PERFORMANCE CHARACTERICTICS OF SINGLE STAGE MICRO GAS TURBINE (MGT) RUNNING ON LIQUID BIOFUELS

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DECLARATION

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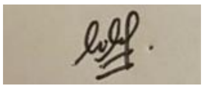

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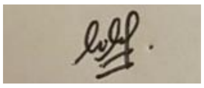

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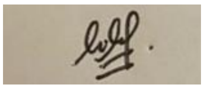

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LIST OF ABBREVIATIONS

MGT	Micro Gas Turbine
CO	Carbon Monoxide
CO_2	Carbon Dioxide
GHG	Green House Gases
NO_x	Nitrogen Oxide
SVO	Straight Vegetable Oil
TIT	Turbine Inlet Temperature

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ABSTRAK

Cecair biofuel semakin diperluas sebagai sekumpulan bahan bakar yang boleh diperbaharui yang berpotensi untuk membantu mengurangkan perubahan iklim, mengembangkan keamanan tenaga, dan meremajakan ekonomi pertanian. Cecair biofuel dapat menjadi sumber tenaga yang ramah lingkungan untuk aplikasi tetap seperti turbin gas. Minyak sayuran sangat mendorong bahan bakar alternatif dari bahan bakar fosil diesel. Minyak sawit adalah salah satu bahan bakar alternatif di mana sifat kimia dan fizikalnya tidak jauh dari diesel. Turbin gas mikro (MGT) adalah sistem generasi beredar berskala padat yang autonomi dan boleh dipercayai yang menyediakan penjimatan tenaga yang mungkin dan menurunkan pelepasan karbon monoksida (CO). Mereka bergantung pada bagian penting dalam pembekalan tenaga yang akan datang untuk kawasan yang jauh dengan atau tanpa kaitan grid.

Dalam projek ini, reka bentuk dan pengembangan ruang pembakaran untuk MGT dilakukan oleh perisian SOLIDWORKS dan simulasi CFD (ANSYS-Fluent) untuk mengoptimumkan geometri ruang pembakaran untuk cecair biofuel rendah dan untuk mencirikan prestasi penyejatan dan pembakaran minyak sawit untuk konfigurasi reka bentuk ruang pembakaran yang berbeza. Reka bentuk ruang khas digunakan untuk mensimulasikan dengan pengangkutan spesies untuk menentukan reka bentuk ruang yang optimum. Reka bentuk ruang pembakaran optimum yang terbaik adalah ruang pembakaran dengan tiub kitar semula berputar dengan saluran masuk tengah dari atas. Sebab untuk memilih ruang ini kerana mempunyai pelepasan CO dan pelepasan NO_x terendah di salur keluar masing-masing dengan 0,045128 dan 3,37E-05 dan mempunyai hasil terendah dari segi suhu, pelepasan CO dan pelepasan NO_x pada kontur dengan nilai masing-masing 2560 K, 0.182 dan 0.000323.

ABSTRACT

Liquid biofuels are getting expanding consideration as a group of renewable fuels with potential to assist with mitigate climate change, further develop energy security, and rejuvenate agricultural economies. Liquid biofuels can be an environmentally benign energy source for fixed applications like gas turbines. Vegetable oils are very encouraging alternative fuels of diesel fossil fuel. Palm oil is one of those alternative fuels where its chemical and physical properties are not far from diesel. Micro gas turbines (MGT) are compact scale autonomous and solid dependable circulated generation systems that provide possible energy saving and lowering the emissions of carbon monoxide (CO). They are depended upon to assume an essential part in upcoming supplies of energy for far away areas with or without associations of grid.

In this project, a design and development of a combustion chamber for MGT was performed by SOLIDWORKS and CFD simulation (ANSYS-Fluent) software to optimize the geometry of combustion chamber for low-grade liquid biofuels and to characterize the evaporation and combustion performance of palm oil for the different combustion chamber design configurations. Distinctive chamber designs were utilized to simulate with species transport to decide the optimum design of the chamber. The best optimum combustion chamber design is combustion chamber with revolve recycle tube with center air inlet from top. The reason for choosing this chamber since it has the lowest CO emission and NO_x emission at the outlet with 0.045128 and 3.37E-05, respectively and it has the lowest result in terms of temperature, CO emission and NO_x emission at the contours with the value of 2560 K, 0.182 and 0.000323, respectively.

CHAPTER 1

INTRODCUTION

1.1 Project Background

The overall energy utilization has expanding rate the last years due to the populace development, the modern turn of events, and the new way of life patterns [1]. There is a continuous energy emergency because of expanding use and reducing assets of fossil fuels and another factor is environmental issues [2].

Today, energy-concentrated exercises are the most elevated supporters of the increasing in carbon dioxide (CO_2) emissions and fossil fuel combustion efficiency represents 90 % of the absolute CO_2 emissions. The overall typical yearly advancement speed of 2.4 ppm in environmental CO_2 focuses in 2012 was fairly high [3]. As of late, by 2030, the CO_2 emission is awaiting to become 51 % as revealed by the Energy Information Administration (EIA). For example, the CO_2 emissions were 28.1 billion tons of metric and in 2030, it were relied upon to arrive at 42.3 billion tons of metric [4].

The high worldwide interest of energy has expanded quickly in the previous decade with a revealed proportion of yearly addition of 2.3 % in 2013 [5]. With expanding energy requests and different environmental concerns like pollutants and greenhouse gases (GHG), center of attention is made upon the unconventional energy sources which have low emissions alongside possible to bring to the table great efficiency. Considering the common conditions, the endeavours are made for creating proficient energy conversion technologies with less unfavourable effect on environment [6].

The International Energy Agency (IEA) conjectures a 70 % increment in worldwide energy interest and a 60 % expansion in GHG emissions in 2050 compared with 2011. Obliging the increment in normal worldwide temperatures to 2 ^{0}C would require a 50 % GHG emissions reduction compared to 2009 levels and restricting the expansion in energy interest to 25 % from today to 2050. Accordingly, the supplanting of fossil fuels with renewable energy source is one of the vital measures to restrict energy related GHG emissions [7].

GHG emissions identified with the human-centred exercises are generally perceived as the main driver to global warming [8]. Expanding concerns with respect to global warming brought about by GHG, which are considerably produced by customary energy resources, e.g., fossil fuels have made huge interest in the exploration in the field of renewable energies [9].

These days, biomass is the predominant renewable energy source among EU-28 with around 66 % of the last energy creation from solid, gases, and liquid biomass sources, and in 2050, it is assessed that bioenergy would add to around 30 % of the worldwide essential energy contribute [10]. Bioenergy is an environmental friendly and effective method for making power and heat, similarly as green hydrogen, synthetic natural gas (methane) and liquid chemicals. In a new report, IEA expressed that in 2018 bioenergies address about half of worldwide complete renewables use 121 GW and in 2023, it will stay at 46 % when it is relied upon to achieve 158 GW introduced power. Biomass energy conversion is a dependable method to produce energy and chemical products whenever contrasted and other renewable sources like solar, wave and wind which have irregular nature and afterward can barely coordinate with energy interest and creation without the utilization of storage systems [11].

In the field of energy creation, expanding consideration should be paid to further developing proficiency and decreasing pollutants. To this end, particularly for private applications, micro cogeneration systems appear to be extremely engaging. Quite possibly the most encouraging cogeneration technologies accessible these days is the micro gas turbine (MGT) which can give a sensible electrical effectiveness of around 30 %, multi-fuel ability, low emission levels and heat recuperation potential, and requirements least maintenance [12].

1.2 Problem Statement

The most practical approach to fulfil the developing energy need in transmission with no expansion of the emissions of greenhouse gas (GHG) is by using alternative fuels. Vegetable oils are very encouraging alternative fuels of diesel fossil fuel. Palm oil is one of those alternative fuels where its chemical and physical properties are not far from diesel. Nonetheless, because of its high viscosity, its immediate use as fuel to supplant diesel suffers from the lower heating value, poor atomization, low evaporation, and high flash-point compared to diesel which require either preheating or mixing with diesel. Since, there are still lack of information of the performance of existing single stage micro gas turbine (MGT) running on liquid biofuel. Therefore, the evaporation and combustion characteristics needs to be investigated to modify the existing MGT combustion chambers to be suitable for the direct use of palm oil as fuel.

1.3 Objectives

1) To design and optimize the geometry of combustion chamber for low-grade liquid biofuels using CFD simulation (ANSYS-Fluent).

2) To characterize the evaporation and combustion performance of palm oil for the different combustion chamber design configurations.

1.4 Scope of Work

This project expects to develop a combustion chamber by testing it with vegetable palm oil. The performance characteristics of micro gas turbine (MGT) is fundamentally focus on combustion, temperature profile and emission. Nonetheless, there are some experiment and simulation should be conducted on the geometry of the combustion chamber. But due to the Movement Control Order (MCO 3.0), the experiment analysis cannot be done since the laboratory have been closed. Therefore, this project is only focus on simulation. Before running the simulation, there are some set up that should be done. After completing the setup, the simulation can be run. The simulation is set to determine the performance characteristics of new design micro gas turbine (MGT) combustion chamber running on liquid biofuels which is vegetable palm oil.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The performance of micro gas turbine (MGT) has been investigated in some publish papers and articles which can be the reference for the current project. The focus of the publish papers and articles are more on the combustion and the emission effect with other alternative fuels.

2.2 Micro Gas Turbine

Compact and powerful machines for energy production, the micro gas turbine (MGT), were conceived and created since the last part of the 40 s in the aircraft industry. Since the 90 s they were acquired, a standard pattern of sharing of the scientific and technological implications of the aeronautical utilizations of propulsion, to the manufacturing sectors as stationary of electricity production [13].

Furthermore, the interest of utilizing MGT as new source for electrical power generation has gotten prevailing since the natural gas is the ordinarily utilized fuel, it is the essential fuel of decision for its accessibility, low costs, and low exhaust gas emissions [14]. Contrasted with gas internal combustion engine at a similar power level, MGT can realize the complete combustion of fuel with essentially low nitrogen oxide (NO_x) emissions however has lower power proficiency and longer beginning up time. Also, the exacting burden of emission limits to power appliance is an extraordinary chance for MGT [15].

MGT lately is given thought for localized generation of renewable energy. There has been a re-established engrossment on the MGT advancement and organization on compact scale distributed cogeneration (DG) and polygeneration thoughts. Engines of MGT function on the essential standard of Brayton cycle, which incorporates compression, combustion, and expansion processes. The design of MGT relies upon the application, despite the fact that they generally comprise of a spiral flow compressor, annular combustor, and single shaft turbine with or without recuperator [16].

MGT are fundamentally of two kinds, the earliest is made out of a rapid single shaft unit passing on centrifugal compressor and outspread turbine (goes from 50,000 RPM to 120,000 RPM) on a comparable shaft as an electrical facilitated machine. In this design, the compressor speed stays steady at generator appraised speed bringing about a critical drop in effectiveness at part load. The subsequent sort utilizes a power turbine turning at 3000 RPM related with a customary generator through gear enclose a split shaft designed though the compressor speed shifts with output load bringing about a superior part load proficiency [17]. MGT are assorted as gas turbines that have output power of under 300 kW. Albeit the range is little, MGT of various sizes have critical differences as far as performance and capital expense. At the point when size expands, productivity increases and capital expense reduces, and subsequently a bigger MGT is best contrasted with different assembly of more modest MGT [18].

The utilization of alternative and renewable fuels in little and huge scale power generation innovations is a vital matter today. In the localized energy creation, biofuels acquired short stock chains offer critical benefits not just as far as decrease of greenhouse gas (GHG) yet in addition of country advancement. Commercial MGT have effectively been tried with biomass inferred fuels, generally utilizing low heating value producer gases or biogas from anaerobic absorption [19].

2.3 Biofuels

Biomass is considered as renewable energy source in the event that it depends on sustainable use and accessible almost around the world. Biomass is a fundamental energy source for humanity since the commencement. The accessibility and assortment of biomass put it as the fourth energy asset after coal, oil, and natural gas [20].

Among the renewable sources, biomass is vital in view of the impressive advantages of its utilization to the financial concern, innovation and environment. Truth be told, since biomass inferred fuels are predictable, the energy systems dependent on these kinds of fuels do not address a basic issue for the conveyance and appropriation grid. Moreover, the utilization of biomass can decrease the emission of greenhouse gas (GHG) and supports monetary turn of events and work in rustic regions. An additional benefit of the utilization of biomass is the like hood to utilize different advancements that permit both compact scale creations, as per the spirit of localization and moderate scale plants. One approach to harvest the energy stock in biomass assets adequately is to change over it into a gaseous or liquid medium, which is simpler to deal with, store and transport [21].

These days, using spotless and renewable energy assets, close to streamlining of power generation systems are considered as commendable choices to overcome the environmental issues raised by fossil fuels. Likewise, such a cleaner creation upholds sustainable energy-based turn of events. The deployment of biomass for creation of heating, cooling, power, transportation fuels and feedstock has gotten perhaps the most encouraging, complex, and discussed alternatives to make a sustainable energy system [22].

Biomass enjoys numerous benefits contrasted with the fossil fuel, it is sustainable, carbon unbiased and since squanders moreover treated for producing it, it can likewise help preventing environmental pollution [23]. It has the capability of producing renewable fuels and power while diminishing emissions of carbon just about 20 % [24].

Biomass-inferred alternative fuels created from renewable biomass are significant attributable to them being conceivably carbon unbiased, delivering cleaner combustion and having sustainable feedstock supply from existing estates. From a carbon cycle viewpoint, carbon dioxide (CO_2) delivered from the combustion of fossil fuels are released into environment without reusing, while biofuels are possibly carbon unbiased as the CO_2 created from the combustion process is reconsumed for the development of feedstock plant [25]. Figure 1 differentiates the emission cycle of CO_2 between biofuels and fossil fuels.

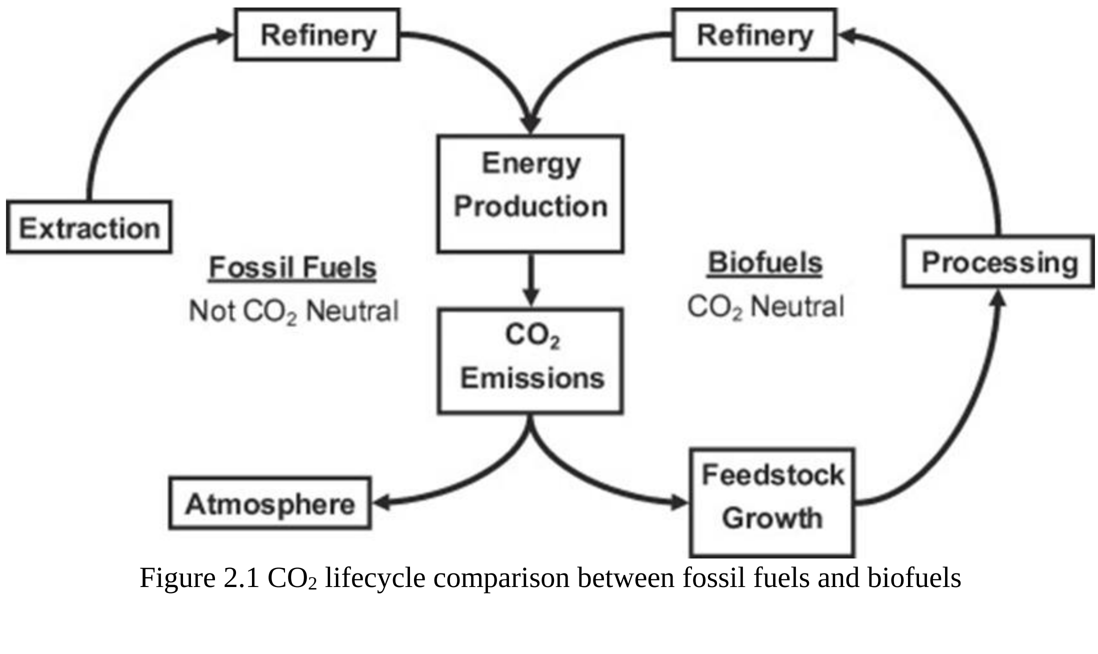


Figure 2.1 CO_2 lifecycle comparison between fossil fuels and biofuels

Biofuels can be grouped dependent on their creation advances: original biofuels, second era biofuels, and third era biofuels. The original biofuels are produced using palatable feedstock like soybean, sugarcane, rapeseed and corn. Biofuel creation from these sources was legitimately or not reprimanded for a flood of food costs. Second era of biofuels from squander and devoted lignocellulosic feedstocks like Swich grass, Poplar or Miscanthus as of now enjoy upper hands over those of original. The fundamental benefits are more significant returns and lower land need. Third era biofuels feedstock, miniature and full scale algae can have an edge over the past two. These marine creatures show the possibility of high yields of biomass without needing any productive land and can possibly be developed in a containment offshore [26].

The liquid biofuel term is alluded to biomass to liquid fuel (BTLF). Liquid biofuels may offer an encouraging alternative. Liquid biofuels are replacement fuel sources to petroleum; nonetheless, some actually involve a modest quantity of petroleum for the blend. The greatest contrast among petroleum and biofuels feedstocks is oxygen content [27]. Liquid biofuels additionally furnish a more extensive viewpoint with different technological aspects for advanced biofuels between 2015 and 2045 [28].

Liquid biofuels are getting expanding consideration as a group of renewable fuels with possible to assist with mitigate climate change, further develop energy security, and rejuvenate agricultural economies. Numerous nations intend to set up or grow the industries of biofuel, and many have likewise set mixing biofuel orders for the transportation area. Appropriately, liquid biofuel creation has expand quickly over late years, and strong development is relied upon to proceed. Most of liquid biofuels are destined for combustion in the engines of automobile either as an added substance or a substitute for fossil fuels and they presently about 3 % of transportation fuel utilize universally [29].

Liquid biofuels can be an environmentally benign energy source for fixed applications like power producing gas turbines [30]. Vegetable oils are a renewable and potentially endless wellspring of energy with energy content close to diesel fuel.

2.4 Performance of Jet A Fuel on MGT

According to Manigandan [4], the investigation of JET-A fuel mixes on the combustion, emission and performance with different added substances utilizing a micro gas turbine (MGT) have been studied. The oxygen measure in mixes fuel and polarization are the critical boundaries in the creation of a higher rate of combustion with low emission. Consequently, different proportions of added substances (pentanol and ethanol) are mixed with biofuel (canola-sunflower oil and rapeseed) to frame the JET-A fuel mixes by utilizing Kay's and Grunberg-Nissan blending regulations.

The combustion, emission and performance boundaries under various engine loads were inspected. Outcomes revealed that every one of the mixes logged higher static thrust with a considerable decrease amount in the fuel utilization. Among various fuel mixes, R20E (20 % Rapeseed, 10 % ethanol, and Stream A 70 %) viewed expansion of 35 % in static thrust related with 41 % decrease in thrust explicit fuel utilization. In addition, the mixes CS20E and R20E (Canola-Sunflower 20 %, 10 % ethanol and JET-A fuel 70 %) viewed 10 % and 24 % expansion in proficiency of thermal separately because of the impact of higher content of oxygen and concentration of ethanol. Likewise, these fuel mixes create low emission of environmental undermining harmful gases, including CO, HC, and NO_x stood out from perfect JET-A fuel. Outcomes uncovered that the obliteration esteems of exergy are higher for the combustion chamber than the rest customary parts of fuel.

2.5 Performance of Straight Vegetable Oil on MGT

According to Prussi [19], a micro gas turbine (MGT) by the utilization of liquid biofuel, straight vegetable sunflower oil (SFO) have been researched. Commercial gas turbines have been effectively tried with eccentric fuels, for example, inferred fuels of biomass; be that as it may, study work on utilizing fuel of Straight Vegetable Oil (SVO) in MGT are scant. The physical and chemical qualities of SVO are not same as fossil diesel oil and somewhat a long way from the normal specialized particulars for gas turbine liquid fuels, not just as far as Lower Heating Value (LHV) and kinematic viscosity, yet furthermore as considers distinctive to be as fuel cold effect, burning effects, pollutant amounts and organization and so on.

Accordingly, specific consideration should be specified to the polarization and dissipation stages, as these are the most basic strides to accomplish consistent and effective long haul activity. An investigation reliant upon mathematical connections open was from the outset received for the investigation of the polarization process, maintained by modelling of computational fluid dynamics (CFD) to abstractly research the stream design. Benchmark boundaries were put and changed so to create a spray of sunflower oil go through dissipation count similar to diesel, and little variations to the line of fuel were designed and introduced on the MGT.

Tests with mixes and SVO were finished to assess the contrast between the standard and the changed device, fed by diesel, as far as output power, performances, and exhaust emissions, which were like the original diesel-fed MGT. Assessed exhaust emissions were true to form good underneath those average of engines diesel of the comparative size fed with SVO. The trial crusade insisted that it is feasible to work a MGT fed with SVO through the reception of small changes and by changing benchmark boundaries.

As indicated by Allouis [31], the experiments carried out for power generation, fuels with various liquid fuels, including commercial diesel oil and its mixes with unadulterated rapeseed oil on low emission MGT have been investigated. A specific consideration was paid both on the assessments and emissions of the micro vibrational appropriations and their relationship under the distinctive fuelling states utilizing another signal preparing dependent a turmoil and nonlinear strategy investigation. It saw that the general conduct of the MGT with mixes fuels was acceptable, and the emission convergences of NO_x, CO and Total Particulate Matter were equivalent to the unadulterated diesel oil ones.

As per Chiariello [32], the 30 kWe commercial MGT suction with mixes of SVO with fossil fuel emission was explored. Both the emission of gaseous and particulate were estimated at full and halfway load for mixes 20 % v/v and 10 % v/v of sunflower and rapeseed oils with JET A1 kerosene. The varieties emissions of carbon monoxide and nitric oxide were considered to assess the conduct of combustor at various mixers and loads. The impacts of the fuel organization on the assortments, as far as measurements and concentrations, of superfine particulate matter was additionally assessed.

The emissions of CO and NO_x are for all intents and purposes uncaring toward the creation of the fuel being the distinctions inside the trial vulnerability of the instrumentation. This shows a comparable generally combustion at both halfway and full load for the five fuels utilized (four SVO mixes and JET A1). Unexpectedly, the emission of molecule matter is multiple times for mixes of rapeseed oil and in excess of multiple times more prominent for mixes of sunflower oil in regards to unadulterated Jet A1. The distinctions are credited to the chemical structure of the vegetable oil tried.

2.6 Performance of Fast Pyrolysis Bio-Oil Fuel on MGT

According to Buffi [33], a compact scale non recovered micro gas turbine (MGT) was concentrated by utilization of Fast Pyrolysis Bio-Oil (FPBO) as fuel, construct in a devoted test bench. The system incorporates a devoted injection line and an altered combustor to consume proficiently large volume parts of FPBO in ethanol arrangement. The impact of bigger volume of combustor improved the combustion of the diesel oil reference and unadulterated ethanol quality as respects exhaust emissions, while keeping up unaltered utilizations of fuel of the first setup.

20/80 and 50/50 % (volume parts) of FPBO/ethanol mixes test showed the engine activity effectively and stable. By expanding the part of FPBO volume in the mix fuel, an increasing in emissions of CO was noticed most likely because of the greater droplets got from the more viscous fuel just as in emissions of NO_x probably because of nitrogen fuel bound. Considering the suggested changes and fuel of FPBO/ethanol mix, the engine arrived at a higher electrical proficiency compared to deliberate with diesel fuel benchmark. A last test with 100 % FPBO feeding showed unstable combustion with the carbon stores presence in the hot bits of the system.

2.7 Performance of Steam Injection on MGT

As indicated by Renzi [34], the micro gas turbine (MGT) performance attributes on the impact of the steam injection has been explored with both natural gas and synthetic gas. Steam injection permits to acquire greater power and proficiencies at the appraised rotational speed. Thought ought to be paid to the danger of the compressor slow down, particularly when utilizing synthetic gas, as the rate of mass flow prepared by the compressor diminishes essentially.

As respects the pollutant emission, synthetic gas combustion incorporates a decrease of around 75 % of NO_x emissions, while CO emissions somewhat increase as for natural gas combustion. In any case, it was found that, with a legitimate fuel and steam injection methodology, the concentration of the mixtures of polluting can be additionally diminished.

2.8 Performance of Organic Rankine and trans-critical CO_2 Cycle on MGT

As per Yoon [35], a micro gas turbine (MGT) was applied with two heat recuperation systems, a trans-critical CO_2 cycle (tCO_2) and Organic Rankine Cycle (ORC) and their performance was thought about. The performance of off design of the two lining cycles with the heap assortment of the MGT was likewise dissected. The performance curve, the adequacy NTU procedure, and the Stodola's condition were utilized to demonstrate the off design activities of all lining cycle parts, similar to a pump, a turbine and heat exchangers. As indicated by the computations, the ORC output power was greater than the tCO_2 cycle when the MGT worked at a full load.

Then again, in light of the fact that the output power variety with the MGT load replace is bigger in the ORC, the tCO_2 output power expands when MGT works underneath 75 % at a section load. Hence, the tCO_2 is reasonable for a heat recuperation system using MGT exhaust gas in where the MGT needs to work at less loads in a significant number of its working time. Then again, the ORC is more appropriate in implementations where the MGT can work at the conditions close to full load.

2.9 Overall

The combustion chamber design dependent on uniformity of temperature and emission of CO is a basic issue in the micro gas turbine (MGT) advancement. Albeit, some regular design and trial concentrates on various micro combustor arrangements were done previously, there is need for additional design and advancement to develop principal issues. However, there is still lack of studies on the performance of the MGT running on biofuel. Hence, the performance of the MGT running on the liquid biofuels must study further on the optimization of energy conversion and efficiency.

CHAPTER 3

METHODOLOGY

3.1 Overview

This study includes simulation and experimental work, to investigate the combustion and performance of the micro gas turbine (MGT) with vegetable palm oil. But due to the Movement Control Order (MCO 3.0), the experiment in the laboratory cannot be done since it has been closed. The temperature profile, flow rate and emission are getting from the simulation using ANSYS-Fluent software.

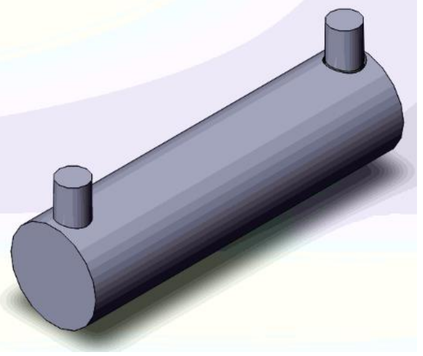
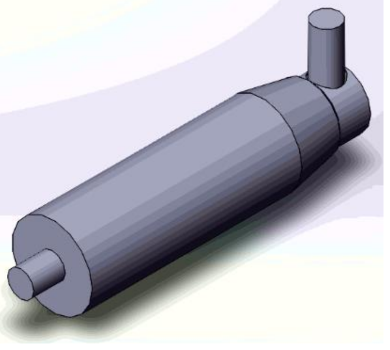
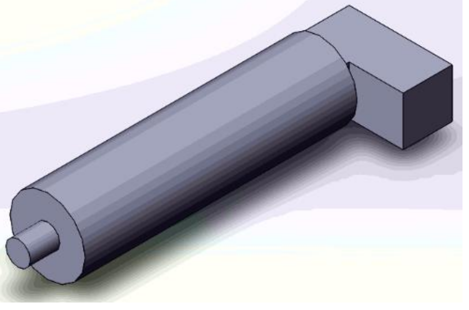
3.2 Methodology Activity

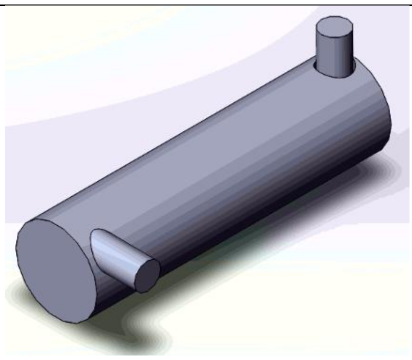
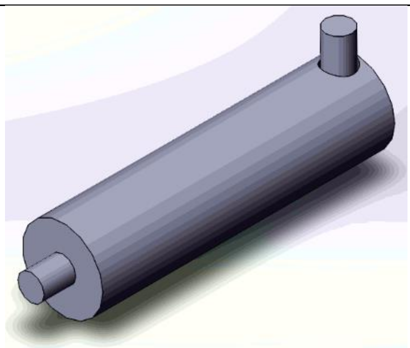
Firstly, the modification of MGT combustion chamber have been made using SOLIDWORKS software. There are several parts have been given to be modify and assemble. The parts include combustion chamber with a cap from air inlet side, combustion chamber with conical exit, combustion chamber with square outlet, combustion chamber with tangential air inlet from top, combustion chamber with center air inlet from top, flame tube with exhaust tube, flame tube with square outlet and revolve recycle tube. Then, the 5 main combustion chamber geometries have been modified by adding the flame tube and revolve recycle tube. The modified combustion chambers can be seen in 3.3. After completing the modification, the computational fluid dynamics (CFD) simulation for all 5 combustion chamber design have been run using ANSYS-Fluent software. The setup for the simulation can be seen in 3.5. The contour results obtained from the simulation are total temperature, mass fraction of CO, mass fraction of NO_x and DPM mass source. Also from the simulation, the average value result for turbine inlet temperature (TIT), CO, NO_x and DPM at the outlet can be obtained.

3.3 Combustion Chamber Design

Table 3.1 shows 5 combustion chamber design that have been modified using SOLIDWORKS software. 5 different design is needed to optimize the best inlet and outlet conditions in the chamber.

Table 3.1 Combustion chamber design

Design	Combustion Chamber Design
A Combustion chamber with revolve recycle tube and a cap from air inlet side	
B Combustion chamber with revolve recycle tube and a cap from air inlet side and center air inlet from top and conical exit tube	
C Combustion chamber with revolve recycle tube and a cap from air inlet side and square outlet	

D Combustion chamber with revolve recycle tube and a cap from air inlet side and tangential air inlet from top	
E Combustion chamber with revolve recycle tube with center air inlet from top	

3.4 Meshing

Figure 3.1 shows meshing size for design A. In the simulation, 3 mm minimum size has been used to get higher quality of the mesh.

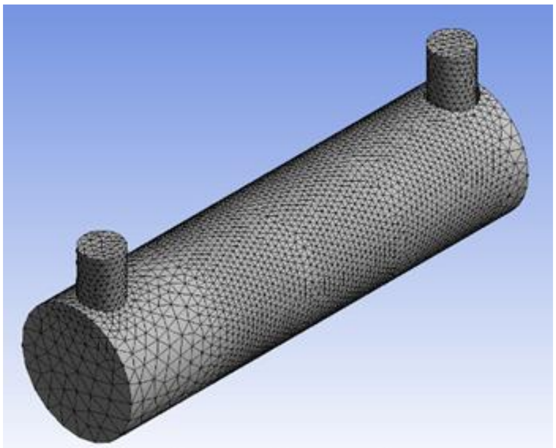


Figure 3.1 Meshing size for design A

3.5 Fluent Setup

1) Set the pressure unit to atm.

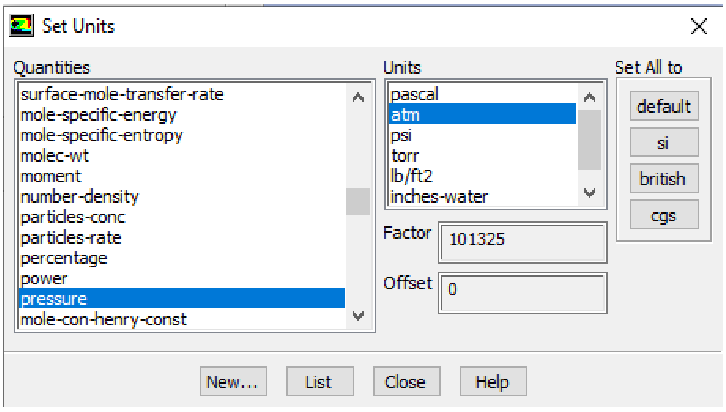


Figure 3.2 Pressure unit setup

2) Click on the energy equation.

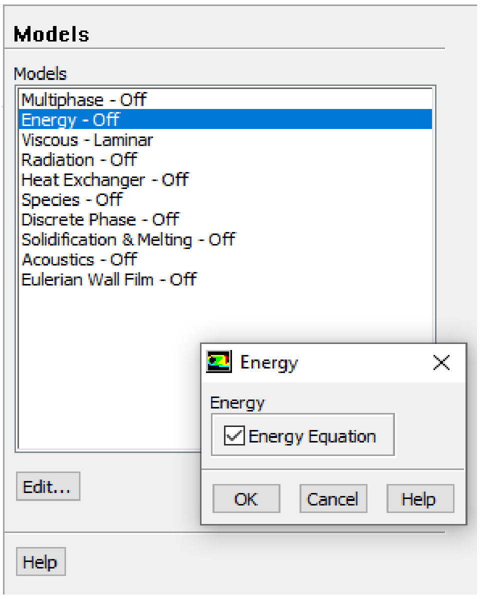


Figure 3.3 Energy equation setup

3) Click on the k-epsilon in the viscous model.

The k-epsilon model is a turbulence model was used because it is suitable for flow with swirling motion, heat transfer and turbulence flow can be predicted through standard k-ε model.

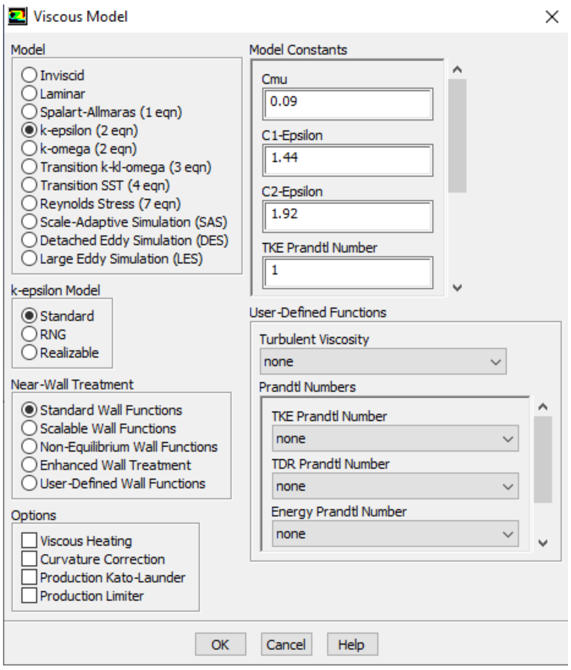


Figure 3.4 Viscous model setup

4) Click on the species transport and Eddy-Dissipation concept in species model.

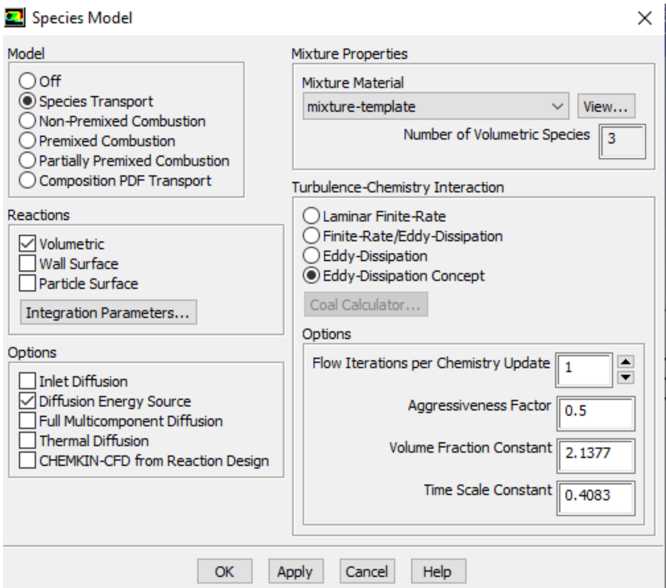


Figure 3.5 Species model setup

5) Change the maximum number of steps to 10000 in discrete phase tracking.

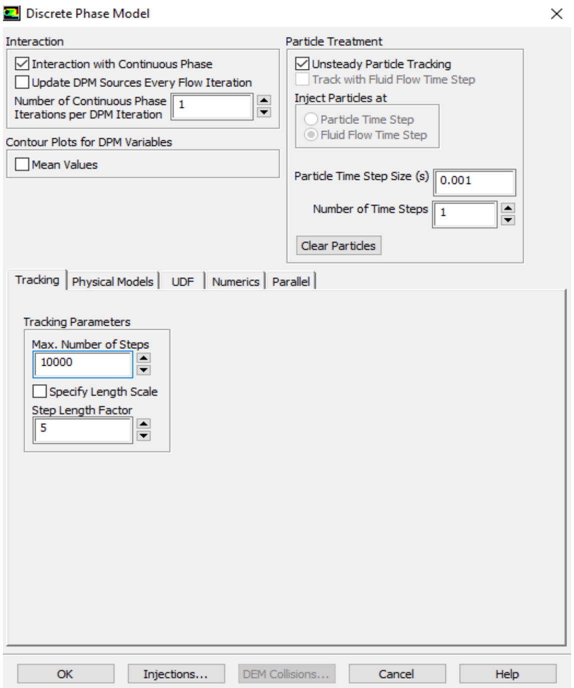


Figure 3.6 Discrete phase tracking setup

6) Click on the temperature dependent latent heat in discrete phase physical model.

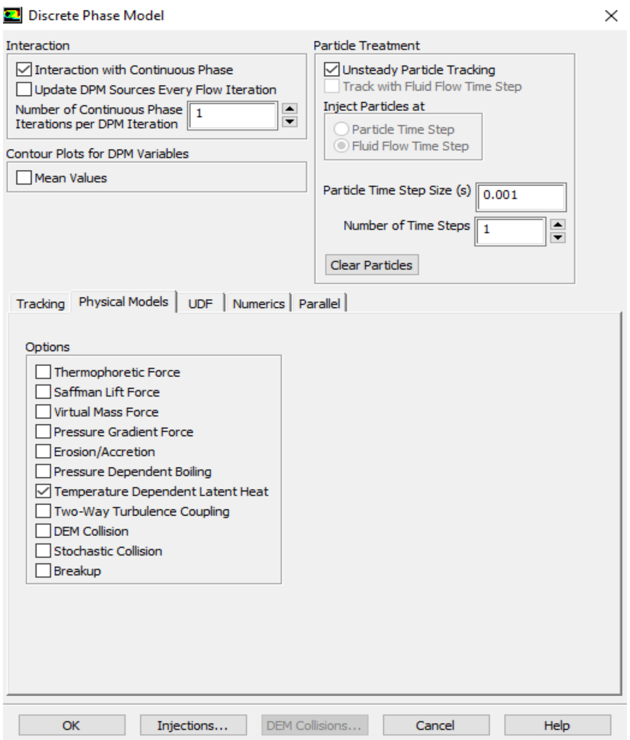


Figure 3.7 Discrete phase physical model setup

7) Add fluid materials for carbon dioxide, carbon monoxide, hydrogen, and methane in fluent database materials.

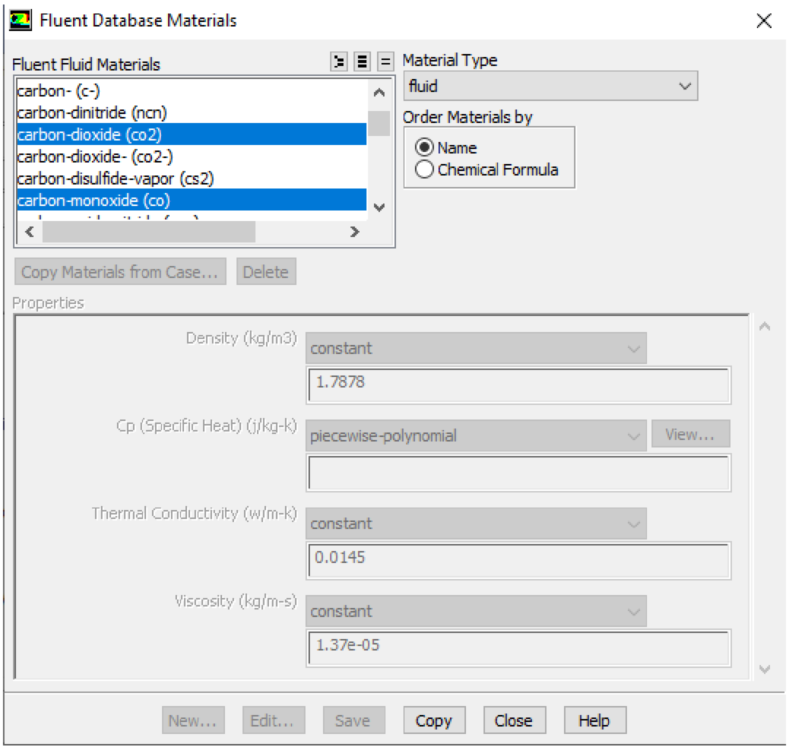


Figure 3.8 Fluid materials setup

8) Add solid material for steel in fluent database materials.

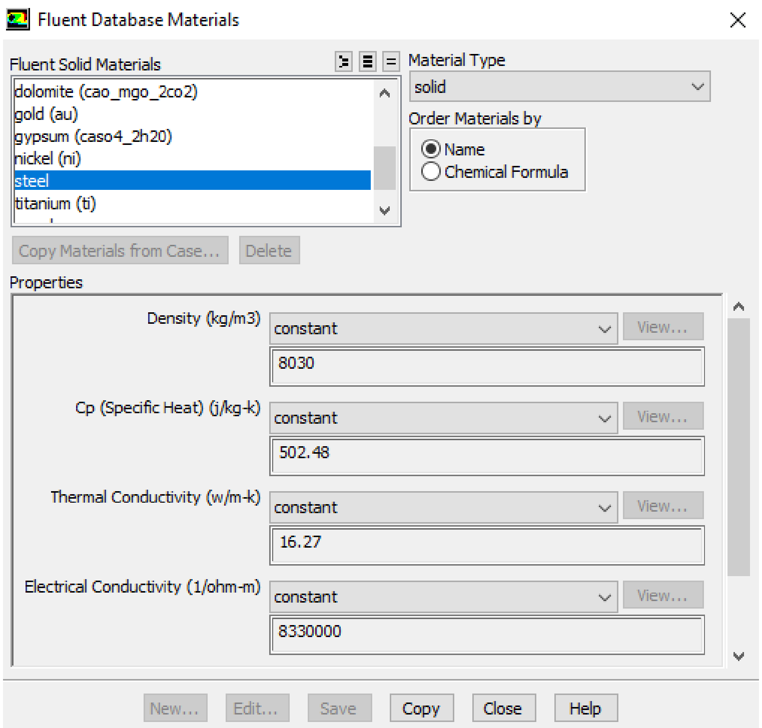


Figure 3.9 Solid materials setup

9) Create a palm-oil material with 885 kg/m^3 density, 1875 J/kg-K specific heat, 0.1717 W/m-K thermal conductivity, 0.05785 kg/m-s viscosity and 772.13 kg/kg-mol molecular weight properties [36].

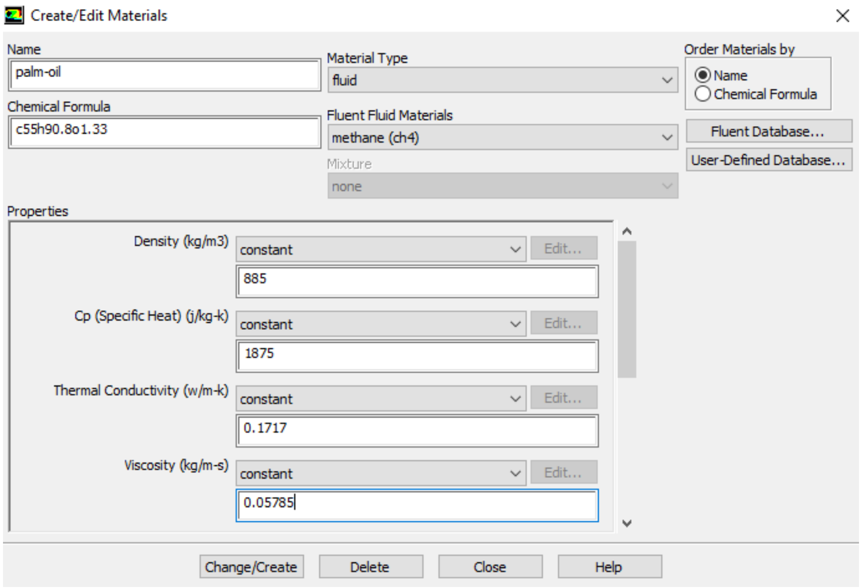


Figure 3.10 Palm-oil setup

10) Convert all the materials from fluid expect for air to the mixture template.

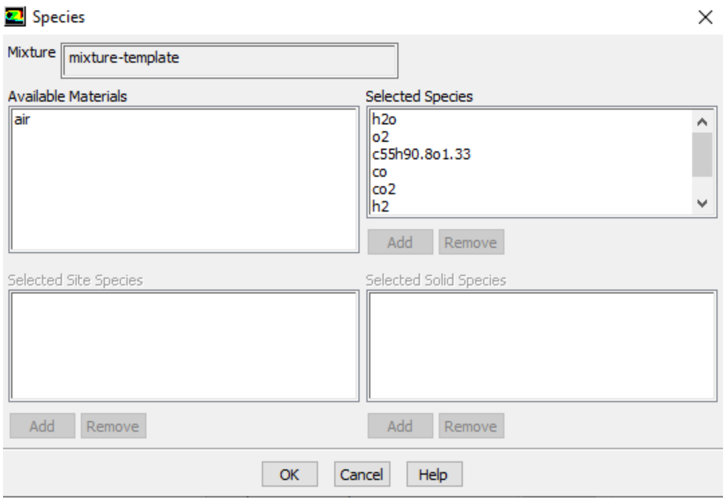


Figure 3.11 Species setup

11) Click on the thermal, prompt and fuel NO_x and choose c55h90.8o1.33 (palm-oil) in the NO_x formation.

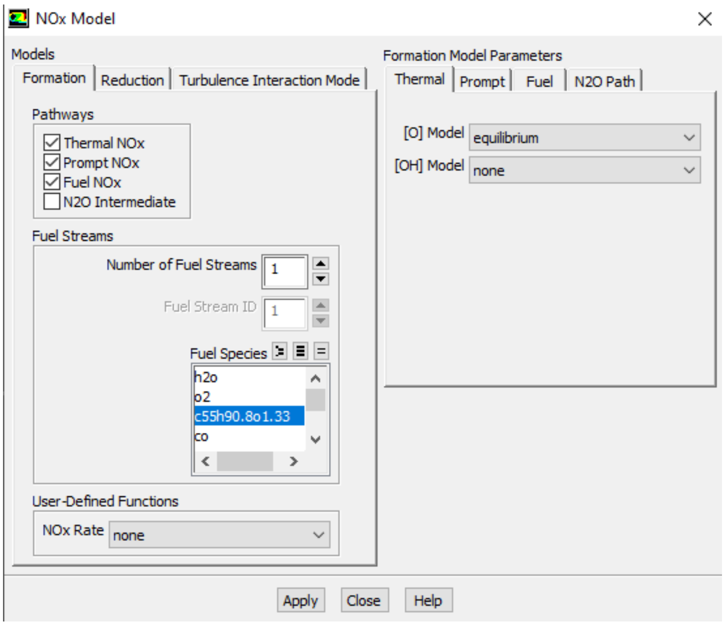


Figure 3.12 NO_x formation setup

12) Insert the value of fuel carbon number to 55 and equivalence ratio to 0.43 in NO_x prompt.

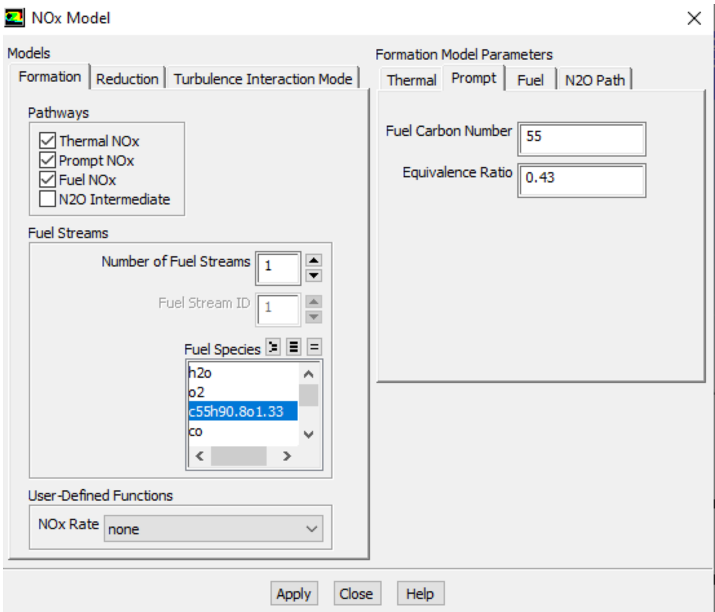


Figure 3.13 NO_x prompt setup