temperature, less CO, NO_X, smoke and HC emissions when compared to mineral diesel.

Aalam [2] in his experiment used mahua oil for biodiesel production using Al_2O_3 nano additives. Results showed that there was increment in calorific value and reduction in flash point. Moreover, there were lower CO and HC emissions, but NOx emissions were found to be increased slightly.

Sivakumar Muthusamy [4] also examined engine with Pongamia methyl ester blended with aluminum oxide nanoparticles at different engine operating conditions and constant speed. Results indicate that the brake thermal efficiency was increased with decrement in Brake specific fuel consumption with additives. Emissions such as CO, HC, and smoke were decreased, while slight increase in NO_X emissions were found.

Hakan Ozcan [5] has also studied in his work about usage and effects of using Al_2O_3 and CuO nanoparticles in compression ignition engine where he found that there is substantial reduction in emissions of all major pollutants including NOx also with improved engine efficiency.

Rolvin D'Silva [6] also validated improved performance of engine with the use of CuO nano particles, where he prepared Pongamia Pinnata biodiesel and then he added nano particles of CuO in it and found improved performance of engine with least CO and NOx emissions and better efficiency.

So, from previous studies it has found that adding nano particles certainly results in increase in efficiency with decrement in emissions specially CO and NOx. The present work deals with the biodiesel preparation first using castor oil and then adding two nano particles in 50ppm proportion i.e. CuO and Al_2O_3 with 15% and 85% diesel. Overall 2 blends are prepared consisting of B15A50C and B15C50C, compared with pure diesel.

2. Biodiesel Production

Castor raw oil was taken in a beaker and heated up to $50^{o}C$, 7gm of potassium hydroxide which is used as a base catalyst for this process, was mixed with 200ml methanol. The mixture was mixed gently and was poured into the oil as soon as the potassium hydroxide was completely dissolved completely. The beaker was kept on the setup in which a heating mantle was fixed to a stand and the temperature was maintained. Given below Fig.2 shows the set up for Transesterification process.

Fig. 2 Transesterification Setup

The stirrer present in the setup was fixed and a magnetic bead was adjusted to the beaker. Methanol starts evaporating at around or above $50^{o}C$. It was kept for six hours and the solution is shifted to the separating funnel in which separation of glycerin will take place when warm water was poured into the funnel. This solution was left for six hours or more than that so that the oil, glycerin, and water will be separated. Given below Fig.3 shows the separation process. At the bottom of the flask water was deposited, above that glycerin and on the top, oil was there as the biodiesel is having less density followed by glycerin and water. This process was repeated for three to four times to collect pure biodiesel. This biodiesel is poured into a beaker along with diesel and stirred well-using stirrer. 15% of biodiesel (Castor 15%) is mixed with 85% of diesel to make it the blend B15P. After the blending, it is divided into two samples for using with two nano fluids.

Fig. 3 Glycerol separation from Biodiesel

3. Nanofluid Preparation

The biodiesel samples were mixed with different nano metal oxide particles by Sonication process. The calculations for amount of nanoparticles was done and 50ppm amount was taken. Biodiesel was taken in a beaker of capacity 1000ml and the nanoparticles were added to it after weighing them on a weighing machine. This solution was kept in the ultra-sonicator as shown in Fig.4, for 40 minutes. After every three minutes, the solution was stirred with a glass stirrer for effective mixing as the nanoparticles start depositing at the bottom of the beaker. Both nano metal oxides were mixed in biodiesel through this process in proportion of 50ppm CuO and 50ppm Al_2O_3 for castor-based biodiesel.

Fig. 4 Ultra-Sonicator

4. Experimental set up and Test procedure

Water cooled 4 stroke CI engine was used for experimental work with rated power of 6.5kW. Engine operation was done on constant power of 1500rpm at various load conditions. Initially the engine was with pure diesel only for getting the reference data and after which it as fueled with B15A50P, B15C50P, B15A50C and B15C50C to check other results. Engine specification details are mentioned below in Table 1. Also, gas analyzer being used to measure HC, CO and NOx emissions has been shown in Fig. 5. The experiment set-up shown in Fig.6.

Table 1 showing specification of engine used

Engine type	4 stroke-water cooled, 1 cylinder
Dynamometer's Arm length	180mm
Cylinder's Diameter	90mm
Length of stroke	115mm
Rated Power	6.5 kW
Diameter of orifice	21mm
Compression ratio	16.5:1

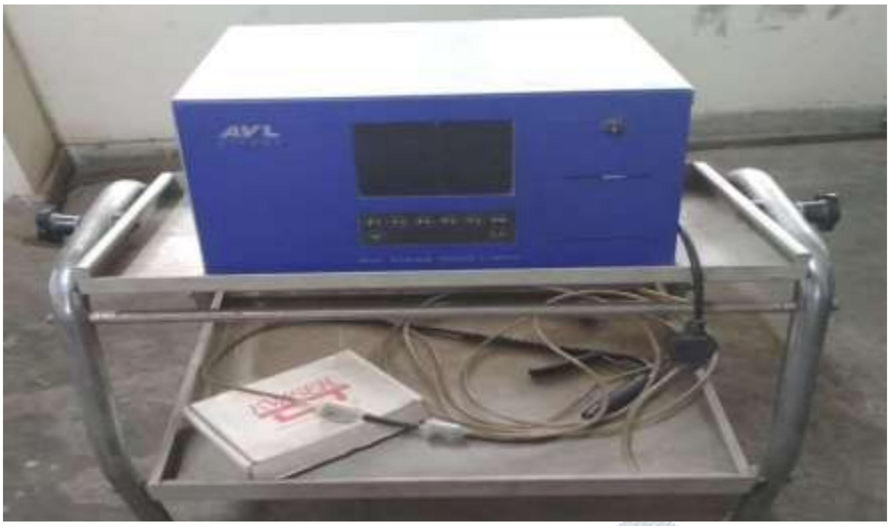

Fig. 5 Gas analyzer

Fig. 6 Diesel engine set up

Table 2 shows the properties of nano metal oxides

Sample	Particle size	Bulk density	True density	Color	Morphology	Atomic weight(g/mol)
Aluminum-oxide Al_2O_3 (purity 99.9%)	50 nm	1.5g/cm^3	3.97g/cm^3	White	Spherical	101.96
Copper oxide CuO (purity 99.9%)	50 nm	0.79g/cm^3	6.4g/cm^3	Black	Spherical	79.54

Table 3 shows the properties of prepared blends including pure diesel

Property	B15C50P	B15A50P	B15C50C	B15A50C	Diesel
Density (kg/m^3)	891	851	814	826	842
Kinematic Viscosity at 40°**C** (mm^2/s)	3.59	3.55	3.17	3.26	3.10
Fire Point (°**C)**	67	71	68	69	65
Flash Point (°**C)**	55	57	59	57	53
Calorific Value (MJ/kg)	44.11	49.67	48.89	40.37	44.52

5. Results and Discussions

The operation of the engine using Pumpkin and castor methyl ester blend with added CuO and Al_2O_3 nano particles was found to be smooth throughout. The performance features such as specific fuel consumption (SFC), brake thermal efficiency (BTE) and also emissions characteristics such as CO_2, HC and CO are plotted against the varied load.

5.1 CO emissions

Emission level for CO emissions at different loads and for different blends are shown below in Fig. 7. From graph, it is observed that B15A50P emits very low CO emissions (0.13%) as compared to other tested blends varying from no-load to full load condition. Initially, at no load condition, all blends emit similar amount. In general, adding nano particles is seriously lowering the CO emissions because of more oxygen content, as compared with pure diesel.

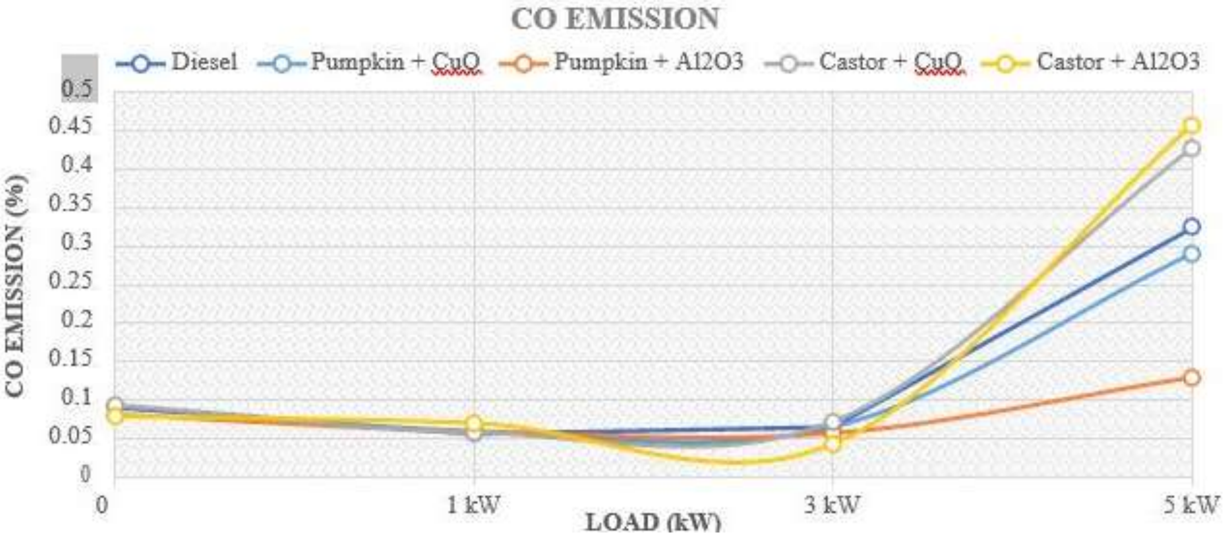

Fig.7 CO emissions Vs Load

5.2 CO_2 emissions

Fig.8 shows variation of CO_2 emissions at different load conditions. For pure diesel, CO_2 emission increased 1.9% at no load to 4.1% at full load (5 kW) condition whereas, for B15C50C maximum reaches to 5.9% at full load whereas, B15A50P shows less CO_2 emissions, varying from 2% to 3.6%, which are least as compared to all other blends.

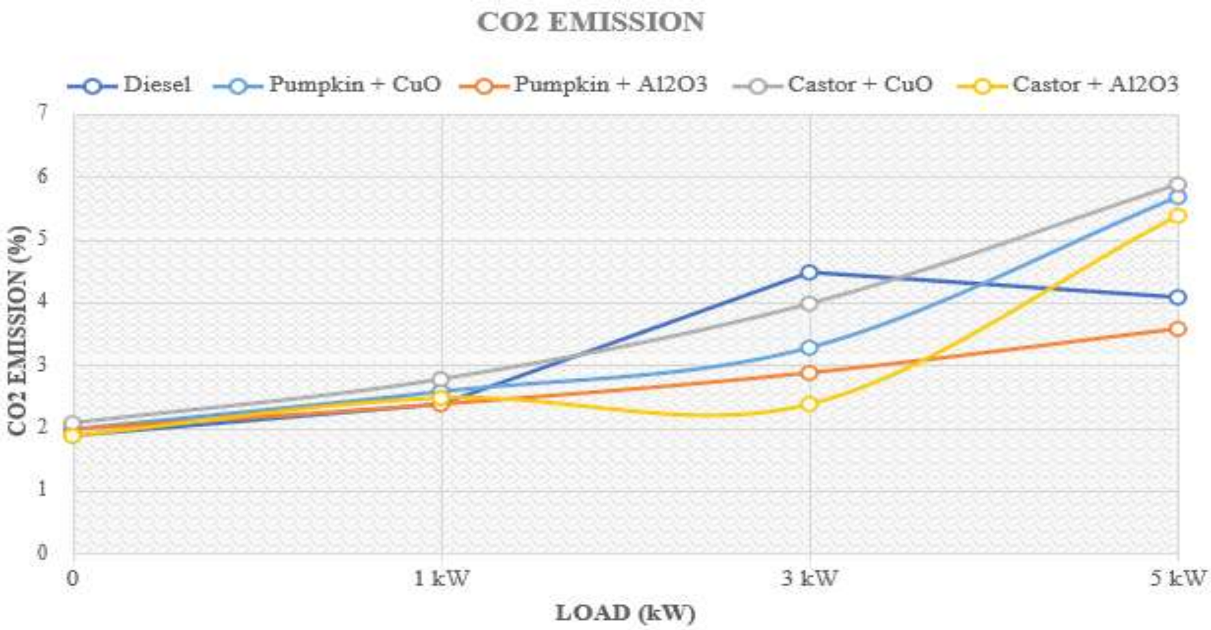

Fig.8 CO_2 emissions Vs Load

5.3 HC emissions

Fig. 9 shows the variation of HC with variation in load for all blends. As per graph, B15C50P shows minimum HC emissions at full load of nearly 82ppm whereas maximum of 148ppm is shown by B15A50C which is even more than pure diesel where emissions are nearly 120ppm.

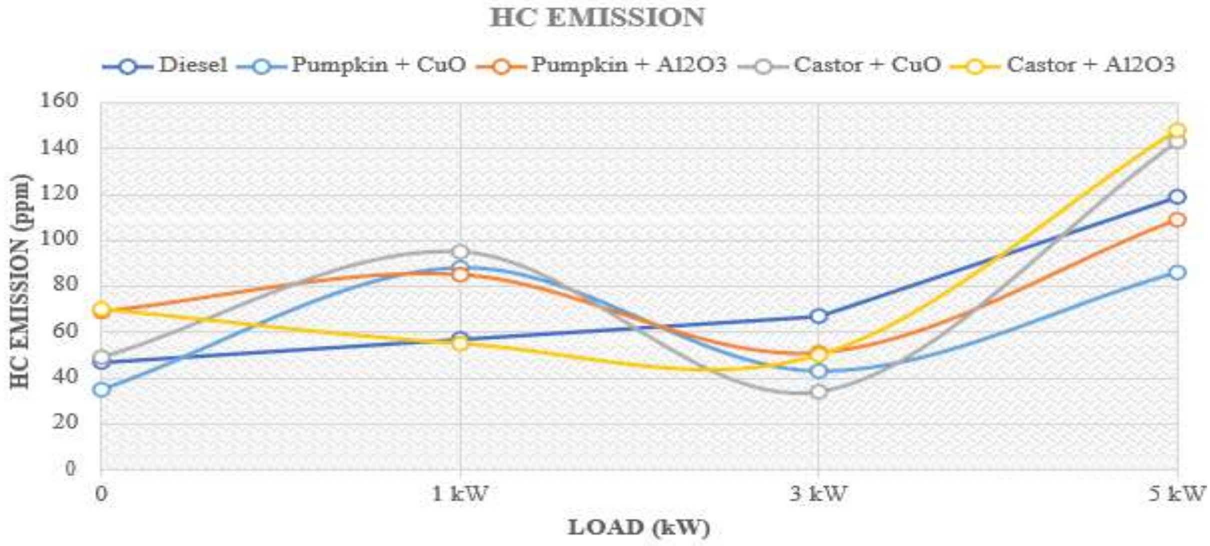

Fig. 9 HC emissions Vs Load

5.4 Brake thermal efficiency

Figure 10 shows variation of Brake thermal efficiency with variable load conditions. With increase in load we can see from the graph that for all blends there was increase in brake thermal efficiency also. B15A50C has shown the maximum increase i.e. 34% at full load condition whereas 26% efficiency came for B15A50P at full load, even for pure diesel also maximum efficiency of 28% nearly was seen at full load.

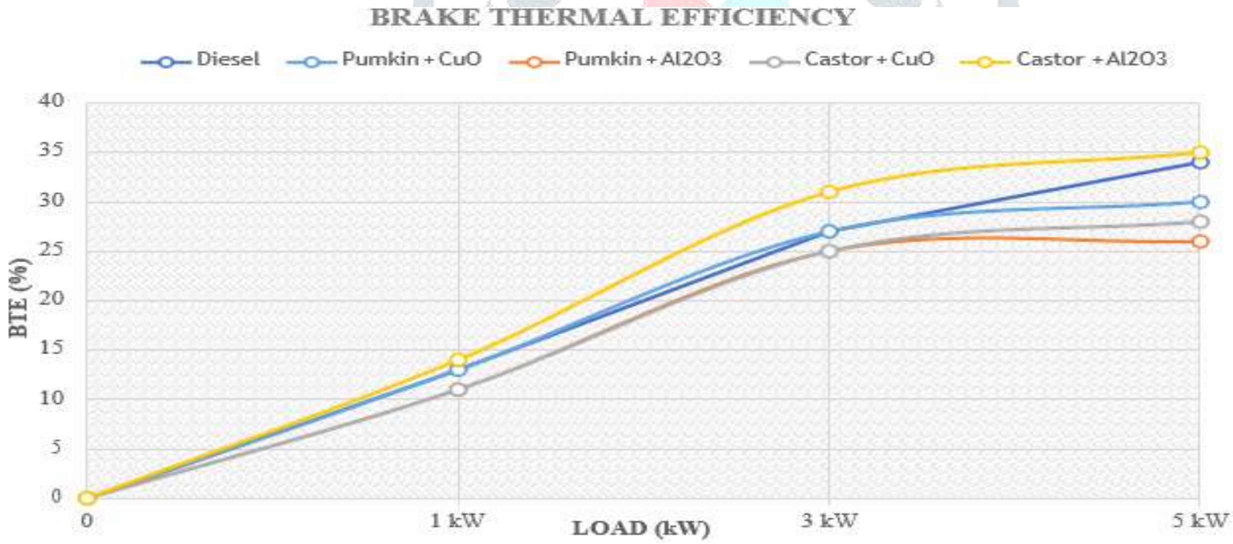

Fig. 10 Brake thermal efficiency Vs Load

5.5 Specific fuel consumption

Fig.11 shows Specific fuel consumption with variable load conditions and graph shows that initially it is increasing with the load, for all blends including pure diesel but after 1kW it starts decreasing for every blend. Minimum specific fuel consumption is 0.232kg/kW-h at full load for pure diesel and B15C50C is very close to it with nearly 0.252kg/Kw-h, maximum specific fuel consumption has shown by B15A50P which is nearly 0.27kg/kW-h.

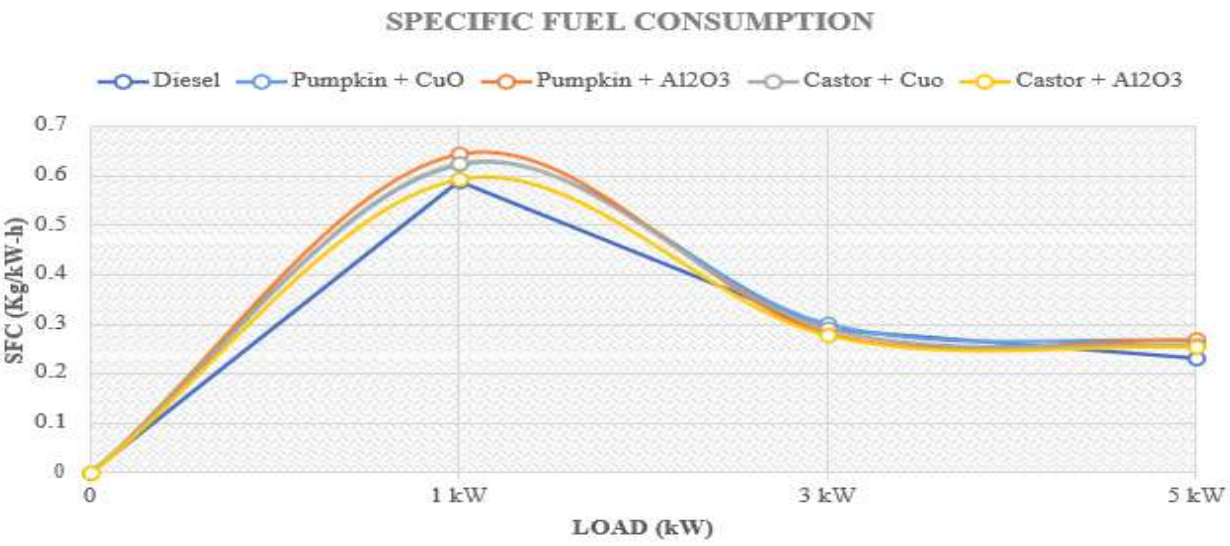

Fig. 11 Specific fuel consumption Vs Load

6. Conclusion

So based on present study, following points can be concluded:

- Although, with increase in engine load, there is increase in brake thermal efficiency for all blends including pure diesel where B15A50C has shown maximum value of 34%.
- Even though, minimum specific fuel consumption is shown by pure diesel at full load having value of 0.232kg/kW-h but B15C50C is very close to it with nearly value of 0.252kg/Kw-h.
- Even though, B15A50P emits very low CO emissions of 0.13% which is least from all tested blends including pure diesel, for B15A50C CO emissions are nearly 0.45%.
- CO_2 emissions has shown increase with load increase for all blends including pure diesel, whereas, for B15C50C maximum reaches to 5.9% at full load whereas, B15A50P shows less CO_2 emissions, varying from 2% to 3.6%, which are least as compared to all other blends.
- There is continuous variation of HC emissions with load where B15C50P has shown minimum HC emissions at full load of nearly 82ppm whereas maximum of 148ppm is shown by B15A50C which is even more than pure diesel where emissions are nearly 120ppm.

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