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Production and Characterization of Biodiesel Fuel Derived from Neem (Azadirachta Indica) Seed using Two Cylinder Diesel Engine Model

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ABSTRACT
As the decreasing availability of the fossil fuel is rising day by day, the search for alternate fuel that can be used as a substitute to the conventional fuels is rising rapidly. A new type of biofuel, Neem oil biodiesel, is introduced in this work for the purpose of fuelling diesel engine. Neem oil was extracted from neem seed by solvent extraction method and biodiesel was produced by transesterification method. The percentage yield of Neem oil and biodiesel were found to be 40% and 75% respectively. The properties were simulated in a model produced using GT power suite. The engine speed was varied and engine performance such as brake power, brake specific fuel consumption, brake mean effective pressure and the emission of biodiesel and petroleum diesel at various speed were determined and compared. The results show the improve performance of biodiesel. The performance characteristics of an engine were studied with biodiesel and petro-diesel. The brake power 31.25 kW, brake torque 102.8 N-mare found higher at 3600 rpm (case 1) and 1200 rpm (case 4) respectively. In biodiesel, specific fuel consumption is found more than the petro-diesel and the CO and CO2 emission were found lower in biodiesel than petro-diesel. The biodiesel have shown better performance than the petro-diesel.

Keywords: *Biodiesel, Neem seeds, GT – power engine, Diesel engine, Characterization.*

1. INTRODUCTION

Energy is very essential in life it is one of the most fundamental requirements for human existence and activities and also the ability to cause change and the impetus behind all motions. Fossil fuels which are non-renewable in nature have been helping the world to meet its energy demand. These fuels are depleting and the world population is increasing every day. The tremendous increase in the production of automotive and other related product results in greater demand for such energy source. As a result, there are challenges in the price and supply of fossil fuels. Also the emission produce by the combustion of fossil fuels contributes to air pollution and global warming. Hence, renewable and clean alternative fuels have received increasing attention for current and future utilization.

Biodiesel as one of the alternatives to fossil fuel for diesel engines has become increasingly important due to environmental consequences of petroleum - fueled diesel engines and the decreasing petroleum resources. Biodiesel is a vegetable oil or animal fat-based diesel fuel consisting of long chain alkyl (methyl, ethyl or propyl) esters [1].

Biodiesel can be produced from natural oil which is renewable resources and animal fats. Vegetable oils have become more attractive owing to its environmental benefits and the fact that it is produced from renewable sources, it is biodegradable and non-toxic. Another advantage using vegetable oils for biodiesel production is that it has high energy content compared to conventional diesel; vegetable oils have 90% energy content of diesel. Vegetable oils are extracted from edible and non-edible, renewable oilseeds such as groundnut, neem seeds, soybean, jatropha seeds, rapeseeds, cotton seeds etc. but the use of non-edible seeds tends to be more cost efficient and economical [2].

Neem seeds are non-edible and very good sources of vegetable oils. Biodiesel can be produced from neem seeds vegetable oils using transesterification process, which is the reaction of the neem seeds oil with alcohol (Methanol) to form Neem Oil Methyl Ester (NOME) and glycerol as by-product. Neem Oil Methyl Ester (NOME) is the chemical term for the biodiesel [3].

Neem (Azadirachta Indica) is a tree of the mahogany family, melieae which is abundantly grown in various parts of Asia and Africa. Neem grows on almost all types of soil. It is typically grown in tropical and Semitropical regions. The neem tree popularly referred in Hausa as DogonYaro, is characterized by it broad dark brown stem and widely spread branches. It is a fast growing plant with long productive life span of 150 to 200 years, its ability to survive on drought and poor soils at a very hot temperature of 44 ^{0}C and a low temperature of up to 4 °C as well as its high oil content of 30.7 to 60%. A mature Neem tree produces 30 to *50* kg fruit every year [4].

The Neem seed fruit is a smooth, olive-like drupe which varies in shape from elongate *oval* to nearly roundish, and when ripe is 1.4 - 2.8 centimeters by 1.0 - 1.*5* centimeters. The fruit skin (exocarp) is thin and the bitter-sweet pulp (mesocarp) is yellowish-white and very fibrous. The mesocarp is 0.3 - 0.5 centimeters thick. The white, hard inner shell (endocarp) of the fruit encloses one rarely two, or three, elongated seeds (kernels) having a brown seed coat. Neem fruit is green in color initially and gradually turns to yellow when fully ripened. A matured fruit is very fleshy and filled with sweetish fluid. Fruit contains 40 - 55% water content [5].

Neem oil is a vegetable oil pressed from the seeds of neem. The oil varies in colour, ranging from yellowish brown to dark brown, it has a strong odour that is said to combine the odours of peanut and garlic, it is bitter in taste due to presence of triglyceride and triterpenoid in its constituents. Neem oil also contains steroids (Campestral, Beta-sisterol, stigma sterol) and a plethora of triterpenoids of which azadirachtin is most widely studied. The percentage of the oil in the seed makes it a good resource and has high potential for production of biodiesel. Neem oil will become a good potential supplier of biodiesel in future. The biodiesel is a mono alkyl ester (Methyl Ester) of long chain fatty acid derived from renewable lipids of neem oil [6].

The Experimental analysis of the engine with various types of biodiesel and their blends conducted by [7] shows that much time and effort is required. In the present investigation, biodiesel is produced using unrefined neem seed oil. The performance tests are simulated in model of two cylinder diesel engine using biodiesel blend and petro-diesel as fuel. The effects of relative air-fuel ratio and compression ratio on the engine performance for different fuels are also analyzed using this model. The performances were compared with that of pure diesel fuel and observed.

2. MATERIALS AND METHODS

2.1 Materials and Equipment

Materials used are: Neem seeds, Petroleum diesel, Methanol, N-Hexane, Reagent water, Acetic Acid, Hydrochloric acid, Chloroform, Iodine Solution, Phenolphthalein Indicator, Sodium hydroxide (NaOH), Potassium iodine solution, and Sodium thiosulfate solution.

Equipment used are: Metal hammer, Digital balance, Magnetic stirrer, Soxhlet extractor and accessories, Reflux condenser, Thermometer, Heating mantle, Stirrer, Reagent bottle, Stop watch, Hydrometer, Separating funnel, Conical flask, Volumetric flask, Desiccators, Beaker, Oven, Mantle and pestle.

2.2 Methods

The methods used in carrying out this research are:
1. Collection and Preparation of seeds
2. Oil extraction
3. Biodiesel production
4. Modeling and simulation of fuel characteristics

2.2.1 Collection and preparation of seeds

Ten kilogram (10 kg) of Neem seeds were collected from available sources within and outside Abubakar Tafawa Balewa University Bauchi Metropolis, the seeds was dried under room temperature to reduce moisture content and increase oil yield. The seed were taken to the chemistry laboratory, faculty of science, Abubakar Tafawa Balewa University Bauchi for oil extraction.

2.2.2 Oil extraction

The process of extraction of vegetable oil involves the removal of oil from plant, components, typically seeds. This can be done via mechanical extraction using an oil mill, traditional extraction using manual pressing or chemical extraction using solvent. The processing of vegetable oil in commercial applications is commonly done by chemical extraction, using solvent extracts, which produces higher yields, fast and less expensive. The most common solvent is petroleum-derived hexane.

In the method mentioned above, a soxhlet extraction which is a laboratory apparatus designed for the extraction of lipids from solid materials is used. A soxhlet Extractor has three main sections: a percolator (boiler and reflux) which circulates the solvents, a thimble (usually made of thick filter paper (which retains the solid to be laved, and a siphon mechanism, which periodically empties the thimble.

Procedure

250ml clean boiling flask was dried in an oven at 105-110 ^{0}C for about 30 minutes. This was then transferred into a desiccator and allowed to cool; a weighed amount of the sample (grounded seeds) was carefully poured into a labeled thimble. The boiling flask was filled with about 300ml of n-Hexane. The extraction thimble was plugged lightly with cotton wool. The soxhlet apparatus was assembled and refluxing was carried out for about 6 hours. The thimble was carefully removed and the n- hexane in the top container of the set up was drained into another container for re use. When the flask was almost free of n-hexane, it was removed and dried at 105 ^{0}C – 110 ^{0}C for an hour. It was transferred from the oven into a desiccator and allowed to cool then weighed. The oil obtained, was therefore stored in hermetically closed bottle.

2.2.3 Biodiesel production

This is the next stage after oil has been produced. Biodiesel production is the process of producing the biofuel, biodiesel, through the chemical reactions of transesterification and esterification.

A measuring cylinder was used to measure 40 ml of methanol and transferred to a 250 ml beaker. An electric balanced was used to measure 1 g of potassium hydroxide. The potassium hydroxide was slowly added to the methanol. The mixture was gently stirred using a glass rod until the potassium hydroxide completely dissolved in the methanol.

200 ml of the extracted oil was measured and transferred into a 500 ml beaker. The potassium methoxide solution prepared was added to the oil. The residual was heated and mixed well using magnetic stirrer. The mixture was transferred to separating funnel and left for 24 hours to settle. The lighter color layer of biodiesel was observed on the surface and a darker colored layer of glycerol was observed in the separating funnel.

2.2.4 Modeling
In building a GT-POWER model the first step is to import the necessary templates from the **Template Library**. The template library contains all of the available templates that can be used in GT-POWER. Some of these templates are copied into the project before they can be used to create objects and parts.

The following engine parameters were modeled using GT – power model suite and all procedures duly followed to obtain optimum results.

i. Cylinder

The Engine Cylinder is somewhat unique, because the majority of the input to the object comes in the form of reference objects, which define sub-models for the cylinder such as geometry, wall temperature, heat transfer, in-cylinder flow and combustion.

ii. Cylinder initial state object

The cylinder initial state can be the same as the initial state of the intake runner and intake port.

iii. Cylinder heat transfer object

This object is used to describe the in-cylinder heat transfer characteristics between the gas and the combustion chamber walls. The Woschni heat transfer model is use because it is the industry standard, easy to use and gives good estimates of in-cylinder heat transfer.

iv. Head/bore area ratio and piston/bore area ratio

The Head/Bore Area Ratio compares the surface area of the head to the bore area. The Piston/Bore Area Ratio compares the surface area of the piston to the bore area. This is a simple way of accounting for heat transfer from a concave head, flat piston combination in an SI application, and a flat head, bowl piston combination in a DICI application, without explicitly defining the detailed geometry.

Another attribute is the radiation multiplier. For SI engines radiation is typically not a factor, and so the recommended value is ign (ignore), which equals 0, meaning radiation will not be included in the heat transfer analysis. Conversely, for diesel engines radiation is important because the soot particles actually radiate. Therefore, the recommended value for diesel engines is 1.

v. Engine crank train

This object defines the engine type, cylinder arrangement, firing order, and other engine block and crankshaft characteristics.

2.2.4.1 Run setup/case setup/plot setup
Once the model is fully built, information such as case specific input, type of simulation, and desired output must be described. Most of this is accomplished through selections under the Run menu.

i. Run setup

Procedure:

Select Run -> Run Setup. There are many folders inside Run Setup and several of the folders have values that are required in order to run the model. Fill in the following values in the TimeControl, Initialization, FlowControl, and ThermalControl folders as shown in figures 1 and 2.

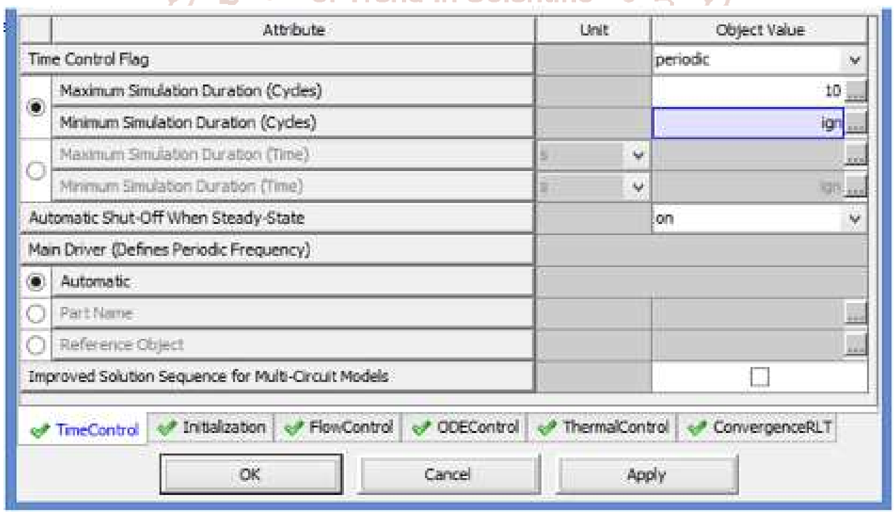


Figure 1; Time control folder

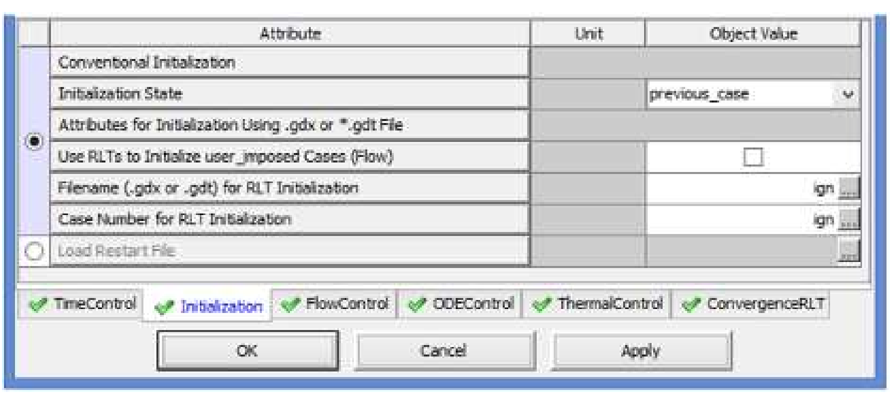


Figure 2; Initialization folder

ii. Case setup

Procedure:

Go to the Run menu and select Case Setup of 3000 RPM. For the Case Label type 'Speed = [RPM]'
For the parameter RPM, type 'Engine Speed' for the Label and 3000 for the Case 1 value.
The text for the Case Label should now read 'Speed = 3000. Make certain that the check box next to Case 1 is checked ON, indicating that Case 1 of the model will run when the simulation is run as shown in figure 3.

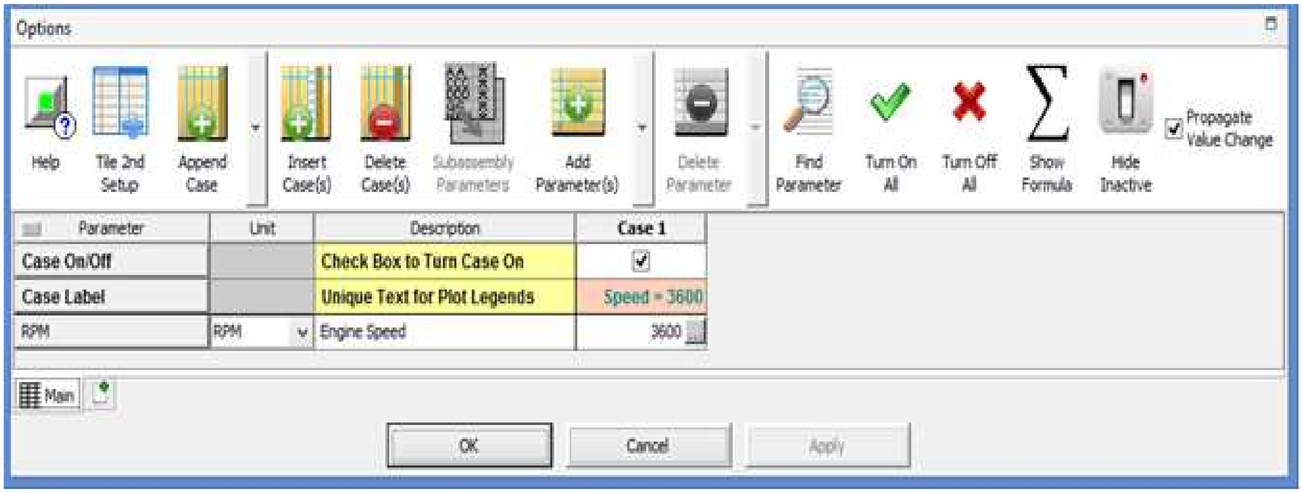


Figure 3; Case setup

ii. Plot setup

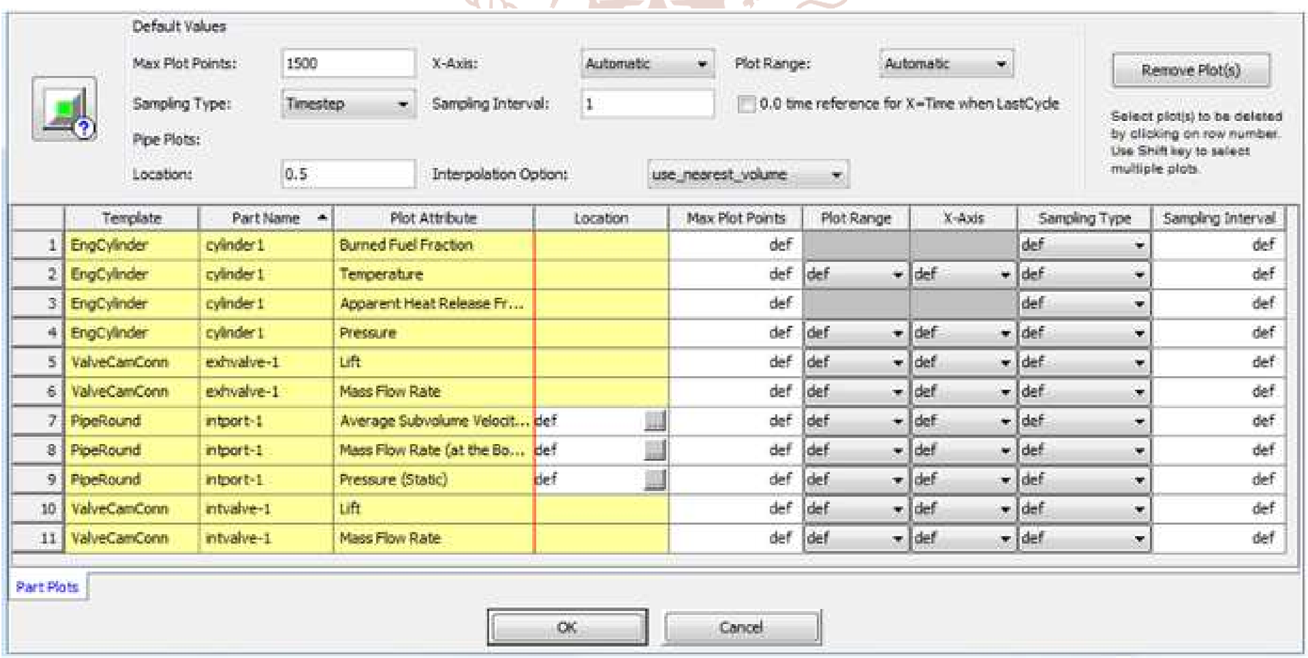
The final item before running the model is to request plots. Every applicable part on the project map has one or more folders for requesting what are referred to as instantaneous plots.

Procedure:

Double-click on the intake port part (intport-1), and go to the 'Flow' folder.

Select (check box on) Pressure (Static), Mass Flow Rate (at the Boundary), and Average Subvolume Velocity (centroid). For the intake and exhaust valves, in the 'Plots' folder, select Mass Flow Rate and Lift. For the cylinder, in the 'Plots: Flow' folder select Pressure, in the 'Plots: Thermal' folder select Temperature, and in the 'Plots: Combustion' folder select Burned Fuel Fraction and Apparent Heat Release Fraction.

All plot selections that have been made in the model can be viewed in one place by going toRun -> Plot Setup. Plot Setup allows the user to change details about each plot. The Plot Setup window should look similar to the figure 4 below.



	Template	Part Name	Plot Attribute	Location	Max Plot Points	Plot Range	X-Axis	Sampling Type	Sampling Interval
1	EngCylinder	cylinder1	Burned Fuel Fraction		def			def	def
2	EngCylinder	cylinder1	Temperature		def	def	def	def	def
3	EngCylinder	cylinder1	Apparent Heat Release Fr...		def			def	def
4	EngCylinder	cylinder1	Pressure		def	def	def	def	def
5	ValveCamConn	exhvalve-1	Lift		def	def	def	def	def
6	ValveCamConn	exhvalve-1	Mass Flow Rate		def	def	def	def	def
7	PipeRound	intport-1	Average Subvolume Velocit...	def	def	def	def	def	def
8	PipeRound	intport-1	Mass Flow Rate (at the Bo...	def	def	def	def	def	def
9	PipeRound	intport-1	Pressure (Static)	def	def	def	def	def	def
10	ValveCamConn	intvalve-1	Lift		def	def	def	def	def
11	ValveCamConn	intvalve-1	Mass Flow Rate		def	def	def	def	def

Figure 4; plot setup

3. RESULTS AND DISCUSSION

Figure 1 shows the brake mean pressure with respect to the varied speed in the simulation model. From the result it was observed that the brake mean effective pressure is maximum and minimum at Case 4 and Case 1 respectively. This indicates that the brake mean pressure is peak value found to be 16.42 bar at Case 4 as the engine speed decreases hence brake power is maximum pressure is at case 4 when the engine speed is 1200 rpm.

Figure 2 shows the brake power with respect to the varied speed in the simulation model. It was observed that the brake power is declining from Case 1 which is maximum speed (3000 rpm) to Case 5 (600 rpm). This indicates that the power at the wheel decreases as the speed decreases.

Figure 3 shows Net Indicated Mean Effective Pressure with respect to the varied speed. The maximum Net IMEP, 18.5 bar is observed at Case 3(1800 rpm) and started declining after Case 3. In Figure 4 the maximum brake Torque, 102.75 N-m is reached at 1200 rpm and start declining as the speed reduces.

Figures 5 and 7 show that the Brake Specific Fuel Consumption, BSFC and Brake Specific CO_2 are maximum at Case 1(3600 rpm) and decline as speed reduce. These show that more fuel is consumed at high speed.

Figures 6, 8 and 9 show that the Brake Specific CO, CO concentration and CO_2 concentration are increasing as the speed reduces with values 0.01052 gkW-h, 1.87532 ppm and 89000 ppm at 3000 rpm (Case 1), 0.01225 gkW-h, 2.62502 ppm and 98900 ppm at 600 rpm (Case 5) respectively.

4. CONCLUSION

Biodiesel production is a modern and technological area for researchers due to constant increase in the prices of petroleum diesel and environmental advantages. Biodiesel from Neem oil was produced by alkali catalysed transesterification process, fuel simulated in a model of two cylinder compression ignition engine. Biodiesel fuel and pure diesel fuel performance characteristics and engine-out emissions in a model of direct injection compression ignition engines. The simulation model developed successfully captures the two cylinder compression ignition engine operating characteristics. The engine performance studies were conducted with a model of 2-cylinder CI engine using GT-Power suite package. The biodiesel has good lubricity as which is greater than petro-diesel when used in diesel engine. Results were validated for brake mean effective pressure, brake power, brake torque, Net mean effective pressure which were improved and low emission of CO and CO2. The biodiesel has good performance to replace fossil fuel and more environmentally friendly.

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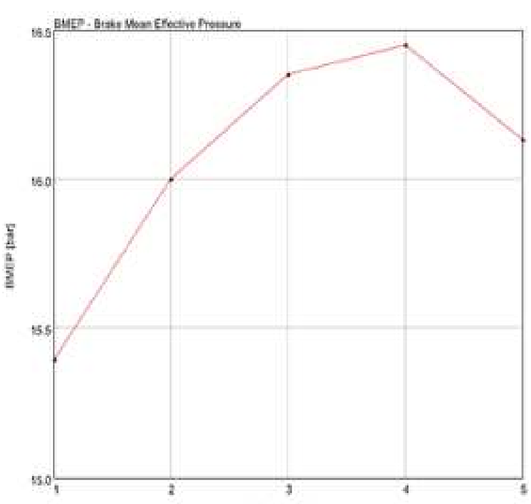

Figure 1 Brake Mean Effective Pressure

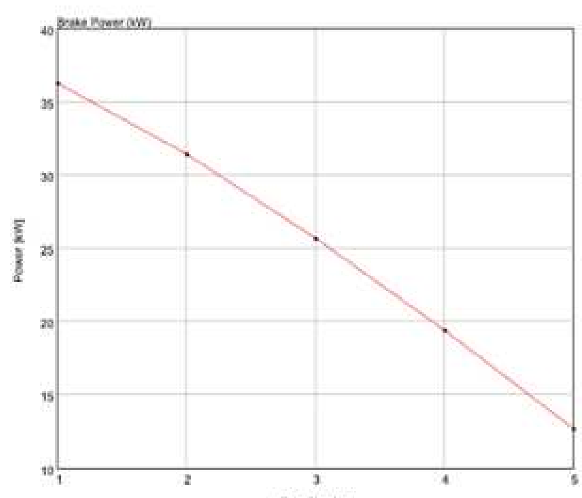

Figure 2 Brake Power

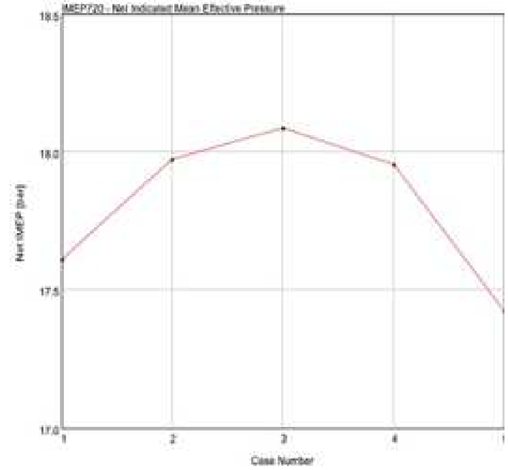

Figure3 Net Indicated Mean Effective Pressures

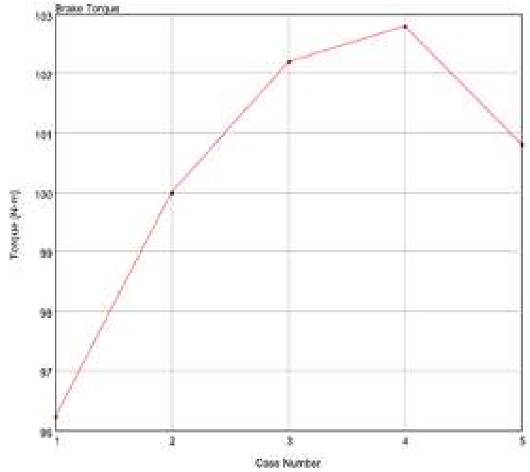

Figure4 Brake Torque

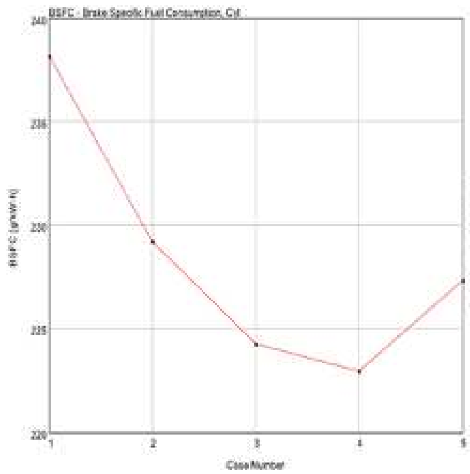

Figure5 Brake Specific Fuel Consumption

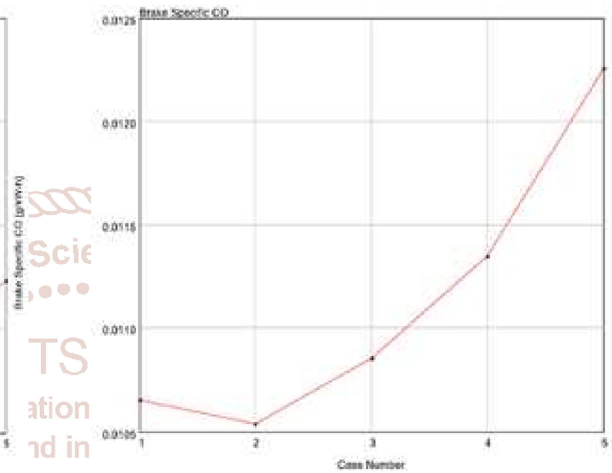

Figure6 Brake Specific CO

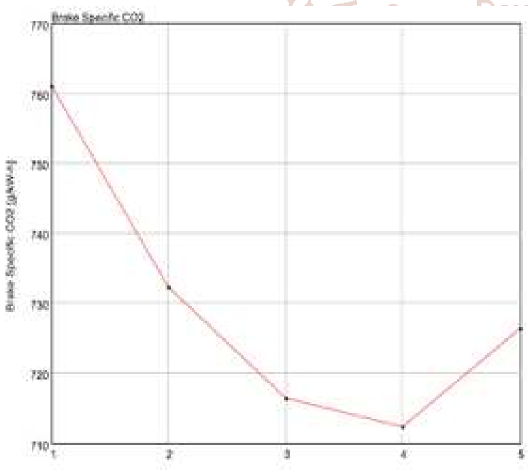

Figure7 Brake Specific CO2

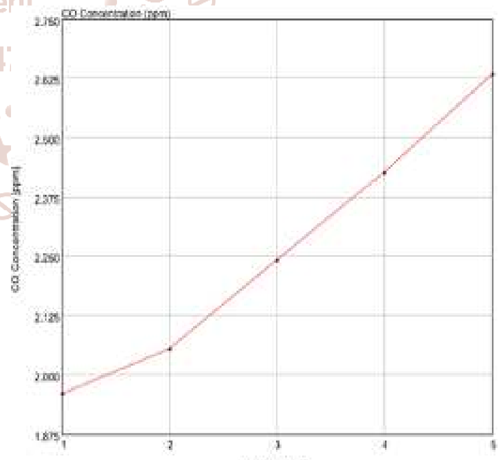

Figure8 CO Concentration

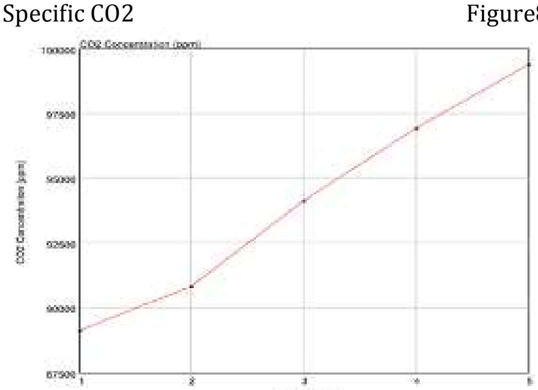

Figure 9 CO2 Concentration