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Evaluation of Combustion and Emission Parameter of CI Engine Using Waste Transformer Oil as Fuel

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Abstract: ***This project gives idea for the effective use of Waste Transformer Oil as an alternate option for petroleum based fuels. Rapid depletion of fossil fuels, increasing pollution and increasing prices of petroleum based fuels have given a base for the research of various fossil fuels. As we all know that, petroleum based fuels are limited in reserves, concentrated in certain regions of the world are shortening day by day. Huge amount of dollars are being invested in research of alternative fuels. Meanwhile, the disposal of waste products like waste transformer oil from different electric power stations from many electric transformers throughout the country is becoming increasingly complex. while biodiesel from certain vegetable oils like Jatropha, Karanja, Soyabean and Rapeseed is acquiring much needed attention. The Waste Transformer Oil is a waste product which comes out from a electrical transformer is used for insulation and cooling purpose. This waste product can be used asansource of fuel for diesel engine applications. The WTO can be used after refining it by transesterification process or catalytic cracking process and then mixed with diesel fuel as an base fuel for evaluating different engine and emission parameters and to use it as an alternate source of fuel. The engine and fuel researchers are devoted to explore alternative fuels as the present world largely depends on petroleum fuel for generating power, vehicle movement and agriculture sectors. Price hike, limited reserve of petroleum oils and stringent emission regulation also forced researchers to find alternative fuels. In Bangladesh, there is limited petroleum reserve to meet the demand of the petroleum product and for this reason it is necessary to spend a lot of foreign currency for importing fuel every year. Recent price hike of petroleum oil incurs lots of money. Bangladesh imports most of the petroleum oils from Middle East. In this point of view, waste transformer oil (WTO) can be an alternative source for petroleum oils. WTO has significant physiochemical properties. WTO can meet a portion of our demand without any hesitation. There is a huge unused amount of transformer oil in Bangladesh which is rejected every year. This oil is not used for any other purpose. So, WTO is an important source for meeting the demand of diesel in Bangladesh. Bangladesh imports approximately 2.4 million ton diesel each year . It is well known that the transformer oil is used mainly in the electrical transformer for insulation purpose. Moreover, cooling is another purpose of using transformer oil in the electrical transformer while the transformer is running. Among various properties, one of the main properties of transformer oil is to sustain high temperature during operation. When an electrical transformer is in operation, the transformer oil is subject to mechanical and electrical resistance. For a certain period of time, it is recommended to check the electrical and chemical properties of the transformer oil. By using WTO, Bangladesh can reduce importing a huge amount of petroleum products from foreign countries. Our attention goes to the WTO. WTO results from the power generation and transmission station. At present 100 per cent transformer oil is not used in place of diesel fuel (DF) to run the engine rather blends of WTO and DF.***

Keywords: Waste transformer oil, WTO characteristics, Diesel fuel

I. INTRODUCTION

The engine and fuel researchers are devoted to explore altermative fuels as the present world largely depends on petroleum fuel for generating power, vehicle movement and agriculture sectors. Price hike, limited reserve of petroleum oils and stringent emission regulation also forced researchers to find alternative fuels. In Bangladesh, there is limited petroleum reserve to meet the demand of the petroleum product and for this reason it is necessary to spend a lot of foreign currency for importing fuel every year. Recent price hike of petroleum oil incurs lots of money. Bangladesh imports most of the petroleum oils from Middle East. In this point of view, waste transformer oil (WTO) can be an alternative source for petroleum oils. WTO has significant physiochemical properties. WTO can meet a portion of our demand without any hesitation. There is a huge unused amount of transtormer oil in Bangladesh which is rejected every year. This oil is not used for any other purpose. So, WTO is an important source for meeting the demand of diesel in Bangladesh. Bangladesh imports approximately 2.4 million ton diesel each year [1]. It is well known that the transformer oil is used mainly in the electrical transformer for insulation purpose. Moreover, cooling is another purpose of using transformer oil in the electrical transformer while the transformer is running. Among various properties, one of the main properties of transformer oil is to sustain high temperature during operation.

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II. LITERATURE REVIEW

A. Engine Characterization Study of Hydrocarbon fuel Derived Through Recycling of Waste Transformer Oil

This work intends to capitalize waste transformer oil (WTO) as a renewable source of fuel in a diesel engine, given the cost of fuel being used is reduced when using waste products. Previously, despite its higher viscosity, WTO is used as such or in blends with diesel in a diesel engine. However, in the current study, efforts are taken to chemically treat WTO so as to bring down its viscosity and make it conducive for diesel engine application. As such, WTO is pretreated with concentrated sulfuric acid and subjected to alkaline trans-esterification with an alcohol and alkali catalyst. Interestingly, the derived hydrocarbon fuel (HCF) discerned the presence of cyclo-hexenol and oxabycyclo-heptane as its major constituents, contrary to the exwastence of methyl esters as reported for other trans-esterified vegetable oils. Subsequently, HCF is utilized in a diesel engine by optimizing the combustion bowl geometry, considering that an engine modification is imperative to effectively operate high viscous fuel like derived HCF in a diesel engine. In this regard, three combustion bowl geometry shapes are preferred viz Piston
1 (shallow depth combustion chamber), Piston 2 (toroidal combustion chamber) and Piston 3 (hemispherical combustion chamber). In the pursuit of experimental investigation of B25 (HCFe 25% and diesel e 75%) and B100 (HCF e 100%), piston 2 showed enhanced engineperformance and emission than the other two configurations. Notably, BTE for B25 with piston
2 is increased by 10.2%, while the emission such as HC, CO and smoke are reduced by 13.3%, 11.7% and 10.1%, respectively, than the conventional piston bowl geometry (piston 3) at the expense of increased NOX emission.

Authors: S. Prasanna Raj Yadav, C. G. Saravanan.
Publishedin:Journal of Energy Institute, http://dx.doi.org/10.1016/j.joei.2014.10.006 Year: 2014.

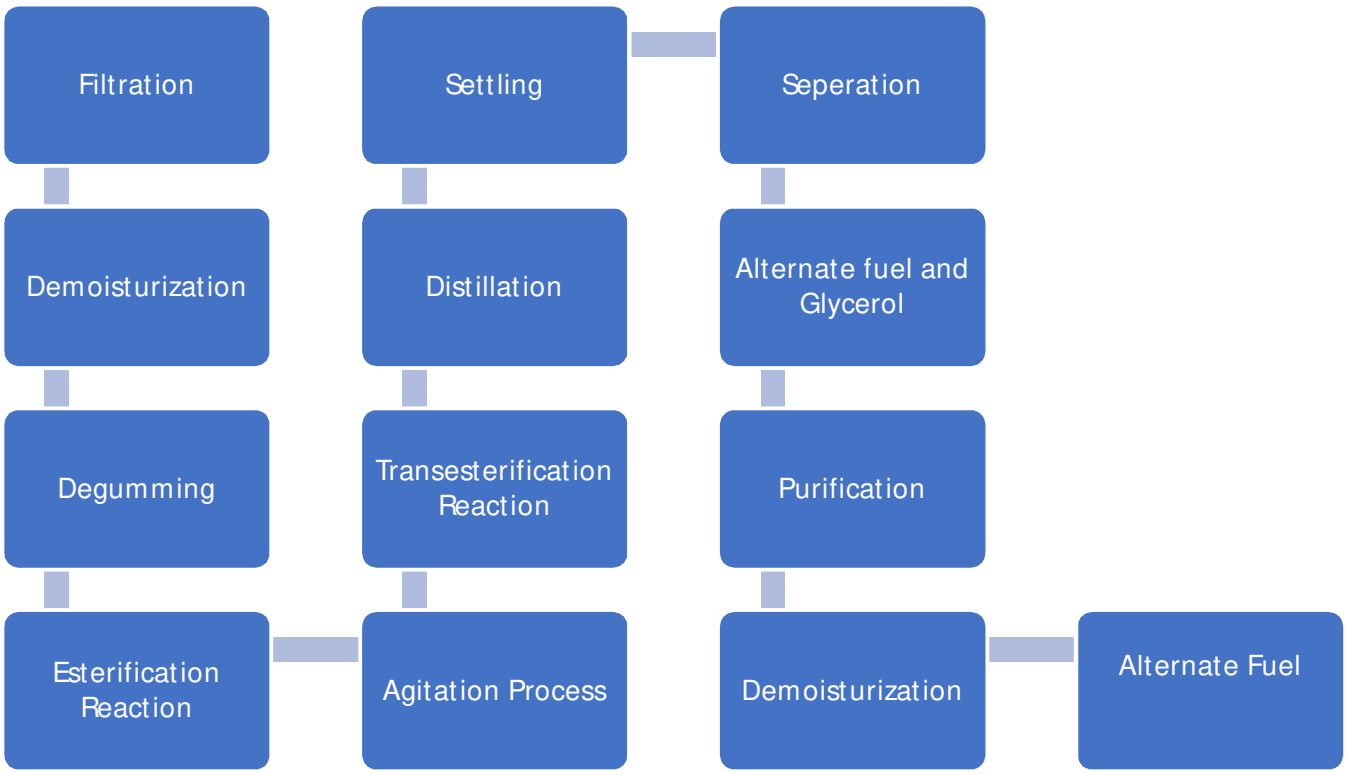
B. Fuel and engine Characterization study of Catalytically Cracked waste Transformer Oil

This research work targets on the effective utilization of WTO (waste transformer oil) in a diesel engine and thereby, reducing the environmental problems caused by its disposal into open land. The novelty of the work lies in adoption of catalytic cracking process to chemically treat WTO, wherein waste fly ash has been considered as a catalyst for the first time. Interestingly, both the oil and catalyst used are waste products, enabling reduction in total fuel cost and providing additional benefit of effective waste management. With the considerable token that use of activated fly ash as catalyst requires lower reaction temperature, catalytic cracking was performed only in the range of 350–400 C. As a result of this fuel treatment process, the thermal and physical properties of CCWTO (catalytically cracked waste transformer oil), as determined by ASTM standard methods, were found to be agreeable for its use in a diesel engine. Further, FTIR analysis of CCWTO discerned the presence of essential hydrocarbons such as carbon and hydrogen. From the experimental investigation of CCWTO – diesel blends in a diesel engine, performance and combustion characteristics were shown to be improved, with a notable increase in BTE (brake thermal efficiency) and PHRR (peak heat release rate) for CCWTO 50 by 7.4% and 13.2%, respectively, than that of diesel at full load condition. In the same note, emissions such as smoke, HC (hydrocarbon) and CO (carbon monoxide) were noted to be reduced at the expense of increased NOX (nitrogen oxides) emission.

Authors:S. Prasanna Raj Yadav, C. G. Saravanan, R.Vallinayagam, S.Vedharaj & William L. Roberts.
Published in:Energy Conservation and Managementhttp://dx.doi.org/10.1016/j.enconman.2015.02.051 Year:2015.

III.PROCESSES INVOLVED

The making of the Alternative fuel for the use of various diesel Engines consists of various steps from extracting the fuel from the Transformer to mixing it with diesel in a chemically balanced way without affecting the properties of diesel and waste transformer oil in a huge manner. These processes are carried out in a certain manner to get the efficient chemically balanced formula for the alternative fuel. The basic step before uing any fuel is Filteration where we just filter the obtained Waste Oil from the Transformer so that the impurities bigger in size can be extricated from the oil and it can be further taken to carry out the other processes with a bit more efficiency.



1) *Filtration:* This method removes impurities that have poor solubility at these reduced temperatures. Another potential method of purification is an energy-intense process that involves distillation of the final biodiesel product.
2) *Demoisturization:* The moisture from the waste transformer oil is removed by heating it at 110oC for 10 minutes.
3) *Degumming:* Degumming is the process of hydrating phosphatides present in an oil by adding water followed by centrifugation. There are only three reasons to degum oil: to produce lecithin (phosphatides), to provide degummed oil for long-term storage or transport, and to prepare for physical refining.
4) *Esterification:* Esterification is the chemical process that combines alcohol (ROH) and an organic acid (RCOOH) to form an ester (RCOOR) and water. This chemical reaction results in forming at least one product of ester through an esterification reaction between a carboxylic acid and an alcohol.
5) *Agitation:* Agitation refers to forcing a fluid by mechanical means to flow in a circulatory or other pattern inside a vessel
6) *Transesterification:* transesterification is the process of exchanging the organic group R″ of an ester with the organic group R′ of an alcohol. These reactions are often catalyzed by the addition of an acid or base catalyst.
7) *Distillation:* It is the process of separating the components or substances (Alcohol) from a liquid mixture by using selective boiling and condensation
8) *Settling:* Settling is the process by which particulates settle to the bottom of a liquid and form a sediment.
9) *Separation:* A separation process is a method that converts a mixture or solution of chemical substances into two or more distinct product mixtures. Here, after settling the biodiesel is separated into two components i.e. Crude Biodiesel and Glycerol.
10) *Purification:* The obtained crude biodiesel is purified by water washing the fuel.
11) *Demoisturization:* Excessive moisture is removed from the fuel.

IV. METHODOLOGY

A. *Engine Details*

ICEngine set up under test is Research Diesel having power 3.50 kW @ 1500 rpm which is 1 Cylinder, Four stroke , Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Compression Ratio 16.00, Swept volume 661.45 (cc)

B. *Combustion Parameters*

Specific Gas Const (kJ/kgK) : 1.00, Air Density (kg/m^3) : 1.17, Adiabatic Index : 1.41, Polytrophic Index : 1.28, Number Of Cycles : 10, Cylinder Pressure Referance : 4, Smoothing 2, TDC Reference : 0

C. *Performance Parameters*

Orifice Diameter (mm): 20.00, Orifice Coeff. Of Discharge : 0.60, Dynamometer Arm Legnth (mm) : 185, Fuel Pipe dia (mm) : 12.40, Ambient Temp. (Deg C) : 27, Pulses Per revolution : 360, Fuel Type : Diesel, Fuel Density (Kg/m^3) : 830, Calorific Value Of Fuel (kj/kg) : 42000

Sr No.	Test Description	Ref Std ASTM 6751	Reference		Diesel	Waste
			Unit	Limit	B00%	W5%
1	Density	D1448	gm/cc	0.800-0.900	0.83	0.835
2	Calorific Value	D6751	MJ/Kg	34-45	42.1	41.7
3	Cetane No.	D613	-	41-55	49	49.1
4	Viscosity	D445	mm2/sec	3--6	2.3	2.4
5	Moisture	D2709	%	0.05%	NA	NA
6	Flash point	D93	°C	-	66	72
7	Fire point	D93	°C	-	72	82

BP= WxNx0.45 x 0.746/5000 (kW) ----(1)

Where, W is load in Ib and N is engine speed in rpm.

Input power=ṁf CV/3600 (kW) ----(2)

Where, ṁf is the mass flow rate of fuel in kg/hr and CV is the calorific value of fuel in kJ/kg.

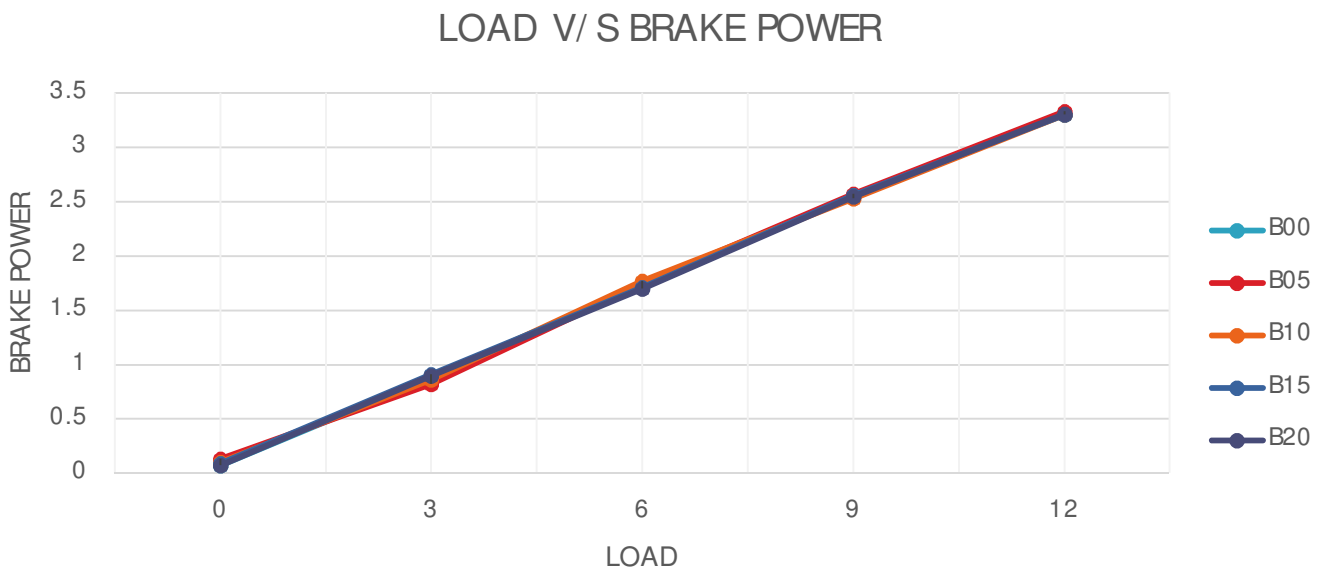
BSFC= ṁf /BP (kg/kWh) ---- (3)

Brake thermal efficiency= 100/(ṁf /BP)(CV/3600) (%) ----(4)

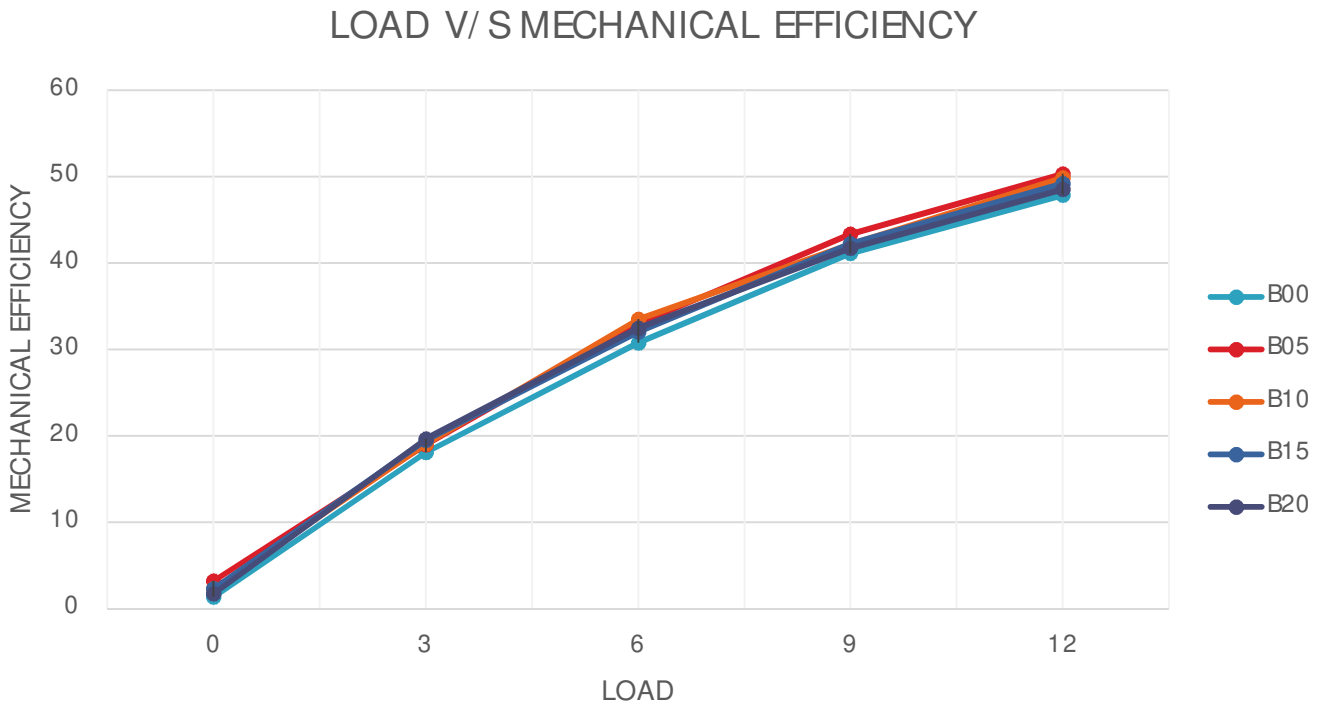
V. RESULTS & DISCUSSIONS

A. *Effects of WTO on Different Engine Parameters*

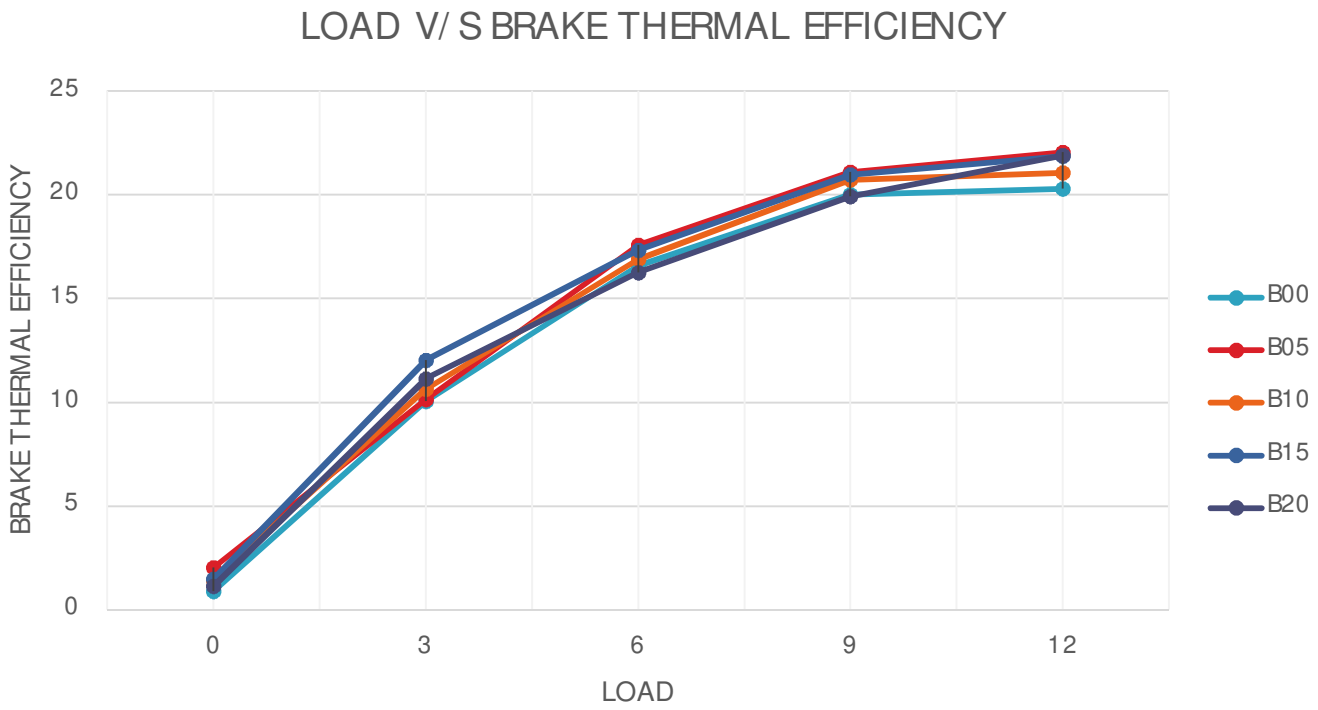
1) *For CR16: LOAD VS BP*



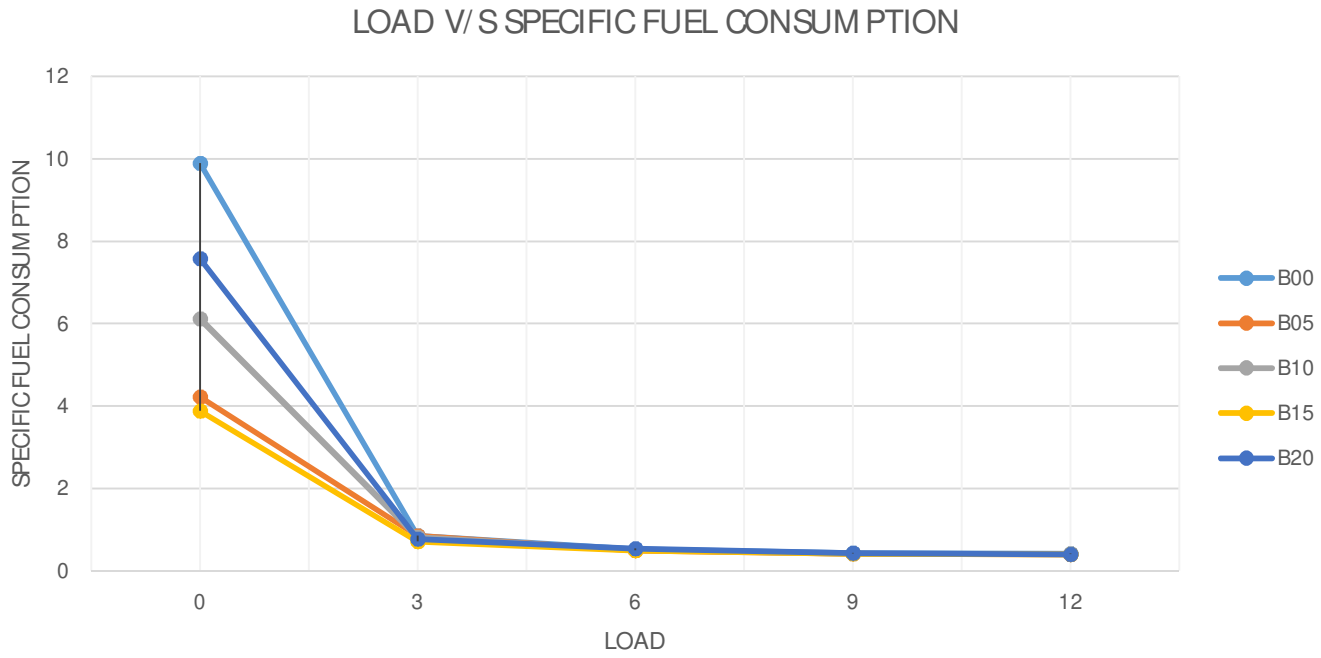
2) *For CR16: LOAD VS MECHANICAL EFFICIENCY*



3) *For CR16: Load vs Brake Thermal Efficiency*

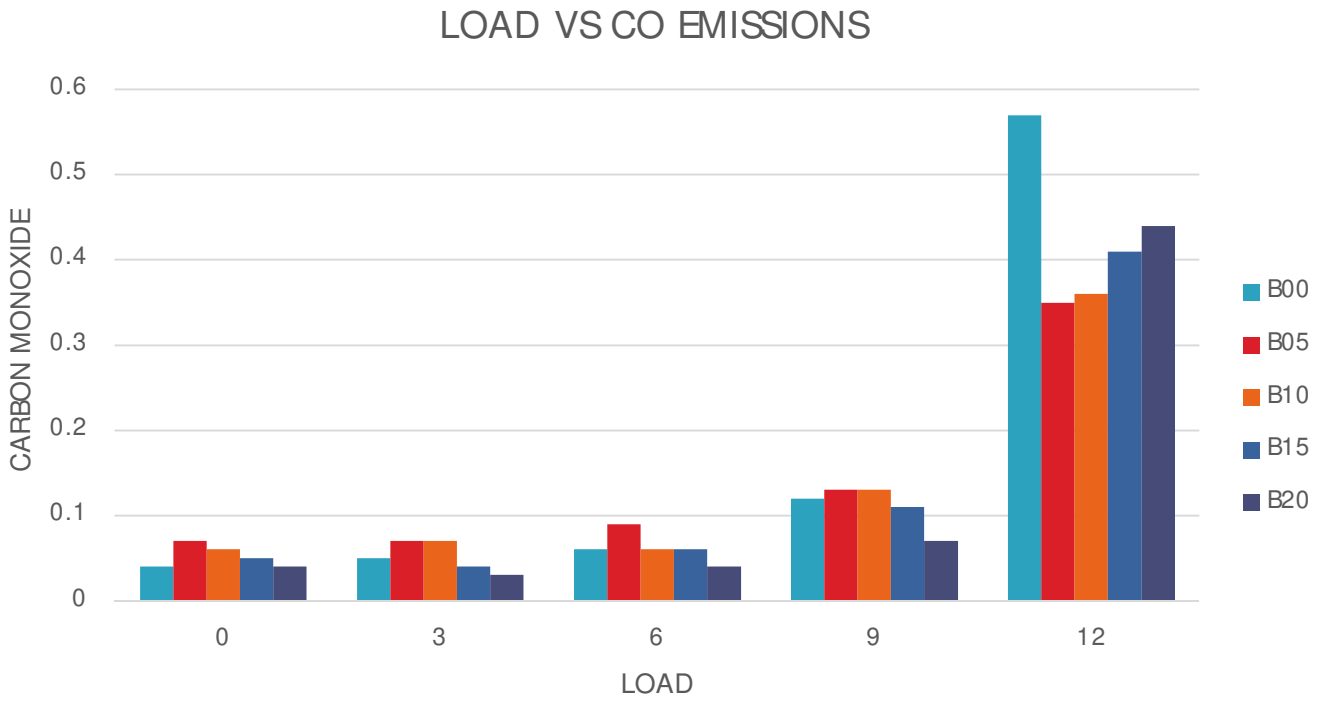


4) For CR16: Load vs Specific Fuel Consumption

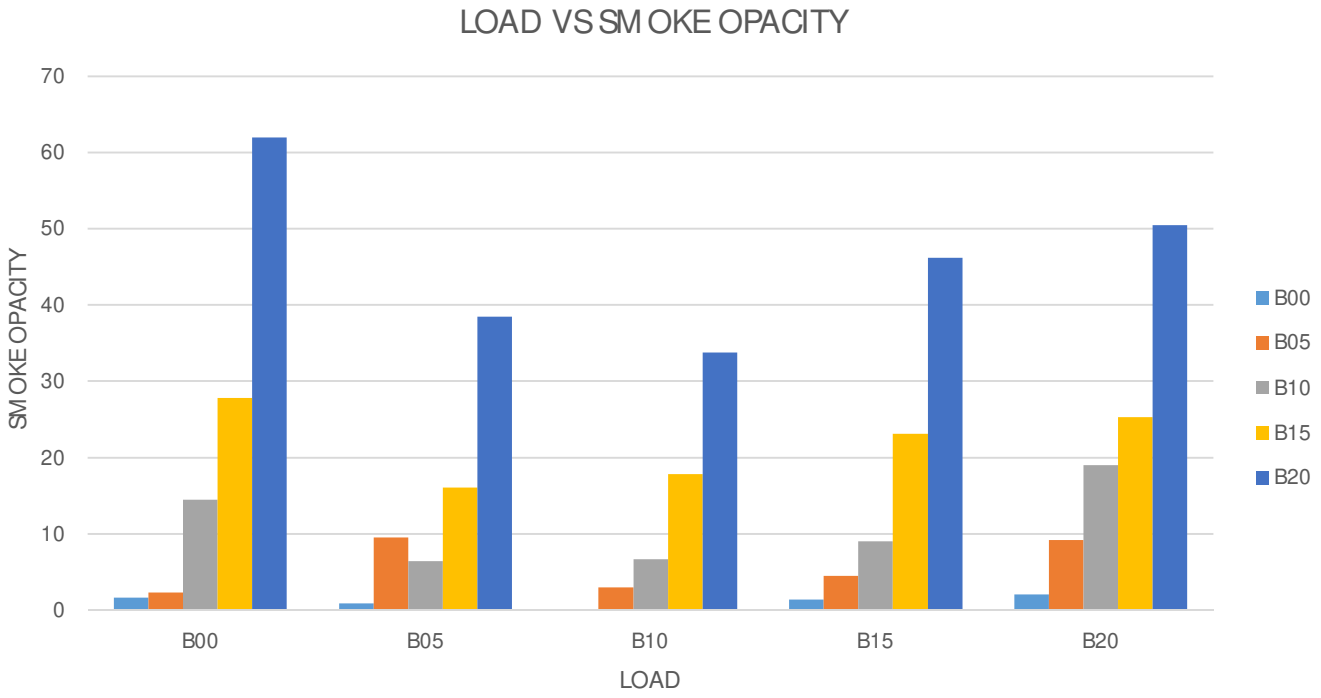


B. Effects of WTO on Different Emission Parameters

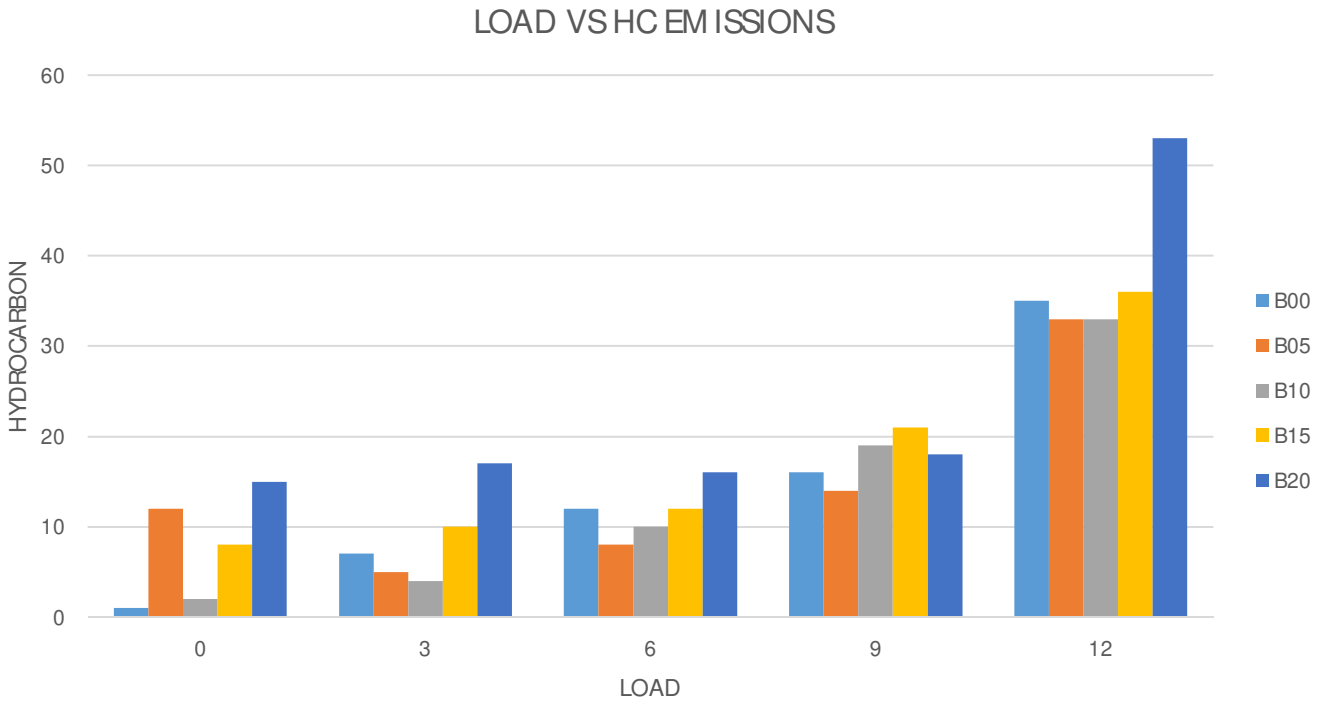
1) For CR16: Load vs co Emissions



2) *For CR16: Load vs Smoke Opacity*



3) *For CR16: Load vs Hc Emissions*



VI. CONCLUSIONS

The objective of this experiment was to use transformer oil as an alternative fuel. The pure diesel was used as base fuel for comparing the properties and pertormance parameters. The pertormance test was conducted on a diesel engine at a constant speed of 800. The results of the current investigation may be summarized as follows:

1) The viscosity of B05 blend is 2.4 and that of pure diesel i.e. B00 was 2.3 and the calorific value of WTO B05 blend was 41.7 compared to 42.1 of diesel. The flash and fire point of WTO was 72 and 82 respectively while for diesel flash and fire point were 66 and 72 respectively. This shows transformer oil is safer for storage

2) The brake thermal efficiency for each blend was found to be high because of proper combustion.The brake thermal efficiency of B05 was 22.05% whereas baseline diesel was 20.31% for the same power output.

3) The fuel consumption for B05 was higher as compared to DF due to the lower heating value.

4) The mechanical efficiency of B05 was 50.29 as compared to 47.88 of diesel fuel.

5) The exhaust gas temperature of blends were higher as compared to diesel fuel due to more residence time and higher viscosity.

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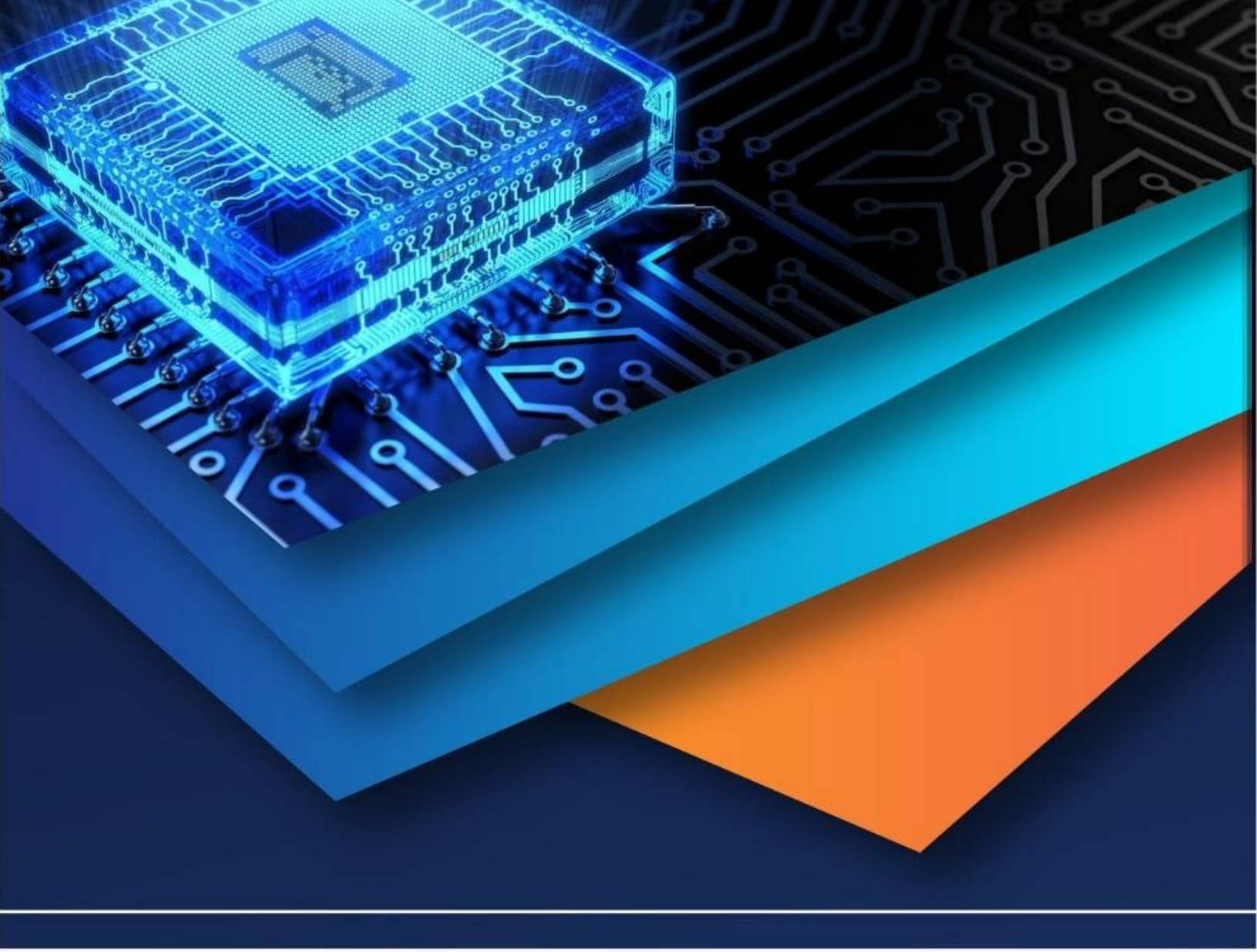

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