BACHELOR THESIS – ME 184841

EFFECT OF PREHEATER OF THE B20 FUEL ON PERFORMANCE, COMBUSTION, AND EMISSION OF DIESEL ENGINE BASED ON SIMULATION

FAIRUZ FAJRI UTOMO

NRP 04211541000020

SUPERVISORS

Prof. Semin, S.T., M.T., Ph.D, C.Eng.

Beny Cahyono, S.T., M.T., Ph.D

DOUBLE DEGREE PROGRAM OF

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SUPERVISOR 1

Prof. Semin, S.T., M.T., Ph.D, C.Eng.

NIP 1971 0110 1997 02 1001

SUPERVISOR 2

Beny Cahyono, S.T., M.T., Ph.D

NIP 1979 0319 2008 01 1008

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EFEK PEMANASAN BAHAN BAKAR B20 TERHADAP PERFORMA, PEMBAKARAN, DAN EMISI DIESEL ENGINE BERBASIS SIMULASI

Fairuz Fajri Utomo

NRP 04211541000020

DOSEN PEMBIMBING 1

Prof. Semin, S.T., M.T., Ph.D, C.Eng.

NIP 1971 0110 1997 02 1001

DOSEN PEMBIMBIMNG 2

Beny Cahyono, S.T., M.T., Ph.D

NIP 1979 0319 2008 01 1008

DEPARTEMEN TEKNIK SISTEM PERKAPALAN

FAKULTAS TEKNOLOGI KELAUTAN

INSTITUT TEKNOLOGI SEPULUH NOPEMBER

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BACHELOR THESIS

Submitted to Comply One of The Requirements to Obtain a Bachelor of Engineering Degree in Double Degree of Marine Engineering (DDME) Program Department of Marine Engineering – Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

Departement of Maritime Studies

Hochschule Wismar, University of Applied Sciences

Submitted by:

FAIRUZ FAJRI UTOMO

NRP 04211541000020

Approved by Bachelor Thesis Supervisors:

1. **Prof. Semin, S.T., M.T., Ph.D., C.Eng** ( )
   NIP 1971 0110 1997 02 1001

2. **Beny Cahyono, S.T., M.T., Ph.D** ( )
   NIP 1979 0319 2008 01 1008

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APROVAL FORM

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Departement of Maritime Studies

Hochschule Wismar, University of Applied Sciences

Submitted by:

FAIRUZ FAJRI UTOMO

NRP 04211541000020

Approved by

The Head Department of Marine Engineering:

Dr. Eng. M. Badrus Zaman, S.T., M.T.

NIP. 1977 0802 2008 02 1007

APPROVAL FORM

EFFECT OF PREHEATER IF THE B20 FUEL ON PERFORMANCE COMBUSTION, AND EMISSION OF DIESEL ENGINE BASED ON SIMULATION

BACHELOR THESIS

Submitted as one of Requirements to obtain Bachelor Degree in Engineering
on
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Bachelor Program in Marine Engineering Department
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

Prepared by:

FAIRUZ FAJRI UTOMO

NRP. 04211541000020

Approved by

Representative of Hochschule Wismar in Indonesia

Dr.-Ing. Wolfgang Busse

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DECLARATION OF HONOUR

I hereby who signed below declare that:

This thesis has been written and developed independently without any plagiarism act. All contens and ideas drawn directly from internal and external sources are indicated such as cited sources, literatures, and other professional sources.

Name	: Fairuz Fajri Utomo
Student ID Number	: 04211541000020
Thesis Title	: Effect of Preheater of the B20 Fuel on Performance, Combustion , and Emission of Diesel Engine Based On Simulation
Departement	: Double Degree of Marine Engineering

Surabaya, July 2019

Fairuz Fajri Utomo

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Supervisor	: Prof. Semin, S.T., M.T., Ph.D, C.Eng.
	Beny Cahyono, S.T., M.T., Ph.D

ABSTRACT

Diesel engine are still major option for main powertrain of a ship nowadays., Indonesian Government starts a new regulation that state all diesel oil have mandatory to blend 20% of palm oil on the diesel oil (B20). The purpose of this agenda is to accumulate funds by the usage of Palm Oil . B20 Biodiesel have some disadvantages compared to pure diesel oil. One of the solution to reduce the disadvantages of B20 Biodiesel is by increase temperature of fuel. In this thesis, simulation method is used by using GT Power Software. The Fuel temperature measured are 30° C,40ºC,50ºC ,60ºC ,70ºC. The simulation is done on several load condition which are 25%, 50%, 75%, and 100% and 3 different engine speed of 1800 ,2000, and 2200 rpm.. The variables analysed is Performance, Combustion , and Emission . Performance consist of Power, Torque, BMEP, and BSFC. Combustion includes Maximum Temperature and Pressure. Emission includes NOx and Hydrocarbon concentration. Results are showing that increase in fuel temperature leads to better performance. Brake power, torque , and BMEP is increasing and BSFC is decreasing. Combustion pressure and temperature increases as fuel temperature increases. On emission side, increase in fuel temperature leads to higher emission.

Keywords: B20, Biodiesel, Diesel Engine, Preheater, Simulation

PREFACE

Alhamdulillah thanks to Allah SWT the God almighty who give the intelligent, strength, and favor so author able to finish this bachelor thesis. This bachelor thesis defines about "**Effect Of Preheater Of The B20 Fuel On Performance, Combustion , And Emission Of Diesel Engine Based On Simulation"** On this occasion the author would to express his immeasurable appreciation and deepest gratitude for those who have helped in completing this bachelor thesis:

1. Author's Family. Author's mother Endah Dwilestari, Author's father Moh Adi Soedarso, Twins brother, Fachrizal Tsany Fajr and Author's brother, Fikri Ibrahim Fils'adi who always mentally, financially support, and the prayers were given to the author.
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8. Rifqi Assidiqi and Muhammad Irsyad Saihilmi as author's friend on Marine Engineering Department
9. Those whose unable to be mentioned

The author also aware in the writing of this thesis is far from perfection and there are still mistaken in this bachelor thesis because there are still many limitations of the author. On writing of this thesis expected to expand knowledge for readers and can be developed for further research.

Surabaya, July 2019

Author

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CHAPTER I
INTRODUCTION

1.1 Background

Starting from September 2018, it's a mandatory to every oil manufacture company to blend biodiesel in amount of 20% to diesel fuels (B20). The regulation was based on Peraturan Presiden No 66 on 2018 about second revision on Peraturan Presiden No 61 on 2015 about accumulation and usage of funds from Palm Oil resources. The first regulation published were Peraturan Menteri ESDM Nomor 41 Tahun 2018 about provision and utilization of vegetable based Biodiesel fuels in order to funding by the Palm Oil Plantation Fund Management Agency.[1]

Biodiesel has some advantages other fuels, the first is reduction of emission. According to the "Clean Alternative Fuels: Biodiesel," produced by the United States Environmental Protection Agency (EPA), here's how biodiesel impacts emissions compared to unblended diesel fuel . Reductions in carbon monoxide emissions of 10% (B-20) and 50% (B-50), particulate emissions of 15% (B-20) and 70% (B-100), total hydrocarbon emissions of 10% (B-20) and 40% (B-100), sulfate emissions of 20% (B-20) and 100% (B-100), and increase in nitrogen oxide emissions of 2% (B-20) and 9% (B-100). However there are some issues like might damage the injector of the engine, and might contain water that can cause corrosion. [2]

Biodiesel blends are have bigger value of viscosity than normal diesel fuels so that it may damage injector and cause clogging on filter parts. In order to decrease its viscosity, it needs a heat exchanger to make it less viscous. Increase in inlet temperature could improve the brake thermal efficiency, Brake thermal efficiency increases at high engine load. The brake thermal efficiency improvement with the increase of biodiesel inlet temperature can be interpreted as a result of breaking and weakening of the fuel chains, so that it leads to the improved combustion [3]

1.2 Problem Statement

From Background above the problem of the implementation of this thesis are

1 What is the best temperature of the fuel that give the best effect on performance?
2 What is the best temperature of the fuel that give the best effect on combustion?

3 What is the best temperature of the fuel that give the best effect on emission?

1.3 Problem Limitation

To focusing the analysis the problem will be given boundary as follows

1. Simulation main engine Mitsubishi 4D30 with Engine Simulation Software,
2. B20 Biodiesel is used as the fuel
3. Varying the temperature of the fuel by the heat from heat exchanger.The temperature used will be 30 ,40 ,50 ,60, ^{o} Celsius
4. Effect on performance, combustion, and emission will be analyzed by the simulation

1.4 Objective of the thesis

- To find the best of preheater of B20 fuel on Performance,
- To find the best of preheater of B20 fuel on Combustion,
- To find the best of preheater of B20 fuel on Emission

1.5 Purpose of the Thesis

Purpose of the thesis is that the simulation can provide good result and the equipment can be implemented to reduce the disadvantages of B20 blends biodiesel.

CHAPTER II
LITERATURE STUDY

2.1 Biodiesel

Biodiesel is an alternative transport fuel to fossil diesel. It is renewable and can be derived from several feedstocks, such as vegetable oils (like rapeseed and palm oil and recycled waste cooking oil , amongst others. The production of biodiesel predominately utilises transesterification to produce a monoglyceride biodiesel (and ~10% glycerol product of total biodiesel yield) from plant oil precursors, with more recent movements adding a catalytic hydroprocessing stage .

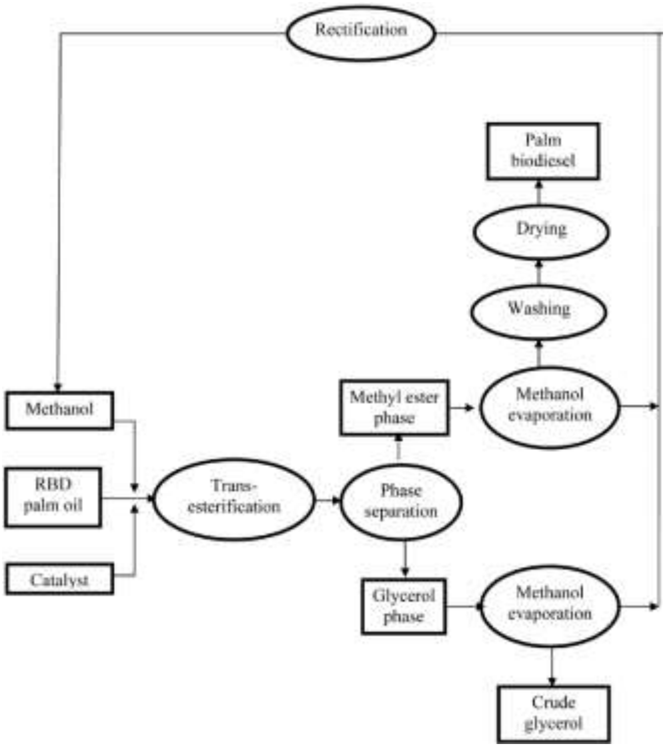

Figure 2.1 Biodiesel Production Process [3]

The Biodiesel on Indonesia is mostly manufactured by PT Pertamina (Persero) . The specification of the fuel are shown in table 2.1.

Table 2.1 Pertamina Biodiesel Properties

No	Charateristics	Unit	Limitation		Test Method	
			Min	Max	ASTM	Others
1	Setana Number or Cetane Index		48	-	D 613	
			45	-	D 4737	
2	Specific Gravity @ 15 oC	kg / m3	815	860	D 1298 / D 4052	
3	Viscosity @ 40 oC	mm2 / sec	2,0	4,5	D 445	
4	Sulfur content	% m / m	-	0,35	D 2622 / D5453/ D 4294 / D7039	
			-	0,3		
			-	0,25		
			-	0,05		
			-	0,01		
5	Distillation 90% vol. evaporation	oC	-	370	D 86	
6	Flash point	oC	52	-	D 93	
7	Pour Point	oC	-	18	D 97	
8	Carbon Residue	% m / m	-	0,1	D 4630 / D 189	
9	Water content	mg / kg	-	500	D 6304	
10	Biological Growth *)	-	-	-	-	
11	FAME * content)	% v / v	-	-	-	
12	Methanol content *)	% v / v	Not Detected		D 4815	
13	Corrosion of Copper Blades	merit	-	Class 1	D 130	
14	Ash content	% v / v	-	0,01	D 482	
15	Sediment content	% m / m	-	0,01	D 473	
16	Strong Acid Numbers	mgKOH / gr	-	0	D 664	
17	Total Acid Numbers	mgKOH / gr	-	0,6	D 664	
18	Particulate	mg / l	-	-	D 2276	
19	Visual appearance	-	Clear and Bright			
20	Color	No. ASTM		3,0	D 1500	
21	Lubricity (HFRR wears his scar. @ 60 oC)	micron		460	D 6079	

The advantages of biodiesel are that it is renewable and although energy density of biodiesel at 39 MJ/kg is marginally lower than the 42.8 MJ/kg of fossil diesel, its GHG emissions are lower: 3kg CO2/litre biodiesel versus 3.16 kg CO2/litre fossil diesel. Including factors such as feedstock carbon sequestration during growth and land use change, two influential factors for biofuel production, is becoming increasingly important, as they directly contribute to the overall carbon impact of the biodiesel. [4]

Table 2.2 Fuel Properties Comparison [4]

Parameters	Method	DF	PB20
Kinematic viscosity @ 40 °C (cSt)	ASTM D7042	3.317	3.617
Heating value (MJ/kg)	ASTM 5468	45.548	43.828
Density @ 40 °C (kg/m^3)	ASTM D7042	822	833
Cetane number (CN)	ASTM D6890	51	53.1
Flash point (°C)	ASTM D93	78	89

Although environmental benefits can be assumed, there are some drawbacks on performance by the usage of biodiesel. Main problem is the forming more deposit than pure diesel fuel . Deposit will occur mostly on the surface of the injector's liner and also the nozzle of the injector.

Figure 2.2 Photographic view on injector nozzle DF (Diesel Fuel) PB (Palm Biodiesel) [4]

Another problems on biodiesel were the increase of NO_x . A possible reason for the increase in NOx emissions may be the increased oxygen level in the blend, which increases local temperatures due to excess hydrocarbon oxidation, and thus it increases the maximum temperature during combustion and thereby increases NOx formation. Therefore, the principal factor leading to the formation of NOx emissions is a high combustion temperature . [4]

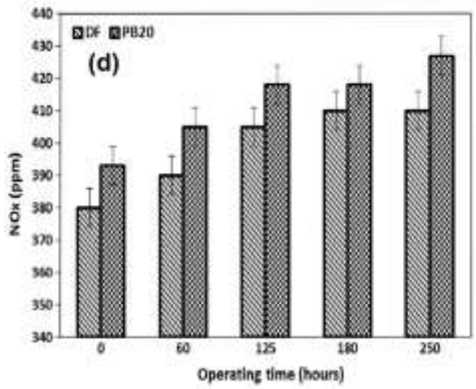

Figure 2.3 NOx emission comparison [4]

2.2 Heat Exchanger

Heat Exchanger is an equipment that provide the transfer of thermal energy between two or more fluids at different temperatures Heat exchanger widely used in heating, refrigeration, air conditioning, power stations, chemical plants, etc.

Heat exchangers are classified according to flow arrangement and geometry of heat exchanger. The simplest heat exchanger is one for which the hot and cold fluids move in the same or opposite directions. This heat exchanger consists of two concentric pipes of different diameters.

- parallel-flow arrangement. In the parallel-flow arrangement, the hot and cold fluids enter at the same end, flow in the same direction, and leave at the same end.
- counter-flow arrangement. In the counter-flow arrangement, the fluids enter at opposite ends, flow in opposite directions, and leave at opposite ends.

The heat transfer surface in heat exchangers can be arranged in several forms. Heat exchangers are therefore also classified as:

- Double pipe heat exchangers. Double pipe heat exchangers are cheap for both design and maintenance, making them a good choice for small industries. In these exchangers one fluid flows inside the tube and the other fluid flows on the outside. Although they are simple and cheap, their low efficiency coupled with the high space occupied in large scales, has led modern industries to use more efficient heat exchangers like shell and tube.'

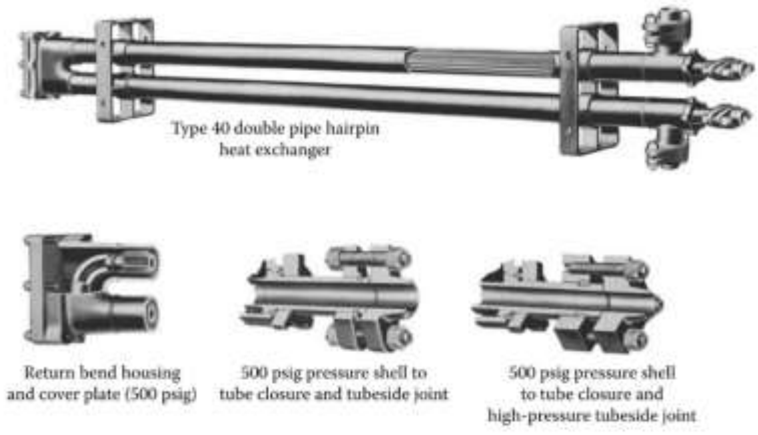

Figure 2.4 Double Pipe Heat Exchanger

- Shell and tube heat exchangers. Shell and tube heat exchangers in their various construction modifications are probably the most widespread and commonly used basic heat exchanger configuration in industry. Shell-and-tube heat exchangers are further classified according to the number of shell and tube passes involved. Shell and tube heat exchangers are typically used for high-pressure applications (with pressures greater than 30 bar and temperatures greater than 260 °C). This is because the shell and tube heat exchangers can withstand high pressures due to their shape. In this type of heat exchanger, a number of small bore pipes are fitted between two tube plates and primary fluid flows through these tubes. The tube bundle is placed inside a shell and the secondary fluid flows through the shell and over the surface of the tubes. In nuclear engineering, this design of heat exchangers is widely used as in case of steam generator, which are used to convert feed water into steam from heat produced in a nuclear reactor core. To increase the amount of heat transferred and the power generated, the heat exchange surface must be maximized. This is obtained by using tubes.

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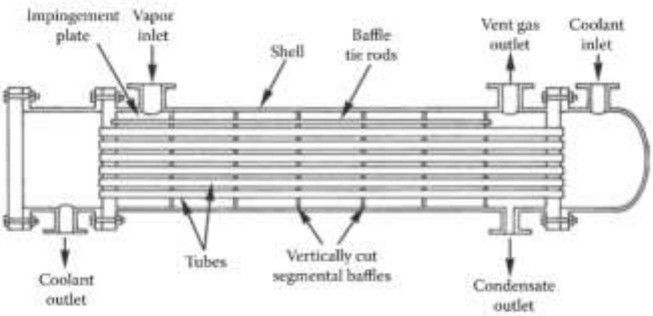

Figure 2.5 Tube Heat Exchanger

- Plate heat exchangers. A plate heat exchanger is a type of heat exchanger that uses metal plates to transfer heat between two fluids. This arrangement is popular with heat exchangers using air or gas as well as lower velocity fluid flow. Example of this type of ~~The classic example of a~~ heat exchanger is found in an internal combustion engine in which an engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. When compared to shell and tube exchangers, the stacked-plate arrangement typically has lower volume and cost. Another difference between the two is that plate exchangers typically serve low to medium pressure fluids, compared to medium and high pressures of shell and tube. [5]

2.3 Engine Performance

2.3.1 Power

Power is the rate of doing work or transferring heat, amount of energy per unit time. The value of engine power measured as described on equation 1 is called brake power Pb. This power is the usable power delivered by the engine to the load- in this case, a "brake." [6]

$$P = 2\pi NT \quad (1)$$

Where N is crank speed and T is Torque

The typical brake power curve is shown on figure 2.6 . The data is obtained from software simulation Brake power is usually measured by attaching a power absorption device to the driveshaft of the engine. Such a device sets up measurable forces counteracting the forces delivered by the engine, and the determined value of these measured forces is indicative of the forces being delivered. [7]

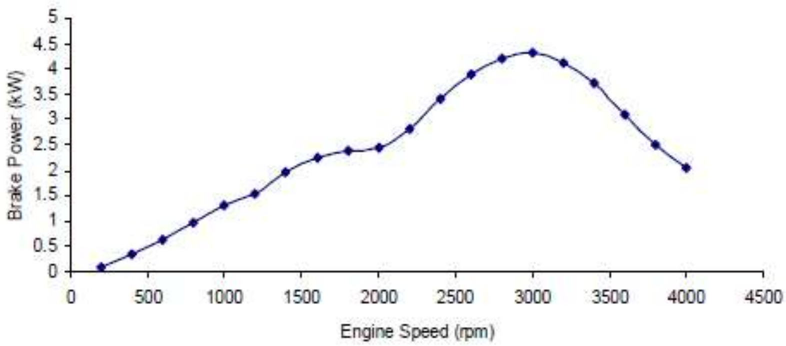

Figure 2.6 Engine Brake Power graph [7]

The brake power of engine lowest on minimum engine speed (rpm) at 200 rpm and after that if the engine speed is increase the brake power is increase too until on engine speed 3000 rpm. The maximum brake power of the engine model is on engine speed at 3000 rpm and after the engine speed is up of 3000 rpm the\brake power is decrease and go to down. [7]

2.3.2 Torque

Torque is an equivalent of rotational of linear force. Engine torque is normally measured with a dynamometer.' The engine is clamped on a test bed and the shaft is connected to the dynamometer rotor. Torque is a measure of an engine's ability to do work.[6]

2.3.3 Specific Fuel Oil Consumption (SFOC)

Fuel consumption is measured as a flow rate-mass flow per unit time m,. A more useful parameter is the specific fuel consumption (sfoc is fuel flow rate per unit power output. It measures how eficiently an engine is using the fuel supplied to produce work: [6]

$$\text{sfoc} = \frac{\text{mass flow rate}}{\text{P}} \qquad (2)$$

2.3.4 Brake Mean Effective Pressure (BMEP)

Mean effective pressure is a valuable measure of an engine capacity to do work independent to engine displacement, it can refer to average pressure acting on piston during its different portion of an engine cycle. BMEP measure is obtained by dividing the work per cycle by the cylinder volume displaced per cycle.

$$\text{Work per cycle} = \frac{\text{P}n_\text{R}}{\text{N}} \qquad (3)$$

where n, is the number of crank revolutions for each power stroke per cylinder (2 for four-stroke cycles; 1 for two-stroke cycles), then

$$\text{mep} = \frac{\text{P}n_\text{R}}{V_\text{d}\text{N}} \qquad (4)$$

The maximum brake mean effective pressure of good engine designs is well established, and is essentially constant over a wide range of engine sizes. Thus, the actual bmep that a particular engine develops can be compared with this norm, and the effectiveness with which the engine designer has used the engine's displaced volume can be assessed. Also, for design calculations, the engine displacement required to provide a given torque or power, at a specified speed, can be estimated by assuming appropriate values for bmep for that particular application.

Typical values for bmep are as follows. For naturally aspirated spark ignition engines, maximum values are in the range 850 to 1050 kPa (- 125 to 150 lb/in2) at the engine speed where maximum torque is obtained (about 3000 rev/min). At the maximum rated power, bmep values are 10 to 15 percent lower. For turbocharged automotive spark-ignition engines the maximum bmep is in the 1250 to 1700 kPa (180 to 250 lb/in2) range. At the maximum rated power, bmep is in the 900 to 1400 kPa (130 to 200 lb/in2) range. For naturally aspirated four-stroke diesels, the maximum bmep is in the 700 to 900 kPa (100 to 130) [6]

2.4 Engine Combustion

2.4.1 Cylinder Temperature

The maximum combustion temperature in the engine cylinder results are shown in figure 2.7 . The experiment uses single cylinder diesel engine and compared with the same engine that has been modified to CNG fuel . It is shown that increasing engine speed of the diesel , will increase the maximum combustion temperature in the engine cylinder.[8]

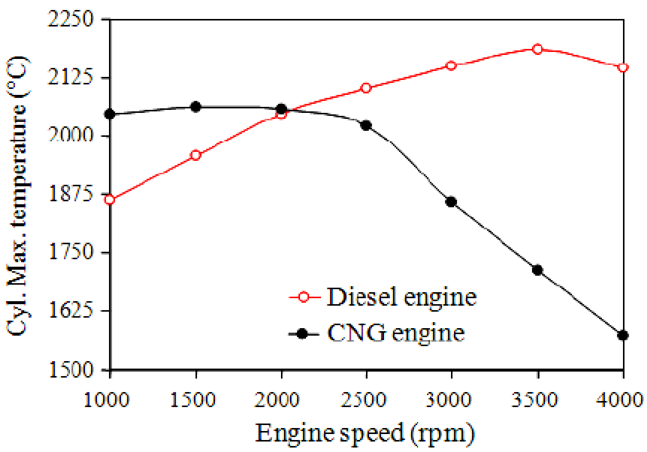

Figure 2.7 Combustion temperature comparison Diesel and CNG [8]

2.5 Engine Emission

2.5.1 NO_x

Nitrogen is released during fuel combustion it combines with oxygen atoms to create nitric oxide (NO). This further combines with oxygen to create nitrogen dioxide (NO2). Nitric oxide is not considered to be hazardous to health at typical ambient concentrations, but nitrogen dioxide can be. Nitrogen dioxide and nitric oxide are referred to together as oxides of nitrogen (NO_x).

Nitrogen dioxide is an irritant gas, which at high concentrations causes inflammation of the airways. NO_x gases react to form smog and acid rain as well as being central to the formation of fine particles (PM) and ground level ozone, both of which are associated with adverse health effects..

NO_x is produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. In areas of high motor vehicle traffic, such as in large cities, the amount of nitrogen oxides emitted into the atmosphere as air pollution can be significant. NOx gases are for med whenever combustion occurs in the presence of nitrogen [9]

On table 2.2 ,the ship's speed is varied to see the effect of the speed difference on duration of sailing, fuel consumption and NO_x emissions from the ships. Speed variation is based on the area of cruise ships, the speed of the port area 1, the speed of the sea area and the speed of the port area [10]

Table 2.3 NO_x Emission results [10]

Speed Variation (kn)	Duratiion (h)	Total Fuel Cons (Ton)	Nox (kg)
4-15-4	31.3	32.1	1830
4-15.5-4	30.6	33.9	1931
4-16-4	29.6	35..7	2036
4-16.5-4	29.2	37.6	2144
4-17-4	28.6	39.6	2256
5-15-5	29.5	32.2	1834
5-15.5-5	28.8	33.9	1935
5-16-5	28.1	35.8	2039
5-16.5-5	27.5	37.7	2147
5-17-5	26.9	39.6	2259

Exhaust emissions are a function of fuel consumption, if the vessel speed increases , the fuel consumption is also increasing, so is the emissions produced.[10]

2.5.2 SO_x

The sulphur oxides or SO_x is produced by the presence of sulphur compound in the marine fuels used in marine engines on board vessel. Better the grade, lower will be the sulphur content as it is removed by refining of the fuel The smoke containing sulphur oxides emitted by the combustion of marine fuel will further oxidise and in presence of catalyst like NO_2, will form sulphuric acid which is a major cause of acid rain.

The emission of SOx contributes in formation of secondary inorganic aerosol gases, fine particles which are harmful to humans. Maritime industry consumes mostly low grade of fuel oil i.e. heavy oil and diesel oil with high sulphur content as compared to any other transportation medium. But due to MARPOL Annex VI stringent norms, marine engines are now using better grade of marine fuel like marine gas oil. [10] Biodiesel produces lower amount of SO_X , the greater the blend percentages, the lower it produces.[11]

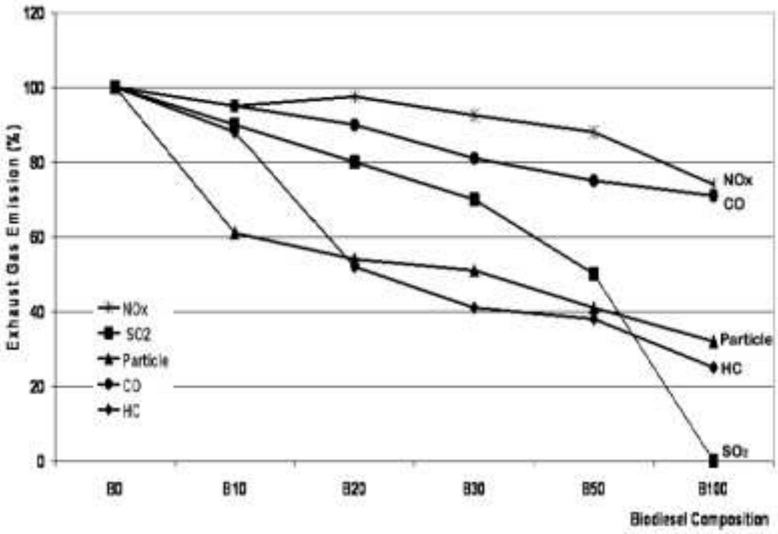

Figure 2.8 Biodiesel Emission [11]

2.5.3 CO Emission

Carbon Monoxide (CO) forms primarily when carbon fuels are not burned completely. Mobile sources account for the majority of CO emissions. These sources include both on-road vehicles (e.g., cars, trucks, motorcycles) and nonroad vehicles and engines (e.g., farm equipment, construction equipment, aircraft, marine vessels). Consequently, high concentrations of CO generally occur in areas with heavy traffic congestion. In cities, as much as 95 percent of all CO emissions may come from motor vehicle exhaust (U.S. EPA, 2008). Other sources of CO emissions include industrial processes, non-transportation fuel combustion, and natural sources, such as forest wildfires.[12]

Carbon monoxide has a poisonous effect caused by reversible displacement of oxygen from haemoglobin in human lungs to form carboxyl-haemoglobin. From this, it became clear and well established that hypoxia was caused by poor tissue in the body and not by the deficiency of oxygen transportation. To support this statement, states that carbon monoxide has 2010 times greater affinity for haemoglobin than oxygen .A little concentration of carbon monoxide in an environment can cause toxic levels of carboxylhaemoglobin. This occurs after carbon monoxide has selectively boundto haemoglobin the oxygen haemoglobin dissociation curve of the remaining oxyhaemoglobin shifts to the left, which reduces the release of oxygen [13]

The exhaust emissions of carbon monoxide from biodiesel are on average 48 percent lower than carbon monoxide emissions from diesel. On figure 2.9 is shown the CO emission on biodiesel blend percentage. CO emission is lower on higher blend percentage biodiesels [14]

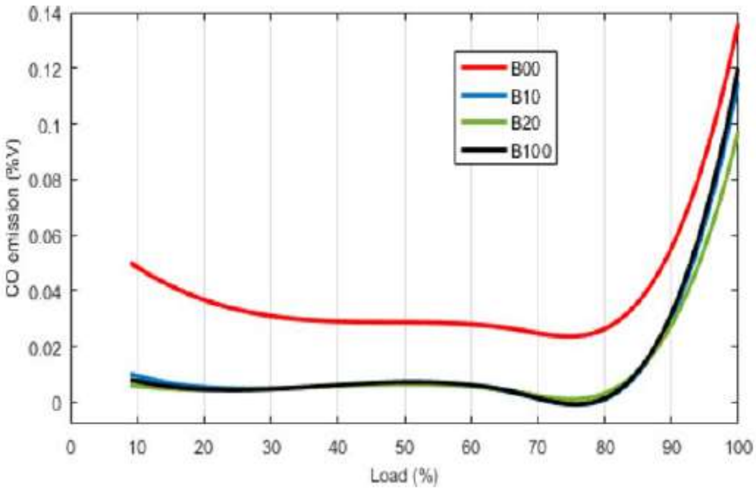

Figure 2.9 CO Emission on Biodiesel Blend [14]

2.6 Effect on Fuel Temperature Increase

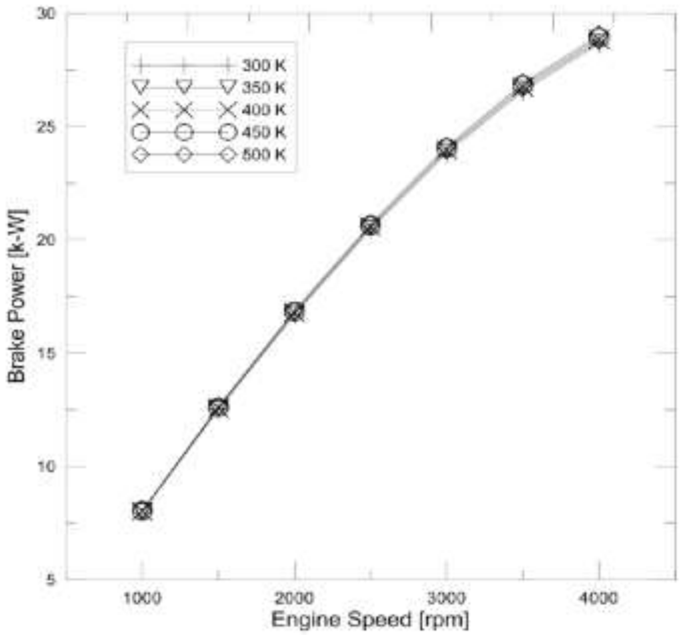

Figure 2.10 Brake Power effect on Temperature Increase [15]

Increase on fuel temperature causes increase on several performance parameters. Brake Power increases as the temperature of fuel increases. Figure 2.10 indicates engine brake power output at full load condition . Higher fuel temperatures increases injection\ pressure Higher injection pressure results in lower ignition delay, which results in the increase of brake power. [15]

Brake Torque increases due to fuel temperature . The fuel density decreases as Fuel Temperature is increased . Higher injection pressure is needed to gain an equal fuel mass in order to produce the same required brake torque. [15]

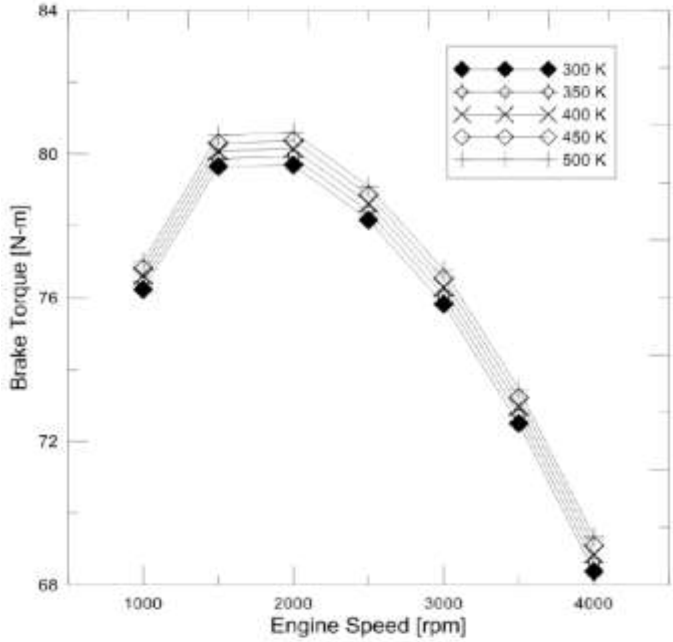

Figure 2.11 Brake Torque effect on Temperature Increase [12]

Increase of fuel temperature makes a changed value of emission. Figure 2.11 shows trends of variation of NOx emissions for the results taken on the conduct of load tes ON Sunflower Seed Biodiesel. The important concern of Diesel engine is higher NOx and it is also noted from this figure that the NOx emission for Diesel operation is found to be 2048 ppm. When Sunflower BioDiesel is used it is 1843 ppm showing beneficial trend that is reduction of NOx to 1848 ppm.[16]

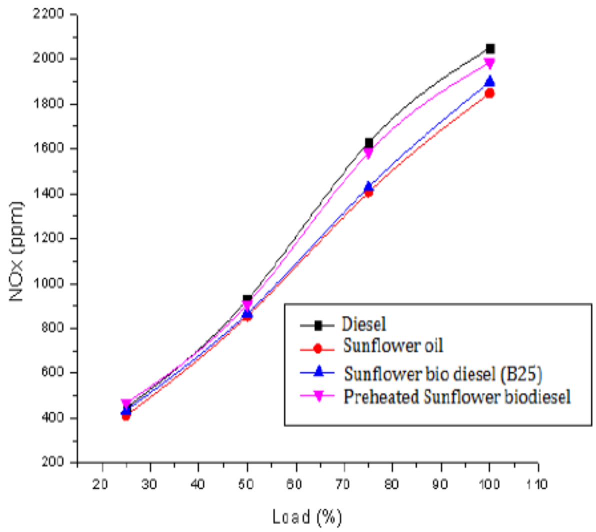

Figure 2.12 NOx emission [16}

Figure 2.12 illustrates the how the unburned Hydrocarbon s are affected for these fuels at varied load conditions". "It is noted that 197 ppm of Unburnt HC is found in the exhaust gas with Diesel fuel. It is increased to 207 ppm when BioDiesel is used indicating incomplete combustion. [16]

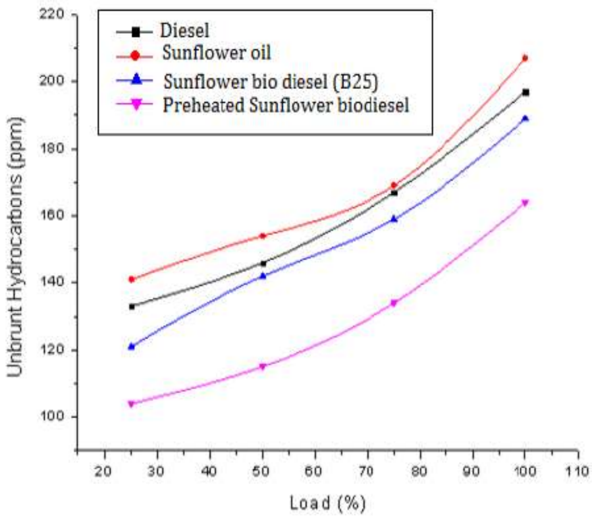

Figure 2.13 Hydrocarbon emission [16]

Graph presents the information about CO emissions for these fuels which are drawn from the measurements by conducting performance tests on the test engine". "The CO emission for when Diesel is used is noted to be 29% by volume which is increased by 3% more when Sunflower BioDiesel is used. For the blend it is reduced to 25% and with preheating of Sunflower BioDiesel a considerable decrease that is to 21% which means an 8% decrease is noticed and is very much appreciable.[16]

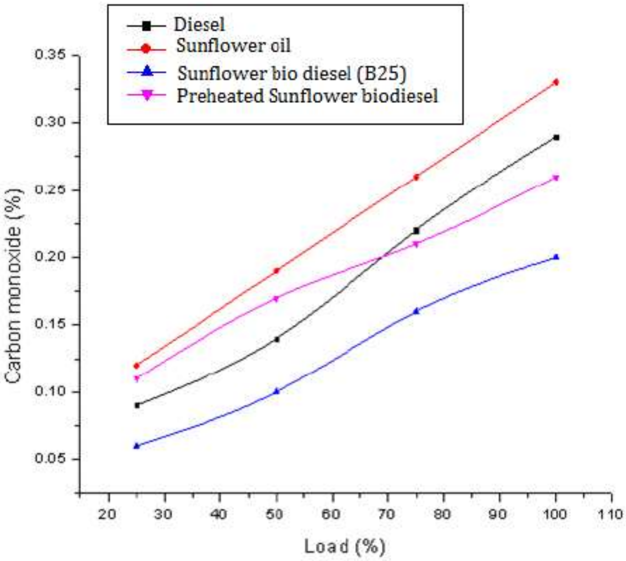

Figure 2.14 CO emission[16]

2.7 GT Power Engine Simulation Software

GT-POWER is an engine simulation software, used by major engine manufacturer for the design and development of their engines. It is applicable to all sizes and types of engines, and its installed base includes a highly diverse group of car, truck, motorcycle, motor sport, marine, locomotive, power generation, mining and construction, agricultural, and lawn and garden equipment manufacturers [17]

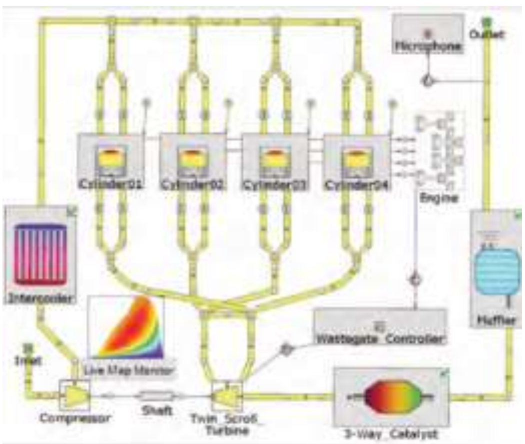

Figure 2.15 Example of GT Power Engine Model, Courtesy of Gamma Technologies [17]

GT-POWER provides feature required to allow the engineer to analyze a number of engine configurations and performance characteristics, including:

- Torque and power curves, airflow, vol. efficiency, fuel consumption, emissions
- Steady state or full transient analysis, under any driving scenario
- Turbocharged, supercharged, turbocompound, e-boost, pneumatic assist
- SI, DI, HCCI and multi-mode combustion, multi-fuel, and multi-pulse injection
- Infinitely variable valve timing and lift (VVT and VVL)
- Acoustic analysis of intake and exhaust systems
- Manifold and cylinder component thermal analysis, with included FE solver
- Controls system modeling, via built-in controls library or Simulink coupling [17]

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CHAPTER III
RESEARCH METHODOLOGY

3.1 Research Methodology

3.1.1 Problem Statement

Identification of the problem on the research is to find the best temperature of preheater on B20 that delivers best performance, combustion , and emission.

3.1.2 Literature Review

Study from journals, books, and internet about the to related subject

3.1.3 System Modeling and Set Up

Creating model of engine on GT-Power software. Steps on making the engine model are as follows

1. Choosing document template

   Creating engine model starts with "document creation wizard". Because the object made in this case is engine, so 'Engine Performance and Acoustics' is chosen.

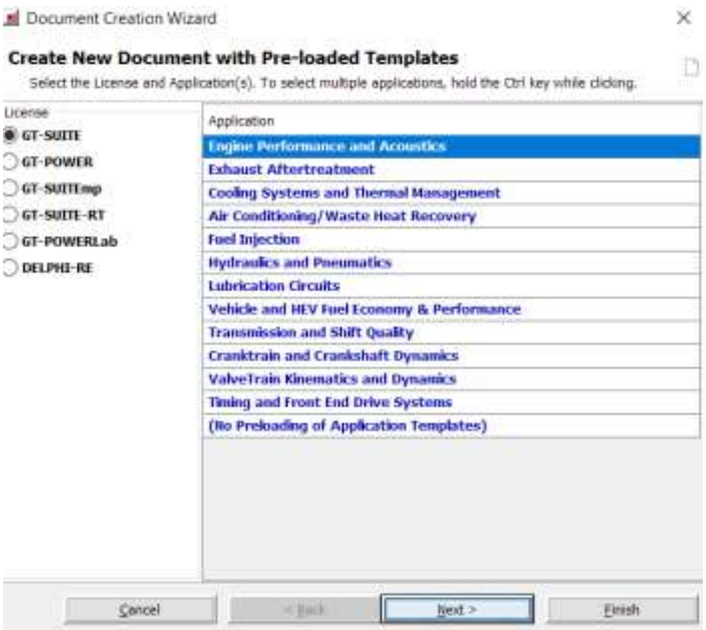


Figure 3.1 Document Creation Wizard

2. Template input

Engine components on GT Power are located on “Template Library”. The Template Library stores every components of the software from engine to drivetrain .

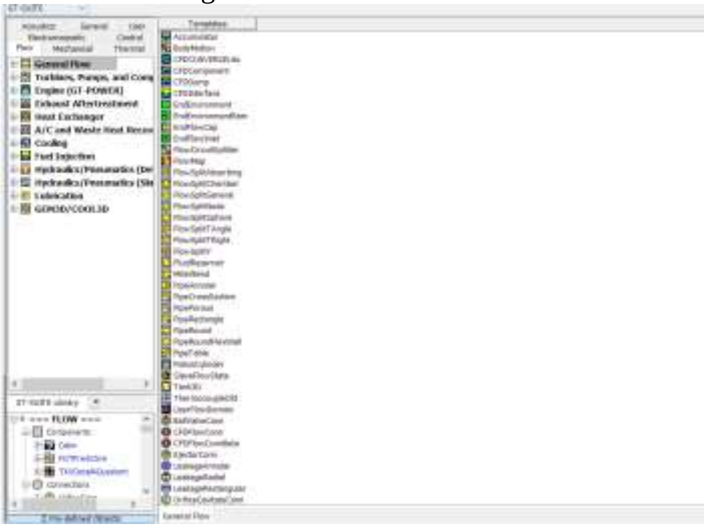


Figure 3.2 Display of Template Library

First step on creating the engine model is by creating the Environment template. The environment template is used for engine intake. Insert the parameters value such as pressure , temperature , and air composition with value of ambient environment as Figure 3.3

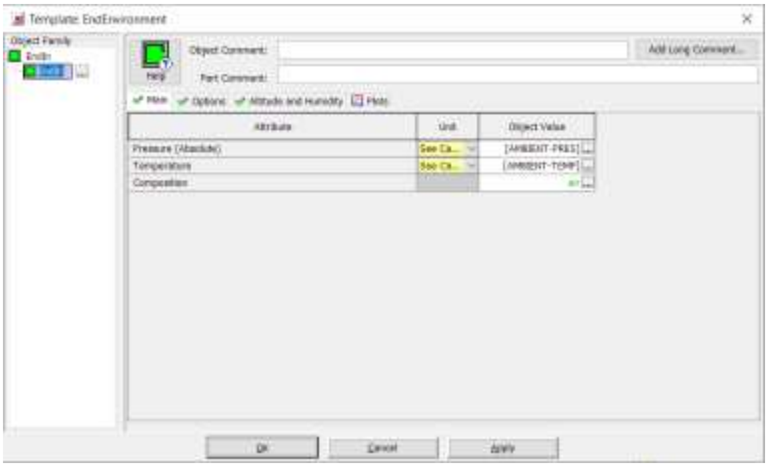


Figure 3.3 Intake environment template

Create the intake pipe . Because the engine is 4 cylinder , it uses “PipeRound” for straight part of the intake pipe and for the branch part uses "FlowSplitTRight" Input on these items are such as pipe diameter and pressure. Figure 3.4 and 3.5 shows the input on the model.

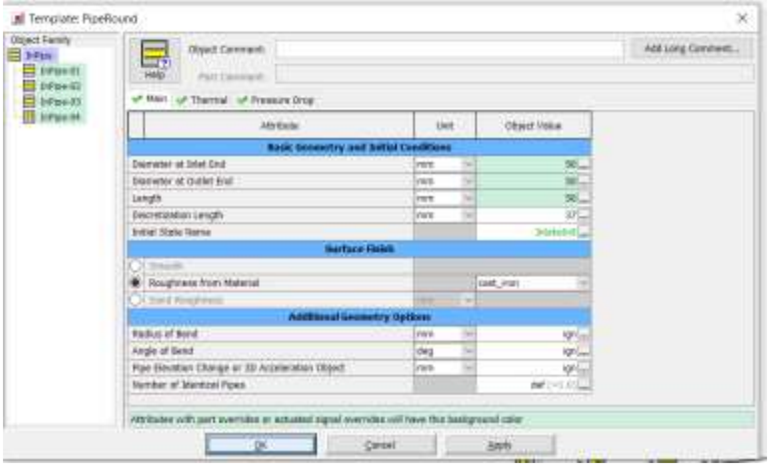


Figure 3.4 PipeRound input

Figure 3.5 FlowSplitTRIght input

Create the Intake Valve by using "ValveCamConn" and name it to " INT_Valve-01" Parameters inserted on the model are such as diameter and timing angle. Figure 3.6 shows the parameter value inserted on the item.

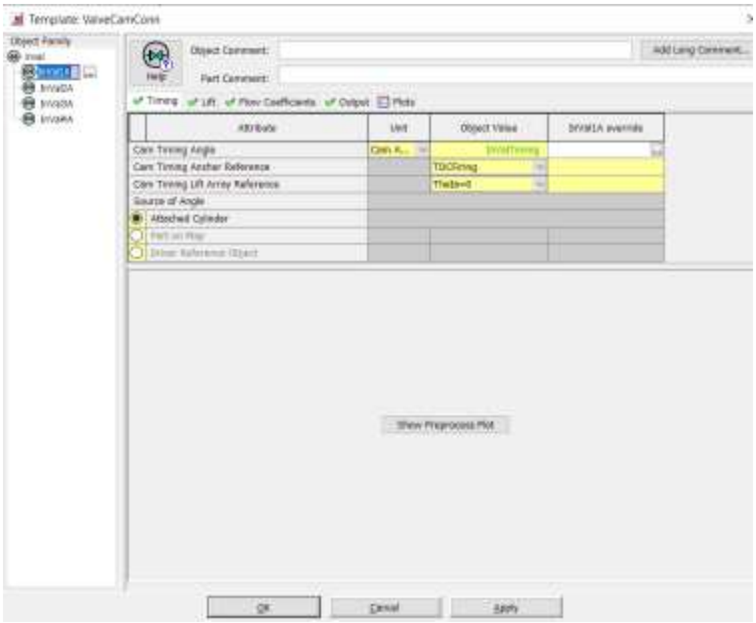


Figure 3.6 Intake valve inputs

Cylinders part also need to be created. Cylinder part is created by using "EngCylinder" object.

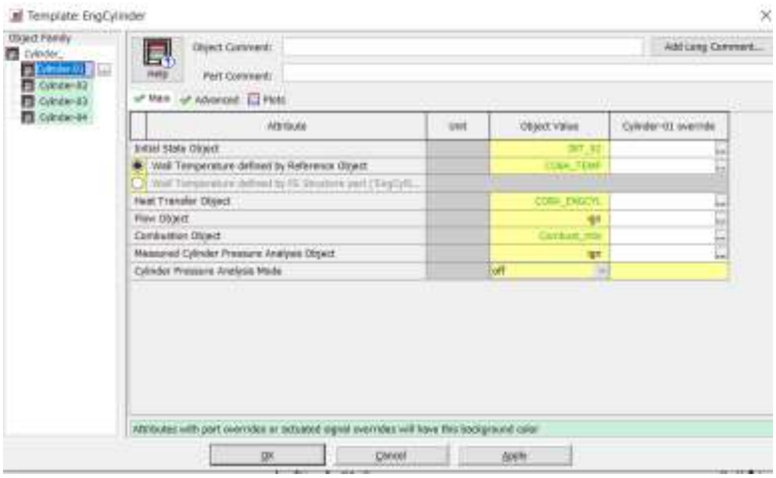


Figure 3.7 Engine Cylinder input

Injector of the diesel engine is created by using the object of "InjProfileCon". Inputs for this object is such as injector diameter, number of holes, and injected fluid settings such as type of the fuel and fluid temperature. The fluid temperature is varied from emperature 30°C ,35°C, 40°C, 45°C, 50°C, 55°C, 60°C, and 65°C.

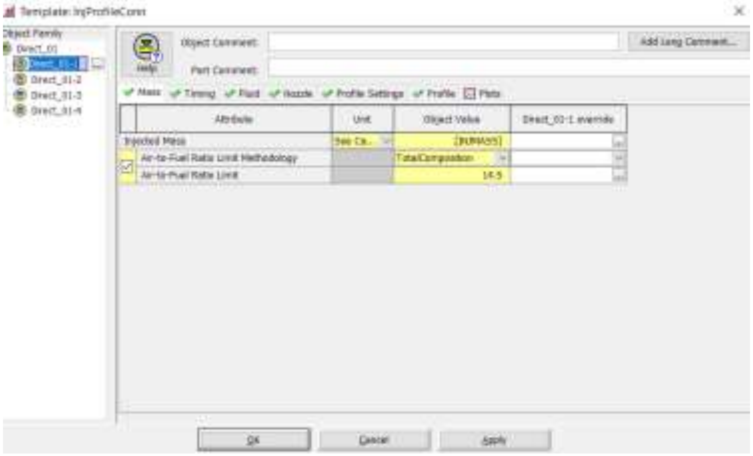


Figure 3.8 Injector input

Engine parameter such as engine type and geometry of the engine parts can be created by using “EngineAnalysis” object.

Figure 3.9 “EngineAnalysis” display

Inside EngineAnalysis on Cylinder Geometry part it can be inserted with the value according to the engine.

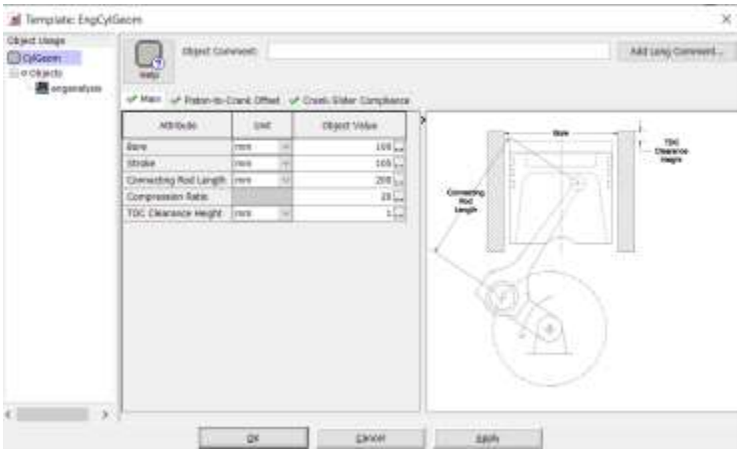


Figure 3.10 Cylinder Geometry input

Detailed engine part components created from object “PistonGuided”’ , “ConnectingRod” ,CrankPin, ‘CrankWeb”, “Journal”, and “Flywheel” .

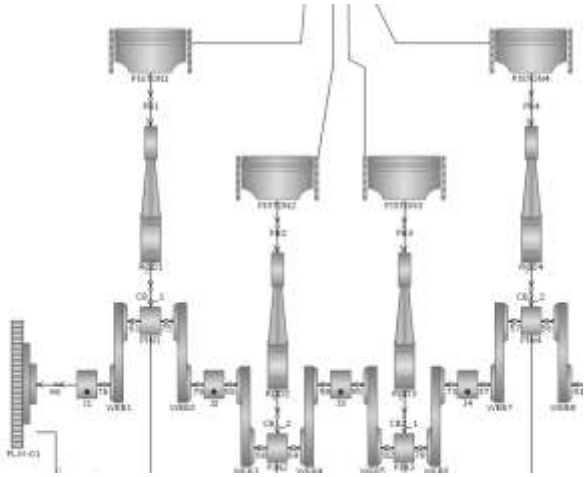


Figure 3.11 Detailed Engine Parts

“PistonGuided” part contains parameters like piston mass, bore, and stroke. The value of the parameters must be same with the one on engine analysis part.

Figure 3.12 PistonGuided inputs

Connecting Rod object contains parameters such as connecting rod mass and length.

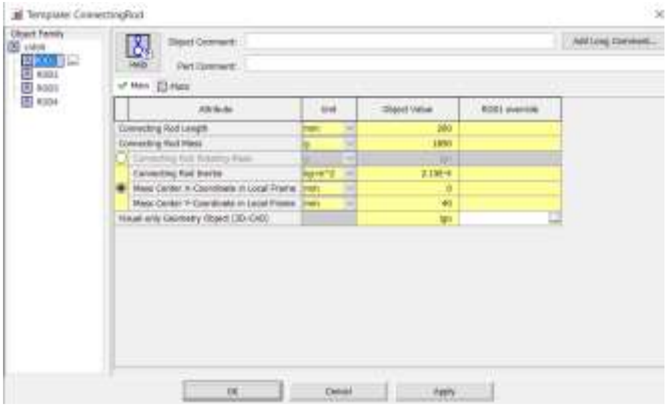


Figure 3.13 ConnectingRod inputs

For exhaust part, the model uses “PipeRound” for the straight pipe part and “FlowSplitTRight” for branch part. The input are shown on Figure 3.14 and 3.15.

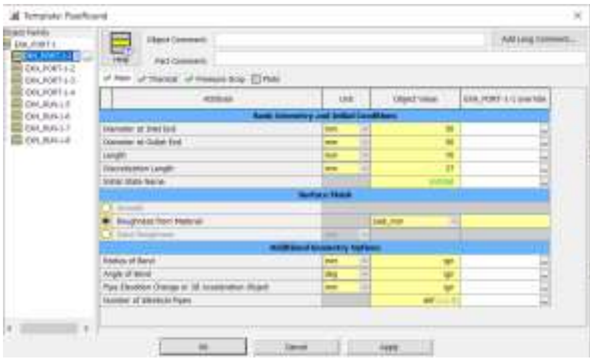


Figure 3.14 Exhaust Pipe input

Figure 3.15 Exhaust branch input

Exhaust valve part uses the “ValveCamConn” part and name it to EXH_valve. Input of the object is shown on Figure 3.16

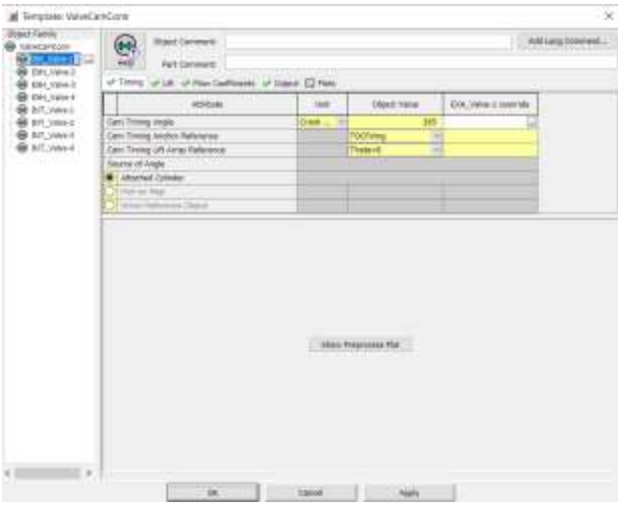


Figure 3.16 Exhaust valve input

Environment part of the exhaust part is using the object of "EndEnvironment" part with the difference from intake part on the gas changed to "BurntGas".

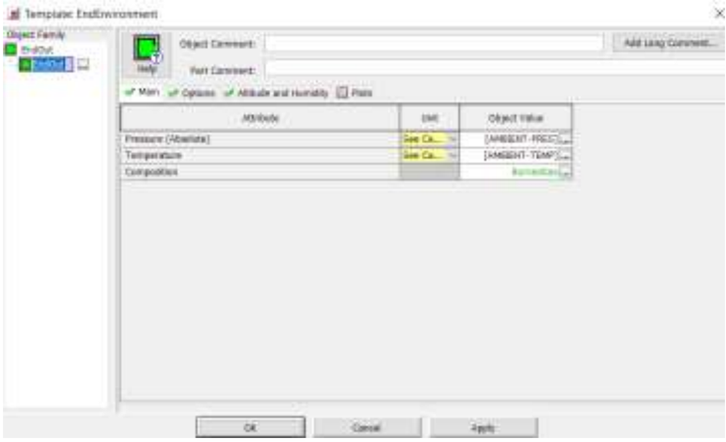


Figure 3.17 Environment input for exhaust

For engine load, object "Torque" is used and the value is varied to the load variable that inserted on the case settings.

Figure 3.18 Torque object input

Table 3.1 Engine Specification [18]

	Value
Displacement	3298 cc, Inline 4 , Naturally Aspirated Direct Injection,
Bore x stroke	100 x 105 mm
Power	90–95 PS (66–70 kW)
Max Torque	22 kgfm
Fuel Injection Pressure	120 Kg/cm2

The simulation is done by variables of Load and Fuel Temperature . The Variables are:

- Load Variables
  - Load 25%
  - Load 50%
  - Load 75%
  - Load 100%

- Temperature Variables
  - Temperature $30^{o}C$
  - Temperature $40^{o}C$
  - Temperature $50^{o}C$
  - Temperature $60^{o}C$
  - Temperature $70^{o}C$

The variables is inputted on the software with the case setup. Rpm o usoide is 1700, 1900, and 1900. The fuel temperature is from the injector object at the Fluid Temperature part and the Load is from Torque object.

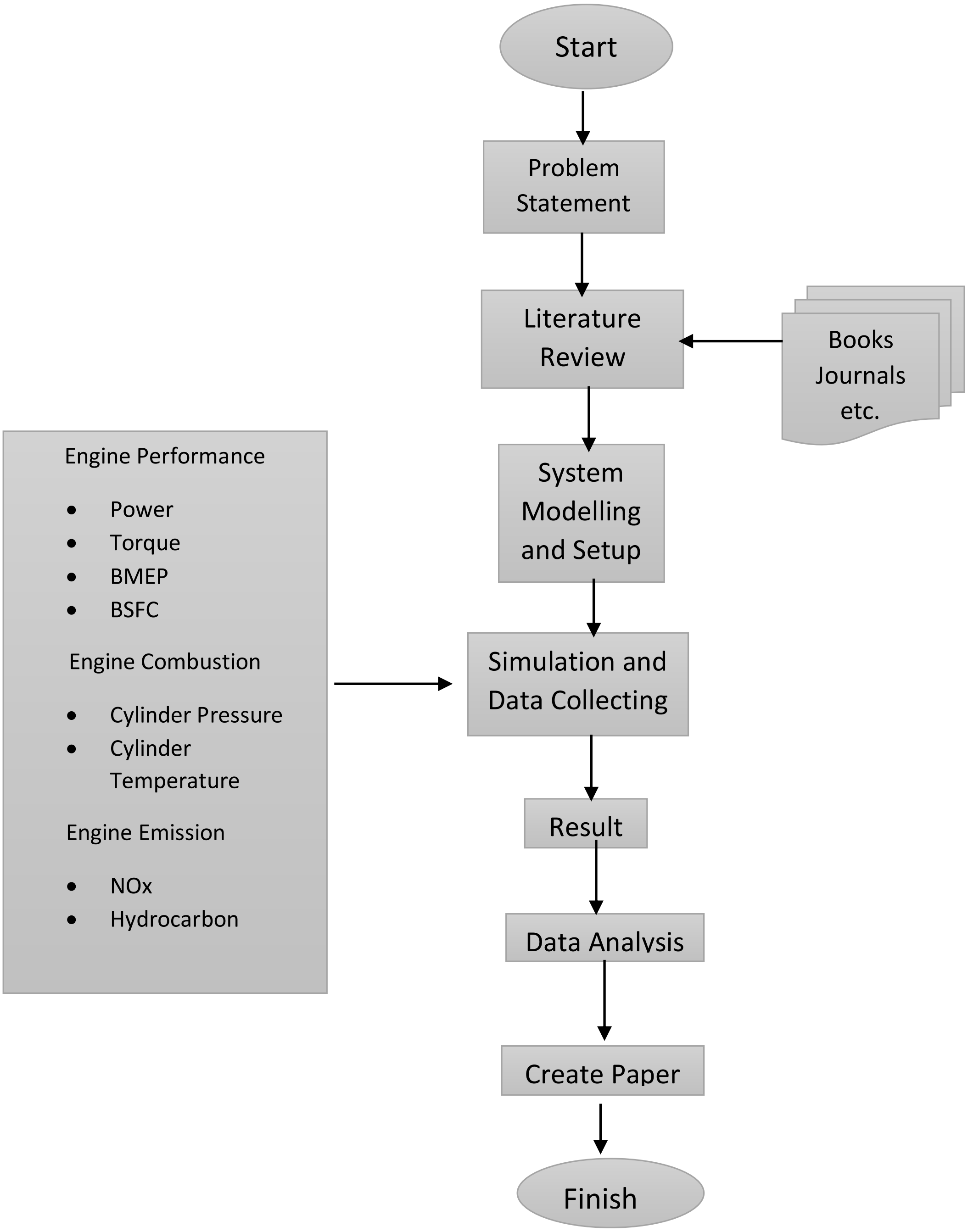
Figure 3.19 Case Setup

- Result Variables
  - Engine Performance
    - Power
    - Torque
    - BMEP
    - BSFC
  - Combustion Data
    - Cylinder Pressure,
    - Cylinder Temperature
  - Emission
    - NOx,
    - Hydrocarbons
    - CO

The result variable is shown on GT-Post within the engine analysis object for Performance and Emission part and at the cylinder for combustion part.

Figure 3.20 GT Post result screen

3.2 Methodology Flowchart



CHAPTER IV
RESULT AND DISCUSSION

In this chapter contains result and discussion about performance and emission test from preheating the B20 biodiesel . The fuel used is Pertamina Solar Diesel Fuel. Performance test in this chapter includes Power. Torque, SFOC (Specific Fuel Oil Consumption) , and BMEP (Brake Mean Effective Pressure). Emission test includes NOx, SOx , and other particular emission.

4.1 Engine Model

The aim of the test is to compare performance and emission of the diesel engine on different temperature of B20 biodiesel The engine used for the simulation is Mitsubishi 4D30 diesel engine The simulation uses one dimensional engine model

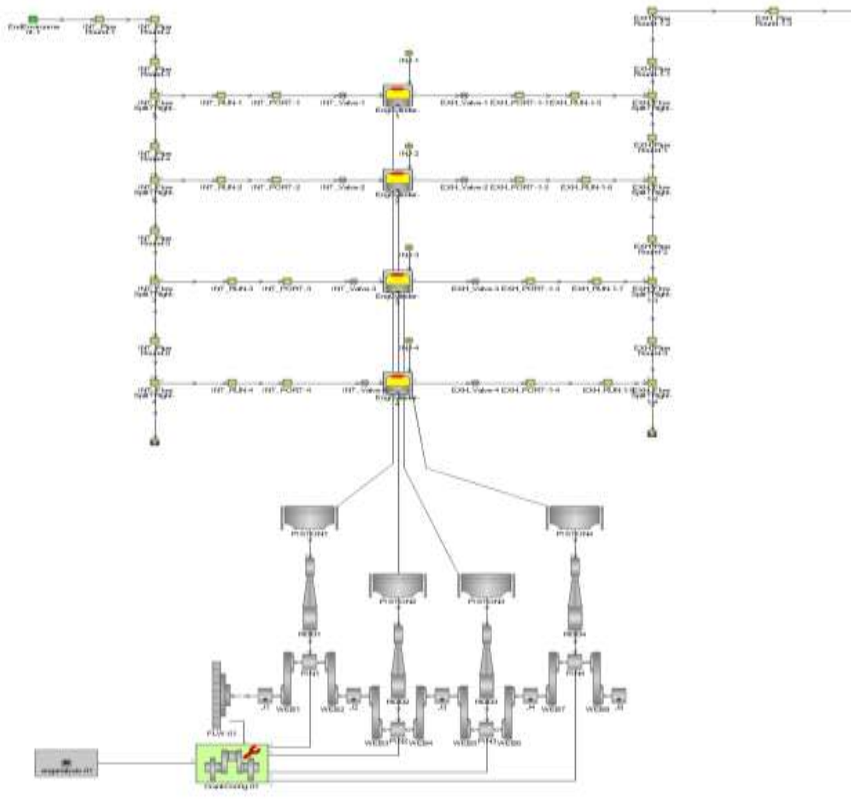


Figure 4.1 Engine model of Mitsubishi 4D30

Engine cylinder input consist of various items such as cylinder geometry, and cylinder mass.

Table 4.1 Geometry Input

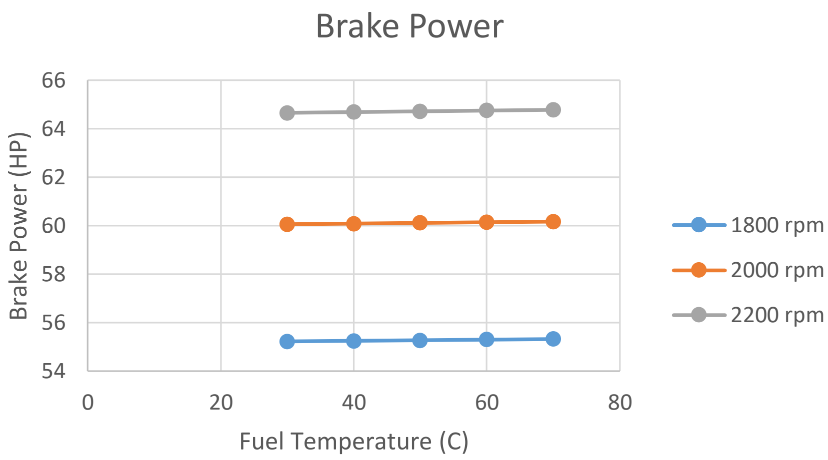
Description	**Value**
Bore	100 mm
Stroke	105 mm
Number of Cylinders	4
Connecting Rod Length	200 mm
Connecting Rod Mass	1850 g
Piston Mass	1000 g

4.2 Simulation Result

The engine is simulated using 20% biodiesel blend at 1800 rpm, 2000 rpm, and 2200 rpm . The simulation is analysed on several fuel temperature which are 30ºC,, 40ºC,50ºC, 60ºC, and 70ºC. Various load condition is used on the simulation, 25%, 50%, 75% and 100%.. The result variables of the simulation are performance, combustion, and emission. Performance includes Brake Power, Brake Torque, Brake Mean Effective Pressure, and Brake Specific Fuel Consumption. Combustion consists of Maximum Temperature and Maximum Pressure of combustion. Emission variable includes NOx concentration and Hydrocarbon concentration.

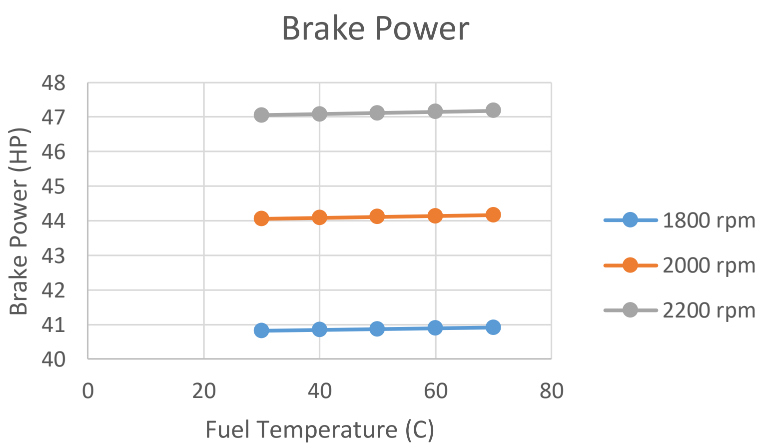
4.2.1 Performance

4.2.1.1 Brake Power

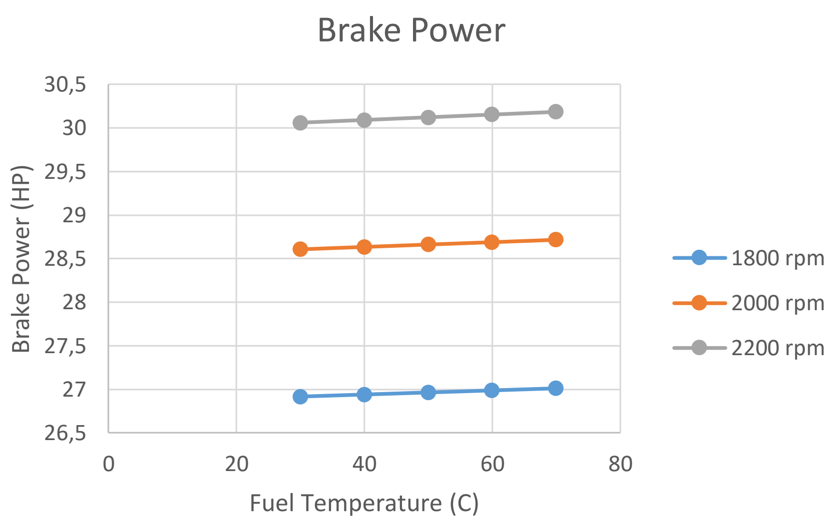


Graph 4.1 Brake Power at 100% Load

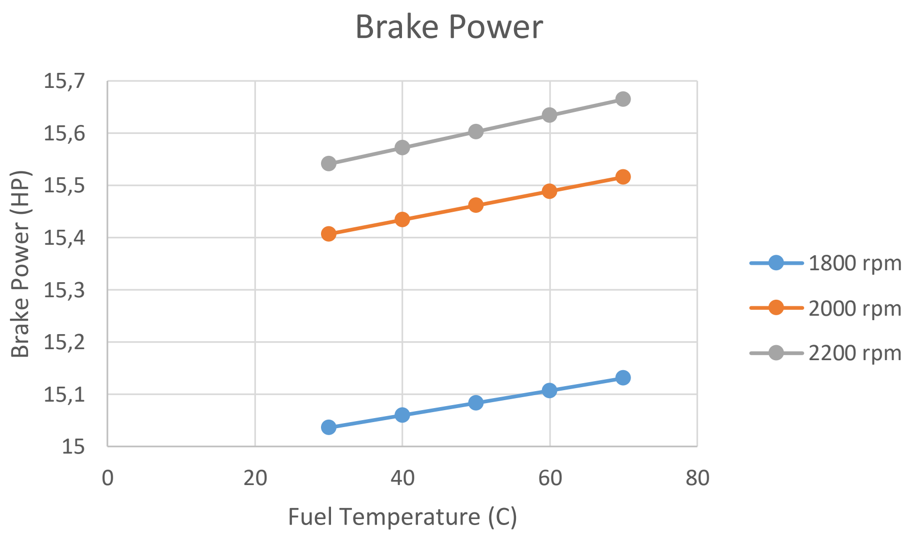
Brake power increases due to increase of fuel temperature. Graph 4.1 shows power to fuel temperature on full load condition. From Graph 4.1, it can be seen that increase of fuel temperature leads to increase on brake power , however on power the value were not much significant . On every temperature increase, the brake power only increases around 0.01 HP. For example from 30ºC to 70ºC with 2200 rpm, brake power only increase from 68.66 HP to 64.78 HP or 0.17%. The trend remains same at different engine speed and load condition Figure 4.2 to 4.4 shows results on different load condition.



Graph 4.2 Brake Power at 75% Load

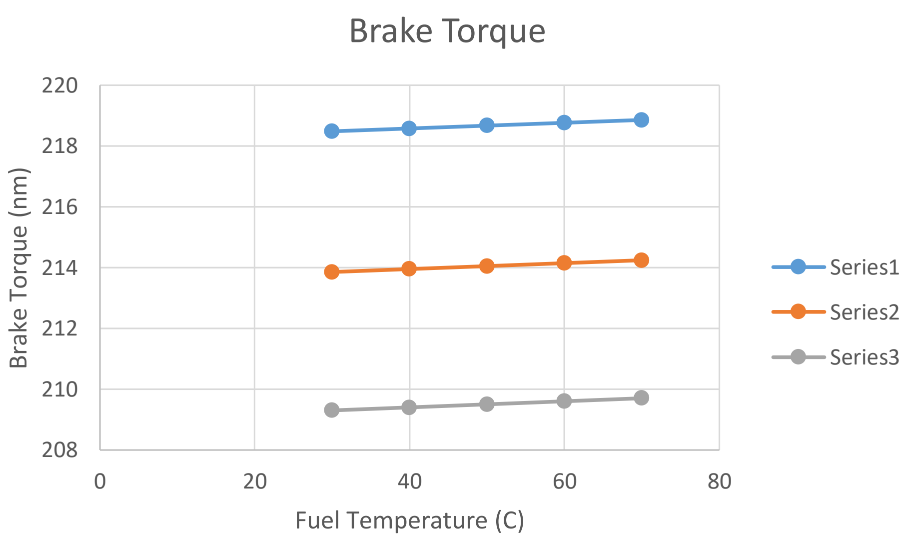


Graph 4.3 Brake Power at 50% Load



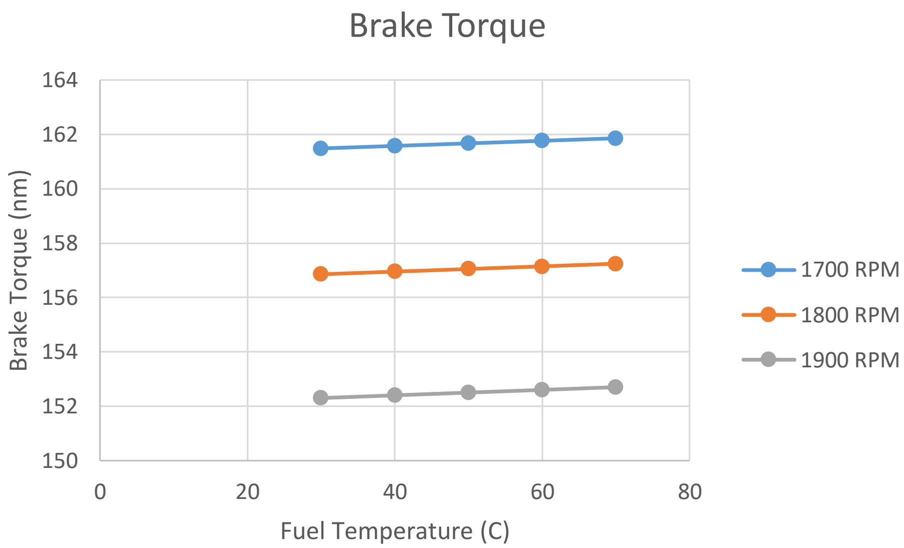
Graph 4.4 Brake Power 25% Load

4.2.1.2 Brake Torque

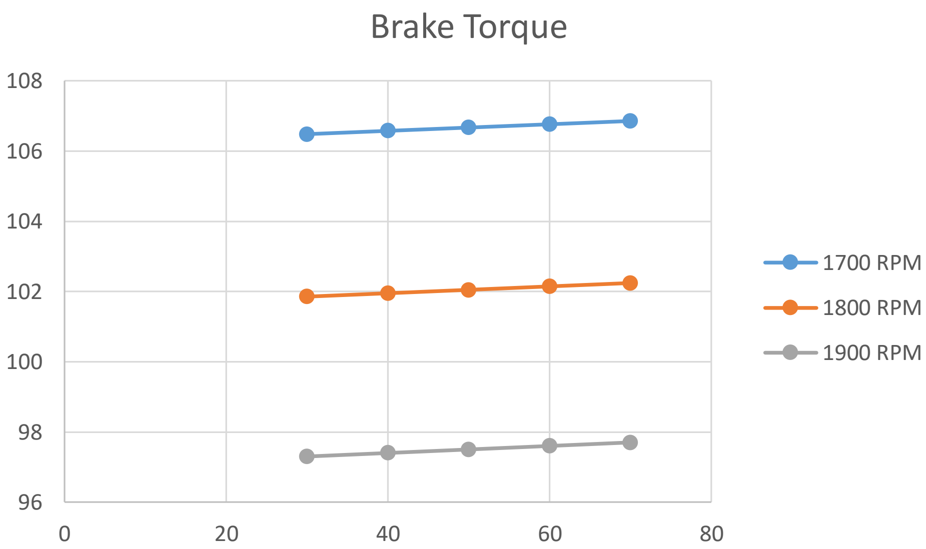


Graph 4.5 Brake Torque on 100% Load

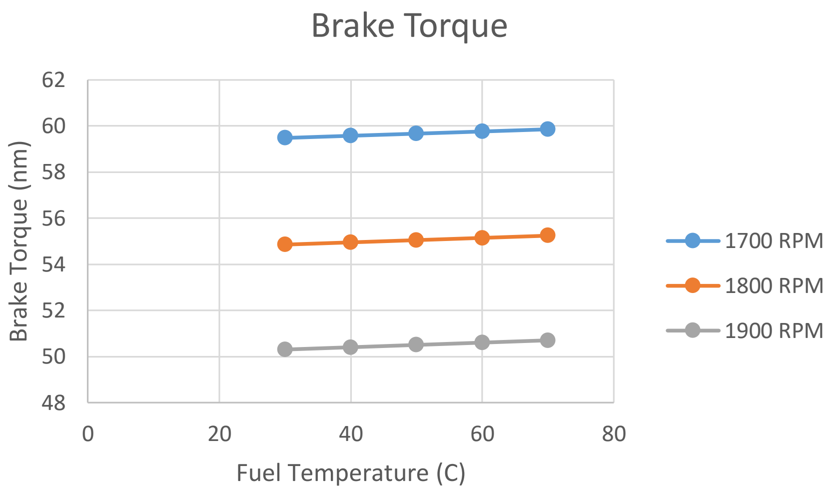
Increase in fuel temperature leads in increase of the value of brake torque. graph 4.5 shows brake torque on 100% load condition. From graph 4.5 it indicates increase in brake torque value on temperature increase. The value increase were quite significant. From the lowest temperature which is 30ºC to highest temperature variable that is 70ºC AT 1800 rpm the torque increases from 218.47 nm to 218.8 nm. It shows similar trend on different engine speed and load conditions. Figure 4.6 to 4.8 shows brake torque on different load conditions.



Graph 4.6 Brake Torque on 75% load condition

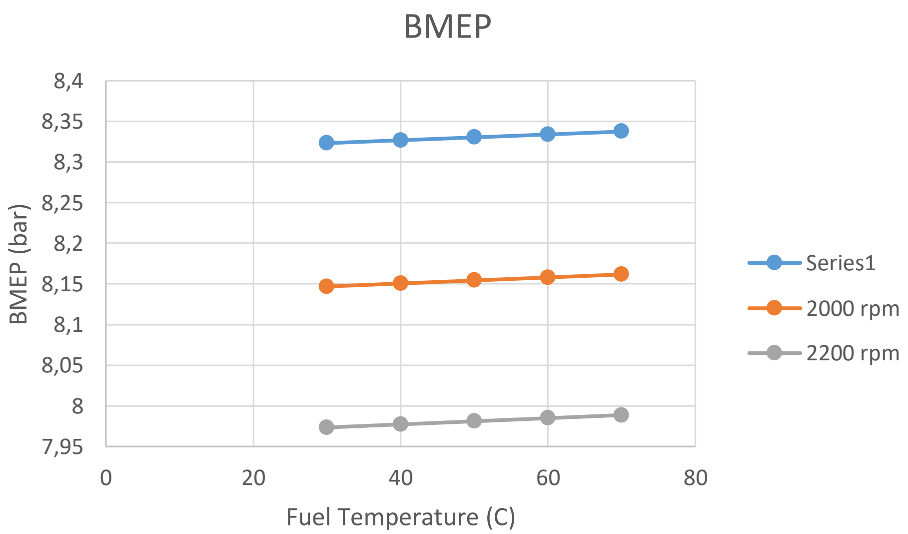


Graph 4.7 Brake Torque on 50% load condition



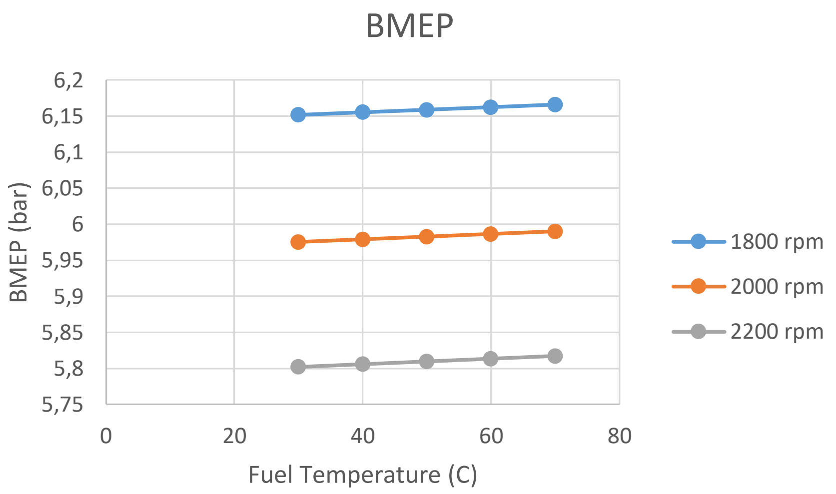
Graph 4.8 Brake Torque on 25% load condition

4.2.1.3 Brake Mean Effective Pressure

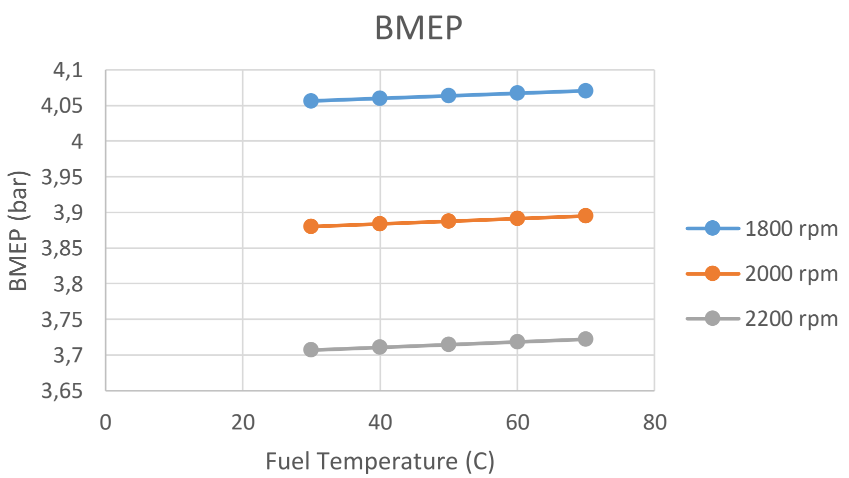


Graph 4.9 BMEP on 100% load

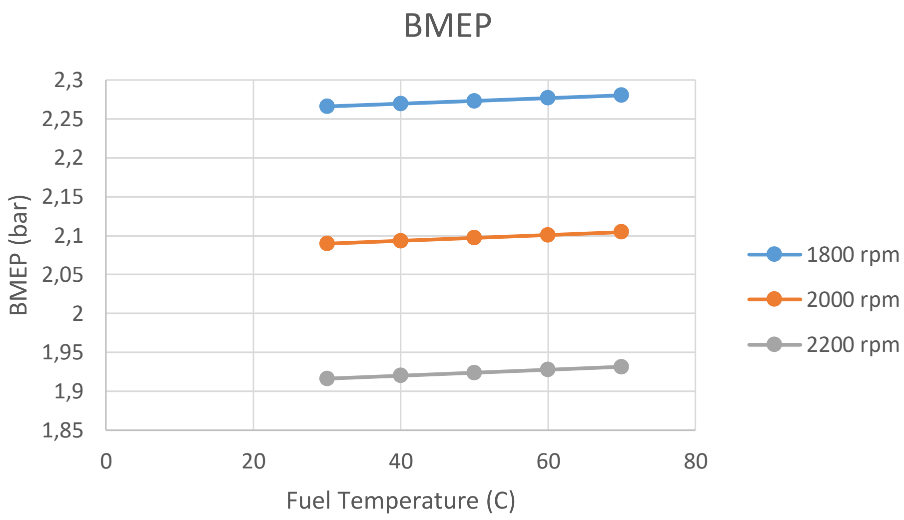
BMEP increases as the inlet temperature of fuel increases. Graph 4.9 shows that BMEP increases as temperature increases on full load condition .From fuel temperature 30ºC to 70ºC, the BMEP increases quite significant by 0.02 bar or 2 kPa. Lowest BMEP value at 1800 rpm full load is 8.32 bar obtained on 30ºC fuel temperature and highest fuel value of BMEP at 8.34 bar obtained on 70ºC Graph 4.10 to 4.12 shows BMEP on different temperature condition.



Graph 4.10 BMEP on 75% load

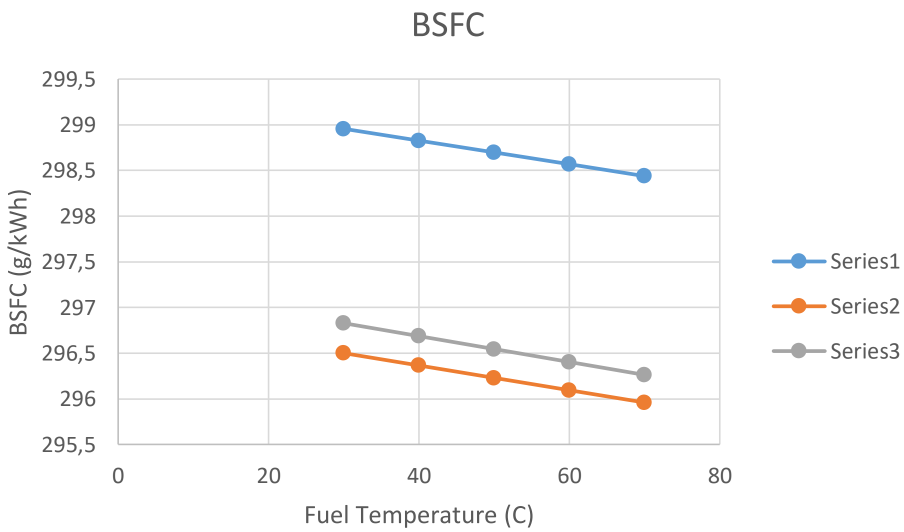


Graph 4.11 BMEP on 50% load



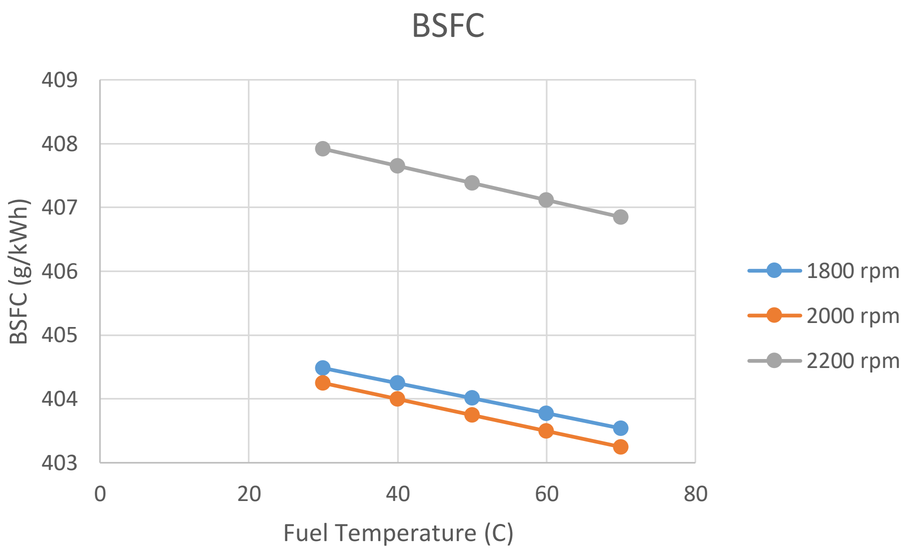
Graph 4.12 BMEP on 25% load

4.2.1.4 Brake Specific Fuel Consumption

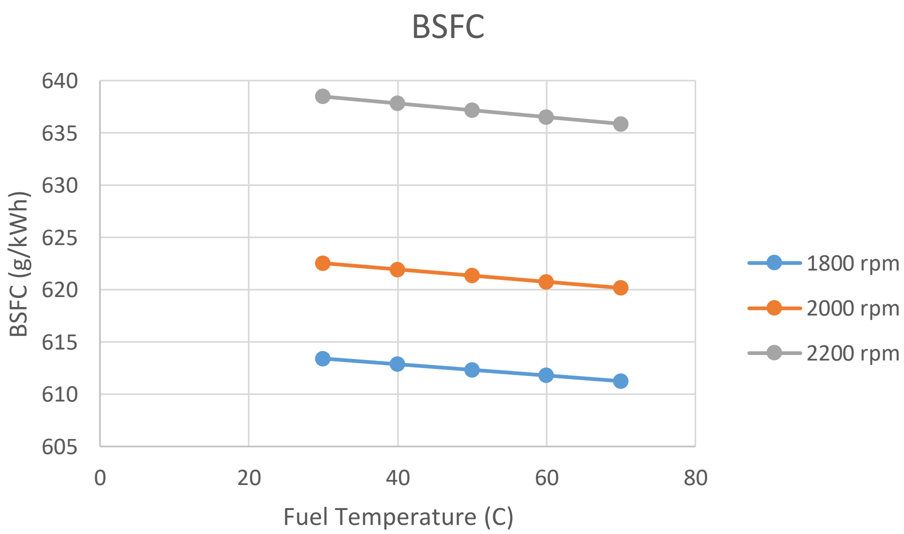


Graph 4.13 BSFC on 100% load

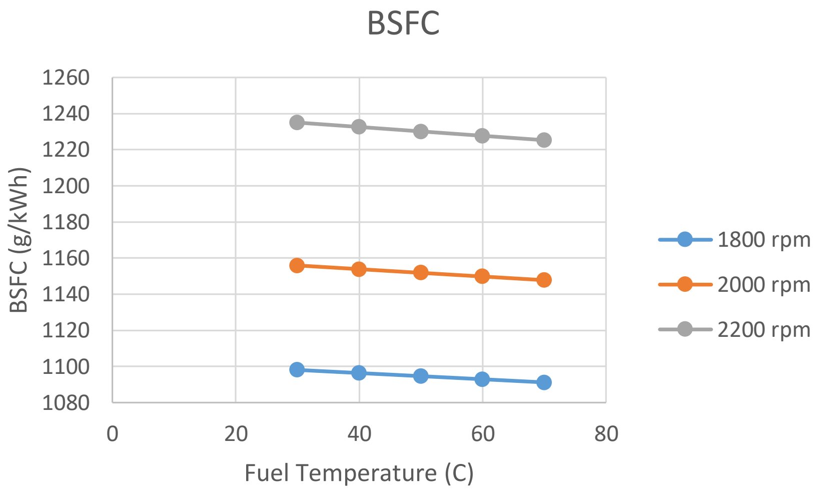
Brake Specific Fuel Consumption , shown on graph 4.13 decreases as inlet temperature increases on full load condition . Highest value of BSFC at 1800 rpm full load is 298.95 g/kWh obtained on 30ºC while the lowest value is 298.44 g/kWh is obtained on 70ºC . Higher value of BSFC is caused by lower energy content of the fuel. Increase on temperature leads to higher energy content of fuel [19] Lowest possible of BSFC is often desired. Graph 4.14 to 4.16 shows the BSFC on different load condition .



Graph 4.14 BSFC on 75% Load



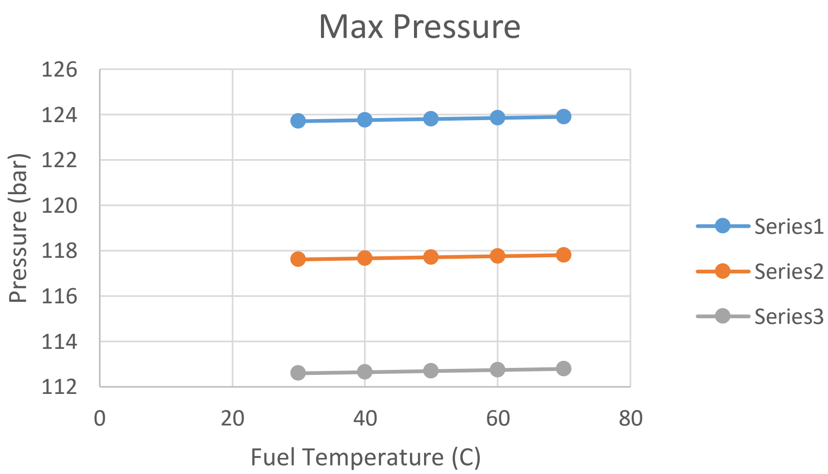
Graph 4.15 BSFC on 50% Load



Graph 4.16 BSFC on 25% Load

4.2.2 Combustion

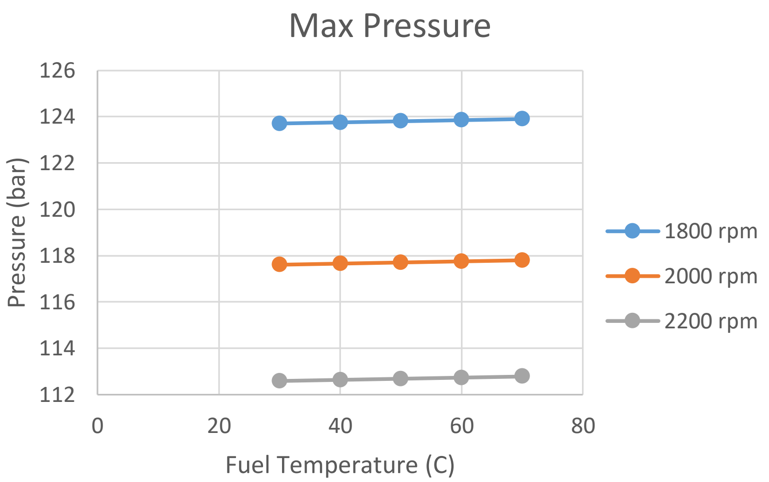
4.2.2.1 Maximum Pressure



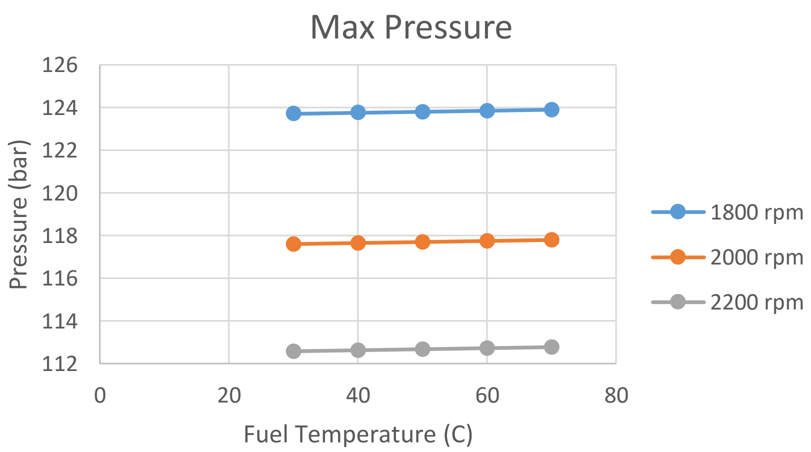
Graph 4.17 Combustion Pressure

Combustion Pressure as shown in graph 4.17 is increasing due to fuel temperature increase. Lowest value of combustion pressure at 1800 rpm full load is

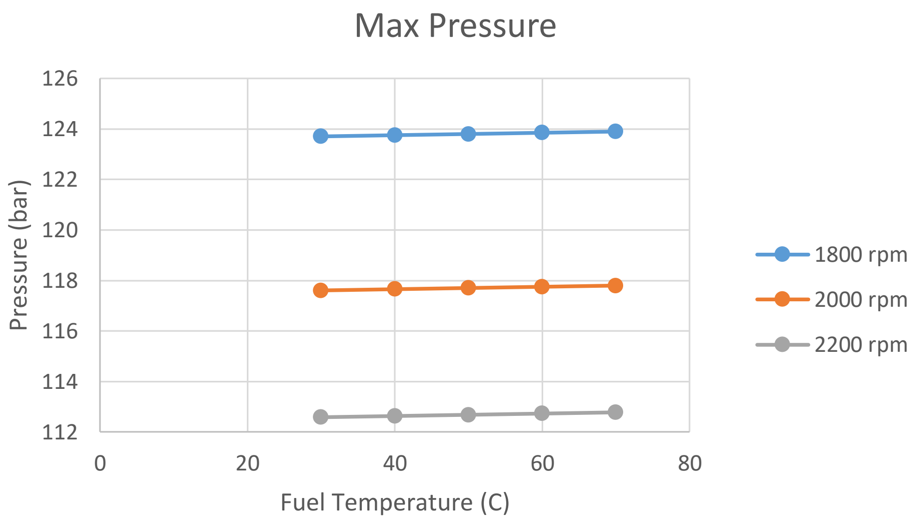
123.70 bar which obtained at lowest temperature variable at 30ºC. Highest value of combustion pressure is 123.89 bar obtained at 70ºC. Graph 4.18 to 4.20 shows similar trend on different load conditions.



Graph 4.18 Combustion pressure on 75% Load

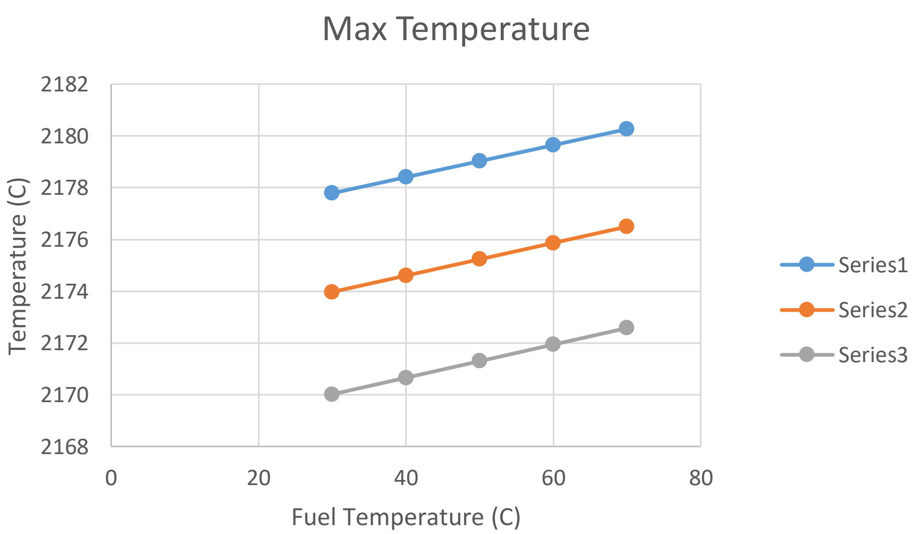


Graph 4.19 Combustion pressure on 50% Load



Graph 4.20 Combustion pressure on 25% load

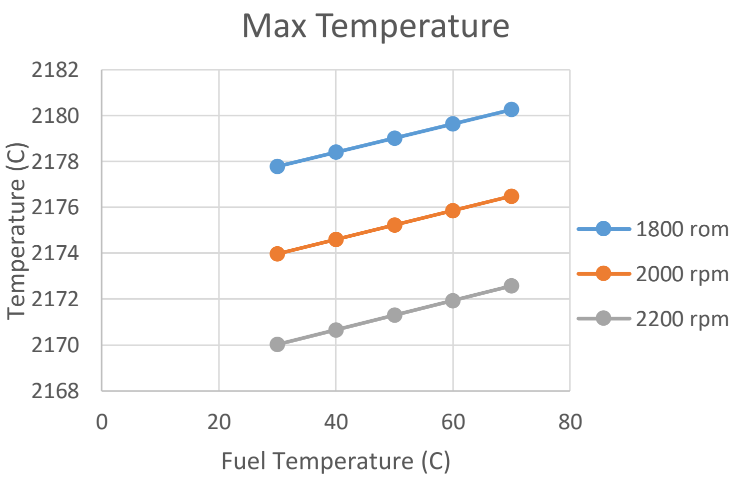
4.2.2.2 Combustion Temperature



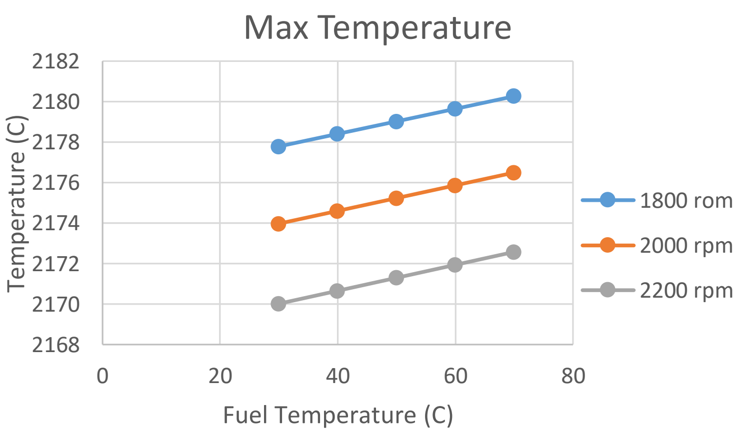
Graph 4.21 Combustion temperature

Graph 4.21 shows increase of combustion temperature due to increase of fuel temperature . Lowest temperature at 1800 rpm full looad valued 2177.78 ºC is obtained on fuel temperature of 30ºC . Highest combustion temperature values at

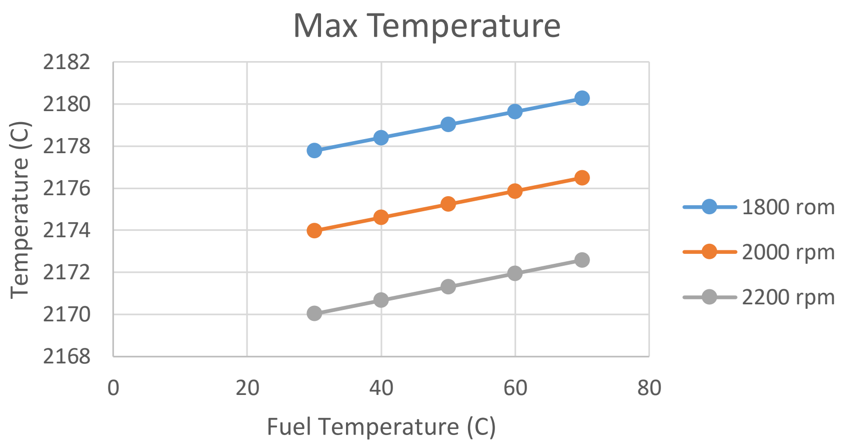
2180.26 ºC on 70ºC fuel temperature. Similar trend is shown on different load condition.



Graph 4.22 Combustion temperature on 75% load



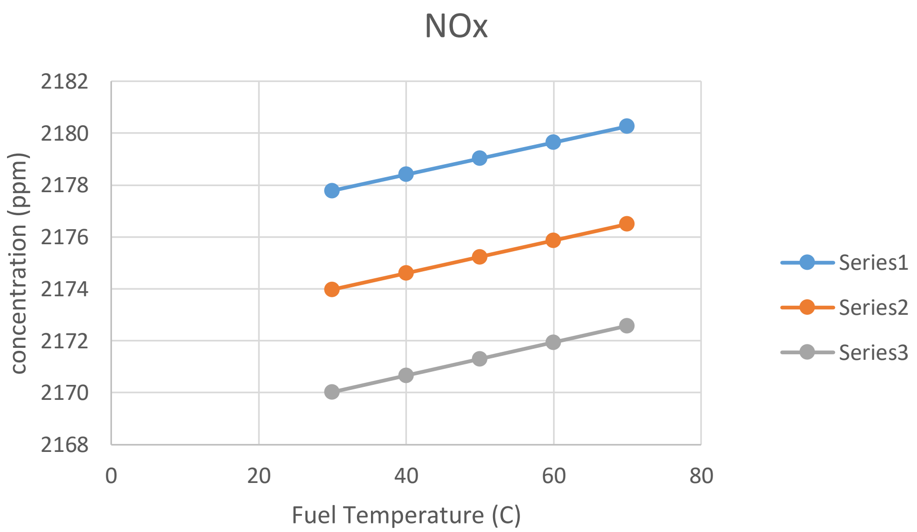
Graph 4.23 Combustion temperature on 50% load



Graph 4.24 Combustion temperature on 25% load

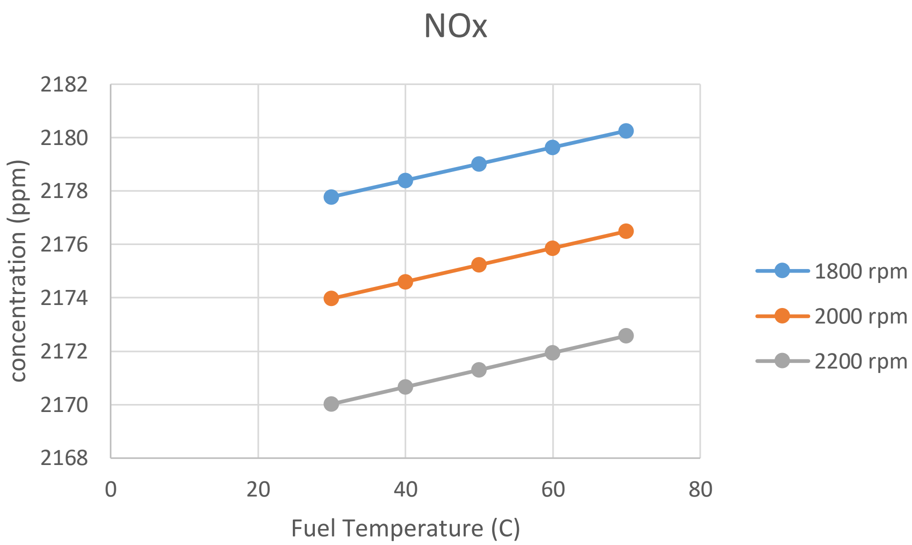
4.2.3 Emission

4.2.3.1 NOx Concentration

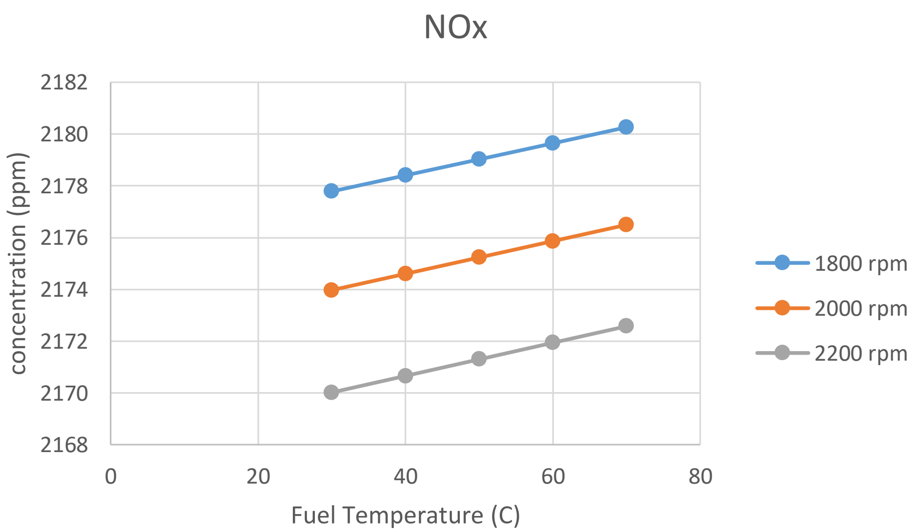


Graph 4.25 NOx concentration on 100% load

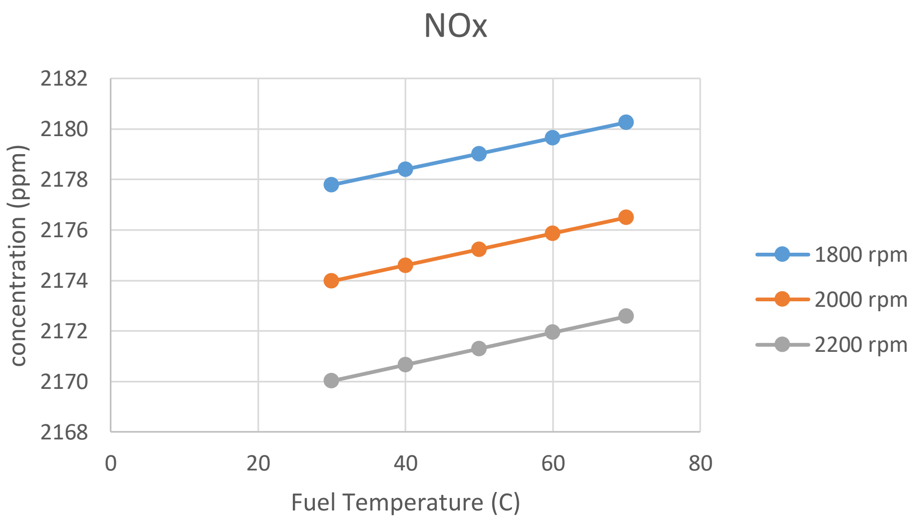
Graph 4.26 describes that increase on fuel temperature leads to higher concentration of NOx emission NOx concentration increases due to formation of NO is depending on higher combustion temperature and more presence of oxygen [19] Lowest NOx concentration , obtained at 30ºC is 4198.12 ppm. Highest value of NOx concentration is 4211.13 ppm obtained at 70ºC. Similar trend is found on different load condition.



Graph 4.26 NOx emission on 75% load

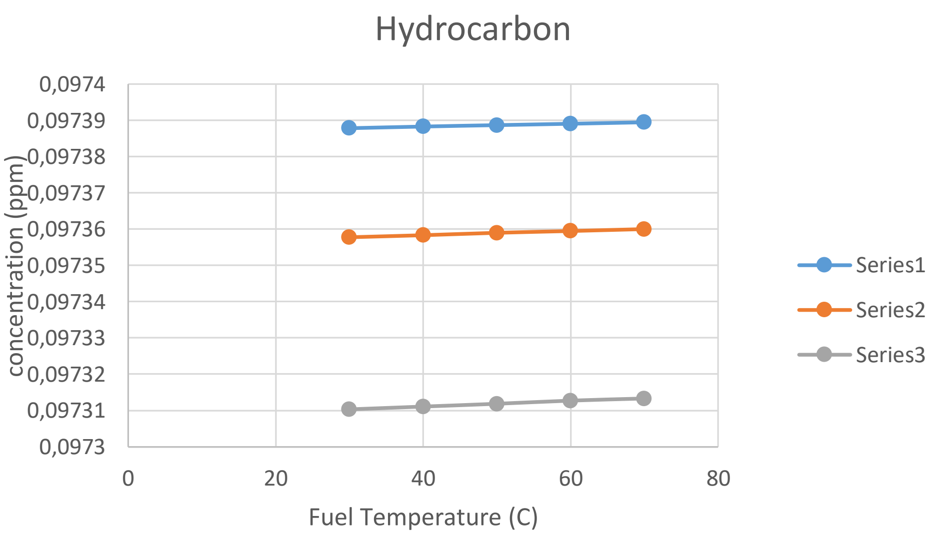


Graph 4.27 NOx emission on 50% load



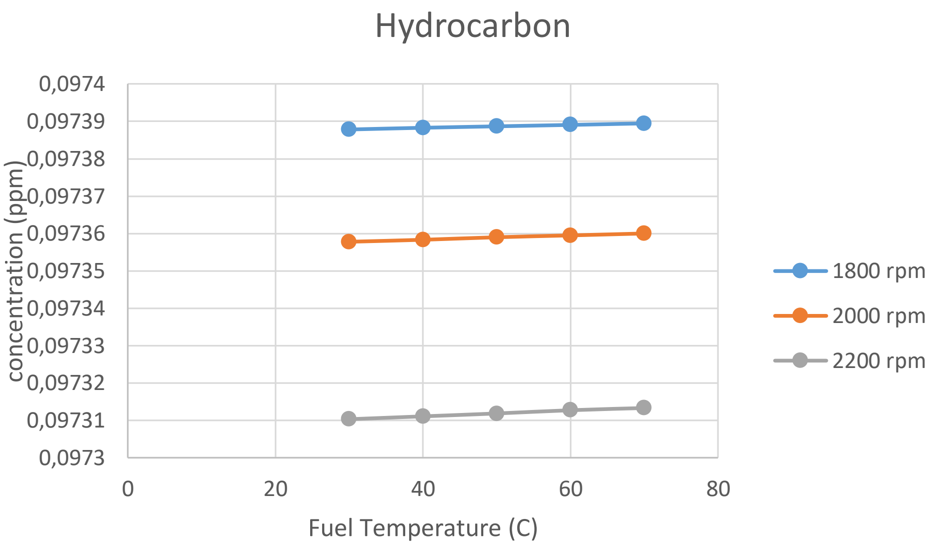
Graph 4.28 NOx emission on 25% load

4.2.3.2 Hydrocarbon Emission

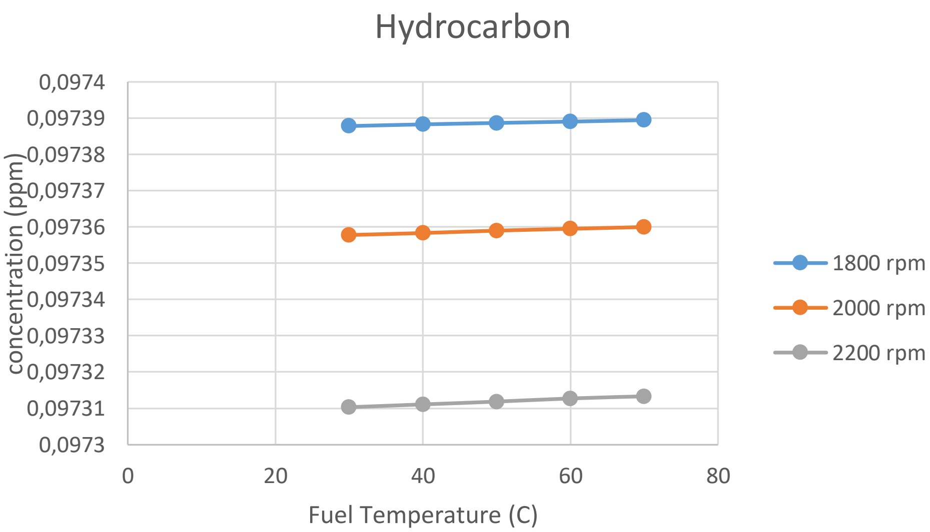


Graph 4.29 Hydrocarbon Emission

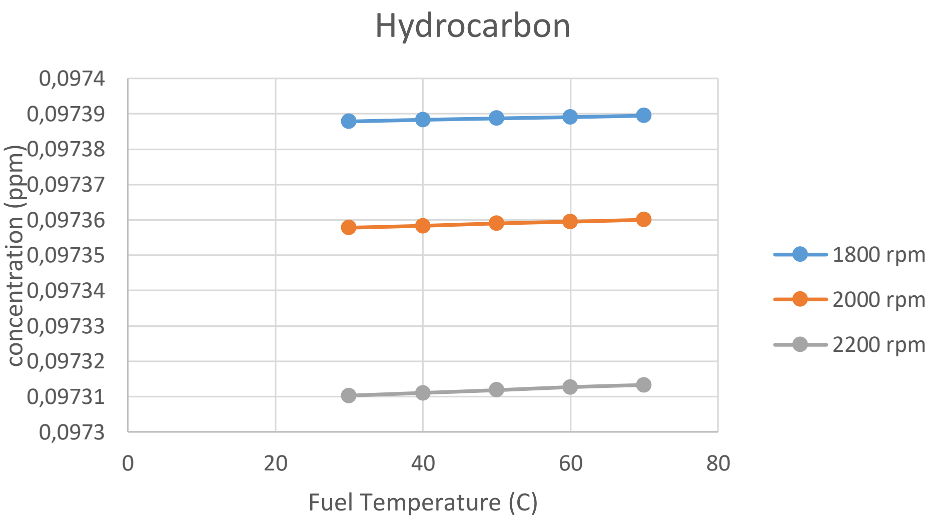
Hydrocarbon emission concentration. increases as fuel temperature increases. Graph 4.20 showing Hydrocarbon concentration in emission due to increase of fuel temperature. Increase of the value were not very significant.



Graph 4.30 Hydrocarbon Emission on 75% load

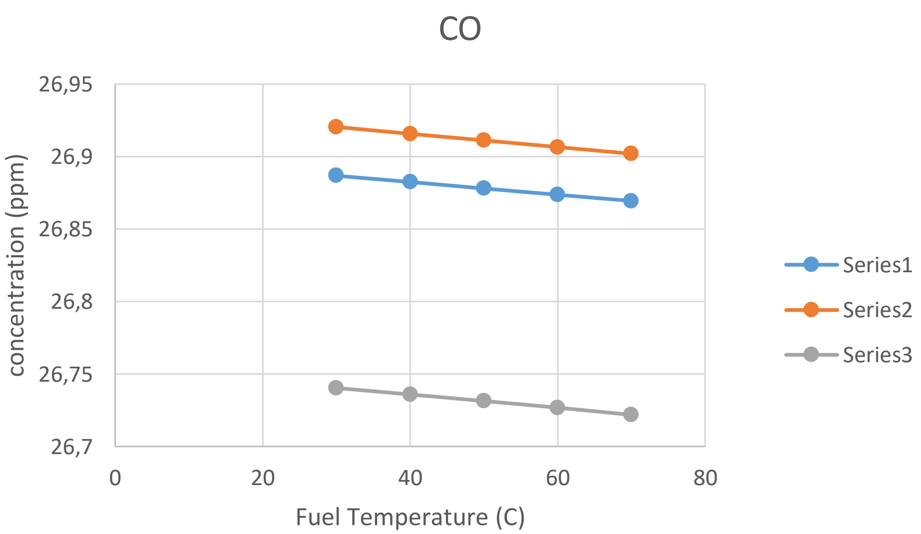


Graph 4.31 Hydrocarbon Emission on 50% load



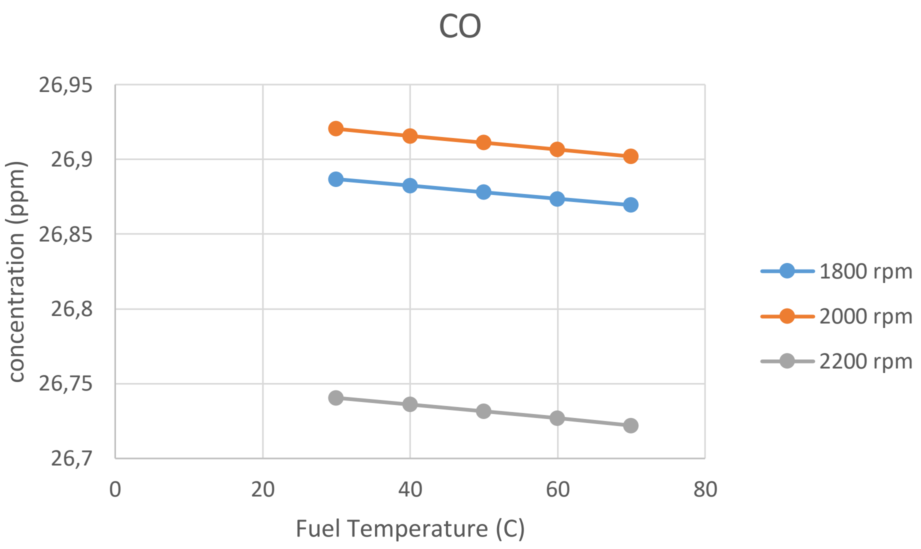
Graph 4.32 Hydrocarbon Emission on 25% load

4.2.3.3 CO Emission

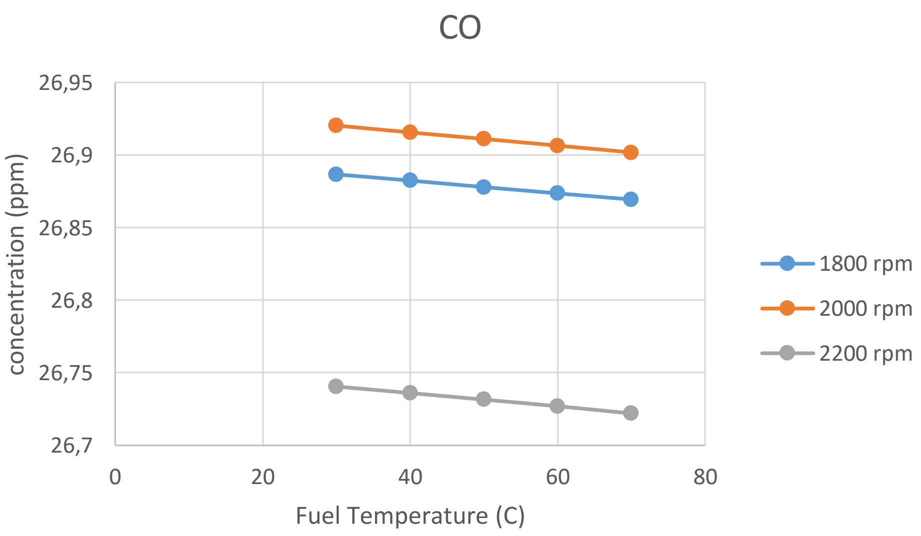


Graph 4.33 CO Emission on 100% load

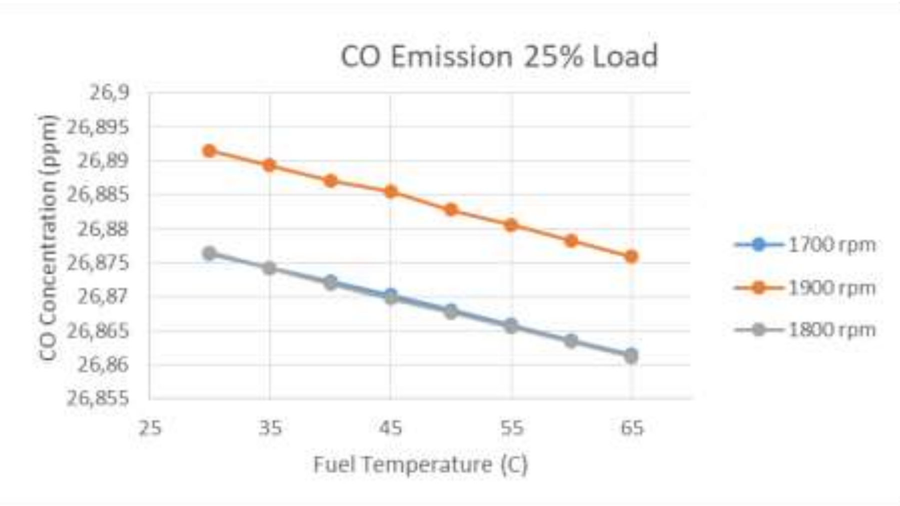
Based on Graph 4.33 CO Emission are decreasing as the fuel temperature increases. Average deficit of CO concentration is 0.057%. . The trend remains same on different load condition.



Graph 4.34 CO Emission on 75% load



Graph 4.35 CO Emission on 75% load



Graph 4.36 CO Emission on 25% load

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CHAPTER V
CONCLUSION AND SUGGESTION

5.1 Conclusion

This chapter concludes the result of the simulation and analysis of the Mitsubishi 4D30 Engine to find the effect of fuel temperature increase by addition of preheater. The conclusions are as follows:

- The Brake Power increases as the fuel temperature increases, although the increase were not much significant. The power increase between the lowest and the highest temperature variable is 0.0853 HP on a full load condition
- Brake Torque increases as the fuel temperature increases. Value increases from 30ºC fuel temperature to 65ºC by 0,335 nm
- Brake Mean Effective Pressure increases as fuel temperature increases. The value increases from lowest temperature variable to highest by 0.012 bar
- Brake Specific Fuel Consumption decreases as fuel temperature is increased. The value decreases by 0.276 g/kWh from fuel temperature at 30ºC to 65ºC.
- The best fuel temperature for Performance side based on this simulation is 65ºC due to highest value of Power, Torque, and BMEP and lowest value of BSFC.
- NOx emission increases by around0.44% as Fuel Temperature Increases.
- Hydrocarbon emission increases Fuel Temperature Increases although the value is not significant.
- CO Emission decreases by 0.06%
- Those were the drawbacks on increasing the fuel temperature. Lowest fuel temperature variable on this simulation (30ºC) were the best for Emission part.

5.2 Suggestion

The research is on the limitation of simulation only. A better calibration with experimental method is needed for improving accuracy of the result.

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ATTACHMENT

Simulation Result

Performance

Beake Power (BHP)

Load 100%

	RPM		
Temp	1800	2000	2200
30	55,2271	60,06379	64,66371
40	55,25085	60,09101	64,69457
50	55,27444	60,11836	64,7255
60	55,29812	60,14568	64,75652
70	55,32193	60,17285	64,78751

Load 75%

	RPM		
Temp	1800	2000	2200
30	40,81884	44,05454	47,05359
40	40,84259	44,08182	47,08443
50	40,86619	44,10918	47,11542
60	40,88983	44,13646	47,14643
70	40,91367	44,16366	47,17738

Load 50%

	RPM		
Temp	1800	2000	2200
30	26,91612	28,60708	30,06135
40	26,93987	28,63436	30,09224
50	26,96348	28,66171	30,12321
60	26,98712	28,68902	30,1542
70	27,01096	28,71624	30,18515

Load 25%

	RPM		
Temp	1800	2000	2200
30	15,03562	15,40652	15,54078
40	15,05938	15,4338	15,5716
50	15,08296	15,46115	15,60259
60	15,10664	15,48847	15,6336
70	15,13045	15,51562	15,66458

Brake Torque (Nm)

Load 100%

	RPM		
Temp	1800	2000	2200
30	218,4818	213,8545	209,302
40	218,5758	213,9513	209,4019
50	218,6691	214,0487	209,502
60	218,7628	214,146	209,6025
70	218,857	214,2427	209,7027

Load 75%

	RPM		
Temp	1800	2000	2200
30	161,4818	156,8542	152,302
40	161,5758	156,9513	152,4018
50	161,6691	157,0488	152,5021
60	161,7627	157,1459	152,6025
70	161,857	157,2427	152,7027

Load 50%

	RPM		
Temp	1800	2000	2200
30	106,4818	101,8542	97,30191
40	106,5758	101,9513	97,40188
50	106,6692	102,0487	97,50211
60	106,7627	102,146	97,60243
70	106,857	102,2429	97,70262

Load 25%

	RPM		
Temp	1800	2000	2200
30	59,48183	54,85422	50,30204
40	59,57584	54,95135	50,40181
50	59,66913	55,04872	50,50213
60	59,76278	55,14599	50,6025
70	59,85697	55,24266	50,70274

BMEP (bar)

Load 100%

	RPM		
Temp	1800	2000	2200
30	8,323117	8,146836	7,973411
40	8,326695	8,150527	7,977216
50	8,33025	8,154237	7,981031
60	8,333819	8,157943	7,984855
70	8,337408	8,161628	7,988676

Load 75%

	RPM		
Temp	1800	2000	2200
30	6,151689	5,975399	5,80198
40	6,155269	5,979099	5,805784
50	6,158824	5,982811	5,809605
60	6,162388	5,986511	5,813428
70	6,165981	5,990199	5,817245

Load 50%

	RPM		
Temp	1800	2000	2200
30	4,056451	3,880161	3,70674
40	4,06003	3,883861	3,710548
50	4,063588	3,88757	3,714366
60	4,067151	3,891275	3,718188
70	4,070744	3,894967	3,722005

Load 25%

	RPM		
Temp	1800	2000	2200
30	2,265975	2,089685	1,916268
40	2,269556	2,093385	1,920069
50	2,273109	2,097094	1,923891
60	2,276677	2,1008	1,927714
70	2,280266	2,104482	1,931533

BSFC (g/kWh)

Load 100%

	RPM		
Temp	1800	2000	2200
30	298,9557	296,5001	296,8281
40	298,826	296,3652	296,6866
50	298,6974	296,2298	296,5452
60	298,5684	296,0947	296,4038
70	298,438	295,9601	296,2624

Load 75%

	RPM		
Temp	1800	2000	2200
30	404,4813	404,2471	407,918
40	404,2445	403,9961	407,6509
50	404,0096	403,7447	407,3834
60	403,7745	403,4944	407,1163
70	403,5366	403,2447	406,8497

Load 50%

	RPM		
Temp	1800	2000	2200
30	613,4039	622,5355	638,4943
40	612,861	621,941	637,8392
50	612,3218	621,3464	637,1845
60	611,7833	620,7537	636,5308
70	611,2394	620,1633	635,879

Load 25%

	RPM		
Temp	1800	2000	2200
30	1098,09	1155,934	1235,074
40	1096,353	1153,888	1232,629
50	1094,634	1151,845	1230,183
60	1092,915	1149,812	1227,745
70	1091,188	1147,796	1225,319

Combustion

Maximum Pressure (bar)

Load 100%

	RPM		
Temp	1800	2000	2200
30	123,7056	117,6071	112,5856
40	123,7538	117,6553	112,6341

50	123,802	117,7034	112,6826
60	123,8501	117,7515	112,7311
70	123,8984	117,7993	112,7796

Load 75%

	RPM		
Temp	1800	2000	2200
30	123,7056	117,6071	112,5856
40	123,7538	117,6553	112,6341
50	123,802	117,7034	112,6826
60	123,8501	117,7515	112,7311
70	123,8984	117,7993	112,7796

Load 50%

	RPM		
Temp	1800	2000	2200
30	123,7056	117,6071	112,5856
40	123,7538	117,6553	112,6341
50	123,802	117,7034	112,6826
60	123,8501	117,7515	112,7311
70	123,8984	117,7993	112,7796

Load 25%

	RPM		
Temp	1800	2000	2200
30	123,7056	117,6071	112,5856
40	123,7538	117,6553	112,6341
50	123,802	117,7034	112,6826
60	123,8501	117,7515	112,7311
70	123,8984	117,7993	112,7796

Maximum Temperature (K)

Load 100%

	RPM		
Temp	1800	2000	2200
30	2450,784	2446,972	2443,022
40	2451,403	2447,602	2443,66
50	2452,021	2448,233	2444,299
60	2452,64	2448,864	2444,94
70	2453,261	2449,493	2445,578

Load 75%

	RPM		
Temp	1800	2000	2200
30	2450,784	2446,972	2443,022
40	2451,403	2447,602	2443,66
50	2452,021	2448,233	2444,299
60	2452,64	2448,864	2444,94
70	2453,261	2449,493	2445,578

Load 50%

	RPM		
Temp	1800	2000	2200
30	2450,784	2446,972	2443,022
40	2451,403	2447,602	2443,66
50	2452,021	2448,233	2444,299
60	2452,64	2448,864	2444,94
70	2453,261	2449,494	2445,578

Load 25%

	RPM		
Temp	1800	2000	2200
30	2450,784	2446,972	2443,022
40	2451,403	2447,602	2443,66
50	2452,021	2448,233	2444,299
60	2452,64	2448,864	2444,94
70	2453,261	2449,494	2445,578

Emission

NOx Concentration (ppm)

Load 100%

	RPM		
Temp	1800	2000	2200
30	4198,127	4236,869	4262,087
40	4202,724	4242,196	4268,09
50	4207,303	4247,51	4274,057
60	4211,864	4252,779	4280,028
70	4216,398	4258,044	4285,957

Load 75%

	RPM		
Temp	1800	2000	2200
30	4198,127	4236,869	4262,085
40	4202,727	4242,199	4268,09
50	4207,306	4247,506	4274,06
60	4211,859	4252,776	4280,028
70	4216,398	4258,044	4285,953

Load 50%

	RPM		
Temp	1800	2000	2200
30	4198,122	4236,869	4262,081
40	4202,726	4242,199	4268,086
50	4207,309	4247,51	4274,061

60	4211,861	4252,78	4280,028
70	4216,398	4258,043	4285,95

Load 25%

	RPM		
Temp	1800	2000	2200
30	4198,122	4236,869	4262,091
40	4202,729	4242,199	4268,086
50	4207,306	4247,51	4274,064
60	4211,863	4252,779	4280,032
70	4216,396	4258,042	4285,957

Hydrocarbon Concentration (ppm)

Load 100%

	RPM		
Temp	1800	2000	2200
30	0,097388	0,097358	0,09731
40	0,097388	0,097358	0,097311
50	0,097389	0,097359	0,097312
60	0,097389	0,097359	0,097313
70	0,097389	0,09736	0,097313

Load 75%

	RPM		
Temp	1800	2000	2200
30	0,097388	0,097358	0,09731
40	0,097388	0,097358	0,097311
50	0,097389	0,097359	0,097312
60	0,097389	0,09736	0,097313
70	0,097389	0,09736	0,097313

Load 50%

	RPM		
Temp	1800	2000	2200
30	0,097388	0,097358	0,09731

40	0,097388	0,097358	0,097311
50	0,097389	0,097359	0,097312
60	0,097389	0,09736	0,097313
70	0,097389	0,09736	0,097313

Load 25%

	RPM		
Temp	1700	1800	1900
Temp	1800	2000	2200
30	0,097388	0,097358	0,09731
40	0,097388	0,097358	0,097311
50	0,097389	0,097359	0,097312
60	0,097389	0,097359	0,097313
70	0,097389	0,09736	0,097313

CO Concentration (ppm)

Load 100%

	RPM		
Temp	1800	2000	2200
30	26,88677	26,92043	26,74045
40	26,88246	26,91569	26,73598
50	26,87799	26,91117	26,73146
60	26,87366	26,90657	26,72688
70	26,86943	26,90196	26,7219

Load 75%

	RPM		
Temp	1800	2000	2200
30	26,88676	26,92044	26,74045
40	26,88247	26,91569	26,73596
50	26,87799	26,91117	26,73145
60	26,87367	26,90659	26,72688
70	26,86942	26,90196	26,7219

Load 50%

	RPM		
Temp	1800	2000	2200
30	26,88675	26,92044	26,74045
40	26,88247	26,91569	26,73597
50	26,87799	26,91117	26,73145
60	26,87366	26,90658	26,72688
70	26,86941	26,9019	26,7219

Load 25%

	RPM		
Temp	1800	2000	2200
30	26,88675	26,92044	26,74045
40	26,88247	26,91569	26,73597
50	26,87799	26,91117	26,73145
60	26,87366	26,90657	26,72688
70	26,86941	26,90197	26,72189

ABOUT THE AUTHOR

The author was born as on 29th July 1997 at Surabaya, East Java. Named Fairuz Fajri Utomo, the author is the first child of 3 brothers from Mohamad Adi Soedarso and Endah Dwilestari. The author completes elementary education at SDN Sompok Semarang on 2009. The author took his junior high school at SMPN 21 Semarang and graduated on 2012. The author took his High School education on SMAN 4 Semarang. On 2015, the author starts his bachelor degree study at Double Degree Marine Engineering Department of Institut Teknologi Sepuluh Nopember , Surabaya , Indonesia and Hoschule Wismar, Rostock Germany. Student number of the author is 04211541000020. The author takes Marine Power Plant (MPP) as his field of study on his bachelor thesis . On 2017, the author took excursion program to Hoschule Wismar, Rostock , Germany. On 2018 , the author took On the Job Training at PT Janata Marina Indah, Semarang, Jawa Tengah. Late 2018, the author took his 2nd On the Job Training at PT Pertamina (persero) Shipping on the New Ship Project Coordinator division and learn many things there.

Fairuz Fajri Utomo
fairuzfajri999@gmail.com