Alternative Fuels from Microalgae for Diesel Engine

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OUTLINE

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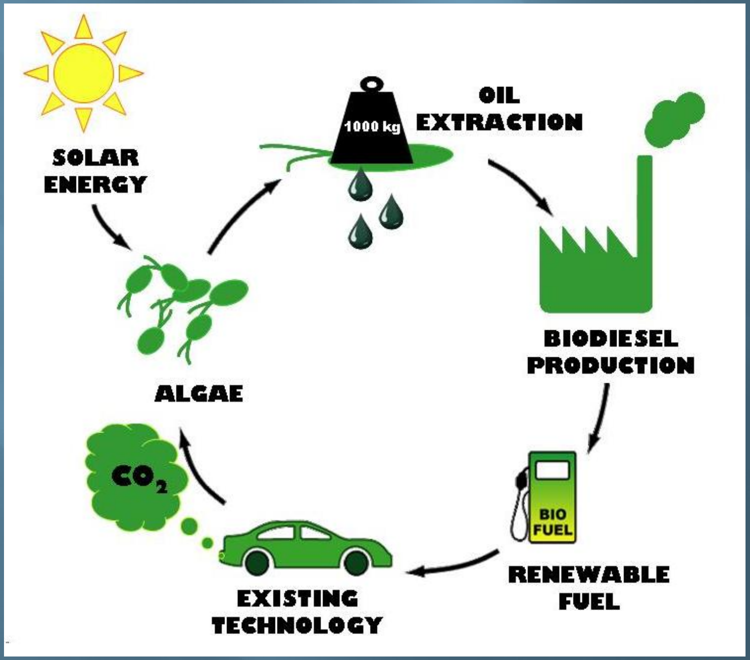
Introduction

Fuels from Microalgae are reported as the potential alternative fuel for replacing the current fossil.

- Microalgae biodiesel is renewable, produce less emissions, and its productivity is many times higher than crops biodiesel
- Many studies have been done on microalgae biodiesel production and its properties, however the performance and the emissions of this fuel in diesel engine has not been reported.

Literature Review (Why microalgae?)

1. It is renewable ,environmentally friendly and it can contribute in reducing the CO_2 level at the atmosphere because microalgae consume CO_2 and converts it to oil (Hossain et al., 2008).



Literature Review (Why microalgae?)

2. Microalgae is non-edible and have the ability to grow in conditions that do not affect the human food production process (Widjaja et al., 2009), (Mata et al., 2010).
3. Microalgae biodiesel production per unit of area is many times higher than crops biodiesel. The productivity of diatom algae are about 46000 Kg of oil/hectare/year (Demirbas, 2007).
4. Some microalgae oil species content about 80% of dry weight (Amin, 2009).
5. Microalgae biofuel is non-toxic, contains no sulphur and highly bio-degradable. After extracting oil the left material can be used as soil fertilizer or to produce ethanol (Demirbas & Fatih Demirbas, 2010)

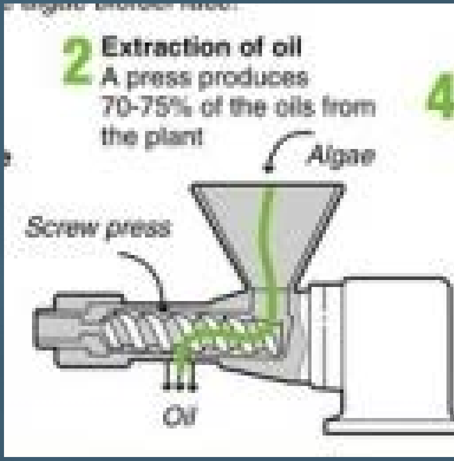
http://www.csa.com/discoveryguides/biofuel/review7.php

Literature Review

(Harvesting microalgae and oil extracting)

- Microscreen, centrifugation, and flocculation are the most common harvesting methods. (Amin, 2009). Centrifugation is efficient and reliable, but expensive for the production of microalgae as energy (Shen et al., 2009).

- The extraction of microalgae oil from the biomass can be in physical or chemical methods. Oil press is used as physical extraction, while chemical extraction is used to make the extraction more effective (Anderson & Sorek, 2009).



Research Aim

The overall aim of this project is to produce and evaluate alternative, renewable and environmentally friendly fuels from microalgae in form of biodiesel and emulsion fuels of biodiesel+water+microalgae and use it in single cylinder diesel engine and tractor engine.

Methodology

The objectives of this study are to;

1. Grow, harvest and lipid extract of fresh water microalgae *Chlorella vulgaris* FWM-CV to produce microalgae biodiesel and enhance the lipid content.
2. Study some of the physical and chemical properties of microalgae biodiesel from FWM-CV and *Chlorella protothecoides MCP-B and its blends.*
3. Produce emulsion fuel from cottonseed biodiesel with water (with and without adding FWM-CV using ultrasound.
4. Evaluate the performance and the exhaust gas emissions components of a single cylinder diesel engine using MCP-B in different blend ratios and the emulsion fuel with and without adding FWM-CV.
5. Evaluate tractor performance and emissions using MCP-B20.

Methodology (growing microalgae)

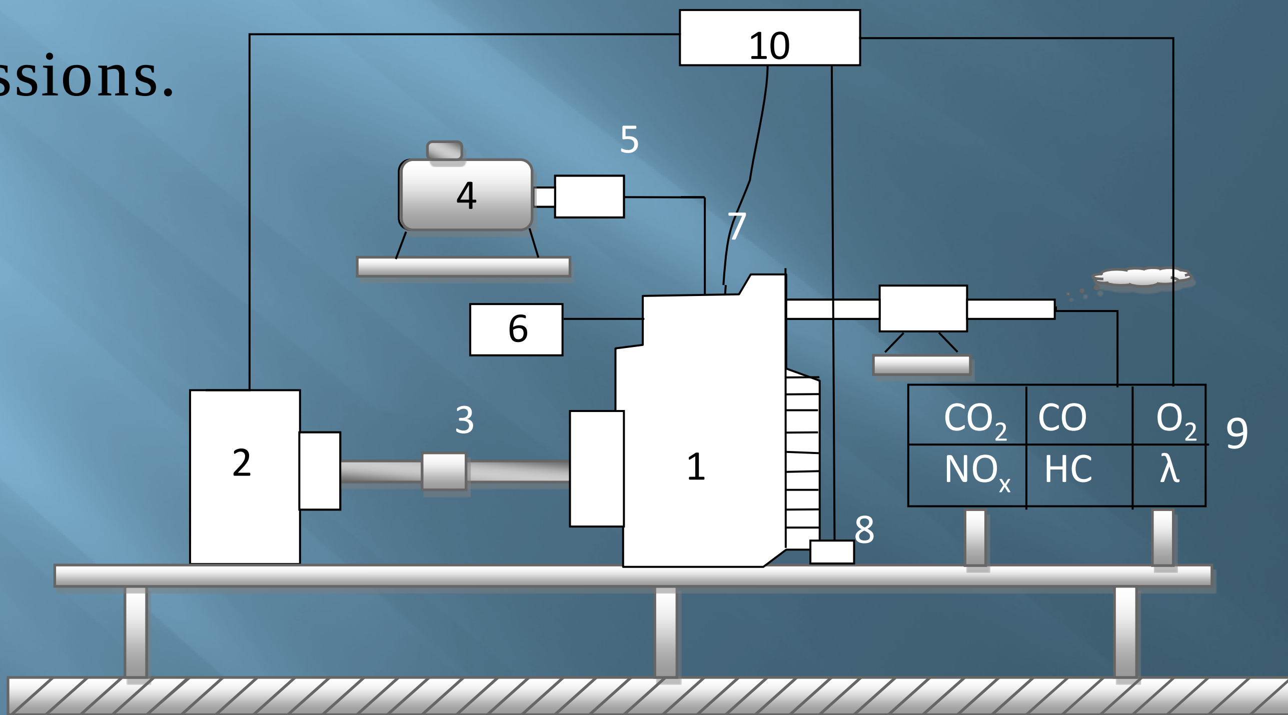
The culture was obtained from the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia. The FWM-CV were grow in MBL medium and the experiment for enhancing the lipid content was performed

Methodology
(microalgae harvesting, oil extracting and transesterification)

- The microalgae have been extracted from the medium using a centrifuge at 8000 rpm for 10 min
- The oil have been extracted from the biomass using the method as in (Folch, 1957) using chloroform/methanol (2/1).
- The transesterification conducted using methanol and NaOH as catalyst.
- The fatty acid methyl esters (FAME) produced after transesterification from FWM-CV and MCP-B100 analyzed using gas chromatography GC ms.

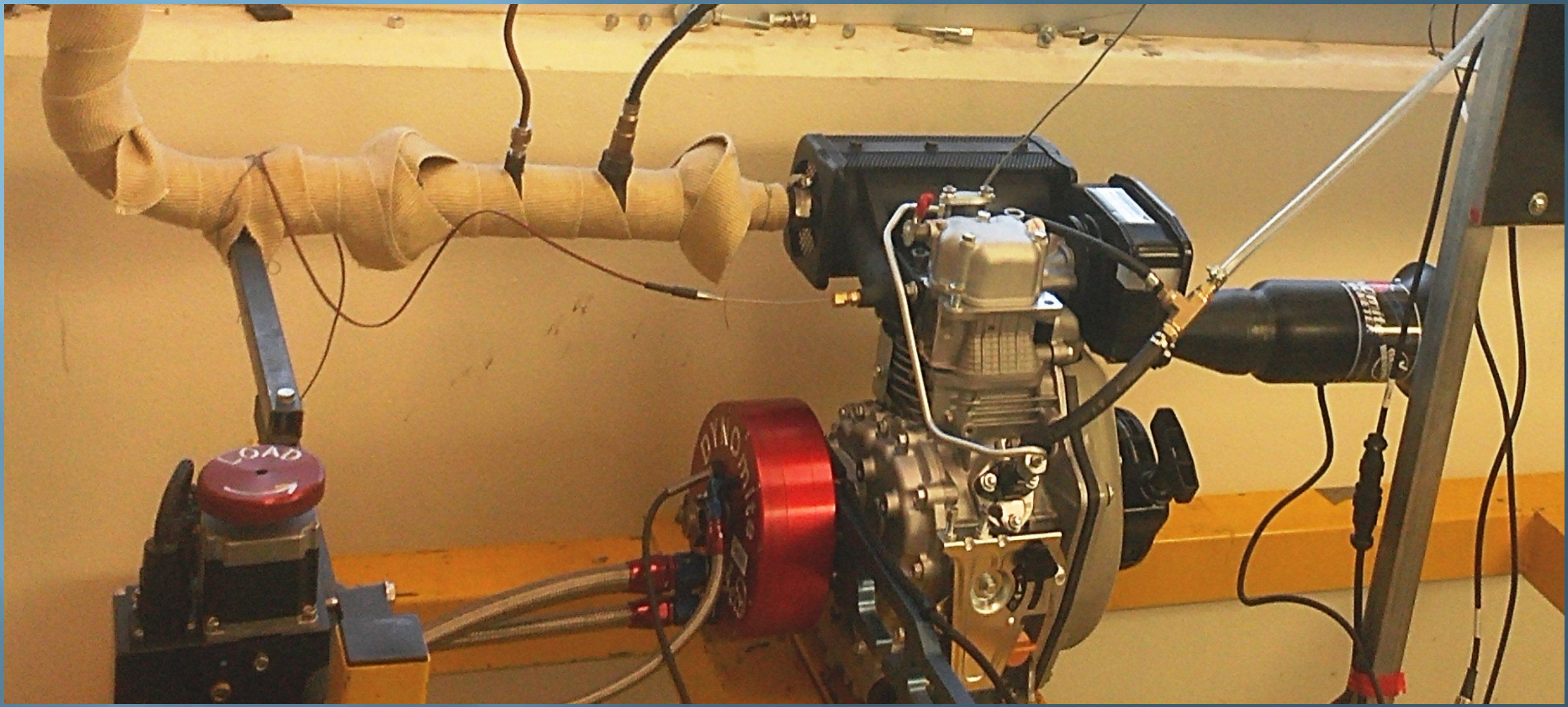
Methodology (engine test)

A single-cylinder four-stroke air cooled direct injection diesel engine is used in the test. To evaluate the engine performance and emissions.



Schematic diagram of experimental setup consist of 1- Engine, 2- Dynamometer, 3-Drive shaft, 4-Fuel tank, 5- Fuel rate meter, 6- Inlet air flow meter, 7-Pressure sensor, 8- Crank angle encoder, 9- Gas analyser, 10- Data acquisition.

Methodology (engine test)



Results

Some physical properties of microalgae *Chlorella vulgaris* FAMEs

	Cetane number	Density (g cm^{-3})	Kinematic viscosity (40 C $mm^2\ s^{-1}$)	Heat of combustion (MJ kg^{-1})
Myristic acid	66.2 [a,b,c]	0.867 [d]	3.3 [e]	38.89 [d]
Palmitic acid	74.5 [a,c]	0.865 [d]	4.38 [e]	39.449 [d,g]
Palmatoleic acid	51.0 [a,b]	0.869 [d]	3.67 [f]	39.293 [d,g]
Stearic acid	86.9 [a]	0.864 [d]	5.85 [e]	40.099 [d,g]
Linoleic acid	38.2 [a,b]	0.886 [d]	3.65 [e]	39.698 [d,g]
α-Linoleic acid	22.7 [b,c]	0.901 [d]	3.14 [e]	39.342 [d,g]

Density, cetane number and kinematic viscosity for *Chlorella vulgaris*, diesel and biodiesel

	Density (kg m^{-3})	Cetane number	Kinematic viscosity (40 °C $mm^2\ s^{-1}$)	Heat of combustion (MJ kg^{-1})
Control	875.31	57.499	4.239	39.608
ISC	873.034	59.224	4.361	39.666
Diesel	838 [c]	46.00 [d]	1.9–4.1 [a]	45.3–46.7 [f]
Biodiesel	860 – 900 [c]	≥47 [e]	1.9-6.0 [b]	39.3–39.8 [f]

Results

The oil from *Chlorella protothecoides* and small sample of *Chlorella vulgaris* were converted to biodiesel.

properties	stage one	Stage two		Chlorella vulgaris (Lee et al., 2010)	Chlorella vulgaris (Mata et al., 2010)
		Control	ISC [a]		
Growing time days	40	75.5	78.5	7	-
Dry weight g L^{-1}	0.487	0.636	0.885	0.5	-
Biomass productivity mg $L^{-1}day^{-1}$	12.16	10.598	14.755	74.2	20–200
lipid content %	10.06	8.94	19.272	14.96-15.58	5.0–58.0
lipid productivity mg $L^{-1}day^{-1}$	1.224	0.74	2.192	11.1 – 6.91[b]	11.2–40.0

Results

Tractor test

Results

Descriptive statistics and ANOVA summary for tractor engine performance and emissions at WOT, rated PTO speed 540RPM (engine speed 2600RPM).

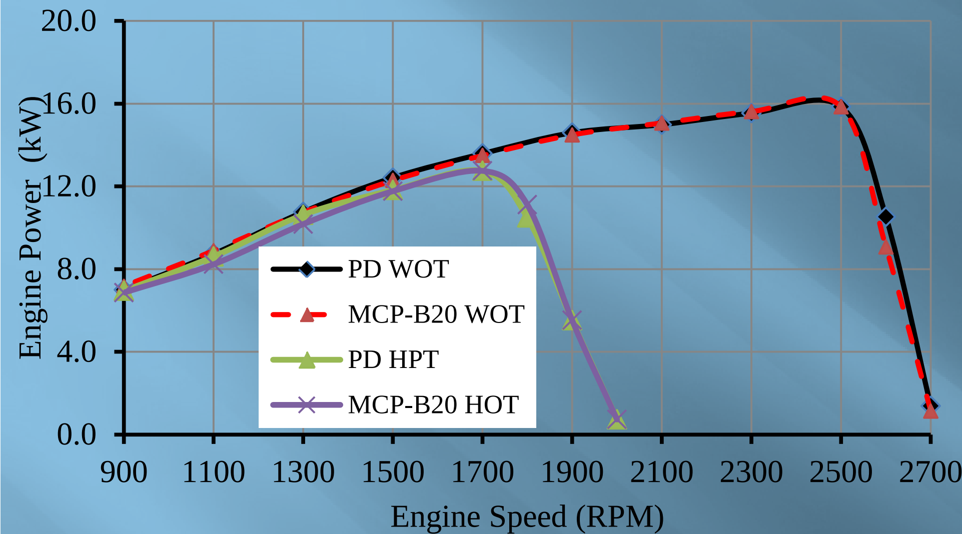
Variable	PD		MCP-B20		ANOVA F
	M	SD	M	SD	
Engine Torque (Nm)	**38.205**	1.246	**35.37**	0.65	16.246***
PTO Torque (Nm)	**220.25**	7.182	**203.9**	3.747	16.294***
Gross input power	**55.347**	2.34	**50.3**	1.949	10.951**
Engine Power (kW)	**10.395**	0.337	**9.627**	0.178	16.206***
PTO Power (kW)	**12.232**	0.399	**11.327**	0.209	16.129***
BSFC (kg/kWh)	**451.645**	31.642	**453.735**	25.47	0.011
Engine efficiency (%)	**18.825**	1.374	**19.162**	1.08	0.149
Noise level (db)	**90.9**	0.408	**90.375**	0.33	3.997
Exhaust temperature (^{o}C)	**356**	4.082	**350**	4.32	4.075
CO_2 (%)	**7.97**	0.049	**7.375**	0.15	56.720***
CO (%)	**0.036**	0.006	**0.250**	0.005	7.188***
O_2	**9.58**	0.258	**10.53**	0.294	23.543***
No	**541.5**	20.68	**493.5**	41.86	4.228
HC (PPM)	**9**	0	**6**	0	
Lambda	**1.835**	0.034	**2.016**	0.0325	59.114***

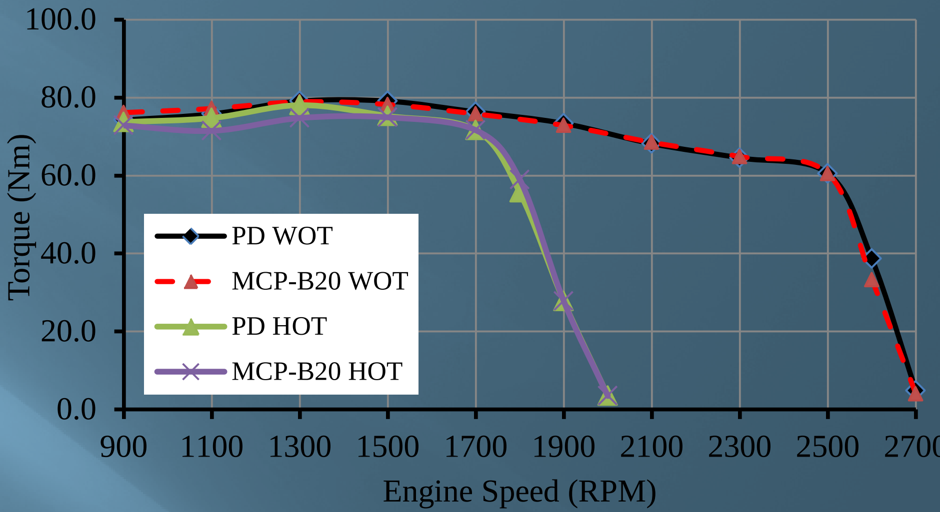
Results

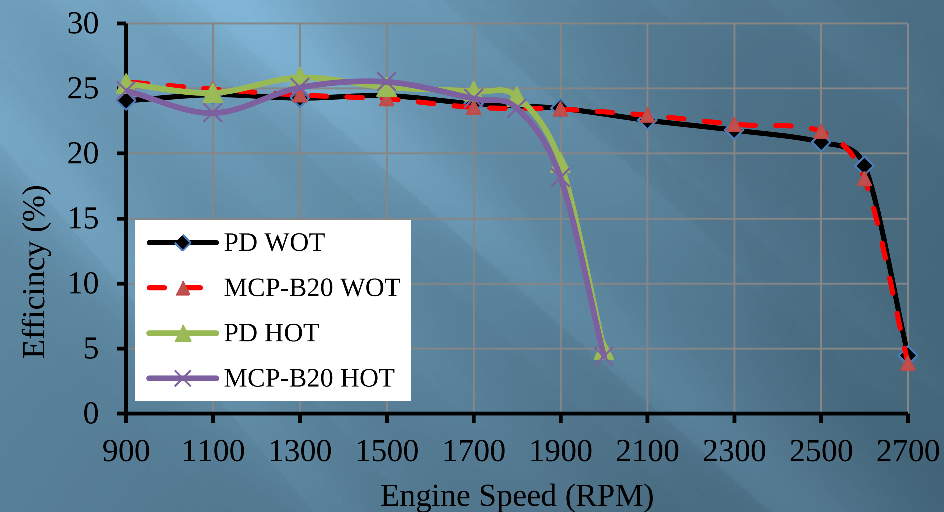
Descriptive statistics and ANOVA summary for tractor engine performance and emissions at WOT, peak PTO torque (1500RPM).

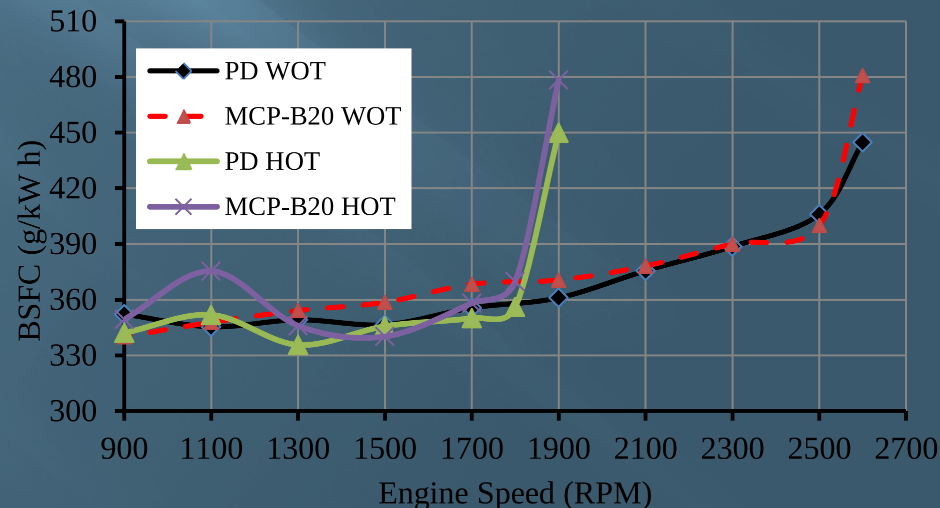
Variable	PD		MCP-B20		ANOVA F
	M	SD	M	SD	
Engine Torque (Nm)	**79.1025**	0.587	**78.235**	0.585	4.38
PTO Torque (Nm)	**456**	3.366	**451**	3.35	4.412
Gross input power	**50.937**	3.118	**50.882**	2.578	0.001
Engine Power (kW)	**12.42**	0.092	**12.28**	0.09	4.292
PTO Power (kW)	**14.6**	0.106	**14.450**	0.109	4.297
BSFC (kg/kWh)	**347.547**	23.798	**359.35**	17.559	0.637
Engine efficiency (%)	**24.454**	1.589	**24.184**	1.158	0.076
Noise level (db)	**86.3**	0.622	**85.9**	0.648	0.793
Exhaust temperature (°C)	**470**	5.77	**480**	5.788	5.985*
CO_2 (%)	**12.105**	0.0914	**12.025**	0.881	1.587
CO (%)	**0.902**	0.015	**0.85**	0.008	37.8***
O_2	**2.98**	0.077	**3.102**	0.074	5.254
No	**970**	5.715	**994**	3.651	50.087***
HC (PPM)	**6**	000	**6**	00	...
Lambda	**1.13**	0.008	**1.14**	0.016	1.2

Results

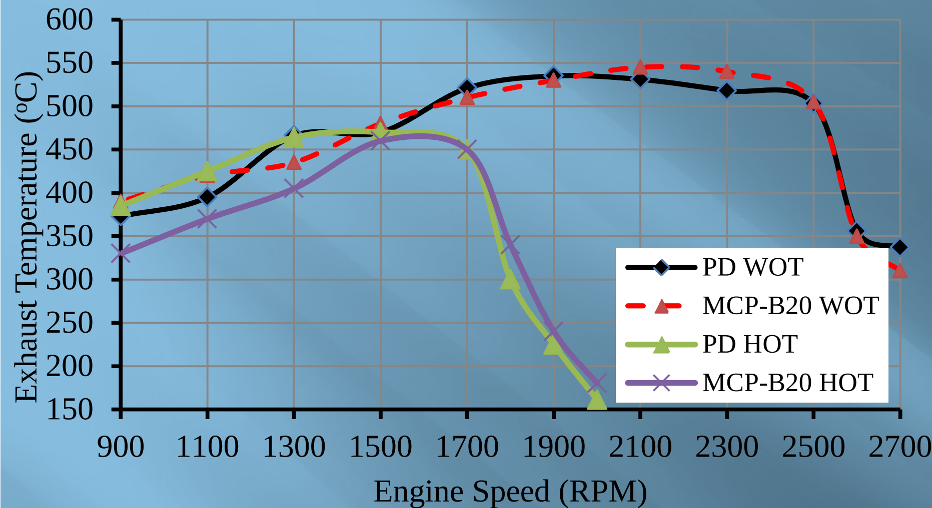

Engine Power (kW)
Engine Speed (RPM)
PD WOT
MCP-B20 WOT
PD HPT
MCP-B20 HOT

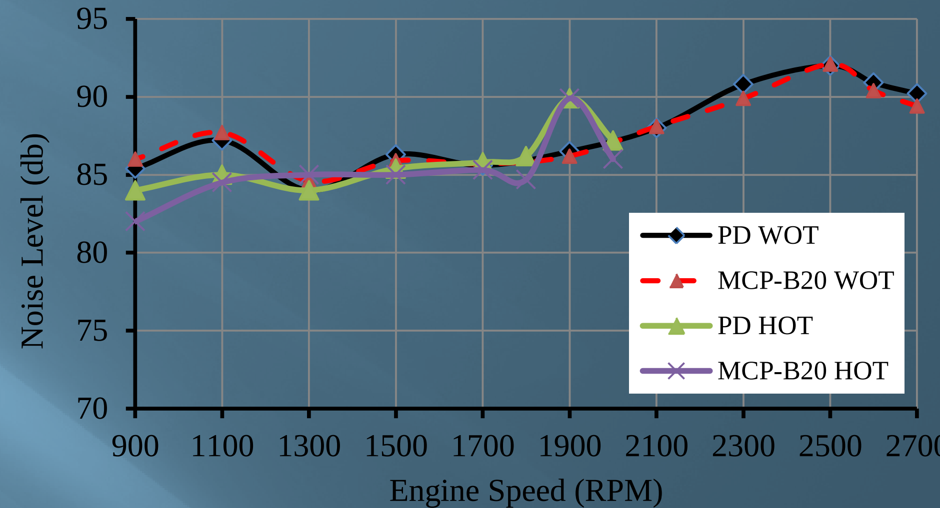

Torque (Nm)
Engine Speed (RPM)
PD WOT
MCP-B20 WOT
PD HOT
MCP-B20 HOT

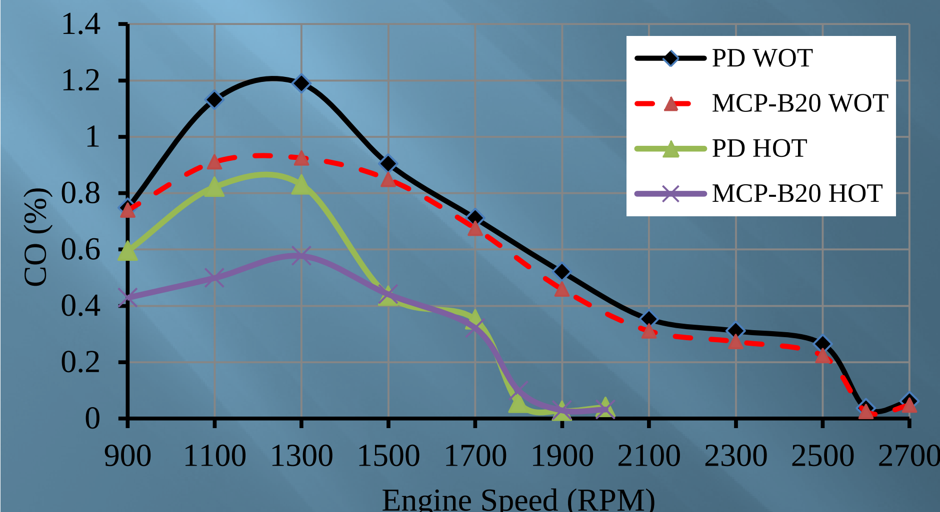

Efficincy (%)
Engine Speed (RPM)
PD WOT
MCP-B20 WOT
PD HOT
MCP-B20 HOT

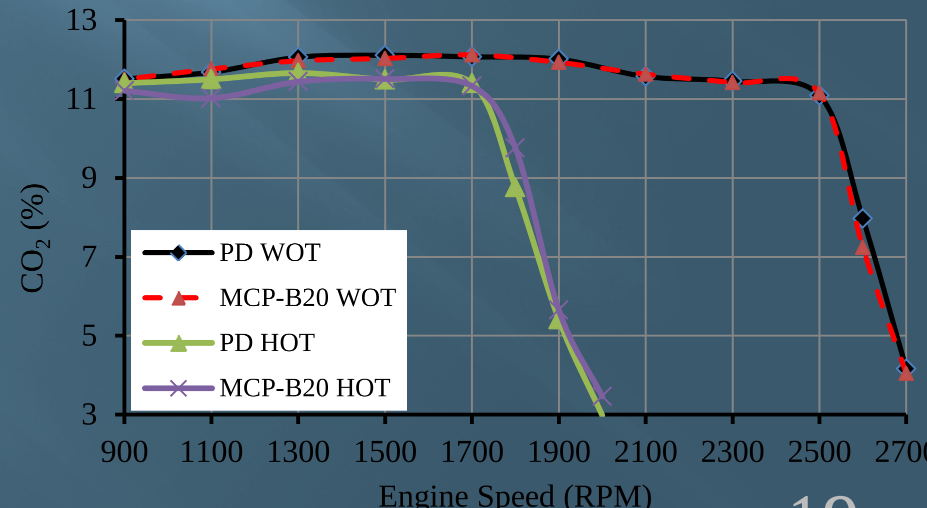

BSFC (g/kW h)
Engine Speed (RPM)
PD WOT
MCP-B20 WOT
PD HOT
MCP-B20 HOT

Results


Exhaust Temperature (ºC)
600
550
500
450
400
350
300
250
200
150
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
Engine Speed (RPM)
PD WOT
MCP-B20 WOT
PD HOT
MCP-B20 HOT


Noise Level (db)
95
90
85
80
75
70
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
Engine Speed (RPM)
PD WOT
MCP-B20 WOT
PD HOT
MCP-B20 HOT


CO (%)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
Engine Speed (RPM)
PD WOT
MCP-B20 WOT
PD HOT
MCP-B20 HOT


CO_2 (%)
13
11
9
7
5
3
900
1100
1300
1500
1700
1900
2100
2300
2500
2700
Engine Speed (RPM)
PD WOT
MCP-B20 WOT
PD HOT
MCP-B20 HOT

Thank you