EVALUATION OF BIODIESEL FROM USED FRYING OIL AS A SUBSTITUTE FUEL FOR DIESEL ENGINES

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Outline of Presentation

- ❖Background
- ❖ Objective
- ❖Material
- ❖Experimental Procedures
- ❖Result Analysis
- ❖Conclusion

Research Background-1

❖The world has for sometimes witnessed growing concern over the environmental impact and rapidly increasing demand for transportation fuels combine with rapidly decreasing mineral oil reserves;

❖The concern and dependence on limited reserves has highlighted the need for searching for alternative fuels for internal combustion engines;

❖Biofuels can play an important role in addressing both the greenhouse gas emissions of transport and the dependency on petroleum-based fuels.

Research Background-2

- **Numerous studies on the utilization of biodiesel from used frying oil methyl ester (UFOME) as well as its blends in engines have been done. However, most of these studies were focused on short-term tests on different types of diesel engines in terms of gas emissions (CO, CO2, NOx, un-burnt hydrocarbons, etc.) and engine performances (power output, specific fuel consumption, etc).**

- **Most of the previous research has not taken into account the combustion chamber (CCD) deposit formation when the diesel engines were fuelled with biodiesel from UFO. CCD is a severe problem in internal combustion engines.**

Research Backgrounds-3

From this background, the objective of my study were:

- **To produced biodiesel from waste used frying oil;**
- **To investigated the performance and emissions of a diesel engine operating on biodiesel blended fuels;**
- **To evaluated the combustion deposits formation of the diesel engine operated on biodiesel blended fuels.**

MATERIAL – production of UFOME-1

- **Used waste fry oil (UFO) were collected from different local restaurants;**

- **UFO samples were first filtered to remove dirt, charred food, and other non-oil material;**

- **UFOME (Biodiesel) was prepared using an alkali catalyzed method (transesterification);**

- **Methanol was mixed with NaOH added to the reactor containing oil;**

- **Biodiesel was washed with the water twice to remove the traces of glycerine, un-reacted catalyst and soap formed during the transesterification**

MATERIAL-biodiesel blend preparation-2

Although several blends with a wide composition spectrum were prepared by splash blending, the tests were carried out with:

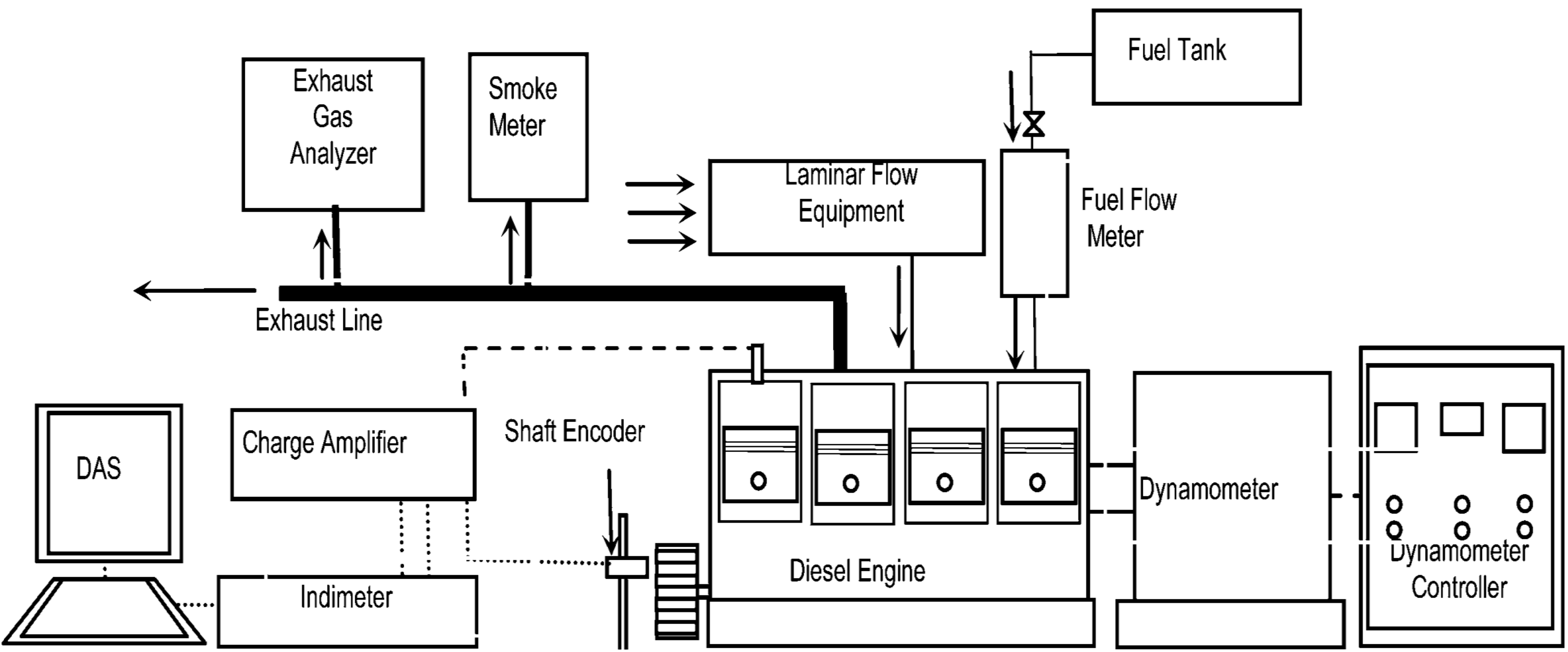
- **B30 (30% biodiesel-70% diesel by volume),**
- **B70 (70% biodiesel-30% diesel by volume),**
- **B100% (net biodiesel).**

These blend ratios were chosen to see whether clear difference could be detected in their performance ability and CCD formation rates.

TEST ENGINE
Specifications -1

ITEM	SPECIFICATION
Type	Isuzu KB-250 Four Stroke
Number of Cylinder	4
Bore	93 mm
Stroke	92 mm
Maximum Speed	2800 rpm
Maximum Power	46 kW
Compression ratio	18.4:1
Injection timing	14^{o} BTDC

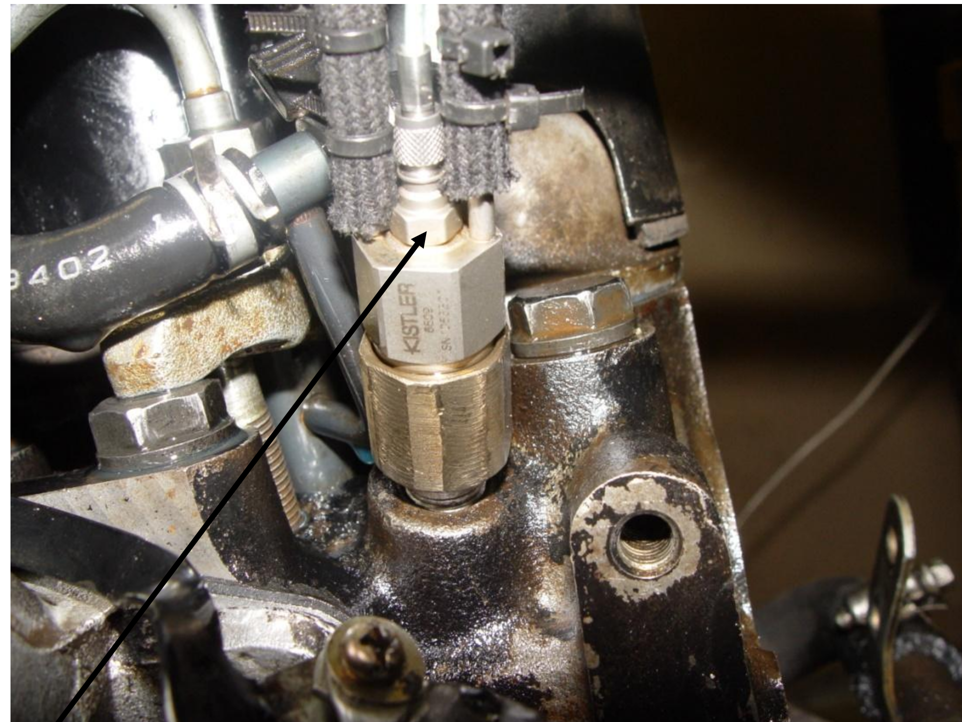
Experimental set-up -2



EXPERIMENTAL METHODS AND TECHNIQUES

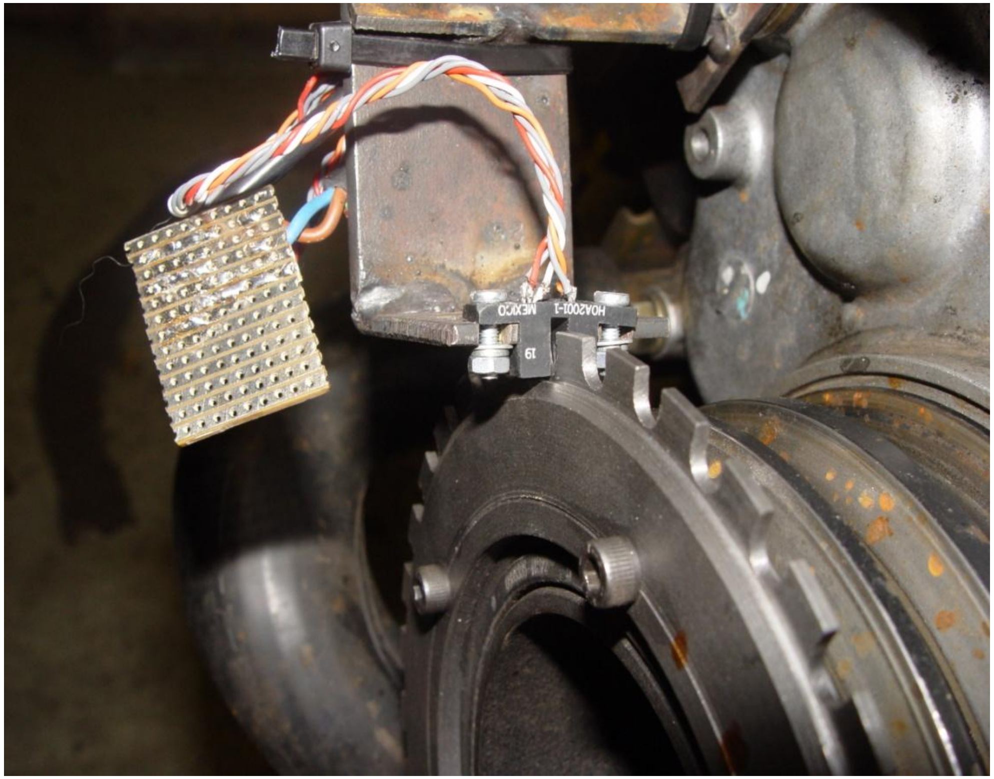
- **Pressure sensor -Kestler Model No. 6005- Combustion pressure;**
- **Magnetic Pick up sensor - Crank angle position;**
- **Different thermocouples – Exhaust, water temperatures**
- **Tune gas analyser model 4/5 Analyser - HC (ppm), CO (%), CO_2 (%) and NOx (ppm) concentrations;**
- **Smoke meter (model LCS 2100);**
- **Fatty acids composition - gas chromatography-mass spectroscopy (GC-MS)-Agilent 6890N gas chromatograph coupled to an Agilent 5973 inert mass-selective detector (MSD);**
- **SEM - for morphology; and**
- **X-Ray diffraction (XRD) for elemental composition.**

Adapter and location of Combustion Pressure Sensor



Pressure sensor

Figure 2 shows the position of the pressure sensor on the test engine



A 36-tooth gear was also manufactured and then fitted onto the crankshaft pulley of the test engine.

A magnetic pick-up [Model HOA2001-(19)] attached to the gear sensed the location of the top dead centre (T.D.C).

TEST PROCEDURES
Performance and Emissions (PE) -1

- **The experimental work started with a preliminary investigation of the engine running on pure diesel fuel in order to determine the engine’s operating characteristics and exhaust emission levels, constituting the ‘baseline’ that is compared with the corresponding cases when blend fuels were used.**

TEST PROCEDURES continued (PE)-2

- The same procedure was repeated for each blend fuel by keeping the same operating conditions.

- For every fuel change, the fuel lines were cleaned and the engine was left to operate for about 15 minutes to stabilize at its new condition.

TEST PROCEDURES

Combustion Chamber Deposits Generation (CCD)-3

- **The same engine used in performance and emission testing was operated for 40 h under cycled conditions that approximated city-suburban driving conditions to generate combustion deposit from the test fuels. The combustion chamber deposit (CCD) test cycle is shown in the next slide.**

- **The engine was run continuously for 8 h followed by 16 h heat soak period. This heat soak period led to a rapid build-up of deposit. This procedure was repeated until 40 h on the test cycle had been completed. At the conclusion of each cycle of the test, the engine was dismantled, visually inspected and rated according to the Coordinating Research Council (CRC) for combustion deposits test procedures.**

Test Cycle for Combustion Chamber Deposits

Hours	Engine speed (rpm)	Engine Load (Nm)
2	2800	100
2	2600	100
4	2500	110
Engine off for 16 hours		
6	2500	110
2	2400	110
Engine off for 16 hours		
8	2400	110
Engine off for 16 hours		
8	2200	90
Engine off for 16 hours		
2	2200	90
6	2200	90
Overall cycle duration = 40hrs		

Standard test methods for the determination of fuel related properties-4

Property Parameters	Diesel	UFO	Test Method
Density @ 20 ^{o}C kg/m^{3}	**840**	**870**	ASTM 4052-
Viscosity @40 ^{o}C cSt	**2.2**	**3.6**	ASTM D445
Sulphur content, %	**0.29**	**-**	ASTM D5453
Flash Point, ^{o}C	**62**	**163**	ASTM D93-
Ash content	**0.0.01**<	**-**	ASTM D842-
Water content %	0.0		ISO 12937
Cetane	**51**	**56**	ASTM D613
Net heat of combustion (MJ/kg)	**43**	**40**	ASTM D240

CCD Sample Collection and analysis procedures-3

- **After rating process, the deposit from each of the four combustion chamber region, cylinder head region and piston top region was scraped using gasket scraper and fine wire brush.**

- **The sample material from respective region of the four cylinders was then mixed together to form one large average sample for the respective region.**

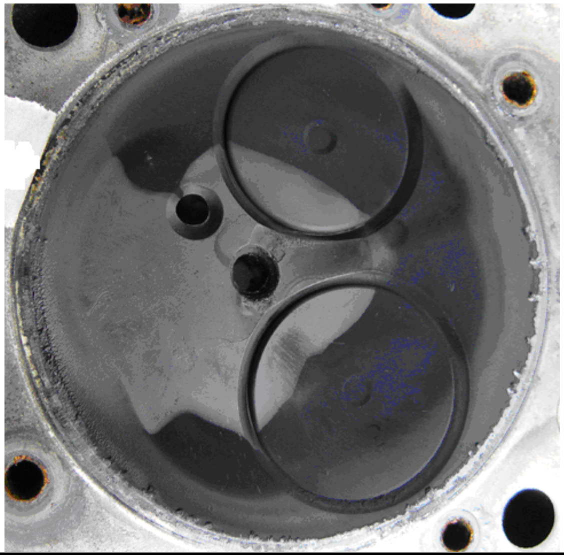
CCD Sample Collection and analysis procedures-3 Continued

- **Quantitative analysis of combustion deposit formation was carried out by weighting the scraped deposit samples from the test fuels.**

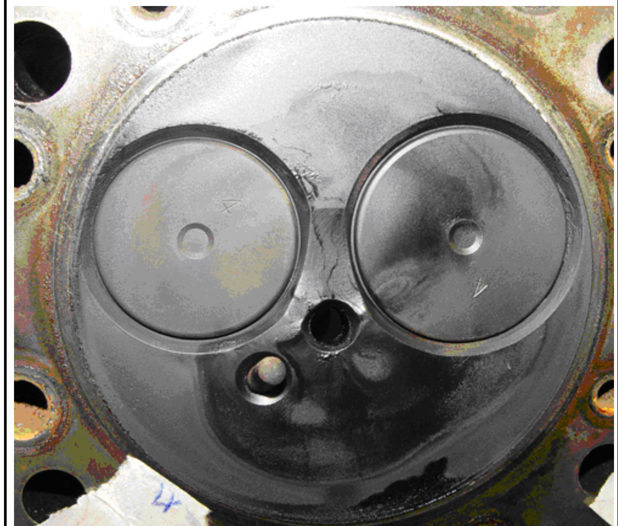
- **Then, the analytical analysis was characterised by using a scanning electronic microscopy (SEM) for morphology (thickness, homogeneity and microstructure), X-Ray diffraction (XRD) for elemental composition and the nitrogen adsorption for surface area and pore size distribution.**

RESULTS ANALYSIS

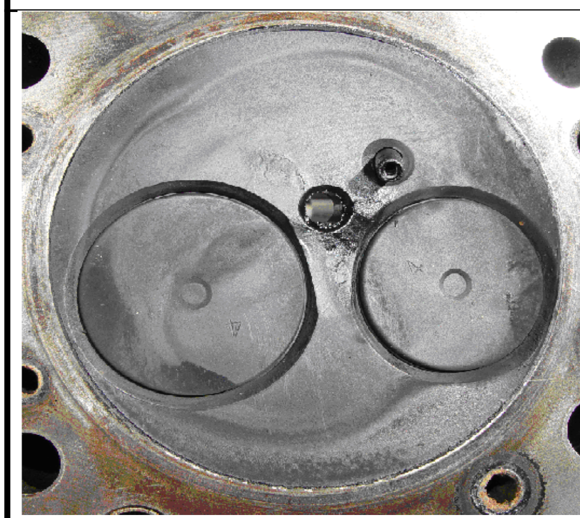
Effects of the biodiesel Addition on the carbon chamber deposits after 40 h of engine operations



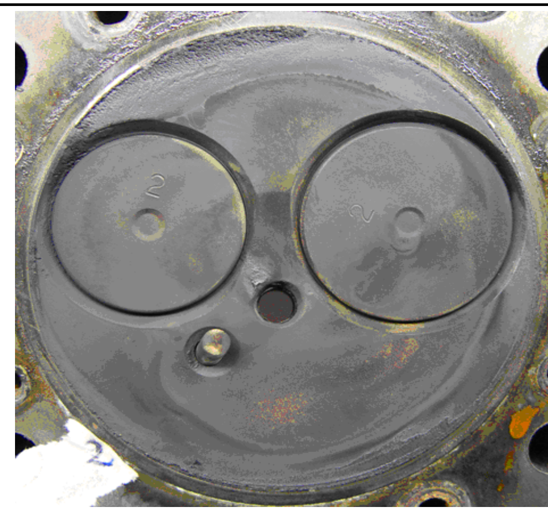
CD for diesel fuel



CD for B30



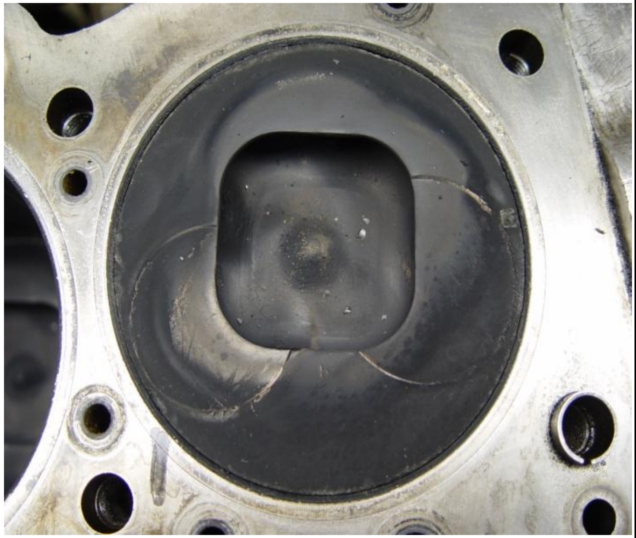
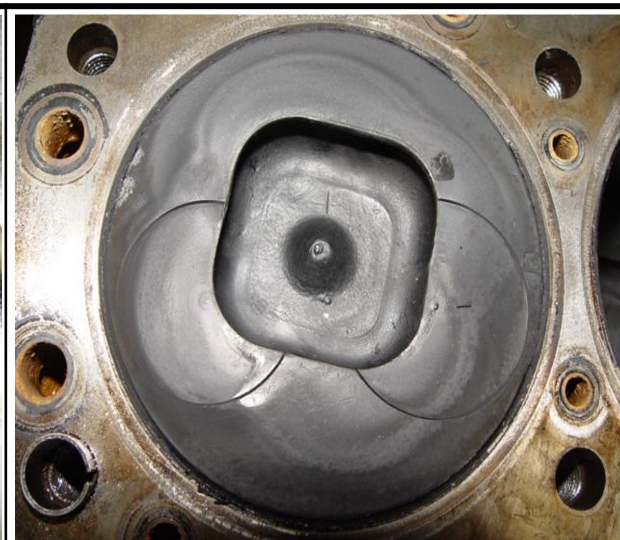
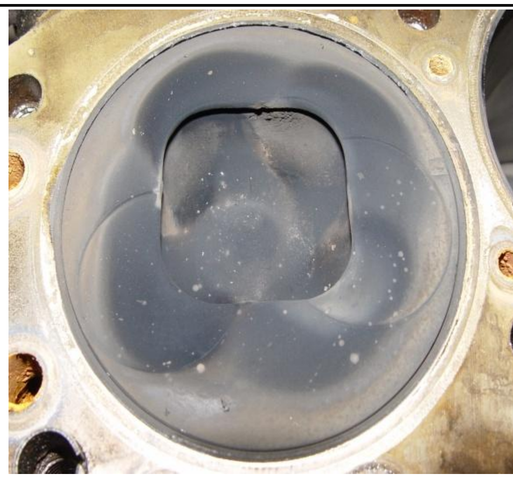
CD for B70



CD for B100

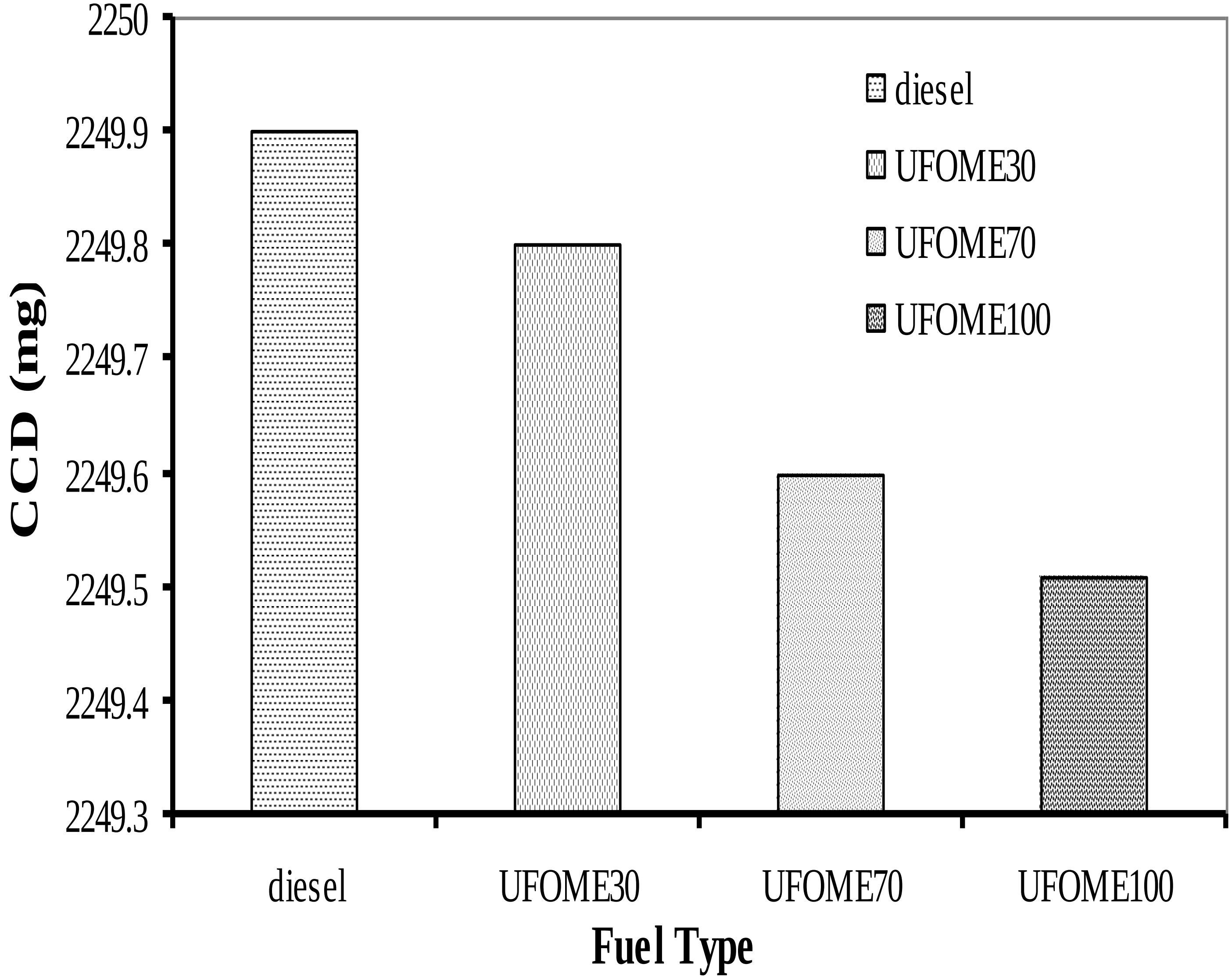
RESULTS ANALYSIS

Effects of the UFOME Addition on the carbon deposits on piston top after 40h of engine operations

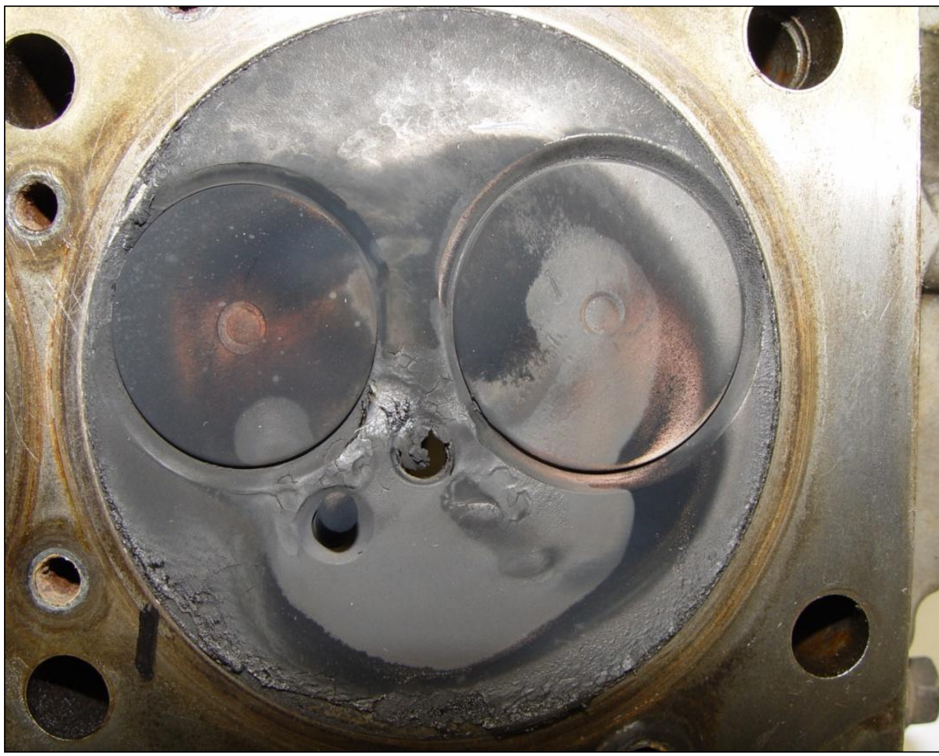
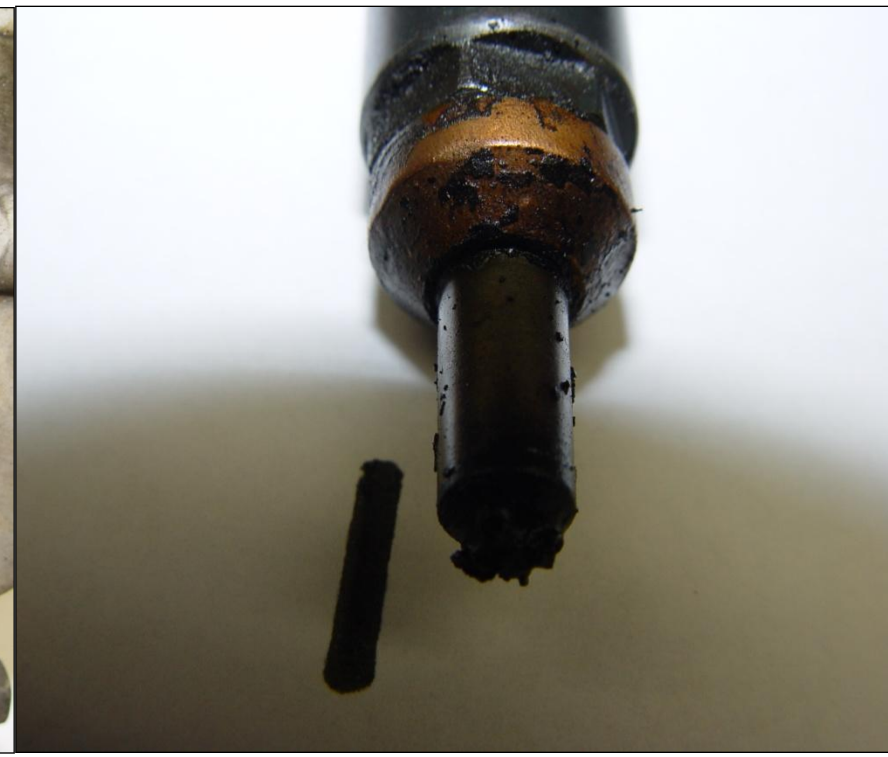
	
CD for diesel fuel	CD for B30
	
CD for B70	CD for B100

RESULTS ANALYSIS

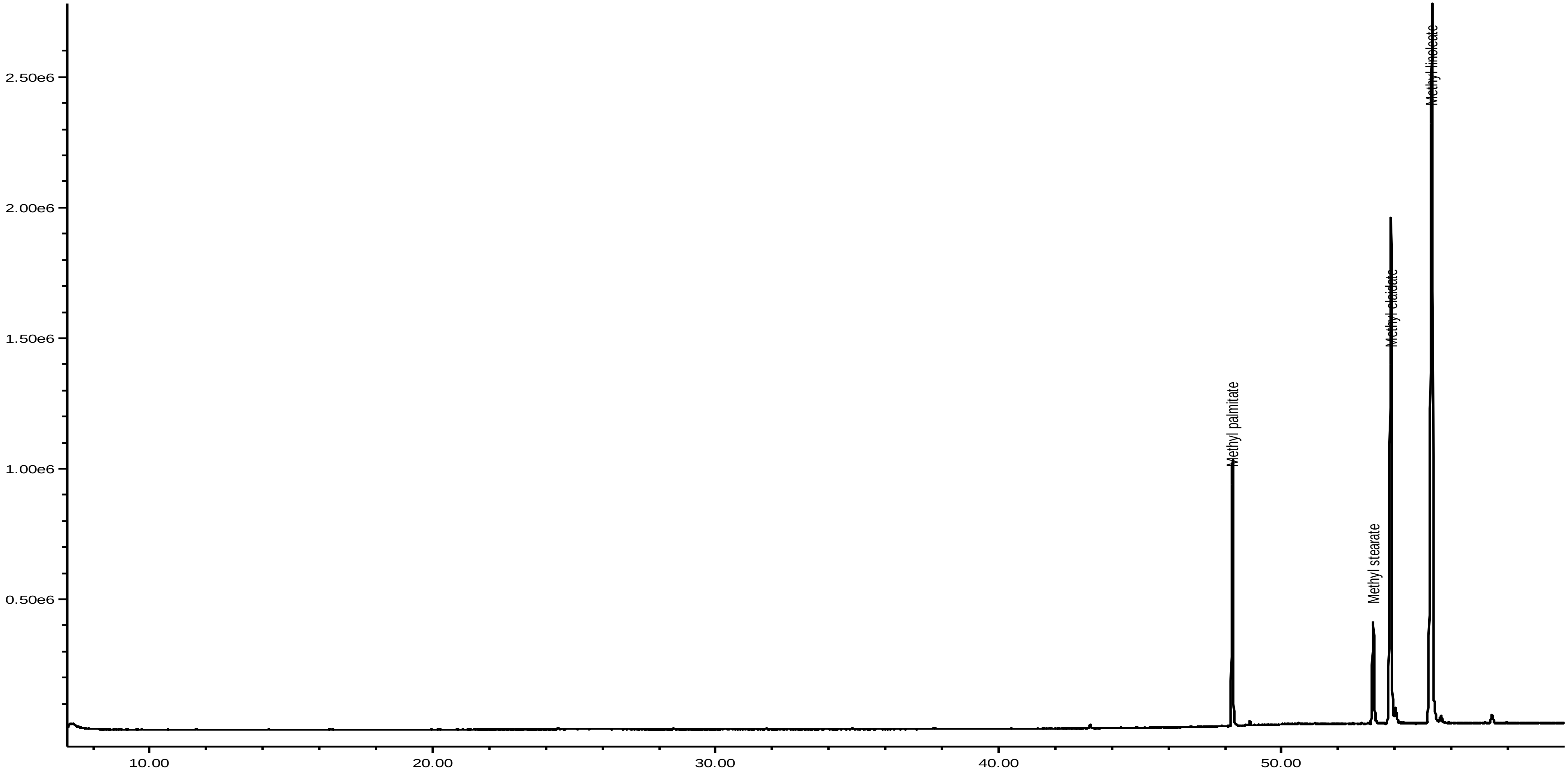
Effects of UFOME addition on CD formation



The biodiesel that was used for the blend was incorrectly processed and is clearly showing a huge carbon build-up on these engine parts.

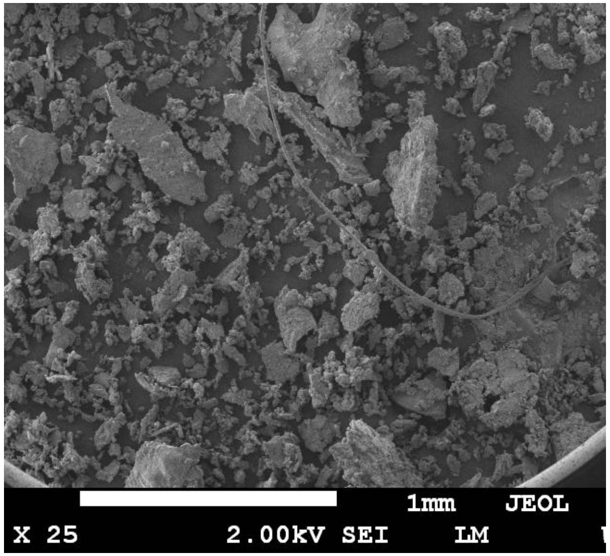
RESULTS ANALYSIS Fuel composition by Gas Chromatography



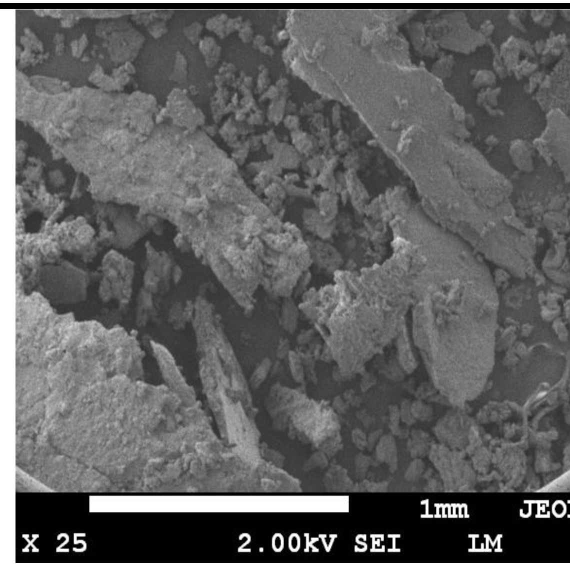
Main Components: Palmitic acid (saturated)-10.3%, Stearic acid (saturated)-5.8% , Oleic (mono-unsaturated)-28%, Linoleic (poly-unsaturated)-54.6%

RESULTS ANALYSIS

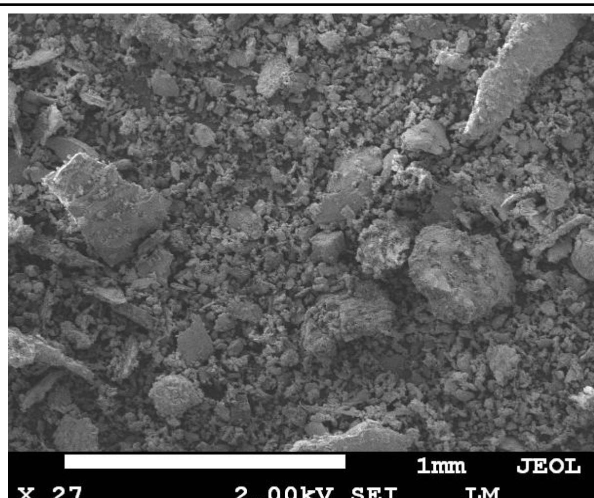
SEM micrograph of combustion chamber deposits for test fuels



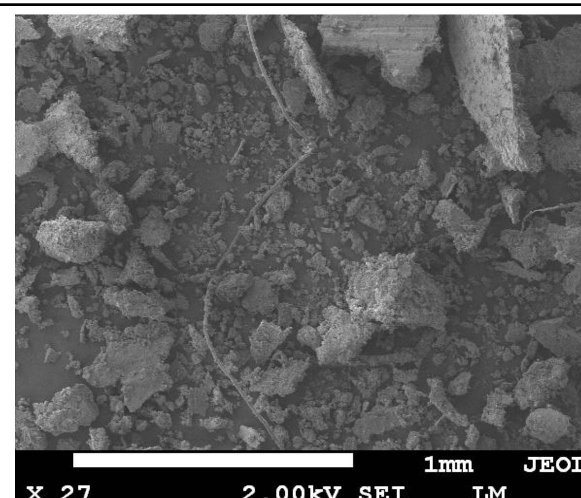
CD for diesel fuel



CD for B30



CD for B70



CD for B100

COMBUSTION PRESSURE

- The measured in-cylinder pressure data is used to analyze the combustion process and the events in the combustion chamber.

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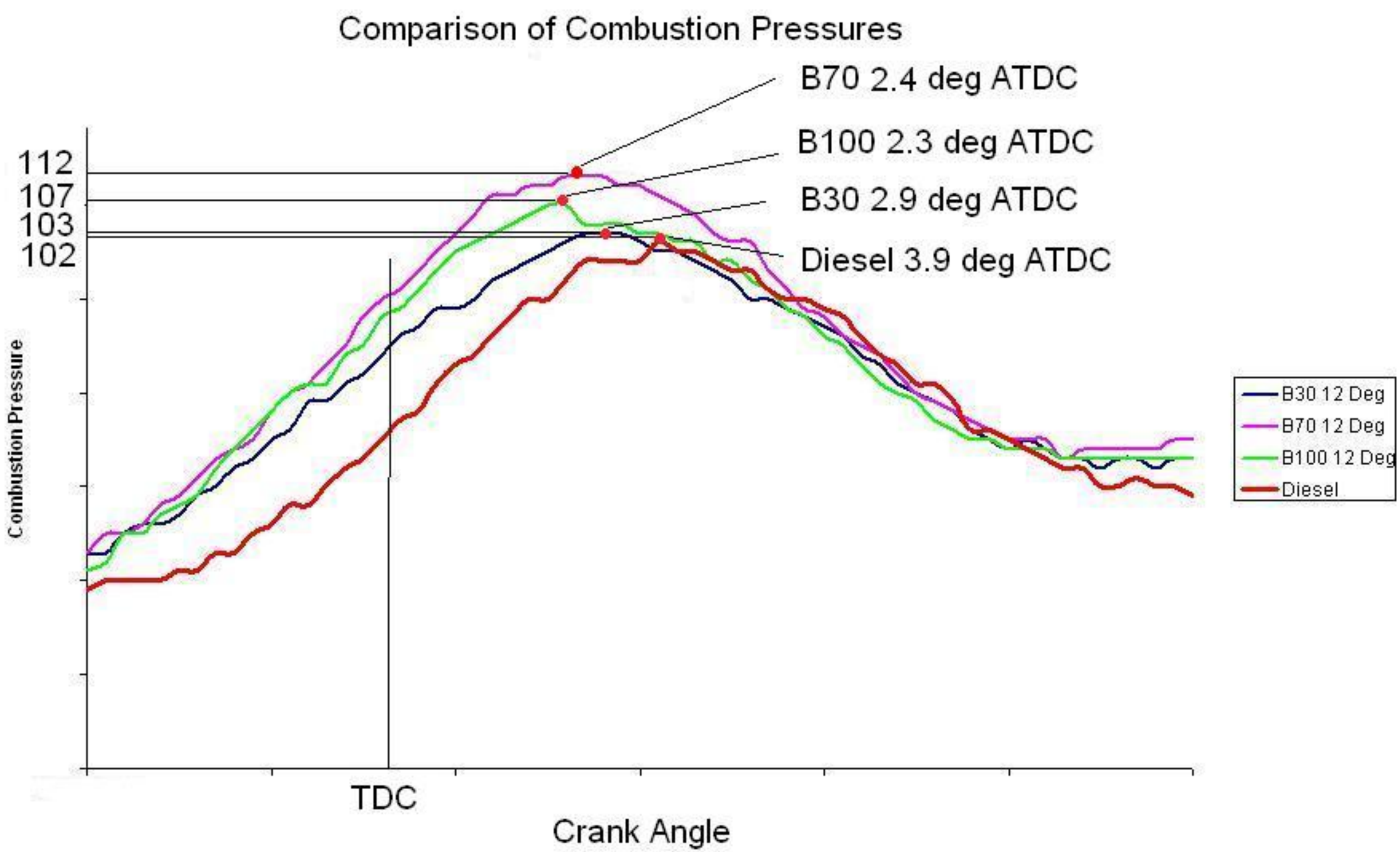
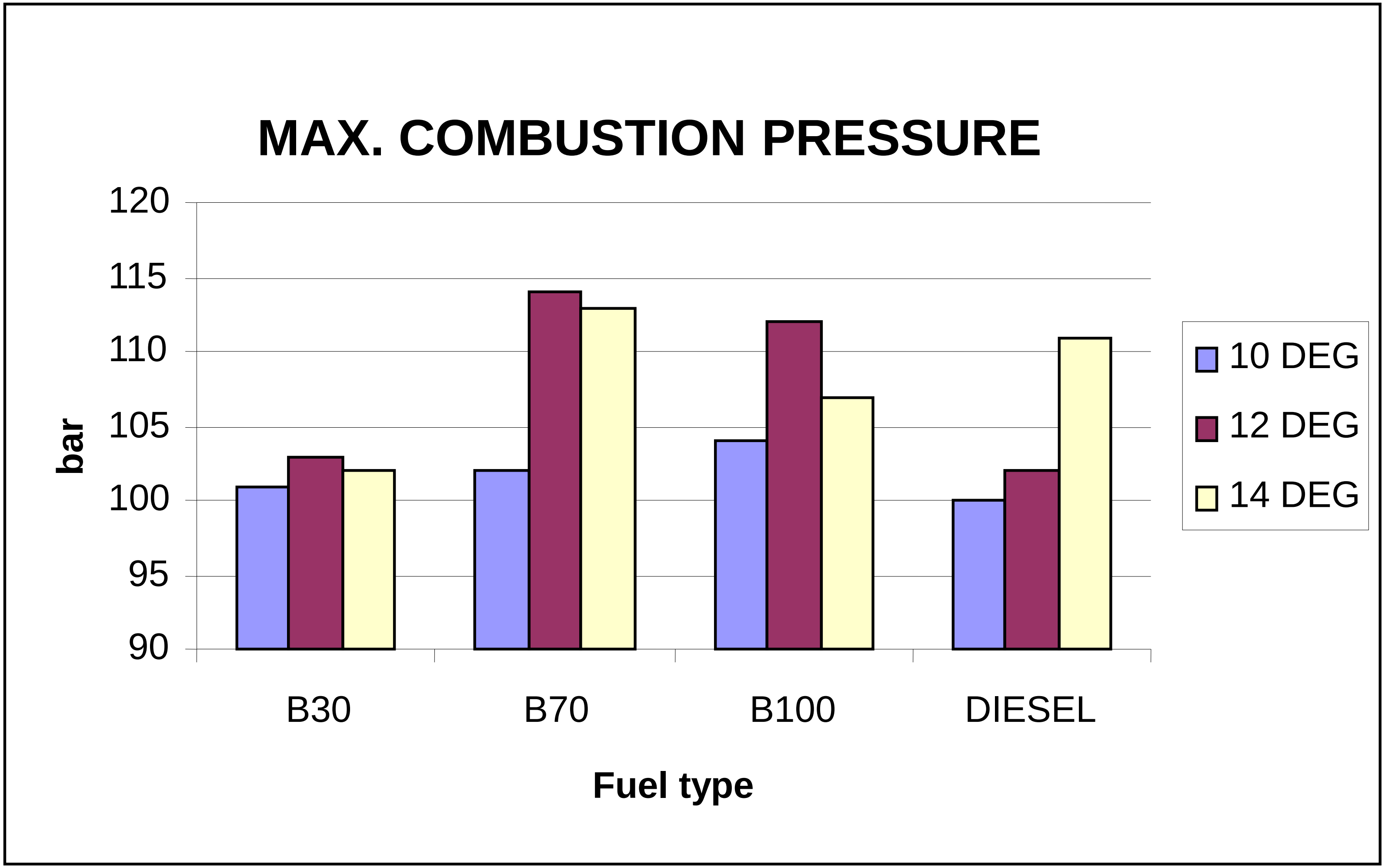
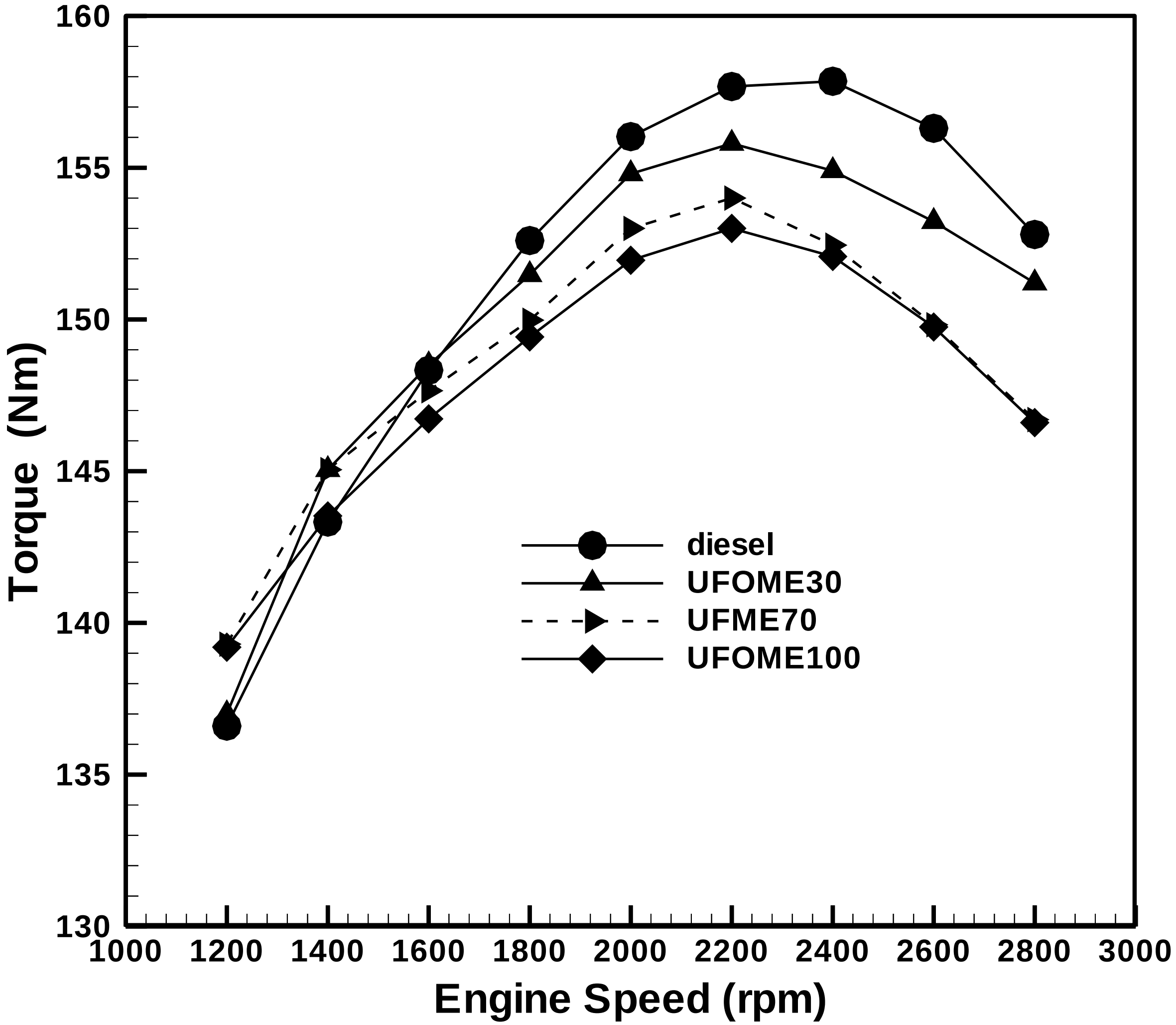

Comparison of Combustion Pressures
B70 2.4 deg ATDC
B100 2.3 deg ATDC
B30 2.9 deg ATDC
Diesel 3.9 deg ATDC
112
107
103
102
Combustion Pressure
TDC
Crank Angle
B30 12 Deg
B70 12 Deg
B100 12 Deg
Diesel



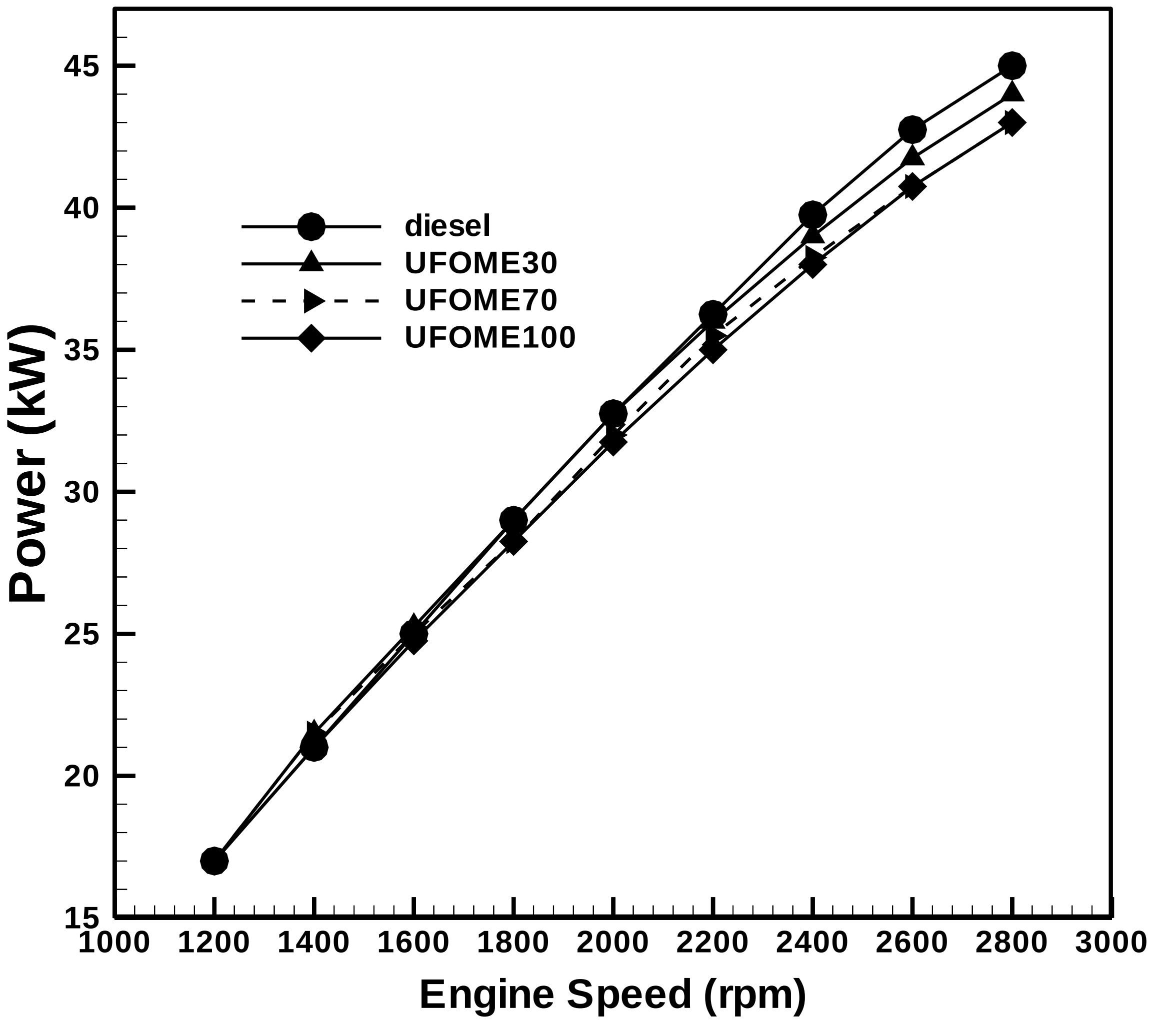
Effects of injection position on maximum combustion compression @ 2400 r/min

RESULTS ANALYSIS -Engine Torques



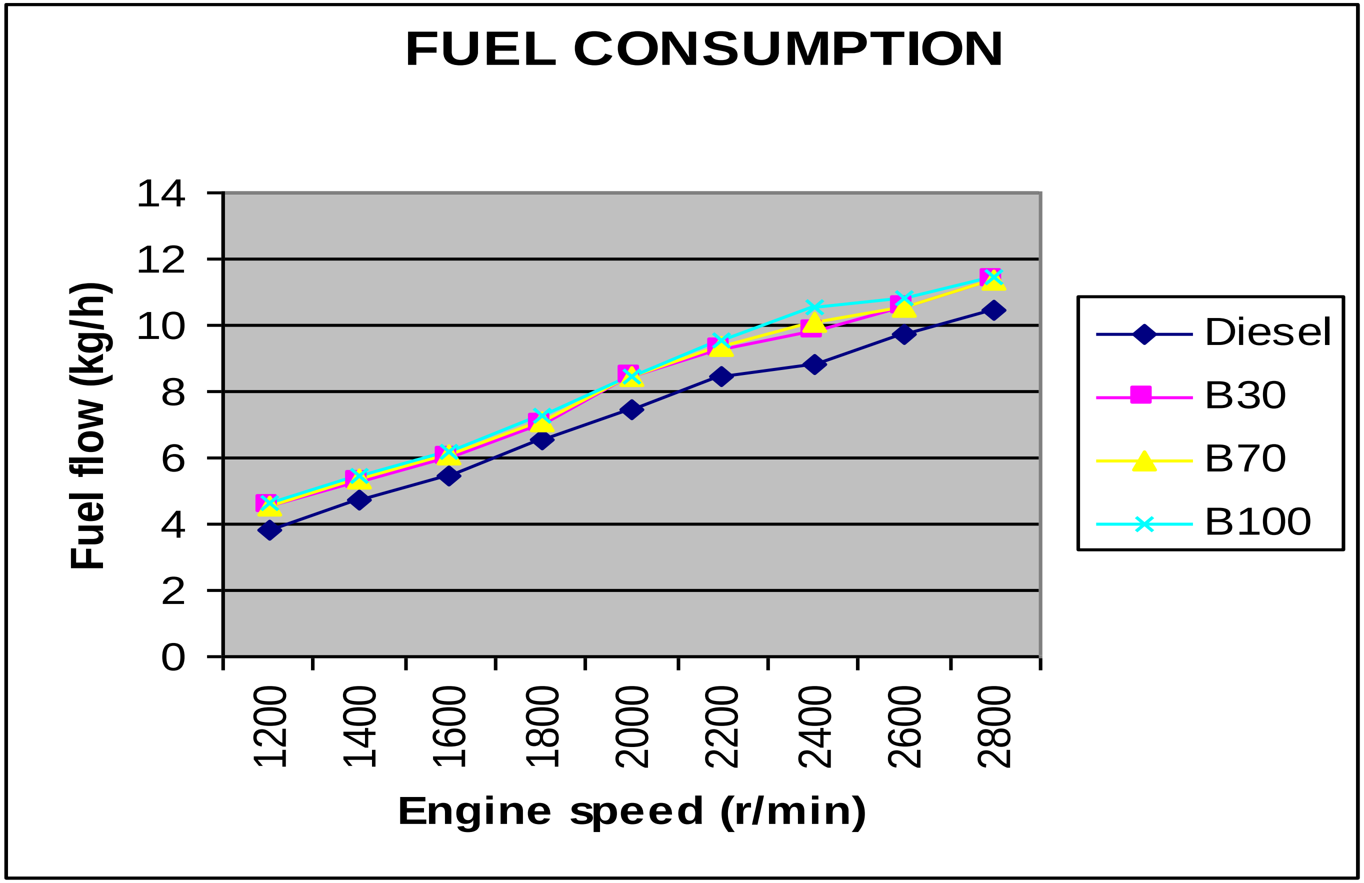
Diesel-158 Nm **B30-156.1Nm** **B70-154.3Nm** **B100-153.5Nm**

RESULTS ANALYSIS -Engine Power



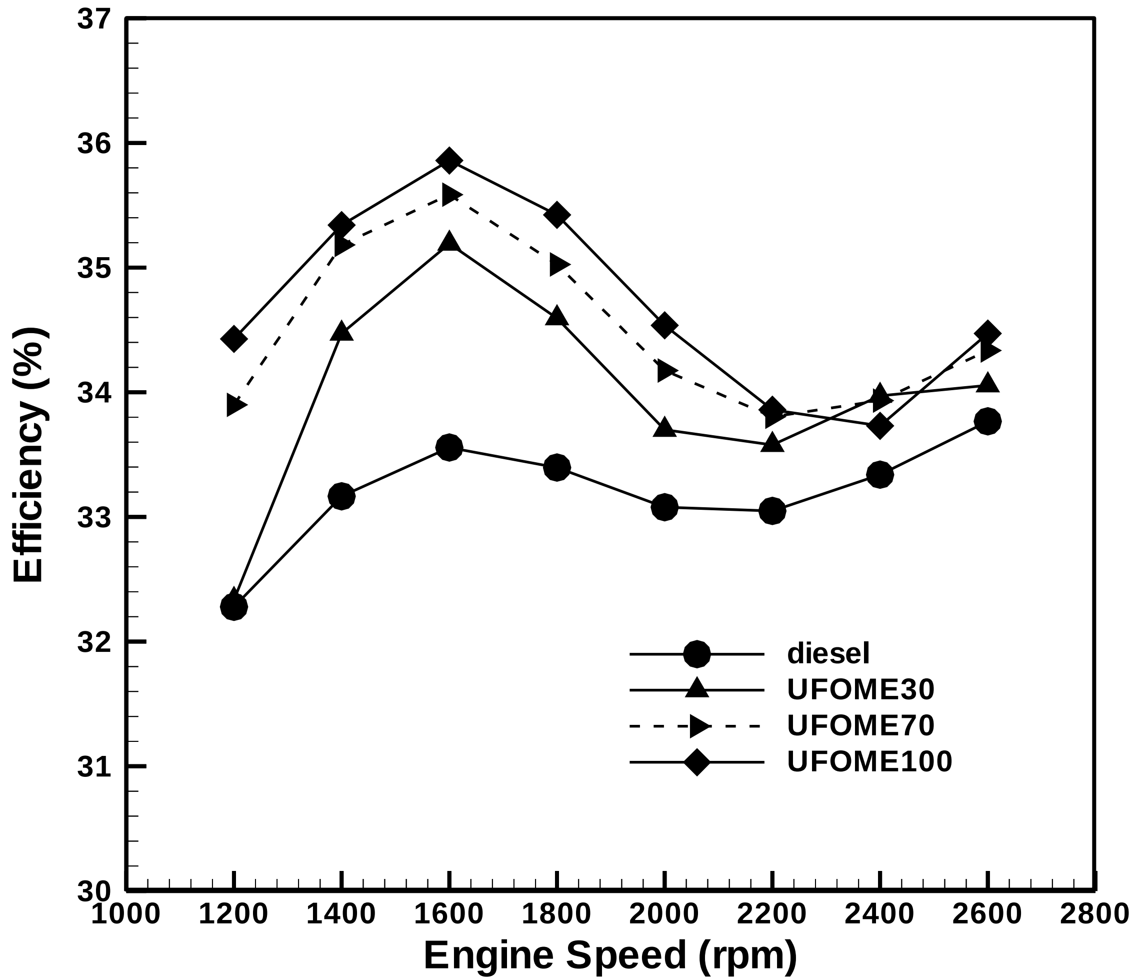
Slight difference - amount of biodiesel shows a degreasing trend.

FUEL CONSUMPTION



The average fuel consumption of B100 is 12% higher than that of diesel fuel.

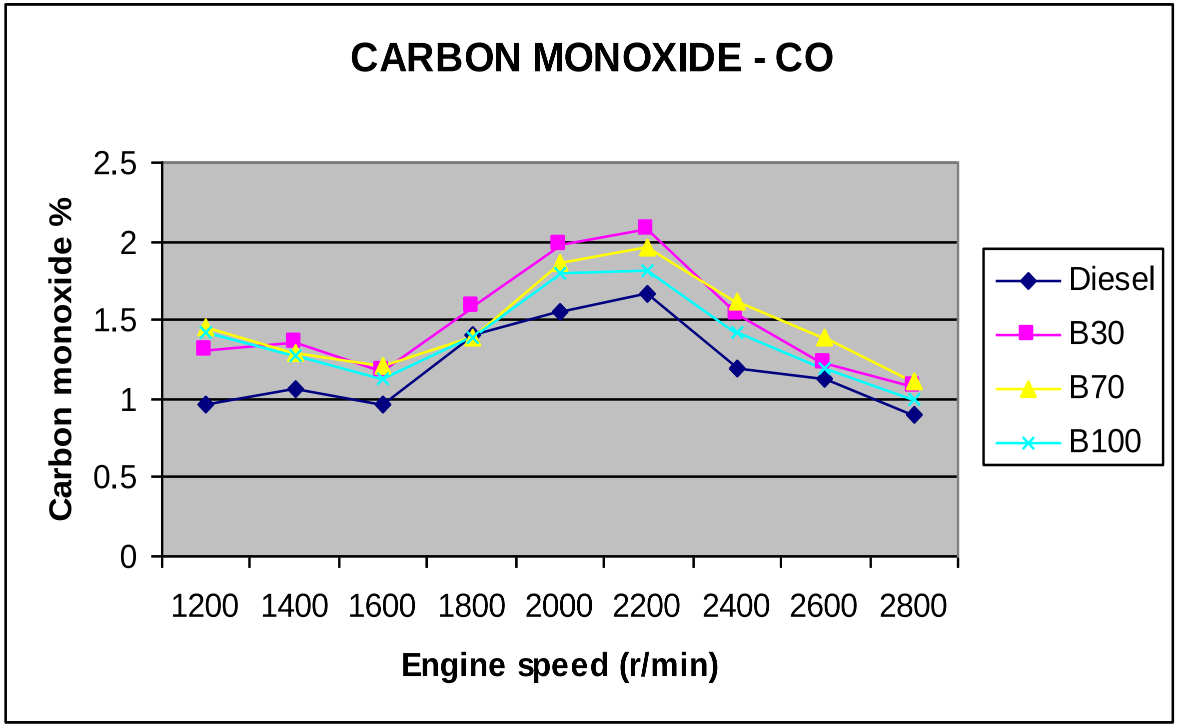
RESULTS ANALYSIS
Engine thermal efficiency



B100 and its blends present better brake thermal efficiency than diesel.

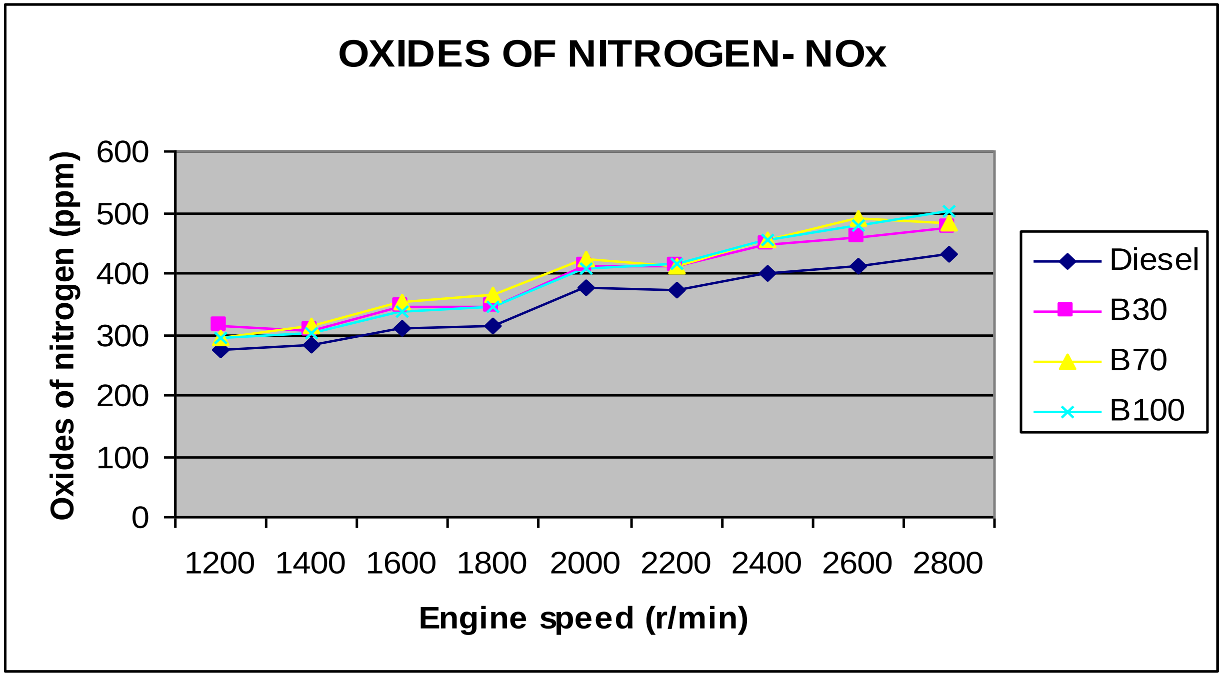
EXHAUST EMISSIONS

1. Carbon Monoxide



Rate of CO formation is a function of unburned gaseous fuel availability and mixture temperature.

2. Oxides of Nitrogen (NOx)

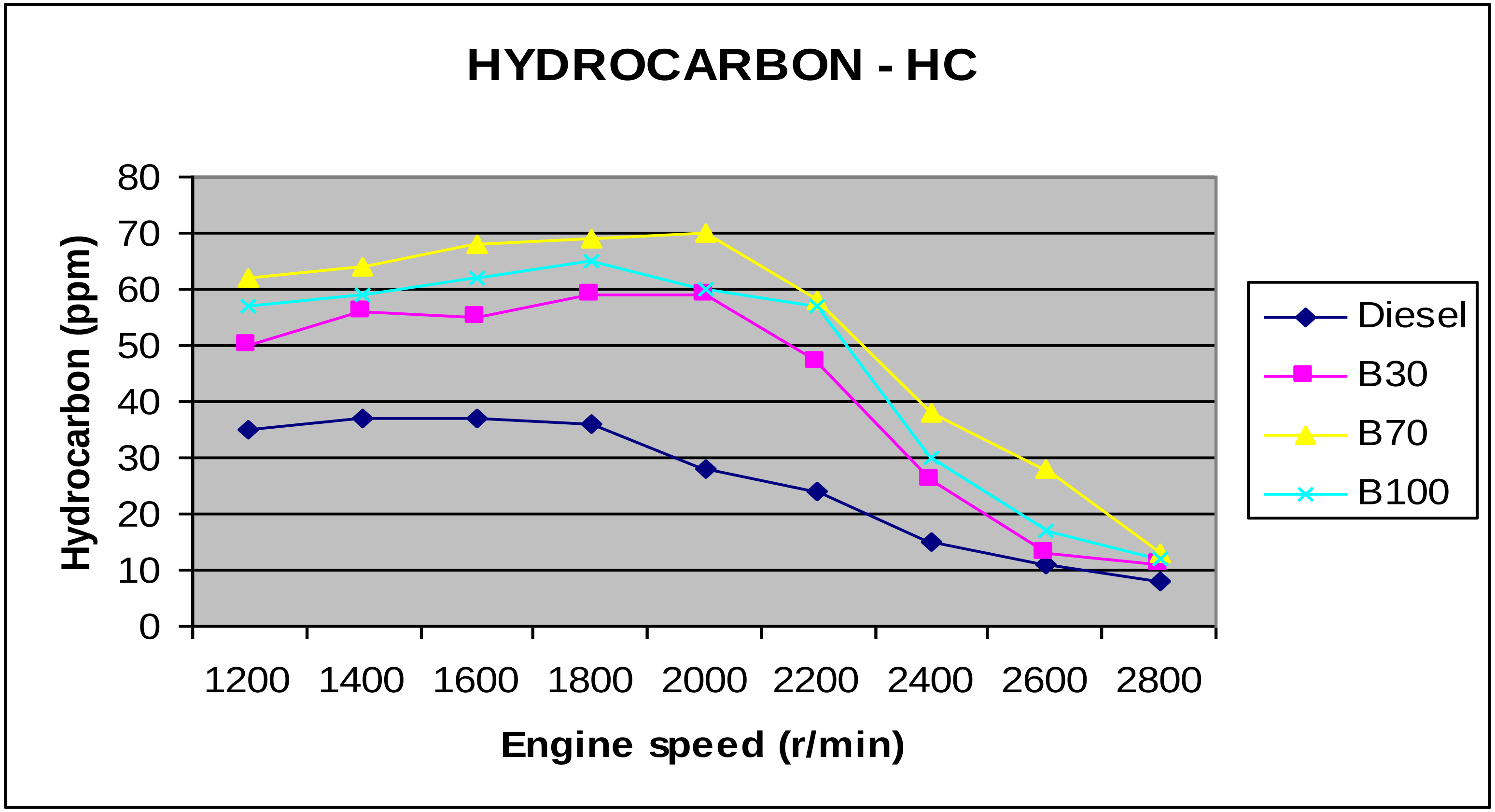


The formation on NOx is favoured by high oxygen concentration and high charge temperature. This is evident that there is higher oxygen content available in the surrounding air.

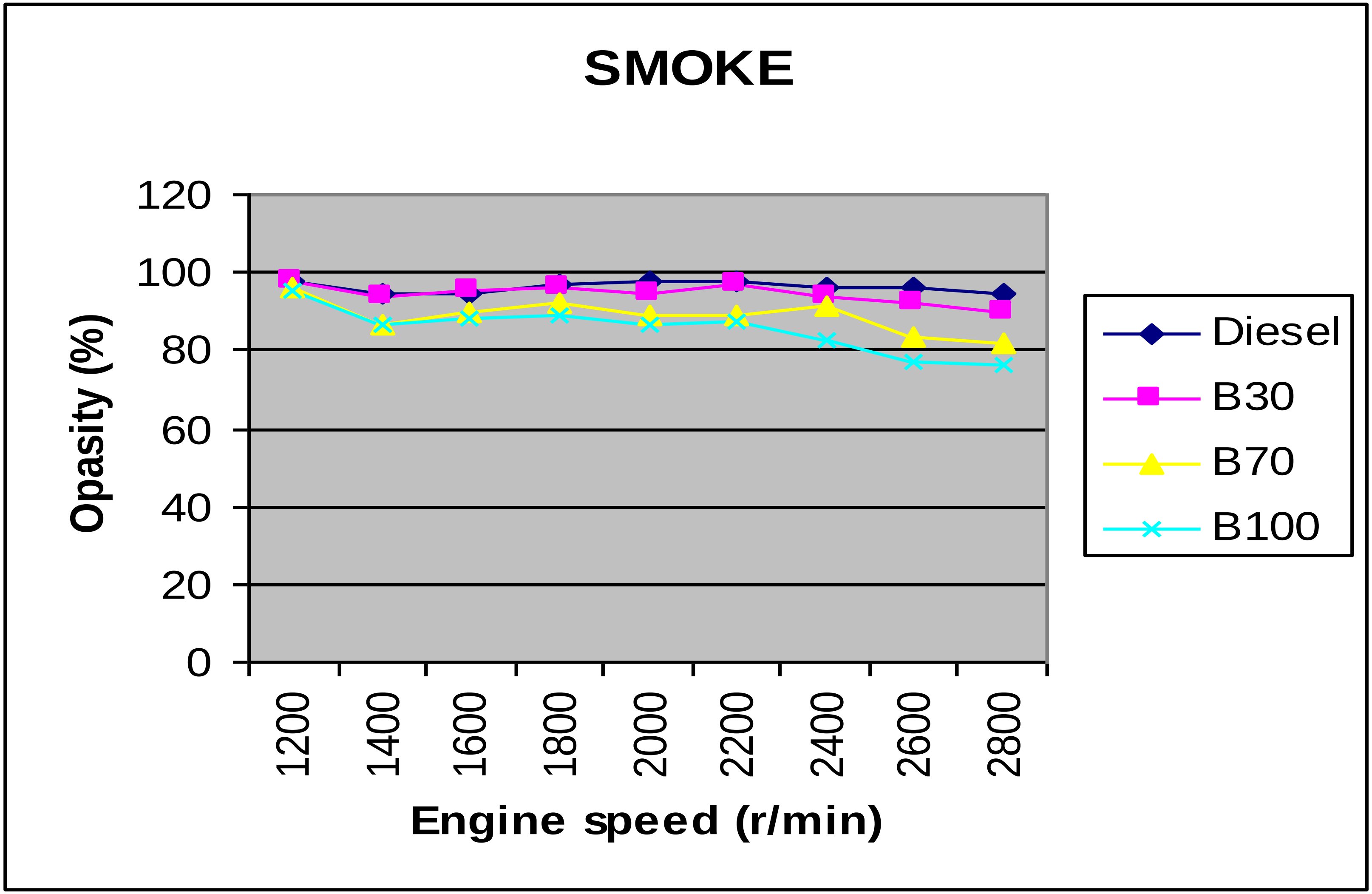
Reported by Freedman, Pryde and Mounts (1984:1641) and Jones and Ready (1998:4)

Drawback – adding a cetane improver additive

Unburned Hydrocarbon (HC)



Biodiesel and its blends are higher than diesel especially at low engine speed.



Smoke emitted by B70 and B100 is significantly lower (20%).

CONCLUSION

The performance, emission and deposit characteristics of the diesel engine fuelled with the biodiesel and its blends were investigated and the following conclusions can be drawn:

- **Biodiesel/blends presented better brake thermal efficiency than diesel fuel. This is due to the higher density and lower heating value of the biodiesel than that of diesel fuel. Increasing fuel density increases the energy content of the fuel brought into the engine at a given injector setting.**

CONCLUSION - Continued

- **Engine tests showed that the performance parameters of the biodiesel/blends fuels did not differ greatly from those of diesel fuel. Slight power losses were experienced with the biodiesel/blends fuels. This may be due to the lower heating value of the blends fuels.**

- **The engine operated on the biodiesel100 and their blends resulted in higher NOx, HC, CO and lower exhaust smoke concentrations than the diesel fuel case.**

- **From the deposit characteristic results, it was found that the biodiesel 100 produced lowest fraction of carbon deposits as compared to diesel fuel and other biodiesel blends fuels.**

ACKNOWLEDGMENTS

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