ANALYSIS OF THE EFFECTS OF GASOHOL (ALCOHOL/GASOLINE) FUEL MIXTURES AT DIFFERENT COMPRESSION RATIOS AND ENGINE SPEEDS ON SPARK INITION ENGINE EMISSIONS WITH ANSYS

2023
MASTER THESIS
MECHANICAL ENGINEERING

HASSAN MCHEIK

Thesis Advisor
Assoc. Prof. Dr. SAMET USLU

ANALYSIS OF THE EFFECTS OF GASOHOL (ALCOHOL/GASOLINE) FUEL MIXTURES AT DIFFERENT COMPRESSION RATIOS AND ENGINE SPEEDS ON SPARK INITION ENGINE EMISSIONS WITH ANSYS

Hassan Ali MCHEIK

Thesis Advisors
Assoc. Prof. Dr. Samet USLU

T.C.
Karabuk University
Institute of Graduate Programs
Department of Mechanical Engineering
Prepared as
Master Thesis

KARABUK
January 2023

I certify that in my opinion the thesis submitted by Hassan Ali MCHEIK titled "ANALYSIS OF THE EFFECTS OF GASOHOL (ALCOHOL/GASOLINE) FUEL MIXTURES AT DIFFERENT COMPRESSION RATIOS AND ENGINE SPEEDS ON SPARK INITION ENGINE EMISSIONS WITH ANSYS" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Samet USLU ....
Thesis Advisor, Department of Mechanical Engineering

This thesis is accepted by the examining committee with a unanimous vote in the Department of Mechanical Engineering as a Master of Science thesis. 16.01.2023

Examining Committee Members (Institutions)	Signature
Chairman : Assist. Prof. Dr. Süleyman ŞİMŞEK (IAU)	....
Member : Assoc. Prof. Dr. Samet USLU (KBU)	....
Member : Assoc. Prof. Dr. M. Erdi KORKMAZ (KBU)	....

The degree of Master of Science by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

Prof.Dr.Müslüm KUZU ....
Director of the Institute of Graduate Programs

“I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well.”

Hassan Ali MCHEIK

ABSTRACT

M. Sc. Thesis

ANALYSIS OF THE EFFECTS OF GASOHOL (ALCOHOL/GASOLINE) FUEL MIXTURES AT DIFFERENT COMPRESSION RATIOS AND ENGINE SPEEDS ON SPARK INITION ENGINE EMISSIONS WITH ANSYS

Hassan Ali MCHEIK

Karabük University
Institute of Graduate Programs
The Department of Mechanical Engineering

Thesis Advisor:
Assoc. Prof. Dr. Samet Uslu
January 2023, 56 pages

Over the years, the prices of oil derivatives are increasing, and global concerns are increasing about the depletion of oil, due to the noticeable increase in the consumption of the derivatives extracted from it, also there are increasing concerns about the climate and the public health of humans and all living creatures, and all of this is caused by emissions as a result of the excessive use of these oil derivatives. The purpose of this experiment is to analyst fusel and gasoline several mixtures and compare their performance, emissions, and combustion with the pure gasoline under several loads inside the spark ignition engine (SI). Also, this study tries to proof if this new type of biofuel (fusel oil) is good to be an alternative fuel. These experiments can be time and money consuming, so using computer software capable of fixing problems instantly is the best option. The ANSYS program is one of the best engine simulation software to read both of result the emission and the engine performance at the same time so in this study, Computational fluid dynamics (CFD) is used due to the capability of using a new type of fuel inside it. Carbon monoxide (CO) emissions from fusel oil/gasoline blends are higher than inside a pure gasoline cylinder, but nitrogen oxide (NO_x) emissions are reduced when using gasoline/fusel oil blends.

Key Words : Fusel oil, computational fluid dynamics, emissions, alternative fuel, spark ignition engine.

Science Code : 91413

ÖZET

Yüksek Lisans Tezi

ALKOL/BENZIN YAKIT KARIŞIMLARININ FARKLI SIKIŞTIRMA ORANLARINDA VE MOTOR DEVIRLERINDE BUJI ATEŞLEMELI MOTOR EMISYONLARINA ETKISININ ANSYS ILE ANALIZI

Hassan Ali MCHEIK

Karabük Üniversitesi
Fen Bilimleri Enstitüsü
Makine Mühendisliği Anabilim Dalı

Tez Danışmanı:
Doç. Dr. Samet USLU
Ocak 2023, 56 sayfa

Yıllar geçtikçe, petrol türevlerinin fiyatlarının artması ve petrolden çıkarılan türevlerin tüketimindeki gözle görülür artış nedeniyle petrolün tükenmesiyle ilgili küresel endişeler artmakta, ayrıca iklim ve halk sağlığı ile ilgili artan endişeler bulunmakta ve tüm bunlar bu petrol türevlerinin aşırı kullanımı sonucu ortaya çıkan emisyonlardan kaynaklanmaktadır. Bu deneyin amacı, fuzel yağı ve benzinin çeşitli karışımlarını analiz etmek ve buji ateşlemeli motor (SI) içinde birkaç yük altında performanslarını, emisyonlarını ve yanmalarını saf benzinle karşılaştırmaktır. Ayrıca bu çalışma, bu yeni biyoyakıt türünün (fuzel yağı) alternatif bir yakıt olup olmadığını kanıtlamaya çalışmaktadır. Bu deneyler zaman ve para alıcı olabilir, bu nedenle sorunları anında düzeltme yeteneğine sahip bilgisayar yazılımı kullanmak en iyi seçenektir. ANSYS programı, hem emisyon sonucunu hem de motor performansını aynı anda okuyabilen en iyi motor simülasyon yazılımlarından biridir, bu nedenle bu çalışmada, yeni bir yakıt türü kullanılabilmesi nedeniyle Hesaplamalı Akışkanlar Dinamiği (CFD) kullanılmıştır. Fuzel yağı/benzin karışımlarından ortaya çıkan karbon monoksit (CO) emisyonu saf benzin silindirinin içindekinden daha yüksektir, ancak diğer yandan benzin/fuzel karışımlarını kullanırken nitrojen oksit (NO_x) emisyonları azalmıştır.

Anahtar Kelimeler : Fuzel yağı, hesaplamali akiskanlar dinamigi, emisyonlar, alternatif yakıt, buji ateşlemeli motor.

Bilim Kodu : 91413

ACKNOWLEDGMENT

First of all, I would like to thank my project advisor, Assoc. Prof. Dr. Samet Uslu for giving me this chance to go through enriching and studying my thesis. This thesis would not have happened without his assistance. I'd want to take this chance to thank my adviser for his helpful advice and ideas during my thesis.

I would like also to thank my family for believing in me and specially my parents, and finally I would like to thank the mechanical faculty at the university. I am thankful to Karabük University for providing the necessary equipment and simulation software to complete the current work.

CONTENTS

Page

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

SYMBOLS AND ABBREVITIONS INDEX

SYMBOLS

K	: Kelvin
°C	: Celsius
m	: Meter
Kg/h	: kilogram per hour
$m.\frac{}{s}$	: meter per second
[Pa]	: Pascal
kW	: Kilo watt
g/h	: Gramm per hour
kg/m^3	: Kilogram per meter cube

ABBREVITIONS

CO : carbon monoxide

CO_2 : carbon dioxide

C : Carbon

H : hydrogen

HCCI : Homogeneous charge compression ignition

IMEP : Indicated Mean Effective Pressure

LPG : liquefied petroleum gas

SI : spark ignition engine

CI : compression ignition engine

NO_x : Nitrogen oxides

HC : Hydro carbon

HEF : Hydrous ethanol fuel

CFPP : cold filter plugging point

WCO : waste cooking oil

SFC : specific fuel consumption

w/w : Water weight

H_2O : Water

BTE : Brake thermal efficiency

CN : Cetan number

rpm : Round per minute

EGT : Exhaust gas temperature

η g : Efficiency of the generator numerous

NOI : Number of injectors

IDC : Injector duty cycle.

WOT : Wide open throttle

ETE : Engine thermal effective

ET : Engine torque

PART 1

INTRODUCTION

With the development of technology and after doing research and tests and reading several theses and scientific articles, we were able to understand a number of factors that lead civilizations to hire scientists in order to develop a new energy source owing to the extensive usage of petroleum resources and because of this increasing of demand on this petroleum derivatives their price is increasing which are also thought to be nearly exhausted.

The need for these derivatives is certainly rising as result of the population's growth and the expansion of factories, and as a result, there will be a larger need for transportation, which will result in more traffic, increased emissions, and increased strain on these derivatives in other hand the most emission is coming from the noxious exhaust fumes thrower from the petroleum-based vehicle engine, as a result, nations and societies have turned to its scientists to discover new renewable energy sources for them with minimal emissions, they will be an effective substitute for oil derivatives the nearest chemical compounds with characteristics comparable to those of oil were then sought for by scientists, and among these derivatives biofuels and biodiesel especially fusel, biogas, ethyl-alcohol(ethanol), methyl-alcohol, liquefied petroleum gas (LPG) [1].

There are several alternative fuels available for conventional engines. Since carbon dioxide (CO_2) and the other emissions are the main cause of decrease our reliance on fossil fuels, biofuels are the best choice due to the less emissions compared to the traditional one. There are several alternative fuels available for conventional engines. Since CO_2 and the other emissions are the main cause of decrease our reliance on fossil fuels, biofuels are intended to minimize these emissions.

For instance, the most popular alternative gasoline SI engine fuel for light commercial vehicles is methanol and ethanol, which is a first-generation biofuel generated from agricultural products like maize. Biobutanol or (n-butanol) is considered one of second-generation also these biofuels can made from non-edible plants or from plant parts that ejected like wastes [2]. Biofuels can be used as a fuel for internal combustion engines because it has similar physical properties to gasoline. compared to ethanol, n-butanol has a higher energy density, is less corrosive, and is much less contaminated with water [3,4]. Therefore, existing fuel supply infrastructure can be used for n-butanol. additionally, n-butanol is more compatible with existing engines when blended with gasoline as a potential replacement for ethanol [5]. On the other hand, traditional benzene engines are less efficient than diesel engines therefore, in order to meet his CO_2 emission targets for future passenger cars, the fuel economy of gasoline engines needs to be improved in other side to improve heating efficiencies of gasoline engines [6].

to improve the heating efficiencies the researchers prefer to upgrade in the engines by using the homogeneous charge compression ignition HCCI with the SI, and this is a modern combustion in gasoline engines can be achieved by increasing the compression ratio [7]. And heating the intake air [8,9]. That lead to increase in efficiency however, residual gas trapping is one of the most effective ways to increase cylinder temperature, reducing the need for increased intake air temperature in passenger car gasoline engines [10,11]. And that is done by closing the exhaust valves before the top dead center (TDC) to keep a little bit of hot gas inside the piston and now after upgrading engine it will be easiest to use the new generation of biofuels and in this case the fusel oil.

As known the ethanol is one of the best blending products using in the SI engine but this component cannot be alternative fuel by 100% so to get a product, we go to make some research about the nearest product and has more properties lead to make him a good biofuel and one of the best alternative fuels in SI engine so we go with the fusel depending on the other researchers that are interested in fusel oil because it has characteristics similar to ethanol. After fermentation process the product obtained is the fusel oil, which is an oxygenated compound with a high research octane number and this number is equal to 105 like the ethanol octane number [12,13]. This makes it look like a suitable alternative fuel, especially for spark-ignition engines.

1.1. HISTORICAL BAKGROUND

1.1.1. History of fusel oil

When a grain spirit with a low alcohol concentration separated into a second phase in extremely cold weather, Scheele described the second phase as being "nauseous-smelling" and white in appearance. Despite the fact that the word "fusel" was not utilized in his explanation, this is arguably the oldest instance of fusel oil to be documented[14]. He said that when this substance was added to good brandy, the odor of common grain spirit was imparted on it, giving the brandy a disagreeable aroma. The distillate of fermented potatoes was used to create the fusel sample that Dumas [15] examined.

Dumas produced a sample that boiling at temperature 130° to 132°C with the empirical formula C5H120 after many fractional distillations and water washings. The discovery that Dumas' chemical was "hydrate of amylene" or amyl alcohol. More potent member of the homologous series that also contains methanol and ethanol, was made in 1839 by Cahours.Cahours' identification was verified by Dumas and Stas (1840). J. B. Biot is credited by Pasteur (1855) with discovering the optical activity of fusel oil boiling between 130°C and 132°C. Since the optical activity of fusel oils from various sources differed, Pasteur came to the conclusion that at least two chemicals one optically active and the other inactive were present. As a result, fusel oils with variable optical activities simply reflect the proportions of the two substances. The results of several researchers' investigations were used to determine the structure of the amyl alcohols found in fusel oils. Isoamyl (3-methyl-l-butanol) and active amyl (2-methyl-l-butanol) were identified as the fusel oil alcohols by Pedler (1868), Erlenmeyer and Hell (1871), and Kramer and Pinner (1870). Le Be1 created techniques in 1873 and 1876 for extracting the crude fusel oils' active amyl fractions, which were comparatively pure. He also researched the procedures for creating similar chemicals from active amyl alcohol. A little earlier, in 1852, Wurtz developed an interest in the alcoholic compounds found in fusel oils that had boiling points in between those of ethyl alcohol and the amyl alcohols. He produced many compounds from isobutyl alcohol after isolating it. An additional primary alcohol, known today as the main ingredients of the combination, was separated from the fusel oil mixture by Chancel in 1853, bringing the total number of primary alcohols to four strokes. Fig 1.1 shows a schematic of a fusel oil experiment in the past.

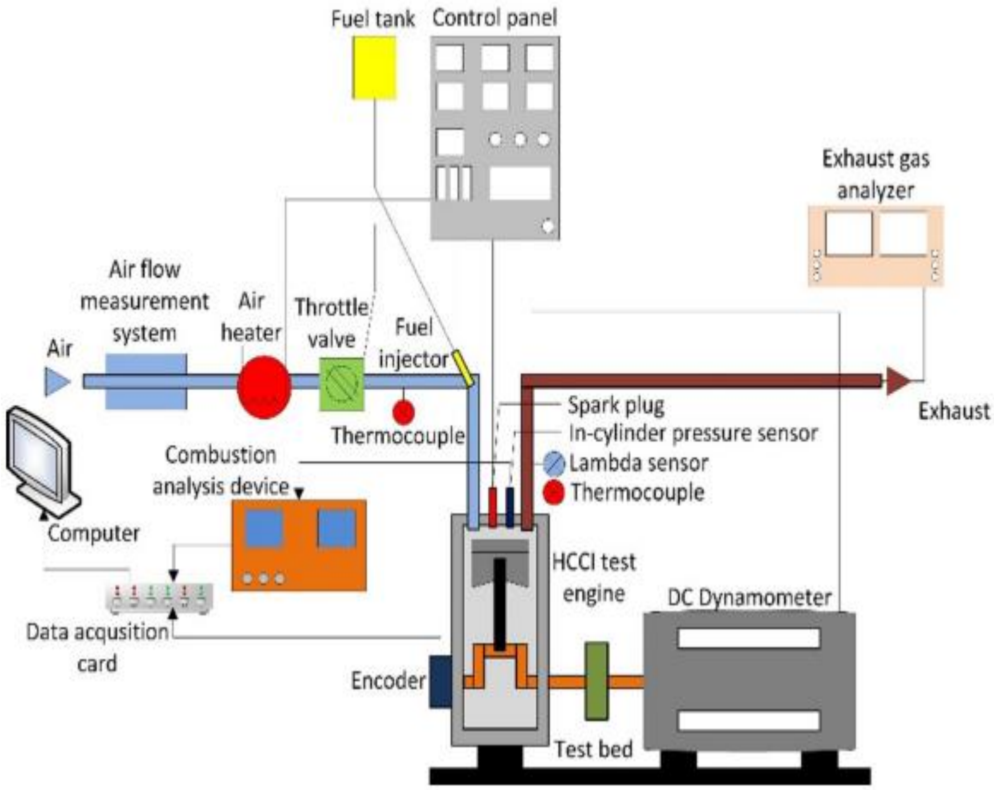

Figure 1.1. Schematic of fusel oil experiment [16].

1.1.2. History of gasoline

The gasoline is a volatile, combustible combination of liquid hydrocarbons (HC), gasoline is largely produced through the refining of petroleum. Petrol and benzene are two terms used to describe gasoline outside of North America. In the past, four occasions had a substantial impact on the production of gasoline. The first was when Edwin l. drake drilled the country's first oil well in 1859, close to Titusville, Pennsylvania. The Pennsylvania oil boom, the first significant event in the American oil business, was started by the well, which wasn't the first in the world and was just 70 feet deep.

In the 19th century, distillates of coal tar and lighter fractions of crude oil distillation were used as automotive fuels. The first gasoline pump was created on September 5, 1885, by Sylvanus Bowser in Fort Wayne, Indiana, and given to Jake Gumper in the same city. The first gasoline-powered tractor was developed on September 6, 1892, by John Froehlich in Iowa. It powered with a single-cylinder vertical gasoline engine positioned on rafters and include tank with plunger carrying one barrel of fuel. Froehlich founded the Waterloo Gasoline Tractor Engine Company, which the John Deere Plow Company eventually purchased.

The first US patent for an internal combustion car was granted to Charles Duryea of Springfield, Massachusetts, on June 11, 1895. As a straightforward byproduct of petroleum distillation, gasoline was being produced by oil firms by the early 20th century. Laws against storing gasoline on private property were in effect throughout the 1920s. A cracking method for turning oil into gasoline was invented by William Miriam Burton on January 7, 1913.

On January 1, 1918, the first gasoline pipeline in the US started delivering fuel 40 miles from Salt Creek to Casper, Wyoming, over a three-inch pipe. Charles Kettering made kerosene-compatible modifications to internal combustion engines. The cylinder head and pistons were broken, nevertheless, by a kerosene-powered engine that banged. Thomas Midgley Jr. identified the origin of the thumping as the drops of kerosene evaporating after burning. Midgley conducted research on anti-knock chemicals, leading to the addition of tetraethyl lead to gasoline.

Ethyl gasoline was sold for the first time in US history on February 2, 1923. Almere McDuffie created the first commercially successful catalytic cracking technology for the petroleum industry in Dayton, Ohio, in 1923. This process had the ability to double or even treble the amount of benzene generated from crude oil using then-current conventional distillation techniques. Gasoline ranged in octane from 40 to 60 by the mid-1920s. The petroleum sector had abandoned kerosene by the 1930s. The catalytic breaking of low-grade fuel into high test gasoline was created in 1937 by Eugène Houdry. Compression ratios rose and fuels with higher octane levels were developed in the 1950s. As the amount of lead rose, new refining techniques (hydrocracking) started. The first commercially viable zeolite catalyst for the catalytic breaking of petroleum into lighter products like gasoline was invented by Charles Planck and Edward Rosinski in 1960 and was granted a US patent. Fuels without lead were first made available in the 1970s. Lead was eradicated from 1970 to 1990, due to the new Act of the Clean Air. The way to make gasoline was changed in 1990 with the goal of eradicating pollution.

1.2. SIGNIFICANCE OF THE RESULTS

Trucks and all other vehicles with SI engines use gasoline fuel extensively. It provides several performance, efficiency, and safety advantages. Additionally, gasoline fuel is crucial for many uses, but it is depleting with time. Finding an alternative fuel to replace the conventional and outdated gasoline and evaluating its performance inside the engine as well as whether it will cause any modifications or problems with the engine's performance as well as determining whether it can be used entirely or in combination inside the engine cylinder became important study topics in recent years.

1.3. ASSUMPTIONS

- Using the fusel oil with 100% inside the SI engine with stable operation with minimum emissions.
- Upgrade the characteristic of fusel oil to be better than old fusel with high concentration of H_2O, also upgrades the properties of the fusel to be used in both engine types.
- Decrease the emission emitted from the automobile engine due to the complete combustion that will decrease the HC and the CO emissions.
- Save the environment because emissions have a very bad impact on the global warming.

1.4. PROBLEM STATEMENT

Negative effects like the following might arise from using gasoline fuel in engines:

- Low engine performance.
- Increase of emissions.
- high price of gasoline with rising of consumption.

1.5. LIMITATIONS

Experiment during this study were directed by using two cylinders, with the same specific measurement, same dimensions are used for the both side of fuel. Each cylinder is for a specific type of fuel. The first cylinder is 100% pure gasoline and the second is 100% fusel oil. Blends from both type of fuels are also used in this experiment. The tests took place using CFD two dimensions Ansys software with specific properties and boundary conditions are selected.

1.6. RESEARCH QUESTIONS

- What is the barrier that avoid the using of fusel oil like an alternative fuel by 100 percent?
- What is the advantage and disadvantage of the water in the fusel oil?
- What is the best engine for the fusel oil?
- What is the advantage and disadvantage of fusel-oil?
- What is the component of fusel oil?
- What the effect of ethanol butanol methanol on the fusel oil?

PART 2

LITERATURE REVIEW

Solmaz [17] studied at 2500 rpm and four different engine loads, the performance, emissions, and combustion properties of fusel oil in a SI engine were examined. period taken for thermal convection, engine torque, and a crank angle corresponding to 50% of the total mass fraction of combustion In addition, the use of fusel oil increased CO and HC emissions by up to range between 20 and 25 percent simultaneously due to The poor combustion performance of fusel oil also this poor combustion reduced NO_x emissions by approximately 30 to 32 percent .by the way This study studied the effects of fusel oils on the performance of the SI emissions, and combustion behavior. For that the F50 (50% gasoline + 50% fusel oil) and F100 (totally fusel oil) were tested in one cylinder 4-stroke research engine with injection. The experiment was performed at an engine speed of, Cylinder pressure, releasing heat ratio, indicated mean effective pressure IMEP, engine torque, Brake specific fuel consumption (BSFC), CO, HC, and NO_x emissions were investigated. They resulted that the use of fusel oil in the IMEP and heat release rate decreased when fusel oil was used. Additionally, the performance and emissions of the fusel oil must be dehydrated prior to use in internal combustion engines. Additionally, ignition timing optimization should be performed for optimal work. Therefore, the combustion and performance characteristics of fusel oil can be improved.

Calam et al. [18] studied the experimentally and investigated the effect of unleaded gasoline and fusel oil blends on engine performance and emissions in SI engines. Testing was conducted under full load conditions using a 4-stroke, single cylinder, fuel injected SI engine. Set the ignition timing to the maximum engine torque position. Tests were run at various engine speeds using fusel oil and gasoline mixtures resulted that the high latent heat of vaporization of the fuel blend results in lower end-of-burn temperatures and lower NO_x emissions compared to unleaded gasoline.

Ipci et al. [19] conducted a thorough analysis of the possible use of fusel oil as a clean and renewable energy source in internal combustion engines has several intermediate qualities and various types of combustion. They discovered that crude fusel oils contain around 5-20% water by volume, which reduced engine torque and increased brake fuel consumption on both compression ignition (CI) and SI engines due to the fusel oil's poor calorific value. As a result, a vehicle with the same amount of storage travels less distance overall. Due to the presence of water, using fusel oil decreases NO_x emissions on both SI and CI engines, making it more compatible with spark engines. As opposed to that it's increase the CO emission.

Simsek et al. [20] examined the effect on engine performance and emissions of using a blend of unleaded gasoline and improved fusel oil. A four-stroke, single-cylinder, and SI engine was used for the experiment. The tests were run at constant speed and under varying loads. Test fuels were blended with fusel oils in increasing proportions from 10% to 50%. Engine performance and emissions were measured under each load. During testing, it was observed that engine torque and specific fuel consumption increased as the amount of fusel oil in the mixture increased. Increasing the amount of fusel oil in the blend reduces NO_x, CO and HC emissions, they result that Increasing in engine torque with 10 to 30 percent of blending fuel capability of using the fusel oil like fuel in the spark engine.

Awad et al. [21] studied how different fusel oil-gasoline mixtures affect a SI engine's performance and combustion characteristics. As a result, they conclude that the fusel oil's water content was reduced, which improved the fuel blend's combustion and performance characteristics and led to more stable engine running. The engine torque and force raise while the using of fusel oil as a mixture with the usage of gasoline. While using fusel fuel the NO_x reduce but on the side the CO and HC rise.

Yilmaz [22] study the fused oil and pure diesel were combined in certain ratios. At various engine loads and speeds, the test fuel's effects on combustion, engine performance, and exhaust emissions were thoroughly examined. A single-zone combustion model and the first thermodynamic model were both utilized to determine the rate of heat release. Compression traces for F5 and F10 were acquired in comparison to diesel under identical full load operating circumstances. A specific fuel consumption calculation has been made, as a result the cylinder pressure value and the increased fuel oil consumption better, lower latent heat of evaporation than pure diesel Gas temperature dropped because of the blended fuel's low calorific values and water content, which also led to a decrease in NO_x emissions. Due to the high oxygen concentration in the combustion chamber, the smoke emissions were decreased.

Awad et al. [23] studied morale statistic from the statistical analysis of the fuel oil portion in the mixture was employed in this investigation. In addition, a SI engine was used to evaluate the fuel in a comparative investigation of the impact of fuel characteristics on combustion at various open throttle positions (load) and 4500 rpm. They result that after the fuel oil's moisture content was reduced by 13% and 7%, respectively, the heating value and carbon (C) content were dramatically increased. Viscosity and density increased by removing moisture content, brake strength and BSFC are enhanced. Better engine combustion results from lower moisture content.

Wang et al. [24] examined the novel biodiesel manufacturing method employing enzymatic synthesis, fusel alcohol, and fatty acid esters in a solvent-free system has been developed. This technique has significantly improved the low temperature performance of biodiesel. The ideal conditions for the enzymatic reaction between fusel alcohol and waste cooking oil (WCO) esters were identified as immobilized lipase 14% (w/w), total water content 5% (w/w), 40 C, three-times daily feeding, and 200 rpm shaking. In the best circumstances, the ester yield was 90.4%. The fusel alcohol esters' cold filter plugging point (CFPP) was 11 C, which is 16 C lower than the methyl esters of the WCO. This study looked at the CFPP outcomes and the green enzymatic synthesis process. As a result, the novel biodiesel manufacturing method, which involved the enzymatic synthesis of fusel alcohol and fatty acid esters in a solvent-free environment, significantly enhanced the low temperature performance of the fuel. The novel biodiesel manufacturing method, which involved the enzymatic synthesis of fusel alcohol and fatty acid esters in a solvent-free environment, significantly enhanced the low temperature performance of the fuel.

Awad et al. [25] studied the effects of fusel oil blending with gasoline on fuel combustion have been experimentally explored to assess engine performance enhancement and exhaust emission. Test fuel for the four-cylinder SI engine included F10, F20 (10% and 20% by volume of fusel oil), and pure gasoline as a baseline fuel. Engine speed was increased while maintaining a constant throttle valve setting of 45%. As result, under conditions of a rich air-fuel mixture, the blend fuel's increased octane number and oxygen content boost fuel mixture combustion and engine performance. Looking at it from a different angle, more research on the functional safety of electrical and/or electronic systems.

Mayer et al. [26] studied how fusel oil's impact on Hydrous ethanol fuel (HEF) distillation might be measured. In light of the fact that the higher alcohol concentrations in the input stream were underestimated, their impact on the distillation process should be less than what was shown in the studies. Based on the data, it was determined that small-scale gasoline ethanol production does not require the removal of fusel oil during the distillation process. Eliminating this procedure might result in cheaper operational and investment expense.

Omar et al. Analyzed the 10 and 20% blending fusel oil gasoline before and after extraction the H_2O continent and used in the internal combustion and they resulted that the fusel oil mass fraction will increase after the elimination of the H_2O more than that the time of combustion operation will be shorter also this elimination to an increasing on the torque pression and engine heating coefficient but in other hand the number of C increase that lead to more CO emission so the conclusion from the study of Omar is that the fusel oil without H_2O are best than the fusel oil before extracting H2O and this result is obvious in the Fig 2.1.

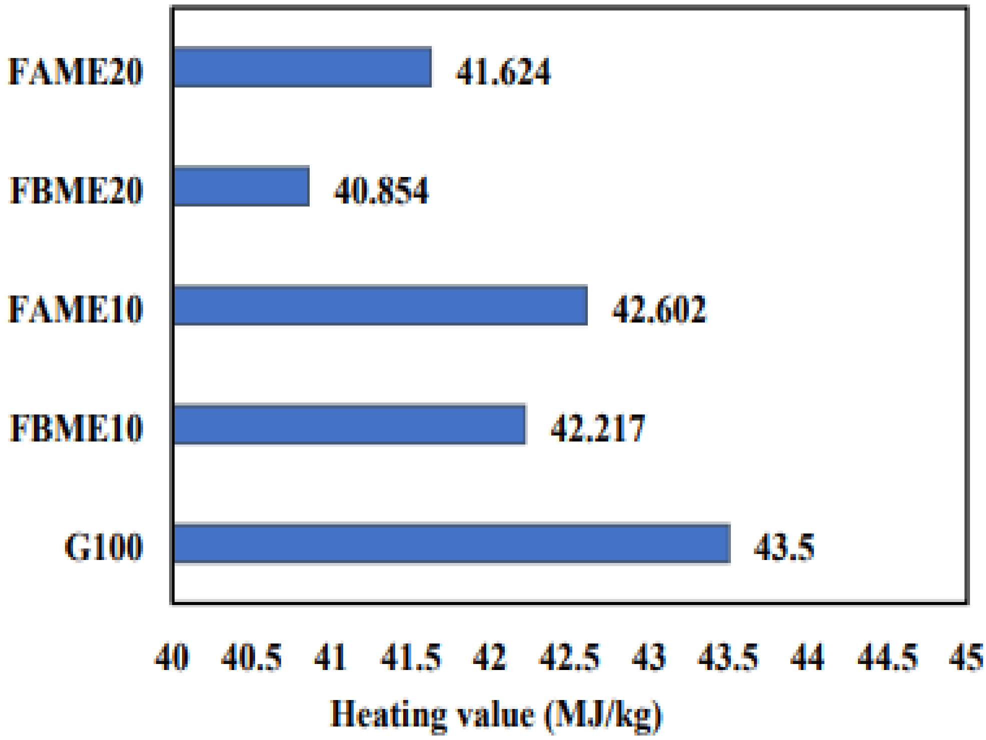

Figure 2.1. Heating value with blending fusel gasoline with/without water[27].

PART 3

THEORETICAL BACKGROUND

3.1. DEFINITION

Fusel oil is one of the most popular types of biofuels used in the world and it's also the most familiar type of second partition from alcohol. The fusel is a chemical product created by transesterification and it can be used in the both type of engine the gasoline and the diesel one. Most of important fusel properties are shown in Table 3.1.

Table 3.1. Resume of fusel properties part 1 [26].

Reference	Sources	I-Propanol	Isobutyl alcohol	Active amyl alcohol	Isoamyl alcohol
Baraud (1961)	Apples	---	2.6	18.2	79.2
	Molasses	15.0	15.7	28.3	41.0
	Barley	7.6	33.5	18.2	40.7
	Sulfite liquor	15.4	37.5	8.5	38.6
Ikeda (1956)	Thompson seedless	0.8	7.4	16.7	75.1
	Emperor	5.6	10.8	15.4	68.2
	Muscat Alexandria	1.2	5.5	16.0	77.3
	Mixed	4.9	21.3	11.1	62.7
Webb Kepner (1961)	Muscat raisin	0.7	4.9	19.3	75.1
	Zinfandel	2.3	15.6	16.8	65.3

Also, the fusel oil is one of the, higher alcohols and specifically the amyl alcohol or congeners and this type of alcohols is done by using a specific operation called distilling fermented carbohydrates, all agriculture products that contain sugar like potatoes, apple, beets and more products can be fermented produce fusel oil and we can see the properties of this type of fusel oil in and Table 3.2 below.

Table 3.2. Resume of fusel properties part 2 [26].

Reference	Sources	I-Propanol	Isobutyl alcohol	Active amyl alcohol	Isoamyl alcohol
Kumamoto (1932)	Kaoliang Molasses Sweet potato	6.8 2.8 0	0.7 0 0	19.3 19.1 86.1	73.2 78.1 13.9
Ogata (1953)	Sweet potato	8.4	6.8	46.2	38.6
Enders (1938)	Fermented wood sugar	0.3	21.0	34.2	44.5
Boswell and Gooderham (1912)	Beet molasses	0	8	56	36
Hellstrom (1943)	Sulfite liquor	2	23	13	62

3.2. OBJECTIVE

- Use a new corporation of fusel oil by 100 percent in the engine with stable functionality
- Define the most compatible engine for this type of new fusel oil
- Decreasing the emission produced from the engine combustion reaction
- Proof the capability of using the fusel oil with no effect
- Get the best component to make the best fusel oil.

3.3. STATEMENT SOLUTION

The specialized energy is One of the key characteristics of several alcohol biofuel, like ethanol and fusel oil [27]. Biofuels can have a start combustion process issues because of their high humidity. Engine performance is impacted by the high concentration of H2O and this content has negative effects on combustion efficiency [18].

According to Safieddin et al. [19] the longer flame generation and propagation times of fusel oil were caused by its increased moisture content, which reduced the thermal effectiveness of the brakes. Additionally, he claimed that using pure fuel oil or 50% fuel oil reduced the SI engine's torque by an average of 6% and 2%, respectively with the BSFC increasing.

According to Awad et al. [27] the engine strength and energy dissipation for F20 (20% fusel - 80% gasoline) were somewhat lower than for pure fuel, but the fusel used in this operation was bigger so depending on Calam et al. [18] we can deduce that the high level of moisture content influenced combustion time, which lengthened both the time it took for the first flame to form and the time it took for it to spread. Additionally, the greatest rate of heat release (ROHR) decreased almost linearly as the fuel test's moisture content increased.

According to Schifter et al. [28] the delayed engine combustion duration caused a 5% reduction in total engine efficiency when the moisture content increased from 20% to 40% per volume. The pace of pressure rise is negatively impacted by moisture content, and low moisture concentrations in the fuel also seem to have little influence on engine combustion. Additionally, the maximum in-cylinder pressure and a slowed rate of heat escape because of the slower flame speed are predicted effects of introducing moisture in SI engines at full engine load.

Lanzanova [29] Reported that raising the moisture level of ethanol improves its fuel consumption by adding more moisture to the gasoline, the cylinder and exhaust temperatures are lowered. So, as shown the fusel oil have a highest percentage of moisture so the combustion will be difficult when we use it alone, so to use the fusel like an alternative fuel we need to extract the moisture from fusel that lead this fusel to be good like new fuel also extracting humidity and water from fusel upgrade the properties of itself, in Obed et al studies, there is no question that among the several forms of alcohol, ethanol includes the highest proportion of conditions of use in passenger automobiles. The primary factors influencing its widespread utilization are its non-toxic structure and large bio-based manufacturing capability. Research octane number, high flame spread velocity, low volatility emissions, safe transportation and storage, high hydrogen and C ratio it is also a dependable fuel as a result of the qualities, particularly for SI engines [30,31].

Fusel oil contains ethanol, so the researchers are interested in it. A byproduct of fermentation, fusel oil has an oxygenated chemical structure and has a research octane number higher than 105, similar to that of ethanol [32,33]. As a result, it seems like a good alternative fuel, especially for SI in other side the diesel engine takes more time to make ignition due to the time to compress the air to make the good ambient for increasing the temperature of air which lead to ignition so depending on this data the spark engine is best for fusel oil. Ethanol is the most product used in blending with gasoline and diesel due to the higher number of octanes that is the main reason to use it, the higher number of octane lead to mace high temperature for the combustion operation from other side the highest level of octane presence in the fuel lead to minimize the time of ignition and make the internal combustion more complete by the way this increasing minimizes also the CO emission.

The SI engine and the CI engine is the most popular type of engine used in the world and as known the first one is used for the gasoline and the other one is used for diesel and they have just a little difference on their work and this difference is the method of ignition of each one in the spark engine the engine depend on the spark to start the ignition that lead to start the combustion operation but in the diesel engine the ignition is began depending on the high pressure that heat the diesel and the air together for high level that make an auto ignition due to the chemical formula of the fuel so in this research the spark engine is the best engine for the fusel oil and that result depend on the higher number of octane in the fusel oil that make the compression ignition is very hard due to the high pressure resistance the high humidity that decrease the temperature of the air and the mixture of fusel with the gasoline or if the fusel is alone the temperature will be less than mixture due to the high quantities of water inside the fusel oil and also inside the chemical formula of fusel that make the auto ignition more difficult on the other side the SI engine start with high current spark that make the beginning of combustion more easy because the presence of high quantities of moisture like every biofuel.

The fusel oil has many advantages and many disadvantage that confirm and reject the usage of this new fuel in the cars and other machines, this advantage and disadvantage are describe briefly. The fusel oil has lot of advantage that make from this product a most familiar type of bio fuel in the world. The fusel oil decreases the NOx and the CO_2 from the ambient in other hand the fusel oil is produced from the ejected agriculture product that mean this type of alternative fuel is coming from trash add to that the fusel oil decrease the temp of gas ejected from the exhaust by the way protect the ozone from the large amount of gas produced from the engine cars. in other hand this biofuel cannot be a completely alternative fuel due to the high BSFC, also the decreasing in temperature leaded from using fusel oil right it decreases the NOx and CO_2, but this decreasing in temperature increases the CO emission due the incomplete combustion also this incomplete combustion increases the HC emission. other advantage and disadvantage shown in Table 3.3

Table 3.3. Advantage and disadvantage of fusel

Advantage	Disadvantage
Easy to be destroy without natural effect	Miscible in water
Produced from trash	Cannot be stored for long time
Decrease the global warming	Awful smell
Decrease the demand on the petroleum	Expensive
It can be extinguished quickly in case of fire	Long producing process

3.4. GOAL OF USING NEW FUSEL OIL

The new fusel oil is same like traditional fusel with different modification in the water where is the water is less in this new type and the goal from using new generation of fusel oil in the internal combustion engine simulation is leaded for many reasons and from this reason The effect of fusel oil on human health long term exposure can irritate the upper respiratory tract, throat, and nose. Cause skin irritation and fat defatting. Dizziness, headaches, or nausea are symptoms of ingestion [34]. The lowest ejection of H_2O of new corporation of fusel oil based on fusel oil Due to the extraction of moisture and some particles of H_2O from the fusel the emission of H_2O decreases in the end of the combustion reaction adding new advantage for the fusel upgrade the combustion reaction, also decrease the time needed for ignition and make it longer with high power that will lead to give more energy for more time and decrease the emission with briefly quantities.

3.5. GLOBAL FUSEL OIL PRODUCTION

Alcohol-based fuels have become common renewable fuels in recent years, and examples include ethanol butanol and methanol [35,36]. Due to its Sustainability, better power density, and lower emissions when compared to methanol fuel, ethanol is currently the most well-established alternatives to fossil-fuels in USA, Brazil, and even South Africa [37,38]

Currently, bioethanol contributes most to green transportation, accounting for around 3% of global energy consumption in the transportation sector. 2019 had a 1.85 percent rise in global ethanol output over 2018 [39]. With around 85% of the world's production, the United States and Brazil are the two biggest producers of ethanol. However, each of these two nations uses a completely distinct fermentation technique [30].

Table 3.4 shows the features of bioethanol production in Brazil and the United States. To increase the required usage of oxygenates fuel additive by 2020, a number of nations have announced an ethanol-gasoline blend. An initiative to promote biomass-based ethanol as a renewable fuel that is blended with gasoline at a 10% ratio, for instance, was launched by the Chinese government [40]. Table 3.4. demonstrates that different feed stocks are fermented to make bioethanol in USA nations and specifically in Brazil and north America.

Table 3.4. Fusel oil production [19]

Ethanol characteristics	Brazil	USA
fermentation process	Recycling of the yeast	Without yeast recycling
yield of fermentation	92%	90%
time of process	12 h	60 h
yeast concentration	12%	4%
bioethanol concentration	12% (v/v)	18% (v/v)
suspension of solid particles	< 1%	< 30%

The quantity of fusel oil produced as a byproduct has significantly increased as the pace of ethanol production has increased, with consequent environmental effects one ton of raw sugar made from sugarcane/sugar beet molasses is thought to produce around 523.8 L of ethanol [41]. Additionally, the distillation of one ton of ethyl alcohol would yield 6.4 L of fusel oil [27].

The overall potential for fusel oil is determined by the aforementioned conversion factor. The expected global output is 550 million liters, which includes 347 million liters of gasoline and 325 million liters of diesel fuel. Table 3.5. displays global fusel oil output by nation from 2009 to 2019.

Table 3.5. Resume of fusel properties [19]

Country	Feedstock's	Target Renewable	Ref.
United States	Corn	136 BL of biofuels by 2022	[42]
Brazil	Sugarcane	20% blending ratio of bioethanol with gasoline	[43]
European Union	Wheat Sugar beets, other grains	10% renewable energy in transport by 2020	[42]
Canada	Corn wheat, straw	5% ethanol	[44]
China	Corn, cassava, wheat, sweet sorghum	10% ethanol-blended gasoline fuels by 2020	[40]
India	Molasses, sugarcane	20% ethanol blending	[45]
Indonesia	Cassava, sugarcane,	25% blending of bioethanol in gasoline by late 2025	[46]
Thailand	Sugarcane molasses, cassava	30% share in total energy consumption by 2036	[47]

Calculations show that the spatial concentration of fusel oil production is quite high. More than half of the world's fusel oil is produced in the United States between 50&55% of the production with Brazil coming in second (29-30%). In 19 in the 20 century, the European Union's fusel oil output remained constant at 27 million liters. From 2009 to 2019, fusel oil production increased by 43%. In same time China produced over 17 million liters of fusel oil, placing it fourth globally. For many years, gasoline additives have included methyl tert-butyl ether (MTBE). the amount of MTBE released has significantly increased due to the increasing usage of biofuels. Because it is a hazardous chemical molecule, MTBE has negative long-term effects on the environment [48]. The phase-out of MTBE in some countries is anticipated to enhance the use of fusel oil as an oxygenate addition to solve this problem. Internal combustion engine use of fusel oil is a viable approach to diversify and partially replace fossil fusel in existing CI and SI engines without engine modification. The majority of the world's fusel oil is consumed in countries with requirements for ethanol blends consequently, fusel oil can significantly lessen dependency on those nations, MTBE [48].

3.6. CHARACTERISTICS OF FUSEL OIL COMPONENT

Chastain et al [15] mentioned that fractional distillation and repeated water washings produced fusel oil that boiled from 130 to 145 degrees "using the empirical formula for amyl alcohol, to 132°C. By fractionally crystallizing the barium salts of their acid esters of sulfuric acid. In 1855 Pasteur separated active amyl alcohol from isoamyl alcohol, and he stated that the boiling point of active amyl alcohol was between 127 and 132 °C under atmospheric pressure. The boiling point of inert isoamyl alcohol was observed to be 129°C.

According to Marckwald and McKenzie [49] active amyl alcohol boils around 128 degrees Celsius. According to more contemporary research by Terry in 1960, the boiling points of active amyl alcohol and isoamyl alcohol, respectively, are 128.5°C and 132.0°C, respectively, at atmospheric pressure.

N-propyl alcohol is stated by Timmermans as boiling at 97.2°C, while isobutyl alcohol boils at 108.0°C. These are the other two main alcohols in fusel oil. The formation of water-alcohol azeotropes with comparable boiling temperatures makes it more challenging to separate the four main alcohols from a crude fusel oil by fractional distillation than the characteristics of the pure compounds would suggest. The alcohol-water binary was first observed by Horsley in 1952. azeotropes of importance in fusel oil distillation Table 3.6.

Table 3.6. H_2O azeotropes of fusel oil component [14].

	Azeotrope	
Alcohol	**B.P., °C**	**Wt. % Water**
Ethyl	78.17	4.0
Isopropyl	80.3	12.6
n-Propyl	87	28.3
Sec-Butyl	87.5	27.3
Isobutyl	89.8	33
n-Butyl	92.7	42.5
Isoamyl	95.2	49.6
n-Hexyl	97.8	75

The characteristics of the active amyl alcohol-water azeotrope are unknown, although it is believed that they are comparable to those of the isoamyl alcohol-water system. Horsley does not include any ternary water azeotropes with two distinct alcohols in-depth research on azeotropic systems conducted by Bukala et al [50]. In 1961 may be useful for recovering higher alcohols from crude fusel oils derived from fermented sulfite liquors from paper and pulp mills. A technique was created to separate the higher aliphatic alcohols in anhydrous state from the crude fusel oil using the benzene-ethanol azeotrope. It is impossible to separate active from isoamyl alcohol.

Terry looked on the development of binary azeotropes involving either isoamyl alcohol or active amyl alcohol and other compounds in an effort to create a system that would enable quick separation of the two amyl alcohols by fractional distillation. The approach failed because, in every example examined, the boiling points of the azeotropes were closer than those of the pure alcohol’s Fig 3.1.

System	B.P. of component (°C.)	Binary azeotropic mixtures		
		B.P. (760 mm.) (°C.)	Alcohol (wt. %)	Alcohol (mole %)
n-Octane	126			
Active amyl alcohol	128.5	117.0	34	40
Isoamyl alcohol	132.0	117.0	30	36
Chlorobenzene	132			
Active amyl alcohol		124.4	43	49
Isoamyl alcohol		123.9	38	44
Ethylbenzene	136			
Active amyl alcohol		125.0	53	57
Isoamyl alcohol		125.7	49	53
Toluene	111			
Active amyl alcohol		109.9	12	12
Isoamyl alcohol		109.7	10	10
2,2,5-Trimethylhexane	124			
Active amyl alcohol		115.5	29	37
Isoamyl alcohol		116.0	26	34
o-Fluorotoluene	114			
Active amyl alcohol		112.0	16	19
Isoamyl alcohol		112.1	14	17
Diisopropyl ketone	125			
Active amyl alcohol		124.1	21	26
Isoamyl alcohol		124.5	8	10
2-Picoline	129			
Active amyl alcohol		132.8	49	50
Isoamyl alcohol		132.8	61	62
2,6-Dimethylpiperidine	128			
Active amyl alcohol		130.7	54	60
Isoamyl alcohol		132.6	76	80
1,2-Dimethylpiperidine	128			
Active amyl alcohol		130.3	Undetermined	—
Isoamyl alcohol		132.5	81	85

Figure 3.1. Azeotropes of alcohol [14].

Fig .3.2 provides information about the densities and refractive indices of the alcohols of interest in fusel oils. Marckwald and McKenzie[49] measured the optical rotational dispersion of pure active amyl alcohol (rotation of plane-polarized light as a function of wavelength). The values achieved by others are listed by Timmermans [51].

Alcohol	Density (gm./ml., 20°C.)	Refractive index (D, 20°C.)
Ethyl	0.7893	1.3614
Isopropyl	0.7851	1.3775 He y
n-Propyl	0.8035	$1.3840_{23.6°}$
sec-Butyl	$4.8109_{15°}$	$1.3995_{15°}$
Isobutyl	0.8020	1.3959
n-Butyl	0.8096	$1.3970_{25°}$
Isoamyl	$0.8059_{25°}$	$1.4048_{25°}$
Active amyl	$0.8154_{25°}$	$1.4088_{25°}$
n-Hexyl	$0.8225_{15°}$	—

Figure 3.2. Densities of fusel oil [14].

Numerous studies have been conducted on the physicochemical characteristics of isoamyl and active amyl alcohol combinations. The density-composition plot was linear, according to Hafslund and Lovell [52] but Ikeda et al. [53] discovered in 1956 departures from linearity, notably in mixes with more than 70% active amyl alcohol concentration. For combinations high in active amyl alcohol, the refractive index-composition curve was also observed to depart from linearity Ikeda et al. Marckwald and McKenzie found a linear link between optical rotation and the chemical makeup of the two alcohols in 1901 [54].

Using eleven distinct mixes, Hafslund and Lovell and Ikeda et al. [52] were likewise able to fit their data for particular rotation as a function of composition to a straight line. These results have shown to be very helpful for quick assessments of mixes of the two alcohols, such as while monitoring the distillation process. Fig 3.3. displays the curves for density, optical rotation, and refractive index as a function of the active amyl-isoamyl mixture's chemical make-up [53,54].

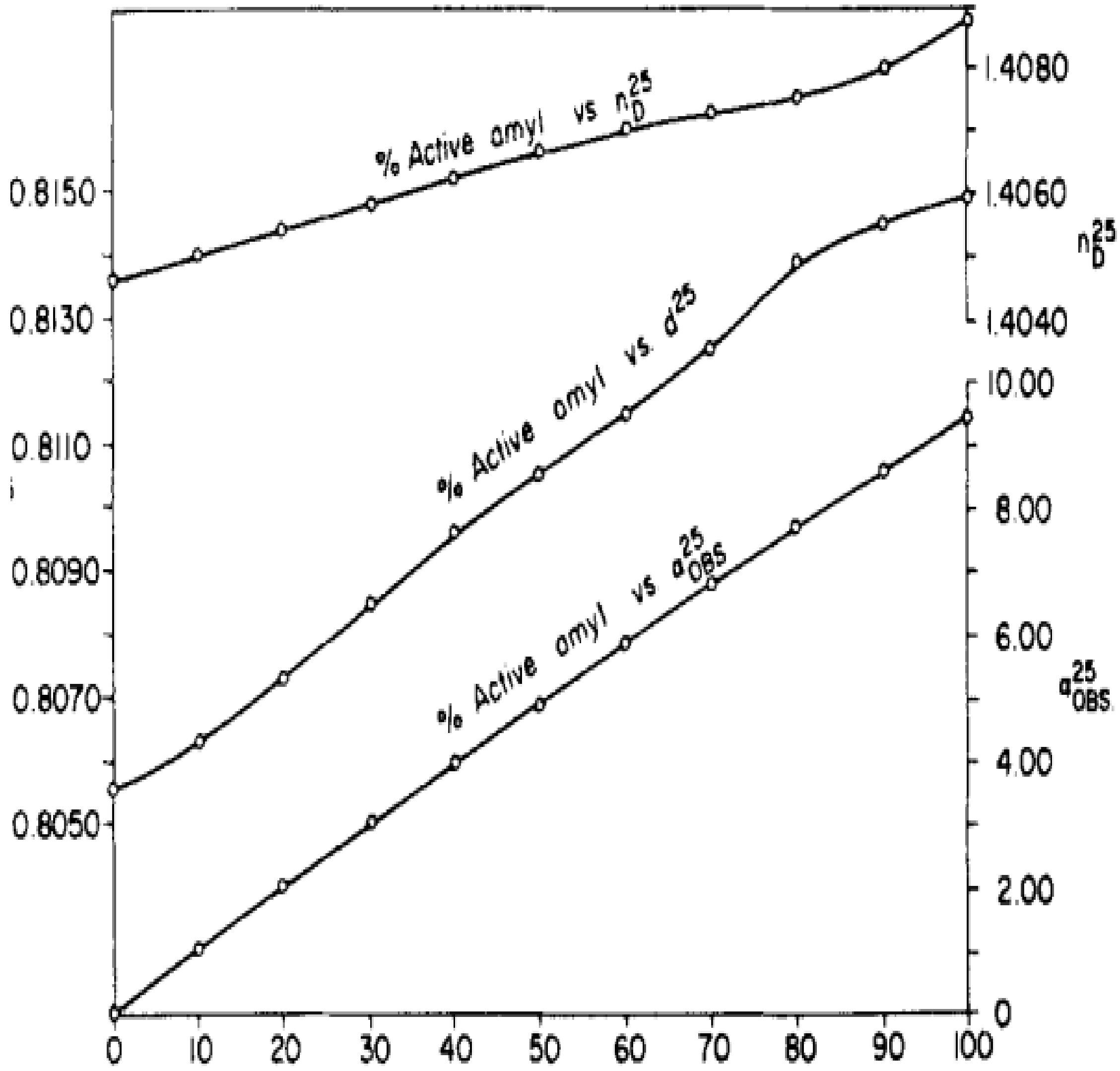

Figure 3.3. Active amyl alcohol [14].

PART 4

METHODOLOGY

Due to the highest price of the fusel oil we turned to the ANSYS software due to the high precision and the presence of the chemical product that we can used to make our biofuel, also this software give us the capability to make the hole simulation of engine from designing to collecting result of the combustion reaction in one app, plus the result will be presented by various graphs and figures with modern simulation resolution to be like the reality experiment.

4.1. MATERIAL

The material section depends on many steps but this step is added in 2 main sector the software and the fluid.

4.1.1. Software

ANSYS Software is shown in the Fig 4.1. (Geometry, space claim) (mesh, mesh) (fluid and combustion, fluent setup).

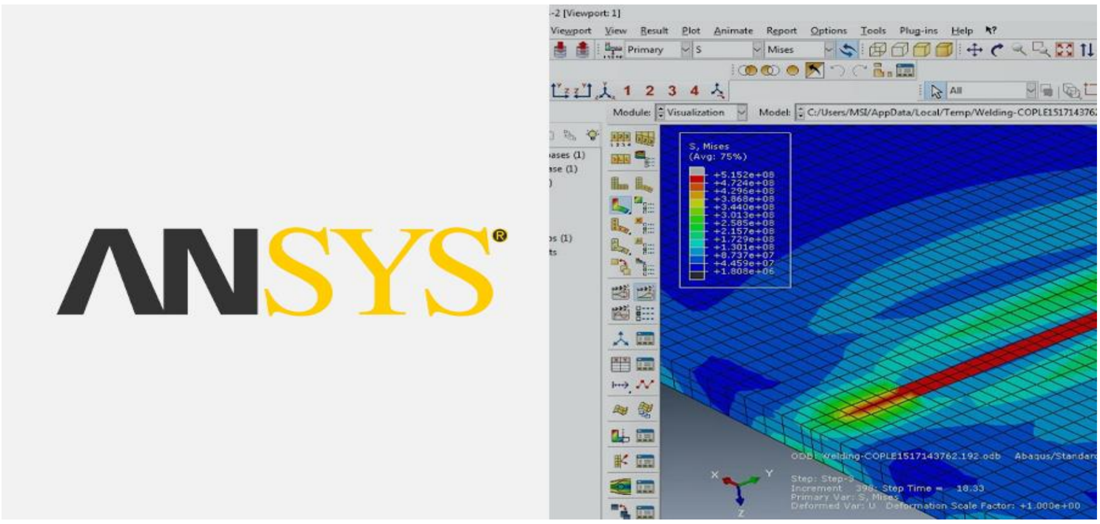

Figure 4.1. ANSYS Application

4.1.2. Fluid

The fluid is divided into many type the gas the liquid and the gel one for this study the fluid used is just two liquids combining with air and this fluid are the gasoline and the fusel oil as obvious the properties of those fluid is demonstrated and shown inside the Table 4.1.

Table 4.1. Fuel Properties [19].

Properties	Gasoline	Ethanol	Fusel oil
Oxygen content (wt. %)	_	34.8	18
Density (kg/m3) at 20 °C	765	795	800.3
Lower heating value (MJ/kg)	43.4	26.8	35.32
Octane number	99	100	98.7
Latent heat at 298 K (kJ/kg)	500	904	874
Flash point (°C)	38	13	42
Stoichiometric AFR	14.7	9	_
Solubility in water (g/l) at 25 °C	Immiscible	Miscible	Miscible
Viscosity, (mm2 /s) at 40 °C	0.76	1.2	4.162
Auto ignition temperature, °C	~300	434	416

4.2. METHODE

ANSYS application is chosen to make this experiment by using CFD section, depending on fluid fluent system simulation and this experiment is done by the listed below steps, the geometry is done by using the following measurement.

4.2.1. Geometry

During this experiment specific measurement should be used because measurement have a huge effect on the result like the length and width, also same measurement should be used in the both cylinders so we can have a fair comparison. Depending on the new design modeler in the CFD application the geometry was done as shown in Fig 4.2. With the measurement defined in the Table 4.2.

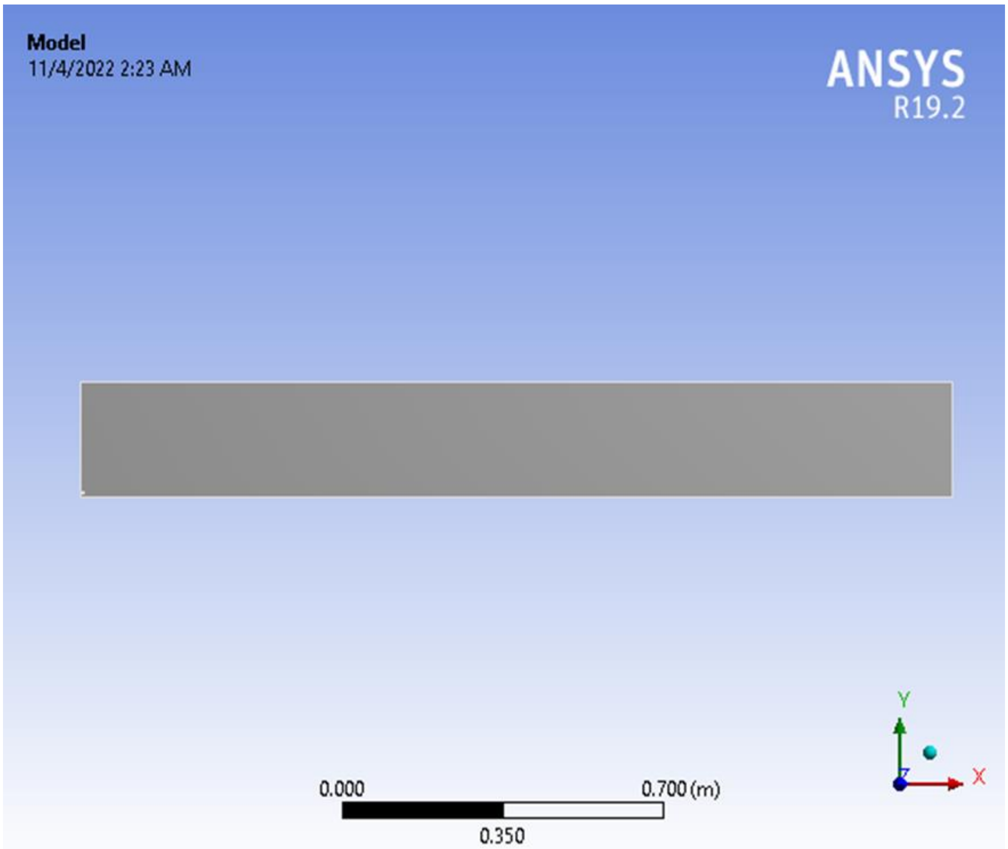

Figure 4.2. Geometry

Table 4.2. Measurement

Bounding Box	
Length X	1.9 m
Length Y	0.24 m
Length Z	0. m

4.2.2. Name Selection

Each part inside this section will be selected separately then their name will be defined, so each part role is known. Name selection is one from the most important steps while working on a CFD application because it has a huge effect on the results. Define the edge and name it before starts the mesh and this edge is named like configure in the Table 4.3.

Table 4.3. CFD Properties

Object Name	*inlet fuel*	*inlet air*	*nozzle*	*wall*	*outlet*	*fluid*	*sym*
State	Fully Defined						
Scope							
Scoping Method	Geometry Selection						
Geometry	1 Edge		2 Edges	1 Edge	3 Edges	1 Face	2 Edges
Definition							
Send to Solver	Yes						
Protected	Program Controlled						
Visible	Yes						
Program Controlled Inflation	Exclude						

4.2.3. Mesh

The mesh operation is the importing of the geometry design and decompose in small pixels by using edge sizing to study it briefly like shown in Fig 4.3.

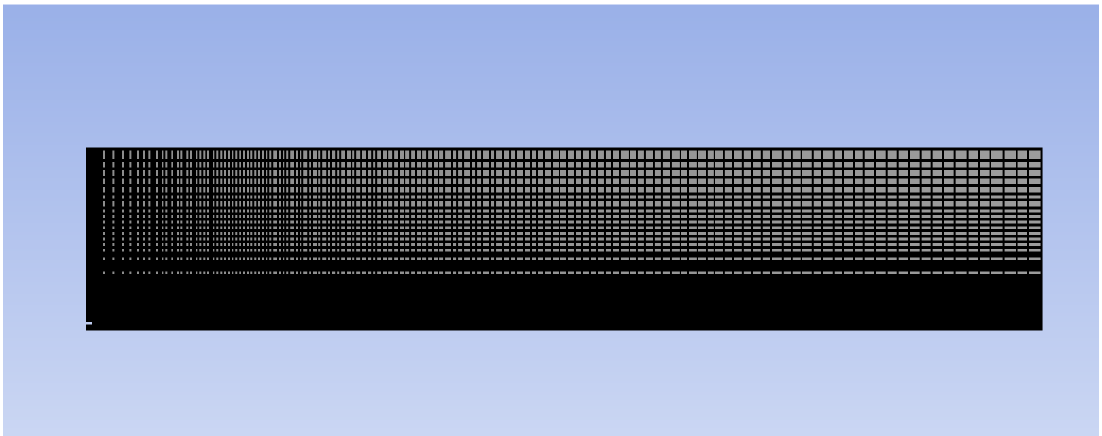

Figure 4.3. Mesh

Edit the element size dimension to get a smooth mesh to get best result for our study like they demonstrate in Table 4.3 generate mesh update it and connect it to the fluent setup.

4.2.4. Setup

Open setup and use our data that we want to generate. In our case I put benzene. turn on the specific equation to calculate and simulate the result that we want before and after combustion: Energy Species Boundary condition. Initialize the data that we putted in the steps before and run calculation with specific iteration.

4.2.5. Result

Read the result from solution and result section duplicate the mesh in CFD and make a new connection with fluid setup to put the data of the other chemical product that we want to study it again in our case we put the fusel oil.

4.2.6. Final step

Make the same steps with different boundary or with the specific properties' boundary of the fusel oil.

PART 5

RESULT AND DISCUSSION

5.1. BASIC DEFINITION

5.1.1. CO emission

Variations in CO emissions as a function of engine load. The engine's operation and the air/fuel ratio have a significant impact on the CO emission concentration. When there is insufficient time for combustion, CO emissions result from incomplete combustion or from a lack of oxygen, both of which are necessary for full combustion. Rich air/fuel combinations burn in the cylinder. Fusel oil with oxygen has been shown to enhance combustion and lower CO emission levels. as opposed to pure fuel [1].

Based on a study by Smollin et al [32].CO is a gas emission, odorless and colorless gas produced from uncompleted combustion and it has many effects on the nature and on the human health. CO is a tasteless, transparent gas. People breathe in CO from the air, which is then absorbed into their bloodstream. Hemoglobin absorbs it and loses some of its capacity to carry O_2. The performance of various organs may be impacted depending on the CO amount in the air, which can cause asphyxiation and result in diminished focus, slow reflexes, and anxiety. The poisoning effects of CO is

- Hypoxia (less oxygen on human blood that make unregularly breathing)
- cell destruction
- Death.

5.1.2. HC emission

Fuels that are transported without burning produce HC emissions, which are caused by incomplete combustion when there is insufficient oxygen and air in the combustion chamber. As the blend's fusel oil content and engine load rise, HC emissions decline. Due to the oxygen content of the fusel oil and the consequent rise in combustion temperature as engine load increases, this decrease happens. Whenever the excess air coefficient setting is (lambda = 1)[1].

Extinguishing the flame before completing its combustion, but rather as a hope, leads to an increase in the HC, and the mixing of oil, rather than fuel, also leads to an increase in this emission, especially in gasoline engines, i.e. spark-ignition engines, and the disruption of combustion due to liquid fuel that contains a large amount of water leads to C deposits and which, therefore, leads to an increase in the emission of HC, and the final reason that I will mention is the leakage to the exhaust valve, the HC should not be an emission during the complete combustion but due to the incomplete combustion this emission will be emitted out of the engine by exhaust and that is leaded from many reasons and this reason is, the error during O_2 distribution that lead to spread torch slowly so not all the fuel will be burned [55].

Soft compression due to the throttle valve being closed, very little quantities of air are pulled into the cylinders during deceleration. As a result, the cylinder has poor compression. Therefore, the combustion will be incomplete, so the HC is released through exhaust. Quenching: the lower heat or temperature of the flame lead to make an incomplete combustion so the HC will be emitted. The HC lead to make irritation of bronchial clenching and mucus membrane also the HC are known to have carcinogenic properties [33,56].

5.1.3. NO_x emission

The exhaust pollution known as NO_x is produced when cylinder temperatures are high. As the engine load grows, NO_x emissions rise, however in our situation, the NO_x emission will be mandated. because the alcohols that make up fusel oil have greater latent temperatures of vaporization and we can proof that depending on other research like research of Simsek [1].

5.1.4. CO_2 emission

The CO_2 is the gas emitted from the combustion operation and the most famous combustion emit this type of gas is the engine combustion in other hand the elevated amounts of atmospheric (CO_2) cause

- critical mineral concentrations such as magnesium and zinc
- decline essential for brain and eye health
- Increase the heat of atmosphere

Individuals' reactions to the same sort of those pollutants' exposure may differ. The more sensitive population group is likely to react more aggressively than the average healthy person. Children, the elderly, and those with heart and lung conditions, such as emphysema and asthma, are more sensitive to exhaust exposure and at increased risk for health problems [57].

5.1.5. Specific heat

the specific heat is the capability of the materials to store the heat energy it called thermal capacitance and this specific heat is related directly with density so if the density of the product is high the specific heat will be low in other way when the density decreases the specific heat will increase and vice versa that information demonstrates that the material with high density can change her temperature fast than low density for example the water is one of the best high specific heat with 4180 (J/kg K) Specific Heat, that mean this material can absorb lot of heat energy so by the way it will be one of best material to decrease the temperature of other heated material.[58]

5.1.6. Octane number

Octane number give a little indicator of the fuel's anti-knocking action. The engine runs more smoothly and the fuel resists detonation better with a higher-octane rating. One of the most important indicators of a gasoline's performance is its octane number, often known as octane value or octane rating. It gauges a fuel's resistance to knock or early ignition. Both octane number and octane rating are used. On a scale with isooctane at 100 (minimum knock) and heptane at 0, octane values are calculated (bad knock). The more compression needed for fuel ignition, the higher the octane rating. High performance gasoline engines use fuels with high octane ratings.

Simply put, an octane rating is a measurement of how heat resistant a gasoline is to avoid knocking. In other words, octane doesn't improve combustion; rather, it stops an engine's air-fuel combination from igniting earlier than it should. The resistance of a gasoline to knocking increases with increasing octane.

5.1.7. Soot

Soot is the second emission ejected from the incomplete combustion of organic (carbon-containing). The black dust or brown powder that produce the soot may contain a number of carcinogens, like arsenic and chromium. People may be exposed to soot by inhalation, ingestion and that is conducted by pollutant air next to the vehicles or factories and this soot are emitted by the engine exhaust, and from any combustion source.

5.1.8. Viscosity

The viscosity is the resistance of the fluid for the deformation in other word way the viscosity is the internal frictional force of the fluid. in general condition the viscosity affected by temperature, pressure, and the deformation ratio also the fluid lose the viscosity under the very low temperature, also the viscosity affect directly on the propagation of the fluid with the increasing of the viscosity the fluid flow becomes very slow.

5.2. EMISSIONS RESULT

5.2.1. CO_2 Mass Fraction

As a definition it's important to say that the CO_2 is the gas emitted after an complete combustion process due to combining of dioxygen and C The quantities of CO_2 increase because of the decrease in CO in the piston, but despite this, the quantities of CO_2 in the mixed fuel remain higher than those in the unmixed fuel because of the negative relationship between CO and CO_2, which means that if the amount of CO in the piston increases, the quantities of the other one decrease [1].

Due to the ethanol and the higher number of O_2 in fusel oil the distribution of CO_2 is fair in all the piston with less mass fraction like they shown in Fig 5.2 due to the complete combustion and the high speed of the ignition operation in other hand the CO_2 in the benzene is distributed unfairly and they start after the middle of the piston and that is happen due to the longtime of ignition, also we can see the highest mass fraction of CO_2 in gasoline comparing with fusel oil in the Fig 5.1. With the adding of fusel the CO_2 emissions have increased in some research due to the improvement of the combustion, so we can say that there are no standard and specific results because they could change from a study to another.

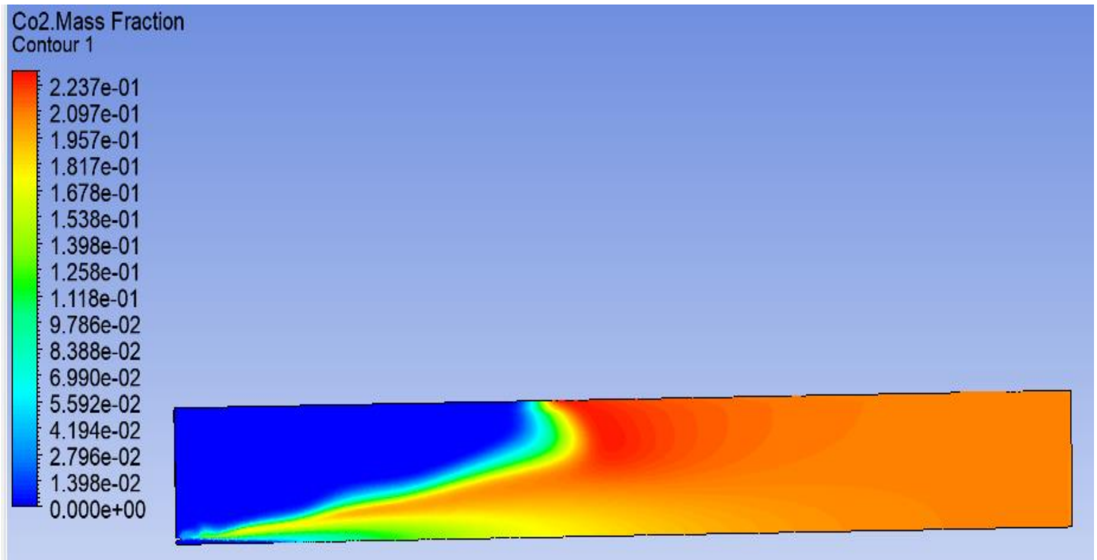

Figure 5.1. Gasoline CO_2 mass fraction

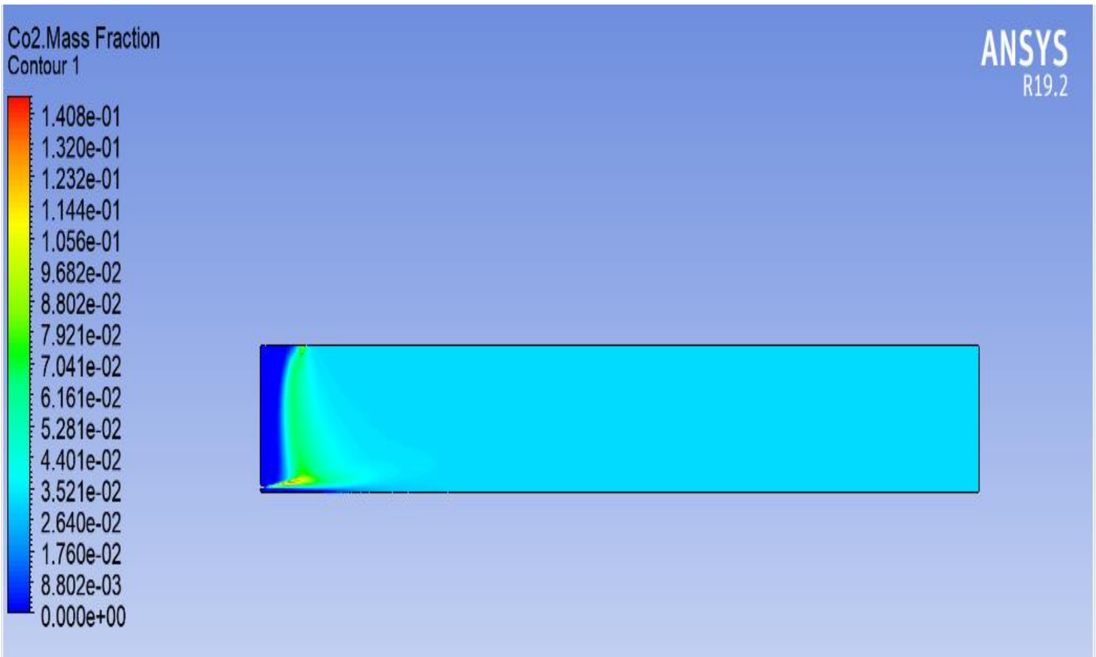

Figure 5.2. Fusel CO_2 mass fraction

5.2.2. O_2 emission

As normal the presence of O_2 in the chemical formula of fusel and the longtime of opening of the air input because of the high density of fusel lead to get a higher number of O_2 inside the piston during the internal combustion Fig 5.4. also, the absence of the O_2 from the chemical formula of gasoline or benzene lead to the decreasing on the number of O_2 inside the piston during the same operation with same condition and under same load in Fig 5.3 and that will be shown how that affect directly on the emissions.

The air-fuel mixture rate rises as a result of the elevated O_2 in the fusel oil cylinder, which shortens the physical delay and speeds up ignition. As a result, we can see that the maximum concentration of O_2 mass fraction in the gasoline cylinder is $2.237e^{-01}$ but on the other side the concentration of O_2 mass fraction inside the fusel oil cylinder reach a maximum of $2.287e^{-01}$ so we can conclude that adding fusel oil to the blend will increase and elevate the O_2. The O_2 will stay released in the air due to the incomplete combustion.

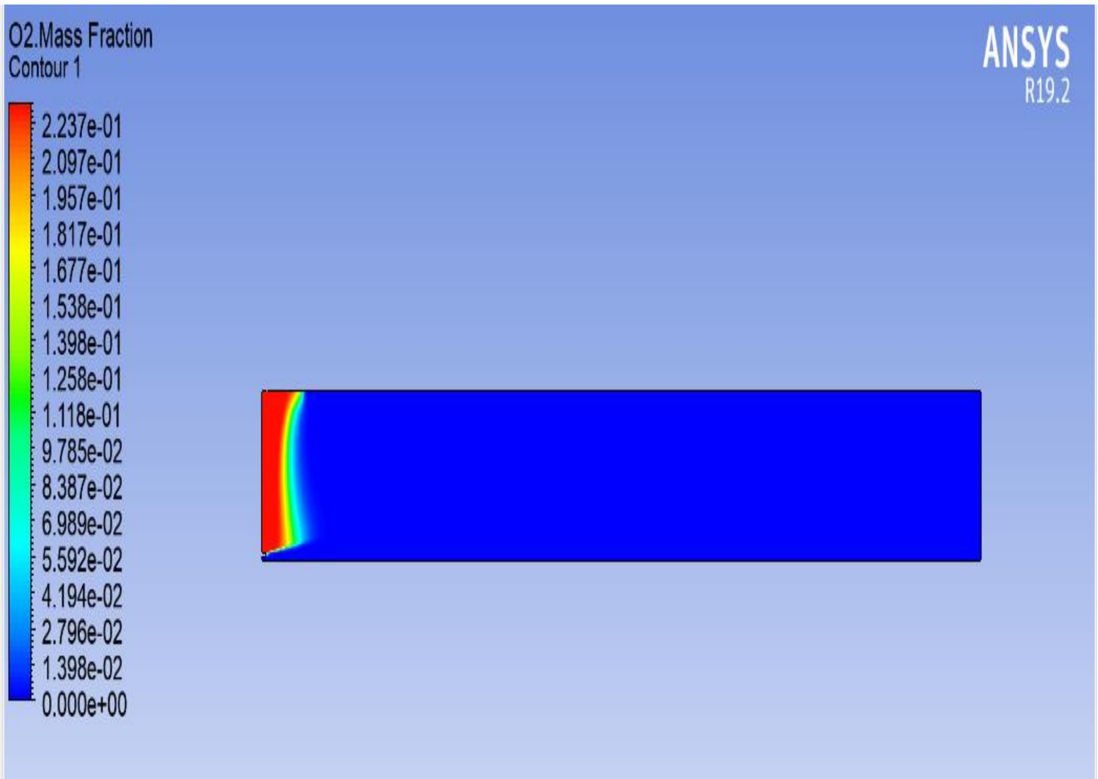

Figure 5.3. Gasoline O_2 mass fraction

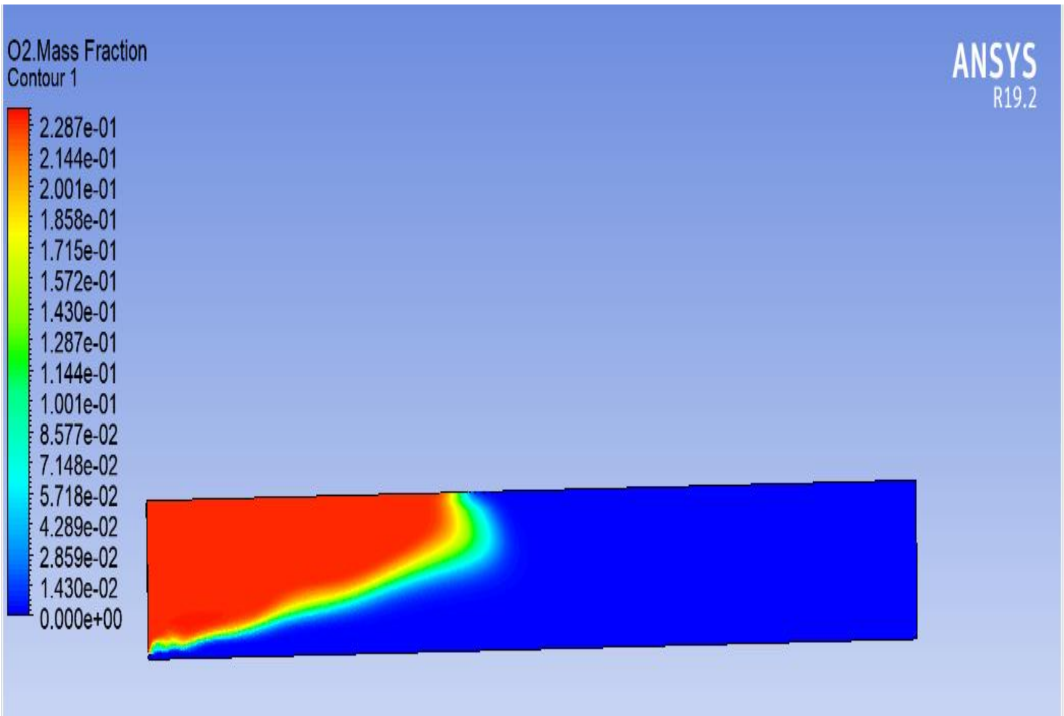

Figure 5.4. Fusel O_2 mass fraction

5.2.3. H_2O Mass fraction

H_2O is the chemical formula of the vapor of water produced during the combustion chemical reaction, as is obvious in the Fig 5.5. and Fig 5.6. the fusel oil has a big quantity of this vapor compare with benzene air and all of that is connected to the presence of H_2O inside the fusel due to the stored place and also due to the presence in the construction of fusel oil and also due to the high presence of oxygen in the chemical formula of fusel that produce more H_2O aligning after the combustion reaction done with average of 0.516/1 for fusel oil and with average of 0.484/1 and this quantities of H_2O vapor will make some effect on the combustion operation like other research's .the temperatures release rates in the cylinder dramatically drop due to the high water content of fusel oil [20,59]. The result is a reduction in the engine's thermal efficiency and an extension of the flame formation and flame propagation times. The flame formation and flame propagation times have a significant impact on the engine's combustion and thermal efficiency [20]. Water content in fuels is also a key cause of tank bottom corrosion and may cause engine components to corrode and clog [60,61].

In addition, water in cold weather may freeze and block the flow of fuel. On the other hand, the presence of water reduces the viscosity of the fusel oil, which enhances its atomization characteristics. Additionally, it lowers the flame and local temperatures inside the combustor, which lowers the thermal NO_x emissions. Additionally, the water in the fuel decreased the amount of soot and particle matter [62,63]. Fuels, and especially fusel oil, are significantly impacted by the amount of water content. In reality, before being used as fuel, the fusel oil's water content needs be removed.

A number of techniques, including distillation, pervaporation, and anhydrous Na_2SO_4, can be used to extract water from fuels or fusel oil. Anhydrous Na_2SO_4 can reduce fusel oil's water content, according to Sasmaz et al. [64] and 0.15 g of Na_2SO_4 per cm3 of fusel oil is the right amount. To reduce the water content of fusel oil, the same salt/fusel oil ratio was applied in this investigation. Pervaporation emerged as an effective membrane[65] separation technique for ongoing water removal, assisting in substrate conversion. On fusel oil that had a water content of 13 to 18 mass percent, Kujawski et al. [66] employed pervaporation before distilling it in four steps. The results revealed that the water content was reduced to 1.59 mass percent at the end of the experiment. According to results it's very obvious thanks to CFD application we can compare the results by only comparing colors between the two cylinders, so it's acceptable to say that the fusel oil has a higher amount of H_2O mass fraction inside the cylinder during the combustion and it will increase and elevate with the elevation of engine load. One more important factor to the rise of H_2O inside the fusel oil cylinder is that he is miscible so in this case he can attract more H_2O during the storage process.

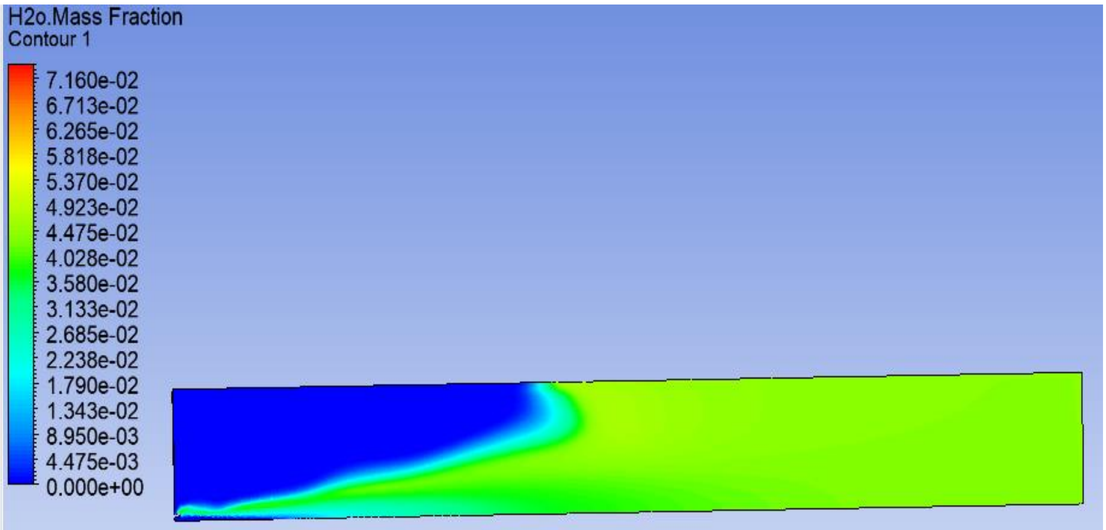

Figure 5.5. Fusel H_2O mass fraction

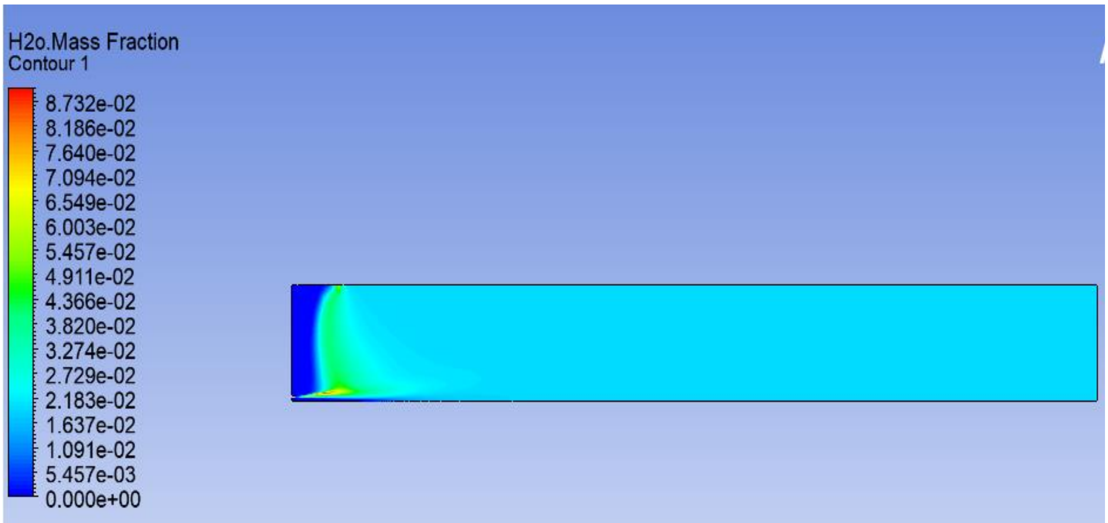

Figure 5.6. Gasoline H_2O mass fraction

5.2.4. Soot emission

The soot is the second emission of the incomplete combustion of any C continent product like fusel oil, natural oil, coal in the Fig 5.7. it's obviously appeared that the gasoline has a very little emission from soot and that lead to the complete combustion that will not eject any type of second emission in other hand the fusel oil had also a little bit of soot but like shown in Fig 5.8. the level of soot emission inside the fusel is bigger than gasoline due to the incomplete combustion at the edge of the piston when engine has high concentration of H_2O that lead to make an incomplete combustion.

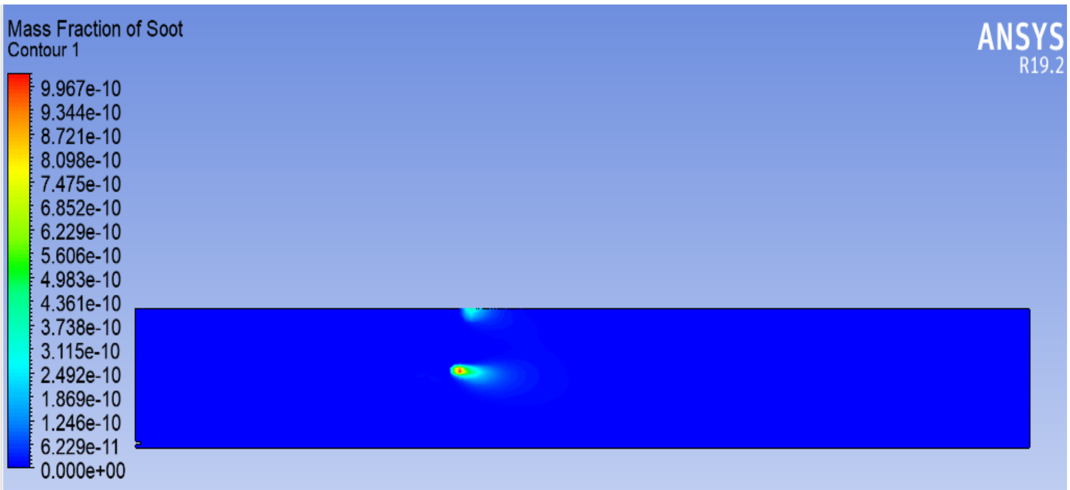

Figure 5.7. Gasoline soot

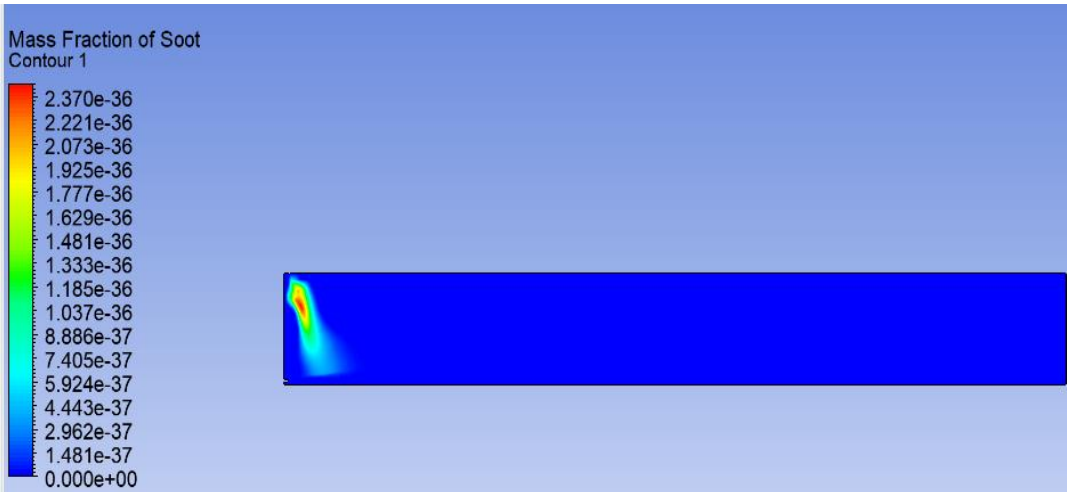

Figure 5.8. Fusel soot

5.3. ENGINE PERFORMANCE

5.3.1. Temperature

The temperature in the fusel oil should be higher than gasoline if we blend it due to the higher number of octane and O_2 inside the fusel oil but due to using 100% percent of fusel oil in the piston the temperature was affected negatively due to the augmentation of H_2O mass fraction and also the H_2O created after the combustion like side effect ejection. That decreasing in temp is shown in the result in Fig 5.10. the temperature of the piston during the combustion of the fusel is less than the gasoline due to the higher number of H_2O mass fraction that mean the humidity that leaded from the presence of the higher number of H_2O affect negatively on the temp and decrease it in other side in Fig 5.9. the temp of the gasoline is high due to the less presence of the H_2O inside piston .this difference in temperature affect also on the combustion operation from one side and affect also on the emissions from the other side and that will be shown on the next result As is obvious in the result that the gasoline has a higher temperature results that fusel oil in the main reason of this result is that the gasoline fuel has a higher flash point and as is know that the flash point is the temperature where the gasoline is going to catch the fire, so in this case we can say that it's a better and good idea to use the gasoline in a warm climate.

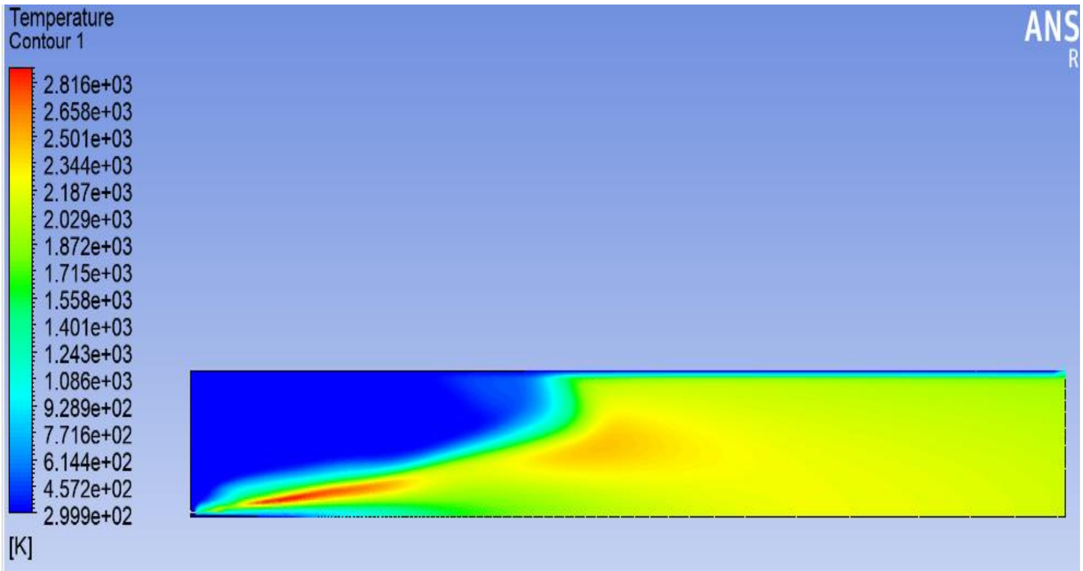

Figure 5.9. Gasoline combustion temperature

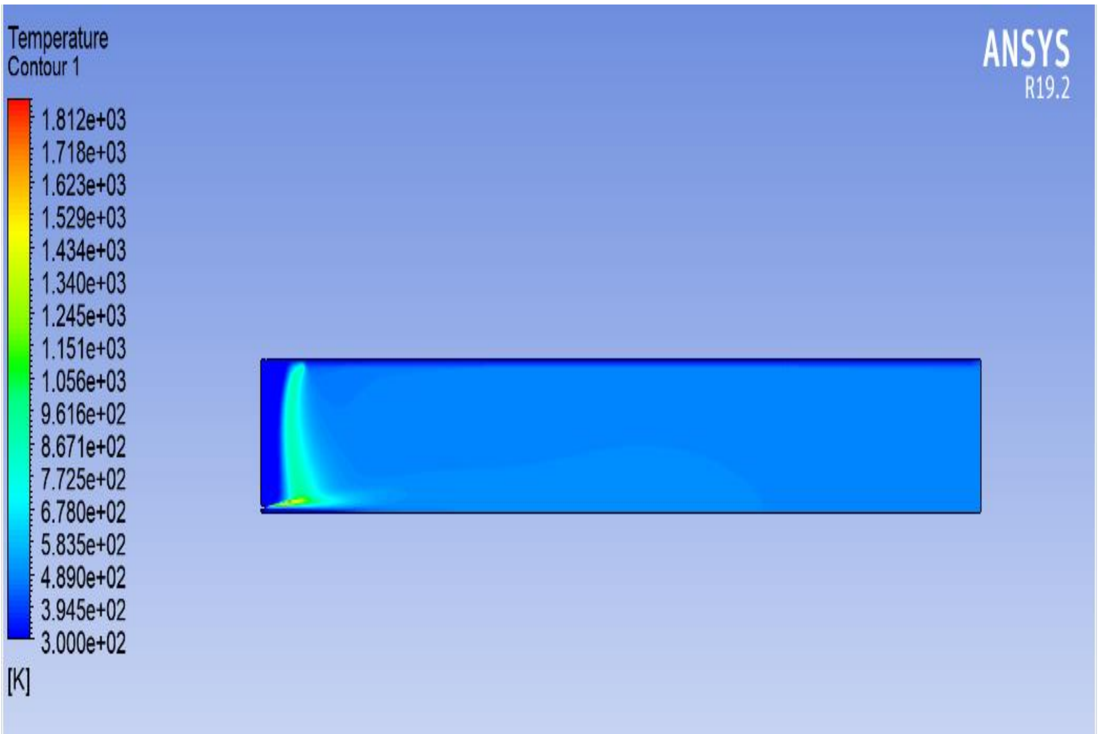

Figure 5.10. Fusel combustion temperature

5.3.2. Velocity

The velocity is an important parameter while testing any type of fuel because the velocity has a huge effect on the engine performance. The velocity results are related to the viscosity results, their relation is opposite. Fig 5.11 result will be describing the distribution of the mixture of air and gasoline that distributed highly in the inlet of the stroke and then this distribution decrease simultaneously to get the end of the piston in other side we can see the distribution of mixture of fusel oil and air in Fig 5.12. start a little bit with high speed but stay in the same speed inside the piston due to the high density and viscosity that avoid the large moderate in speed of the distribution inside the engine that lead to see a high pressure and combustion in the first part of the piston in case of gasoline uses but in the case of fusel we can see that the pressure and the combustion start from the beginning of piston and stay a little high to the end of the piston. The streamline is used in the results shown in Fig 5.11. and Fig 5.12. using the streamline will show the movement of velocity inside the cylinder. One important more result is that velocity will increase with the increase of density, this is due to fusel oil leak reduction, so it's acceptable to say that the fusel oil has a higher velocity.

A streamline is a flow trajectory. Fig 5.11. and Fig 5.12. show the streamlining of velocity inside the cylinder of gasoline and fusel oil respectively. Due to the CFD we can easily compare the velocity streamline of gasoline and fusel based on the color and lines inside the cylinder or it also can be compared by the numbers showed on the side inside the axe.

The velocity is as known the ratio which something moves. The examined speed in this experiment is referred to the fuel and combustion. It's important to mention that the most parameters that effect the velocity are viscosity, density and the pressure. Fig 5.11. and Fig 5.12. show the compared result of velocity between the fusel and gasoline. Based on the results from the CFD software, the maximum velocity of gasoline is 86.0215 $m.\frac{}{s}$ but on the other hand, the maximum velocity of fusel oil is 83.6805 $m.\frac{}{s}$. the gasoline velocity is higher than fusel.

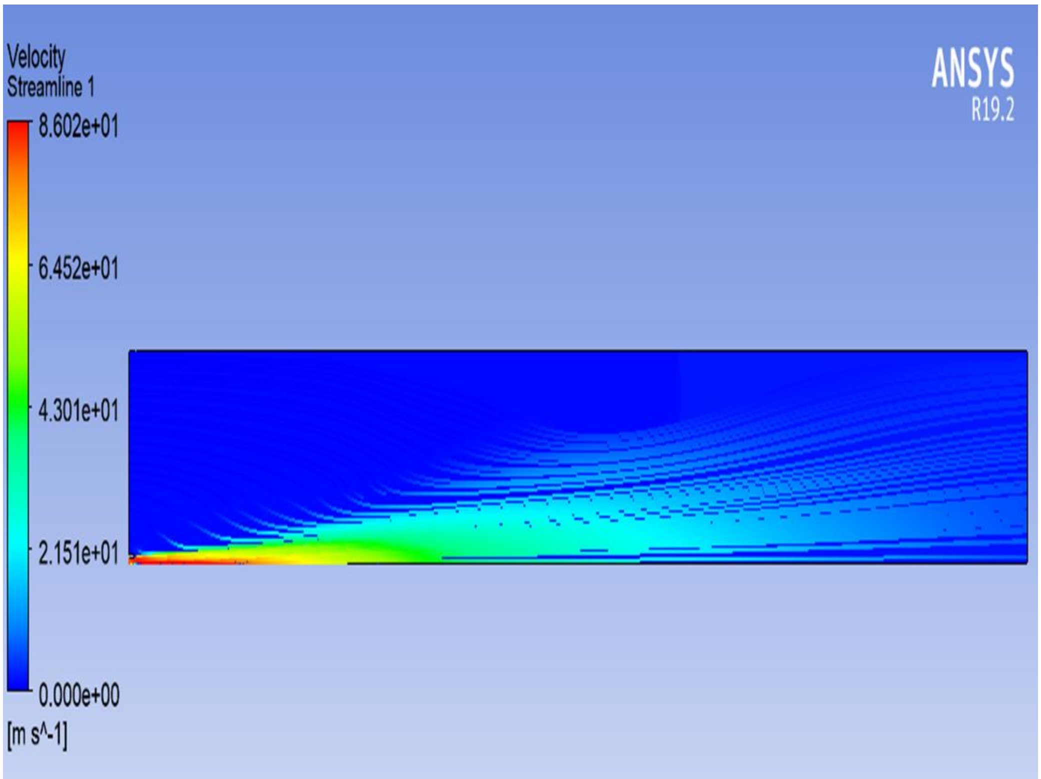

Figure 5.11. Velocity of gasoline distribution

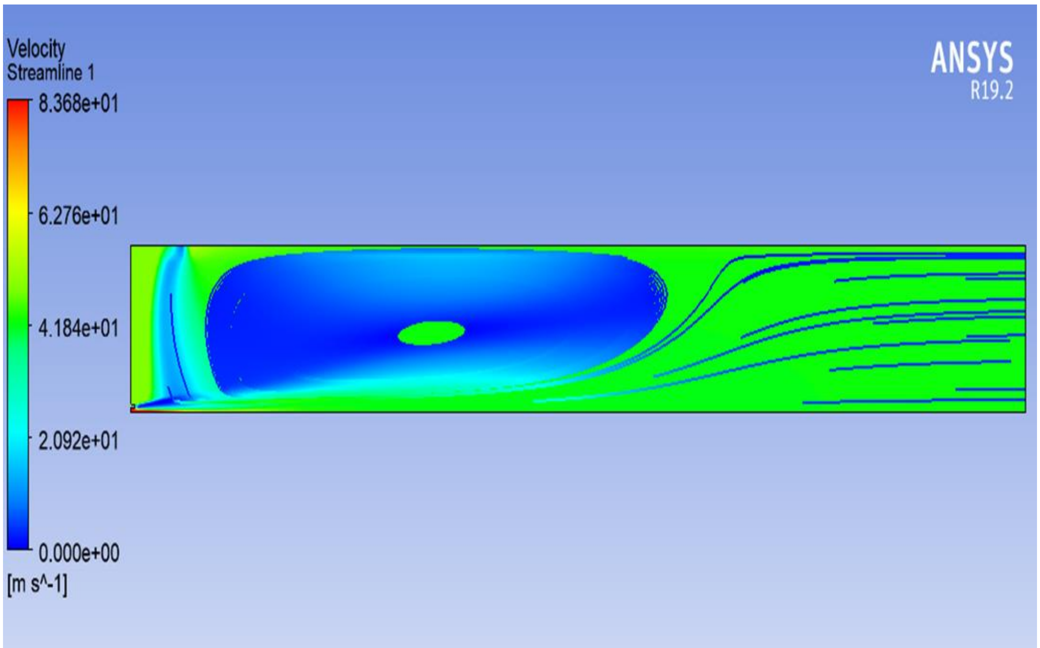

Figure 5.12. Velocity of fusel distribution

5.3.3. Pressure

In Fig 5.14. we can see the pressure of the fusel how they start low then they increase simultaneously to get the end of the piston and that is opposite to the pressure of the gasoline Fig 5.13. which start highly and decrease simultaneously that mean the force of the gasoline start high and decrease a little bit in the end of combustion in other hand the pressure of the fusel oil start low but it been higher than gasoline in the end that mean it make more force in the end of combustion so we can deduce that the gasoline has better start force then better torque and more speed for the engine in the start of ignite and the fusel give more force speed and torque after starting the engine work that mean when the engine is stable work. A lot of experiment predicts that the pressure will reduce with the decrease of pure gasoline inside the mixture. But on the other side different experiments result that the pressure value is reduced. This problem is associated with the reduction of fuel atomization when animal fat is used. The maximum pressure occurred extremely early with gasoline 1075.67 [Pa] but on the other side with fusel fuel the maximum pressure is 933.183 [Pa].Due to the high-octane number inside the fusel oil so he can hold a high pressure than the gasoline so when the fusel oil is compressed and the spark ignite the flame propagation will make a multiple pressure ranged between 70 and 80 bar, and also the pressure plays a significant role in the break thermal efficiency (BTE) results because he has a several impact on the engine performance. So, we can say that the fusel oil has and can hold a higher pressure than the gasoline fuel.

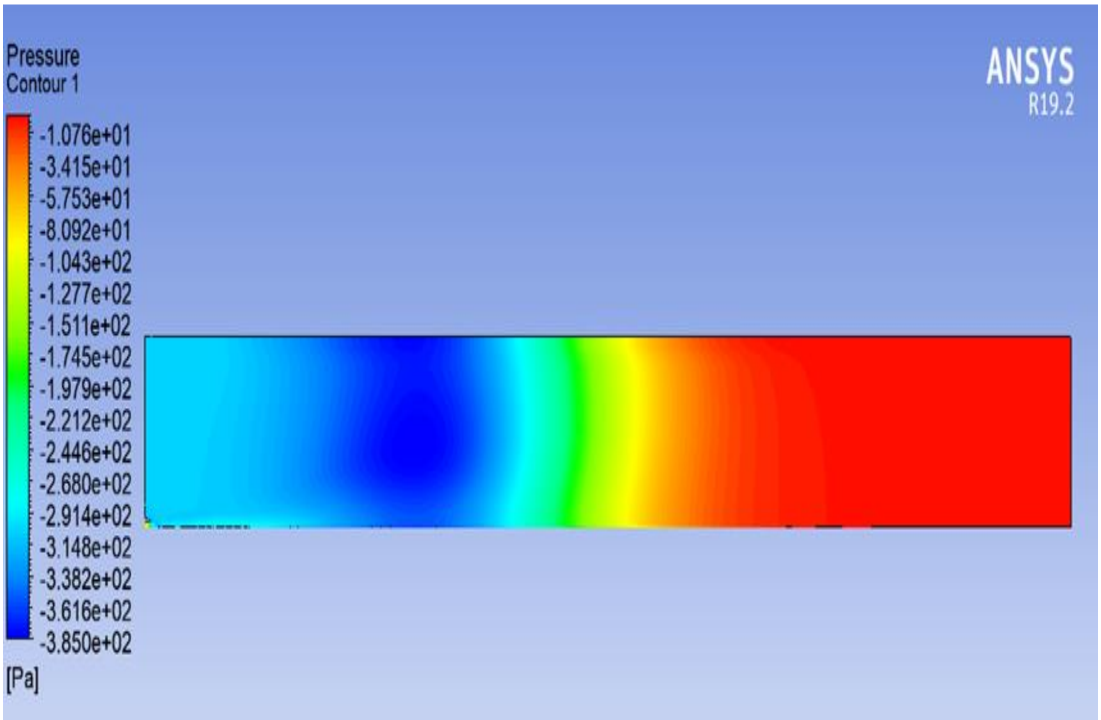

Figure 5.13. Gasoline pressure

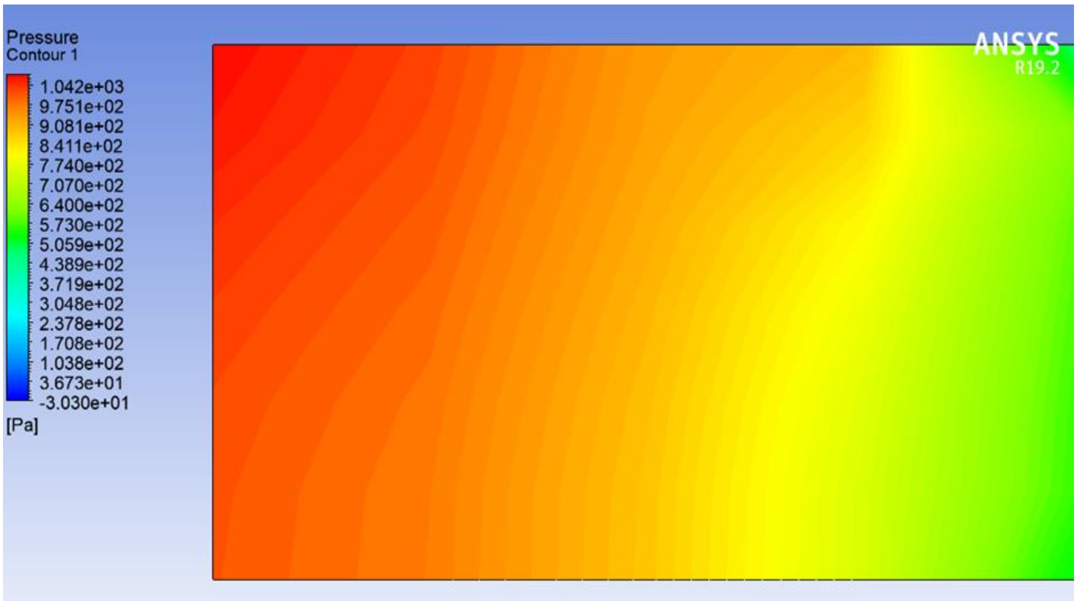

Figure 5.14. Fusel pressure

5.3.4. Fuel mass fraction

To compare and determine the lubricating characteristics of fuel. Fig 5.15. and Fig 5.16. shows the chemical formula of gasoline (C_6H_6) and the chemical formula of fusel oil is ($C_5H_{12}OH$) respectively. The last result show that the viscosity and the density inside the fusel oil is bigger than gasoline so the distribution of the fusel oil mass fraction inside the cylinder will be higher than gasoline by the way in Fig 5.15 the benzene is distributed slowly in the piston and its distributed just in the low part of the beginning of the piston and distribute a little bit on the end with low quantities in other side in Fig 5.16 the fusel oil is distributed in the whole piston to give the same performance of the benzene so what is shown in this two figure that the piston need more fusel oil then gasoline or benzene to do the same performance so the consumption of fusel is higher than gasoline.

When the water increases inside the fusel, the viscosity will decrease, this will effect on the entrance of fusel oil to the ignition chamber. This process will lead to the high consumption of fusel oil. As is well known that fusel is more viscous than gasoline, so he has a better lubrication property, therefore it flows more smoothly inside the combustion chamber than gasoline. Based on the time depending for gasoline and fusel to burn inside combustion chamber, it’s acceptable to say that fusel have a lower time to complete the burning process.

In the other side this high distribution on the low load makes some problem due to the lower function of the engine from one side and due to the lower rpm from the other side next to this reason the lowest load doesn’t need a high temperature so the consumption of fusel oil will not get the end so this eject more fusel particulate matter. To generate the same amount of power using gasoline, more fuel is required. As a result, more fuel is injected, extending the duration of combustion and perhaps leading to incomplete combustion inside the cylinder, this is the bad thing so in this side the emissions will increase because some emissions are related to the engine performances.

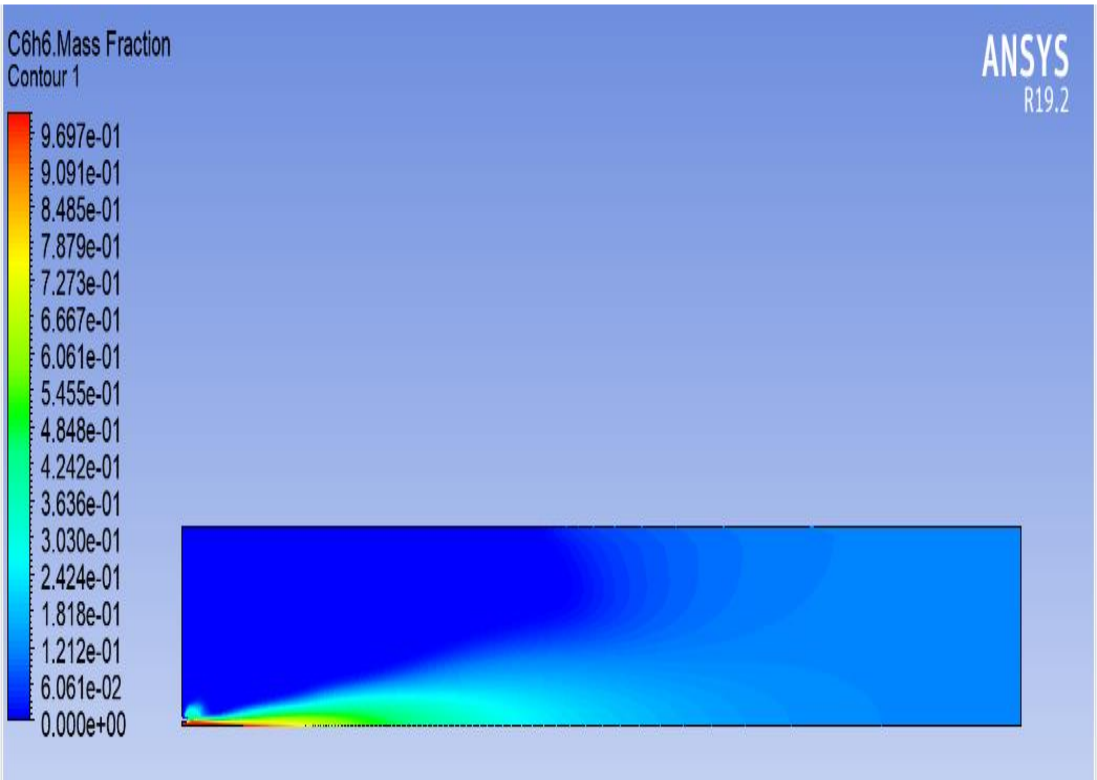

Figure 5.15. Gasolin mass fraction

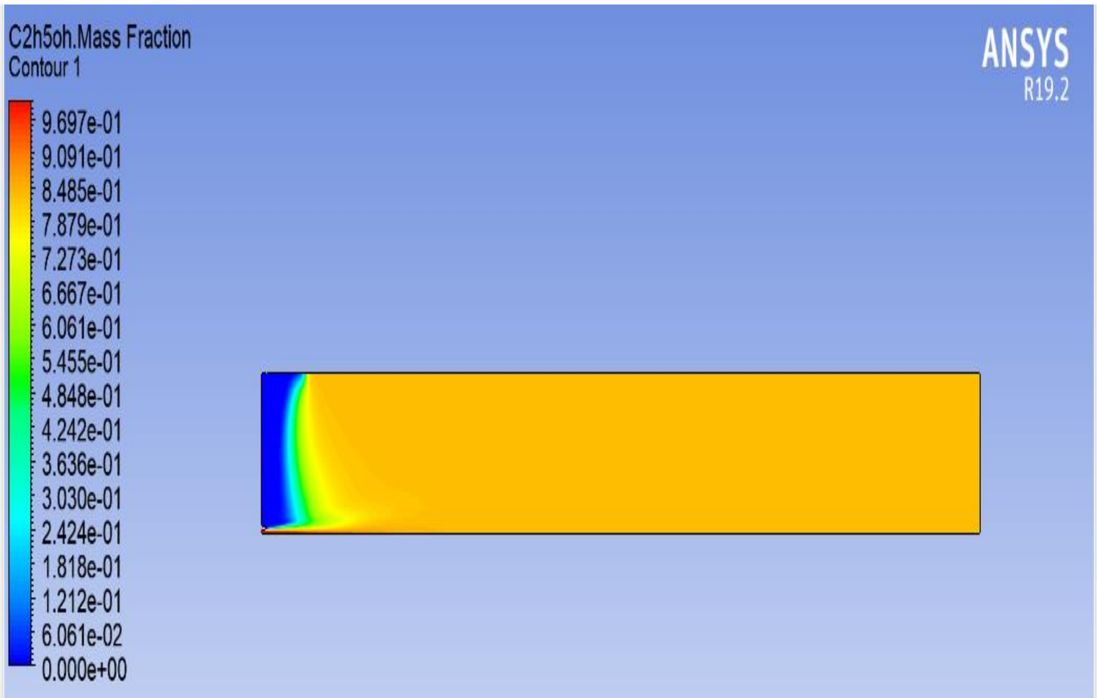

Figure 5.16. Fusel mass fraction

5.3.5. Density

The material substance density is defined as its mass per unit volume d is the density m is the mass and v is the volume and, in this way, we can conclude the density Equation (4.1).

$$d = \frac{m}{v}. \tag{4.1}$$

In terms of grams per cubic centimeter, the density is frequently stated. The density and the viscosity are two proportional related properties effect directly on the combustion process and that effect is connected to the increasing of power with the increasing of the condensation of the fuel that decrease the fluid (fusel, gasoline) leakage also this properties effected on the fluid atomization performance in other hand the high density lead to increasing in the viscosity and that effect negatively on the combustion where the combustion will be incomplete or weak by the way it effect negatively on the emission.

As known the fusel oil has higher density than gasoline so these results cause to increase the mass flow ratio by the way the mixture between fusel and gasoline improve the blended mixture efficiency and like seen the density of the both fluids are shown in Table 4.1 so in Fig 5.17.and Fig 5.18. we can see how the density effect on the distribution of every fuel. First the gasoline on Fig 5.17. are immediately distributed on the first part on the piston and stop the displacement in other hand the Fig 5.18. proof that the density of fusel is bigger than benzene with more distribution inside the piston due the high quantities that injected inside the engine.

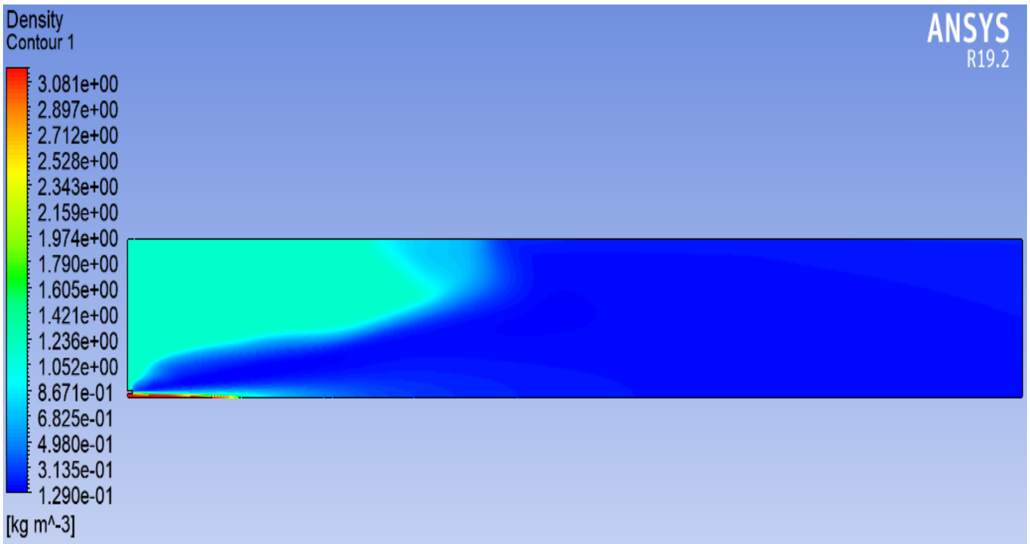

Figure 5.17. Gasoline density

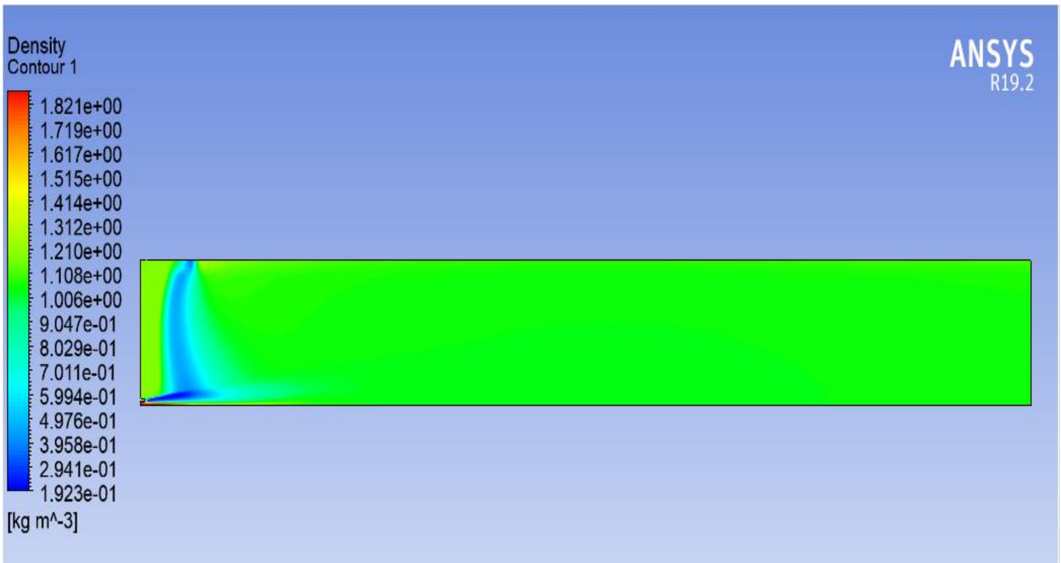

Figure 5.18. Fusel density

5.3.6. Torque

The torque in this research is increased with using the blend of fusel oil due to the increasing in the temperature and pressure by the way increasing in the power of the engine as known the consumption was increasing largely but the good side from this increasing is the highest horse power that are produced from this increasing so depend on the torque Equation 4.2.

$$T = HP * 5252 \tag{4.2}$$

The result deducing from this equation that our blending increases the torque respectively with the increasing in the horsepower also due to the combination of the formula of the torque with velocity or rpm formula Equation 4.3 the rpm of this engine simulation will be increased also.

$$rpm = \left(\frac{HP}{T}\right) * 5.252 \tag{4.3}$$

5.3.7. BSFC

BSFC provides you with information on how much gasoline your engine will consume each hour to create one hp. As cylinder pressure and rpm adjust, BSFC alters. The performance improves with a smaller BSFC ratio. Less efficiency is achieved with higher BSFC values. The BSFC is determined by the following Equation 4.4 and Equation 4.5 [31].

$$BSFC = \frac{Wf}{Pb} \tag{4.4}$$

$$Pb = \frac{Pg}{ng} \tag{4.5}$$

W_f = fuel consumed (g/h)
P_b = brake power (kW)
Pg. = load (kW)
η g = efficiency of the generator numerous

The causes of the modifying in the BSFC are due to the temperature and more other reason like when the temperature of the combustion will decrease the BSFC decrease So, in this research the known about the BSFC is in decreasing and that is resulted from the decreasing in the temperature of the internal combustion operation and the high presence of the H_2O molecules also the fuel injectors also effect on the BSFC so the injector should be putted with a specific dimension and these measurements are calculated by the Equation 4.6.

$$HP * \frac{BSFC}{NOI * IDC} \quad (4.6)$$

NOI: number of injectors.
IDC: injector duty cycle.

5.3.8. Effect of wrong injector

Choosing an injector that is too small will:

- Reduce power at wide open throttle (WOT).
- Cause engine damage from Detonation
- Reduce fuel injector life

Choosing an injector that is too big will:

- Reduce power at small throttle openings and create idle problems
- Cause damage when excess fuel washes oil off the cylinder walls
- Foul spark plugs

5.4. COMPARISON WITH OTHER RESEARCHERS

The Table 5.1. and Table 5.2. describes the result of the research of each of Calam ,Solmaz and Ichingur [18,19,67].In Calam [19] the result of using gasoline blended with the fusel oil with speed increase from 1500 to 5000 rpm also under load increase from 25% to 100% we describe that he had increasing in the engine torque ET, engine thermal effective ETE, CO, HC, BSFC and in the ANTI-KNOCK in other side he had an decreasing in the NO_x and the EGT what is shown also that the other result of the research mad buy calm have same result with different condition. The decreasing in NO_x emission and the EGT in the research of Solmaz proof that the NO_x and the EGT decrease that is compatible with the results deduced on the CFD but we have some different in the BSFC between the five researches the presence of fusel oil with low quantities in the blend fuel decrease the BSFC due the presence of water and this BSFC every time that we use more fusel in the blended fuel opposite of Solmaz who describe in increasing on the BSFC and that is happened due of the low quantities of H_2O inside the chemical formula.

To proof this problem we try to make a new blended with low humidity and we got that the blended fuel with the low humidity give us an decreasing in the BSFC so by the result we had a near result for all researchers and the same result is Increasing in ET, ETE, ANTI-KNOCK CO, HC, emissions decreasing in NO_x and the EGT but the difference that interrupt the coherent of the results is the BSFC that are modified from report to another depending on the humidity.

Table 5.1. Resume of other reports part 1 [68].

Ref / Parameters	(Calam et al. 2015)[18]	(Solmaz 2015)[17]
Engine type for test	Four-stroke, single cylinder, spark ignition Hydra engine	Ricardo Hydra, single cylinder, four stroke, port fuel injected gasoline
Reference fuel	Gasoline	Gasoline
Test condition	1. Different engine speed. 1500, 2500, 35oo and 5000 min^{-1}. 2. Different engine loads 25%, 50%, 75% and 100%. 3. Four test fuela F0, F10, F20 and F30. 4. Fusel oil contains about 10% water.	1. At engine speeds. 2500 min^{-1}. 2. Different engine loads 25%, 50%, 75% and 100%. 3. Three test fuels F0, F50 and F100. 4. Fusel oil contains 10-15% water.
Engine torque	Increased	Decreased
Engine thermal effective	Increased	Decreased
CO, HC emissions	Increased	Increased
NO_x emission	Decreased	Decreased
BSFC	Increased	Decreased
EGT	Decreased	Decreased
Anti-knock	Increased	Increased

Table 5.2. Resume of other report part 2 [68].

Parameters \ Ref	Calam et al[69]	Icingur and Calam[18]
Engine type for test	4 stroke, single cylinder, spark ignition engine	4 stroke, single cylinder, spark ignition engine
Reference fuel	Gasoline	Gasoline
Test conditions	Full load conditions of 3500 rpm/min Different test fuels F0, F5, F10, F20, F30 and F50 Water continent 18%	Different engine speeds 2500,3000,3500,4000,4500 and 5000 rpm four test fuels F0 F10 F20 F30 fusel oil contains 18% water Gasoline Fusel oil
Engine torque	Increasing	Increasing
Engine thermal effective	Increasing	Increasing
CO, HC emission	Increasing	Increasing
NO_x emission	Decreasing	Decreasing
BSFC	Increasing	Increasing
EGT	Decreasing	Decreasing
Antiknock	Increasing	Increasing

PART 6

CONCLUSION

The study aims to investigate if the engine will work normally without any modification while using the fusel oil, if he is more suitable than gasoline and which parameters will affect mostly on this type of oil during the combustion engine. In addition to that, the fuel was examined. The deductions are given as follows. Depending on the result of the CFD calculation of the gasoline and the fusel oil we define that we have 6 main results for this operation.

- The highest coefficient of the combustion inside the engine with the fusel with low quantities of vapor after filtration and ejecting water before using the fusel.
- The high responsibility of ignition with the fusel oil due to the presence of octane.
- The compatibility of the spark engine with fusel oil instead of the diesel engine
- Less emission of the fusel due to presence of high oxygen
- High consumption of fusel due to the high density and viscosity
- The fusel oil can hold and have a higher pressure than the gasoline

In the end of this report, we can deduce that we can use between 70 and 85 % of fusel oil in the engine to get a good performance because the less of power if we use 100%of fusel in the engine on the high torque and that is depend on the low pressure of the fusel and also that the fusel oil is a well and good replacement for the gasoline.

REFERENCES

1. Simsek, S.; Ozdalyan, B. Improvements to the Composition of Fusel Oil and Analysis of the Effects of Fusel Oil-Gasoline Blends on a Spark-Ignited (SI) Engine's Performance and Emissions. *Energies* **2018**, *11*, doi:10.3390/en11030625.

2. Luque, R.; Herrero-Davila, L.; Campelo, J.M.; Clark, J.H.; Hidalgo, J.M.; Luna, D.; Marinas, J.M.; Romero, A.A. Biofuels: A Technological Perspective. *Energy Environ. Sci.* **2008**, *1*, 542–564, doi:10.1039/b807094f.

3. Szwaja, S.; Naber, J.D. Combustion of N-Butanol in a Spark-Ignition IC Engine. *Fuel* **2010**, *89*, 1573–1582, doi:10.1016/j.fuel.2009.08.043.

4. Harvey, B.G.; Meylemans, H.A. The Role of Butanol in the Development of Sustainable Fuel Technologies. *J. Chem. Technol. Biotechnol.* **2011**, *86*, 2–9, doi:10.1002/jctb.2540.

5. Wallner, T.; Miers, S.A.; McConnell, S. A Comparison of Ethanol and Butanol as Oxygenates Using a Direct-Injection, Spark-Ignition Engine. *J. Eng. Gas Turbines Power* **2009**, *131*, 1–9, doi:10.1115/1.3043810.

6. Leduc, P.; Dubar, B.; Ranini, A.; Monnier, G. Downsizing of Gasoline Engine: An Efficient Way to Reduce CO2 Emissions. *Oil Gas Sci. Technol.* **2003**, *58*, 115–127, doi:10.2516/ogst:2003008.

7. Christensen, M.; Hultqvist, A.; Johansson, B. Demonstrating the Multi Fuel Capability of a Homogeneous Charge Compression Ignition Engine with Variable Compression Ratio. *SAE Tech. Pap.* **1999**, doi:10.4271/1999-01-3679.

8. Flowers, D.L.; Aceves, S.M.; Frias, J.M. Improving Ethanol Life Cycle Energy Efficiency by Direct Utilization of Wet Ethanol in HCCI Engines. *SAE Tech. Pap.* **2007**, 1070–1078, doi:10.4271/2007-01-1867.

9. Thrlng, R.H. II !!! The Engineering Society Homogeneous .. Charge Compression .. Ignition (HCCI) Engines. *October* **2011**.

10. Oakley, A.; Zhao, H.; Ladommatos, N.; Ma, T. Experimental Studies on Controlled Auto-Ignition (CAI) Combustion of Gasoline in a 4-Stroke Engine. *SAE Tech. Pap.* **2001**, *110*, 1062–1075, doi:10.4271/2001-01-1030.

11. Li, J.; Zhao, H.; Ladommatos, N.; Ma, T. Research and Development of Controlled Auto-Ignition (CAI) Combustion in a 4-Stroke Multi-Cylinder Gasoline Engine. *SAE Tech. Pap.* **2001**, doi:10.4271/2001-01-3608.

12. McEnally, C.S.; Pfefferle, L.D. Fuel Decomposition and Hydrocarbon Growth Processes for Oxygenated Hydrocarbons: Butyl Alcohols. *Proc. Combust. Inst.* **2005**, *30*, 1363–1370, doi:10.1016/j.proci.2004.07.033.

13. Suslick, K.S.; Fang, M.M.; Hyeon, T.; Mdleleni, M.M. Applications of Sonochemistry to Materials Synthesis. *Sonochemistry and Sonoluminescence* **1999**, 291–320, doi:10.1007/978-94-015-9215-4_24.

14. Webb, A.D.; Ingraham, J.L. Fusel Oil. *Adv. Appl. Microbiol.* **1963**, *5*, 317–353, doi:10.1016/S0065-2164(08)70014-5.

15. Chastain, B.B. Jean-Baptiste Dumas (1800-1884): The Victor Hugo of Chemistry. *Bull Hist. Chem.* **1990**, *8*, 8–12.

16. Calam, A. Effects of the Fusel Oil Usage in HCCI Engine on Combustion, Performance and Emission. *Fuel* **2020**, *262*, 116503, doi:10.1016/j.fuel.2019.116503.

17. Solmaz, H. Combustion, Performance and Emission Characteristics of Fusel Oil in a Spark Ignition Engine. *Fuel Process. Technol.* **2015**, *133*, 20–28, doi:10.1016/j.fuproc.2015.01.010.

18. Calam, A.; Solmaz, H.; Uyumaz, A.; Polat, S.; Yilmaz, E.; Içingür, Y. Investigation of Usability of the Fusel Oil in a Single Cylinder Spark Ignition Engine. *J. Energy Inst.* **2015**, *88*, 258–265, doi:10.1016/j.joei.2014.09.005.

19. Safieddin Ardebili, S.M.; Solmaz, H.; İpci, D.; Calam, A.; Mostafaei, M. A Review on Higher Alcohol of Fusel Oil as a Renewable Fuel for Internal Combustion Engines: Applications, Challenges, and Global Potential. *Fuel* **2020**, *279*, doi:10.1016/j.fuel.2020.118516.

20. Simsek, S.; Ozdalyan, B.; Solmaz, H.; Webb, A.D.; Ingraham, J.L. = Σ 2 / N 2 A) Σ. *Adv. Appl. Microbiol.* **2015**, *5*, 317–353, doi:10.1016/j.fuproc.2015.01.010.

21. Awad, O.I.; Ali, O.M.; Hammid, A.T.; Mamat, R. Impact of Fusel Oil Moisture Reduction on the Fuel Properties and Combustion Characteristics of SI Engine Fueled with Gasoline-Fusel Oil Blends. *Renew. Energy* **2018**, *123*, 79–91, doi:10.1016/j.renene.2018.02.019.

22. Yılmaz, E. Investigation of the Effects of Diesel-Fusel Oil Fuel Blends on Combustion, Engine Performance and Exhaust Emissions in a Single Cylinder Compression Ignition Engine. *Fuel* **2019**, *255*, doi:10.1016/j.fuel.2019.115741.

23. Awad, O.I.; Mamat, R.; Ibrahim, T.K.; Ali, O.M.; Kadirgama, K.; Leman, A.M. Performance and Combustion Characteristics of an SI Engine Fueled with Fusel Oil-Gasoline at Different Water Content. *Appl. Therm. Eng.* **2017**, *123*, 1374–1385, doi:10.1016/j.applthermaleng.2017.05.132.

24. Luo, M.; El-Faroug, M.O.; Yan, F.; Wang, Y. Particulate Matter and Gaseous Emission of Hydrous Ethanol Gasoline Blends Fuel in a Port Injection Gasoline Engine. *Energies* **2017**, *10*, doi:10.3390/en10091263.

25. Awad, O.I.; Ali, O.M.; Zhou, B.; Ma, X.; Thaeer Hammid, A.; Alwan, N.T.; Yaqoob, S.J.; Motahhir, S.; Askar, S.S.; Abouhawwash, M. Utilization of Additive from Waste Products with Gasoline Fuel to Operate Spark Ignition Engine. *Sci. Rep.* **2022**, *12*, 1–14, doi:10.1038/s41598-022-11599-6.

26. Mayer, F.D.; Feris, L.A.; Marcilio, N.R.; Staudt, P.B.; Hoffmann, R.; Baldo, V. Influence of Fusel Oil Components on the Distillation of Hydrous Ethanol Fuel (HEF) in a Bench Column. *Brazilian J. Chem. Eng.* **2015**, *32*, 585–593, doi:10.1590/0104-6632.20150322s00003215.

27. Awad, O.I.; Ali, O.M.; Mamat, R.; Abdullah, A.A.; Najafi, G.; Kamarulzaman, M.K.; Yusri, I.M.; Noor, M.M. Using Fusel Oil as a Blend in Gasoline to Improve SI Engine Efficiencies: A Comprehensive Review. *Renew. Sustain. Energy Rev.* **2017**, *69*, 1232–1242, doi:10.1016/j.rser.2016.11.244.

28. Schifter, I.; González, U.; González-Macías, C. Effects of Ethanol, Ethyl-Tert-Butyl Ether and Dimethyl-Carbonate Blends with Gasoline on SI Engine. *Fuel* **2016**, *183*, 253–261, doi:10.1016/j.fuel.2016.06.051.

29. Ambrós, W.M.; Lanzanova, T.D.M.; Fagundez, J.L.S.; Sari, R.L.; Pinheiro, D.K.; Martins, M.E.S.; Salau, N.P.G. Experimental Analysis and Modeling of Internal Combustion Engine Operating with Wet Ethanol. *Fuel* **2015**, *158*, 270–278, doi:10.1016/j.fuel.2015.05.009.

30. Lopes, M.L.; Paulillo, S.C. de L.; Godoy, A.; Cherubin, R.A.; Lorenzi, M.S.; Giometti, F.H.C.; Bernardino, C.D.; de Amorim Neto, H.B.; de Amorim, H.V. Ethanol Production in Brazil: A Bridge between Science and Industry. *Brazilian J. Microbiol.* **2016**, *47*, 64–76, doi:10.1016/j.bjm.2016.10.003.

31. Dwivedi, G.; Jain, S.; Sharma, M.P. Diesel Engine Performance and Emission Analysis Using Biodiesel from Various Oil Sources - Review. *J. Mater. Environ. Sci.* **2013**, *4*, 434–447.

32. Smollin, C.; Olson, K. Carbon Monoxide Poisoning (Acute) Search Date June 2010 Carbon Monoxide Poisoning (Acute). *Clin. Evid. (Online).* **2010**, 1–12.

33. Bein, K.; Leikauf, G.D. Acrolein - a Pulmonary Hazard. *Mol. Nutr. Food Res.* **2011**, *55*, 1342–1360, doi:10.1002/mnfr.201100279.

34. Class, C.; Name, C. Safety Data Sheet (GHS) Safety Data Sheet (GHS). **2011**, *830348*, 4–9.

35. Del Pecchia, M.; Pessina, V.; Berni, F.; d'Adamo, A.; Fontanesi, S. Gasoline-Ethanol Blend Formulation to Mimic Laminar Flame Speed and Auto-Ignition Quality in Automotive Engines. *Fuel* **2020**, *264*, 116741, doi:10.1016/j.fuel.2019.116741.

36. Xiao, H.; Guo, F.; Wang, R.; Yang, X.; Li, S.; Ruan, J. Combustion Performance and Emission Characteristics of Diesel Engine Fueled with Iso-Butanol/Biodiesel Blends. *Fuel* **2020**, *268*, 117387, doi:10.1016/j.fuel.2020.117387.

37. Ning, L.; Duan, Q.; Chen, Z.; Kou, H.; Liu, B.; Yang, B.; Zeng, K. A Comparative Study on the Combustion and Emissions of a Non-Road Common Rail Diesel Engine Fueled with Primary Alcohol Fuels (Methanol, Ethanol, and n-Butanol)/Diesel Dual Fuel. *Fuel* **2020**, *266*, 117034, doi:10.1016/j.fuel.2020.117034.

38. Li, Y.; Tang, W.; Chen, Y.; Liu, J.; Lee, C. fon F. Potential of Acetone-Butanol-Ethanol (ABE) as a Biofuel. *Fuel* **2019**, *242*, 673–686, doi:10.1016/j.fuel.2019.01.063.

39. Janet L., S.; Jay, R.; Freyr, S. *Renewables 2018-Global Status Report. A Comprehensive Annual Overview of the State of Renewable Energy. Advancing the Global Renewable Energy Transition-Highlights of the REN21 Renewables 2018 Global Status Report in Perspective*; 2018; ISBN 9783981891133.

40. Wu, X.; Zhang, S.; Guo, X.; Yang, Z.; Liu, J.; He, L.; Zheng, X.; Han, L.; Liu, H.; Wu, Y. Assessment of Ethanol Blended Fuels for Gasoline Vehicles in China: Fuel Economy, Regulated Gaseous Pollutants and Particulate Matter. *Environ. Pollut.* **2019**, *253*, 731–740, doi:10.1016/j.envpol.2019.07.045.

41. Taghizadeh-Alisaraei, A.; Motevali, A.; Ghobadian, B. Ethanol Production from Date Wastes: Adapted Technologies, Challenges, and Global Potential. *Renew. Energy* **2019**, *143*, 1094–1110, doi:10.1016/j.renene.2019.05.048.

42. Bicalho, T.; Sauer, I.; Patiño-Echeverri, D. Quality of Data for Estimating GHG Emissions in Biofuel Regulations Is Unknown: A Review of Default Values Related to Sugarcane and Corn Ethanol. *J. Clean. Prod.* **2019**, *239*, doi:10.1016/j.jclepro.2019.117903.

43. de Andrade Junior, M.A.U.; Valin, H.; Soterroni, A.C.; Ramos, F.M.; Halog, A. Exploring Future Scenarios of Ethanol Demand in Brazil and Their Land-Use Implications. *Energy Policy* **2019**, *134*, 110958, doi:10.1016/j.enpol.2019.110958.

44. Mofijur, M.; Rasul, M.G.; Hyde, J.; Azad, A.K.; Mamat, R.; Bhuiya, M.M.K. Role of Biofuel and Their Binary (Diesel-Biodiesel) and Ternary (Ethanol-Biodiesel-Diesel) Blends on Internal Combustion Engines Emission Reduction. *Renew. Sustain. Energy Rev.* **2016**, *53*, 265–278, doi:10.1016/j.rser.2015.08.046.

45. Mandade, P.; Shastri, Y. Multi-Objective Optimization of Lignocellulosic Feedstock Selection for Ethanol Production in India. *J. Clean. Prod.* **2019**, *231*, 1226–1234, doi:10.1016/j.jclepro.2019.05.311.

46. Silveira, S.; Khatiwada, D. Sugarcane Biofuels. *Sugarcane Biofuels* **2019**, doi:10.1007/978-3-030-18597-8.

47. Erdiwansyah; Mahidin; Mamat, R.; Sani, M.S.M.; Khoerunnisa, F.; Kadarohman, A. Target and Demand for Renewable Energy across 10 ASEAN Countries by 2040. *Electr. J.* **2019**, *32*, 106670, doi:10.1016/j.tej.2019.106670.

48. Pongkua, W.; Dolphen, R.; Thiravetyan, P. Bioremediation of Gaseous Methyl Tert-Butyl Ether by Combination of Sulfuric Acid Modified Bagasse Activated Carbon-Bone Biochar Beads and Acinetobacter Indicus Screened from Petroleum Contaminated Soil. *Chemosphere* **2020**, *239*, 124724, doi:10.1016/j.chemosphere.2019.124724.

49. Jarowski, C.I. ProQuest. **1943**.

50. Bandres, M.M.; Caro, P.D.E.; Thiebaud-roux, S. Synthèse de Solvants et Plastifiants d ’ Origine Naturelle Selon Une Application à La Formulation de Vernis à Ongles. Sciences Des Agroressources. Institut National Polytechnique de Toulouse. **2007**, 282.

51. Timirmans.Pdf.

52. Thiede, S.; Horstmann, S.; Meisel, T.; Sinnema, J.; Gmehling, J. Experimental Determination of Vapor-Liquid Equilibria and Excess Enthalpy Data for the Binary System 2-Methyl-1-Butanol + 3-Methyl-1-Butanol as a Test Mixture for Distillation Columns. *Ind. Eng. Chem. Res.* **2010**, *49*, 1844–1847, doi:10.1021/ie9012453.

53. Ikeda, R.M.; Kepner, R.E.; Webb, A.D. Densities, Refractive Indices, and Rotations of Mixtures of Active Amyl and Isoamyl Alcohols Application to Analysis. *Anal. Chem.* **1956**, *28*, 1335–1336, doi:10.1021/ac60116a035.

54. พวงผกา มะเสนา และประณต นันทิยะกุล No Titleการบริหารจัดการการบริการที่มีคุณภาพในโรงพยาบาลสังกัดกระทรวงสาธารณสุข. *วารสารวิชาการมหาวิทยาลัยอีสเทิร์นเอเซีย* **2557**, *4*, 88–100.

55. Cheng, W.K.; Hamrin, D.; Heywood, J.B.; Hochgreb, S.; Min, K.; Norris, M. An Overview of Hydrocarbon Emissions Mechanisms in Spark-Ignition Engines. *SAE Tech. Pap.* **1993**, doi:10.4271/932708.

56. Namazian, M.; Heywood, J.B. Flow in the Piston-Cylinder-Ring Crevices of a Spark-Ignition Engine: Effect on Hydrocarbon Emissions, Efficiency and Power. *SAE Tech. Pap.* **1982**, *91*, 261–288, doi:10.4271/820088.

57. Loladze, I.; Nolan, J.M.; Ziska, L.H.; Knobbe, A.R. Rising Atmospheric CO2 Lowers Concentrations of Plant Carotenoids Essential to Human Health: A Meta-Analysis. *Mol. Nutr. Food Res.* **2019**, *63*, 1–9, doi:10.1002/mnfr.201801047.

58. Ashby, M. Material Property Data for Engineering Materials. *ANSYS Educ. Resour.* **2021**, 35.

59. Hirose, Y.; Ogawa, M.; Kusuda, Y. Constituents of Fusel Oils Obtained Through the Fermentation of Corn , Barley and Sweet Molasses. **2014**, *1369*, doi:10.1080/00021369.1962.10858005.

60. Wines, T.H.; Corporation, P. Improve Suspended Water Removal from Fuels. **2016**, doi:10.1007/978-1-4757-1209-4.

61. Atadashi, I.M.; Aroua, M.K.; Aziz, A.R.A.; Sulaiman, N.M.N. The Effects of Water on Biodiesel Production and Refining Technologies : A Review. *Renew. Sustain. Energy Rev.* **2012**, *16*, 3456–3470, doi:10.1016/j.rser.2012.03.004.
62. Lif, A.; Holmberg, K. Water-in-Diesel Emulsions and Related Systems. **2006**, *126*, 231–239, doi:10.1016/j.cis.2006.05.004.

63. Kannan, G.R.; Anand, R. Experimental Investigation on Diesel Engine with Diestrol e Water Micro Emulsions. *Energy* **2011**, *36*, 1680–1687, doi:10.1016/j.energy.2010.12.062.

64. Sass, J.; Resources, N.; Council, D. Industry Efforts to Weaken the EPA ' s Classification of the Carcinogenicity Of. **2014**, doi:10.1179/oeh.2005.11.4.378.

65. Kumar, S.; Cho, J.H.; Park, J.; Moon, I. Advances in Diesel – Alcohol Blends and Their Effects on the Performance and Emissions of Diesel Engines. *Renew. Sustain. Energy Rev.* **2013**, *22*, 46–72, doi:10.1016/j.rser.2013.01.017.

66. Kujawska, A.; Kujawski, J.; Bryjak, M.; Kujawski, W. ABE Fermentation Products Recovery Methods - A Review. *Renew. Sustain. Energy Rev.* **2015**, *48*, 648–661, doi:10.1016/j.rser.2015.04.028.

67. Ngür, Y.İ.Ç.İ.; Calam, A. ATE Ş LEMEL İ B İ R MOTORDA PERFORMANS VE THE EFFECTS OF THE BLENDS OF FUSEL OIL AND GASOLINE ON PERFORMANCE AND EMISSIONS IN A SPARK IGNITION ENGINE. **2012**, *27*, 143–149.

68. Awad, O.I.; Ali, O.M.; Mamat, R.; Abdullah, A.A.; Najafi, G.; Kamarulzaman, M.K.; Yusri, I.M.; Noor, M.M. Using Fusel Oil as a Blend in Gasoline to Improve SI Engine Efficiencies: A Comprehensive Review. *Renew. Sustain. Energy Rev.* **2017**, *69*, 1232–1242, doi:10.1016/j.rser.2016.11.244.

69. Mansoury, M.; Jafarmadar, S.; Talei, M.; Lashkarpour, S.M. Optimization of HCCI (Homogeneous Charge Compression Ignition) Engine Combustion Chamber Walls Temperature to Achieve Optimum IMEP Using LHS and Nelder Mead Algorithm. *Energy* **2017**, *119*, 938–949, doi:10.1016/j.energy.2016.11.047.

RESUME

Hassan Ali Mcheik, attend schools in Lebanon. He finished his high school education at Saint Mathieu Laporte School-Lebanon, them he began his undergraduate bachelor's program at Matn university college (MUC), Department of technology in 2016. Then in 2020, he started his master's program at Karabük University, Department of Mechanical Engineering.