Palestine Polytechnic University

College of Engineering and Technology
Mechanical Engineering Department

Graduation Project

Production process for biodiesel from Animal fats sources

The Student Work
Ahmad Nassar

Project Supervisor
Dr. Momen Sughayyer

Hebron - Palestine
May - 2011

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Abstract (English)

Production process for biodiesel from Animal fats sources

This project is directed towards supporting the local industry and development through the construction of an experiment prototype to convert animal fats into biodiesel as pave the way for investors to exploit fat destroyed and recycled in order to obtain fuel.

The project included several steps started in a statistical consideration of biomass resources that are available and used in the production of biodiesel in the district of Hebron. Where the study All offer sources of waste animal fats in the Hebron area and the possibility of collected for recycling for the production of biodiesel. After that, study the production process and economic and environmental implications of that. In the final stage was the built as a prototype to convert animal fat into biodiesel funding from deanship of Scientific Research. Been working at different stages of the marketing of the idea of local plants.

Abstract (Arabic)

هذا المشروع موجه نحو دعم الصناعة المحلية وتطويرها من خلال بناء نموذج تجريبي لتحويل الدهون الحيوانية إلى وقود حيوي حيث سيفتح المجال للمستثمرين باستغلال الدهون المتلفة وإعادة تصنيعها بهدف الحصول على الوقود.

المشروع يشتمل على عدة مراحل بدأت بدراسة احصائية للموارد الحيوية المتوفرة والتي تستخدم في انتاج الوقود الحيوي في محافظة الخليل. حيث تم دراسة المصادر التوفرة للمخلفات الحيوية من الدهون الحيوانية في منطقة الخليل وامكانية تجميعها لاعادة تصنيعها بغرض انتاج الوقود الحيوي.ثم تم تحديد الكميات الممكن تجميعها وتقييم التكلفة لعملية التجميع. بعد ذلك تم دراسة عملية الانتاج والانعكاسات الاقتصادية والبيئية لذلك. في المرحلة النهائية تم بناء نموذج تجريبي لتحويل الدهون الحيوانية الى وقود حيوي بتمويل من عمادة البحث. وتم العمل في المراحل المختلفة على تسويق الفكرة للمصانع المحلية.

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Chapter One

Introduction

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1.1 General Outlook

The need for energy is increasing continuously because of the increase in industrialization and population. The basic sources of this energy that we use in Hebron district is petroleum products and natural gas in addition to electricity. All that energy sources are imported at high cost for our economy , which slows our economy growth. There for basing on this problem their is another alternative source of energy in Hebron which can be extracted from organic material such as waste vegetable oil and animal fats in order to produce renewable source of energy called biodiesel.

Waste cooking oil and animal fats can affect human beings health and pollute the environment. The quantity of this waste fats generated per year in Hebron district is very significant. For the matter of fact, the disposal of waste fats is problematic, because the disposal methods contaminate the environment and pose risk to local public health.

The production of biodiesel from waste fats is one of the best ways to utilize it efficiently and economically. The data on the requirements of diesel fuel and availability of waste biomass sources in Hebron indicates that the obtained biodiesel may not replace diesel fuel completely. But, a substantial amount of diesel fuel can be obtained from waste animal fats, which would partly reduce the dependence on petroleum-based fuel.

Biomass is one of the important renewable sources of energy. Fuels from renewable biomass have the potential to reduce the amount of green house gases and particulate matter. This is because the carbon contained in biomass derived fuel is biogenic and renewable. In addition to the other important factor such as reduction of pollution risk and potential economical field. Therefore, petroleum based fuels can be complemented by fuels obtained from renewable sources.

1.2 Objectives of this Project

This project is the second phase of work done in PPU in this field. In phase one afield study for the quantities available have been done and a design for plant to transform cooking oil to biodiesel at low have been done temperature and prototype have been tested , in addition to product testing on ICE.

Phase two, A process will be designed to transform animal fats to biodiesel. This process the subject of this project will work at higher temperature with respect to phase one, because animal fat, some how solid and reaction is not possible between solid phase (fats) and liquid phase (methanol) , their fore it will be an important development to previous phase.

The importance of this Project can be summarized in the following point:

1- The design and construction of a prototype for the purpose of production of Biodiesel from animal fats.

2- The production of Biodiesel from animal fats locally.

3- Supporting the contribution with local industry.

4- Spread the cultural protection and saving in the local society.

1.3 Connections between the Project and Benefited Parties

This project is oriented basically towards local official and private sector concerned in energy industry, which gives information about the ability of production of biodiesel from animal fats. This project supports local economy and especially industry from these sides:

1- Financial benefits from recycling of fats from biological resources resulted from the process of fats production instead of disposability which is expensive economically and environmentally.

2- Provide industrial investments chances in the field of collection and recycling of biological animal fat locally.

3- The help of public institution to develop policies required for health and environment protection in addition to encouragement and support local industry.

1.4 Literature Review

Biodiesel production and all related issue are well studied internationally. some literature review like [1], [2], [3], provide some studies about producing the alternative fuel (biodiesel) from biomass like animal fats with a limit study about the quantity of animal fats in small regions, a financial study to produce it.

1. Biodiesel Production in PPU [1]

This project was consisted of many stages; it begins with a statistical study for the biological resources available which are used for the production of biodiesel. the research was studied for the biomase wastes available from animal fats and vegetable oil in Hebron district with the possibility to be collected and recycled again in order to produce biodiesel fuel. Then possible amounts that should be collected are was determined, that evaluation of the whole cost due to the process of collection and storage will follow. Then after, the production process should be studied taking into account economical and environmental reflections of this process. In the last stage, there was a production of a trial amount was produced using a small plant Specially built this process occur during low temperature.

2. Biodiesel Production in UK [2]

This research was done by Department of Chemical & Materials Engineering University of Auckland, in UK. It was done to produce biodiesel from animal fat, production design and built to produce sufficient biodiesel. Research investigating the transesterification of fats and oil with methanol was performed to improve the economic viability of the production process for biodiesel from oil and fats. The key feature of the new process developed in this work is its ability to operate continuously with a high reaction rate, potentially requiring less post reaction cleaning and product/reactant separation than currently established processes.. The overall conversion based on a single cycle of this process has been between 60 to 96% of the feed stock materials.

3. Biodiesel production in 1ndia [3]

At Tamil Nadu Agricultural University, the BioEnergy Department of the Agricultural Engineering College and Research Institute has invested efforts in this energy challenge proposed by the government to the Indian scientists' community. This unit serves as a model for some industries in the university area. In addition, the TNAU Forest Institute, located outside the main campus, is looking at the optimal biomass source for the production of non-edible oil dedicated to be transformed into biodiesel. The research investing is to improve efficiency and performance of biodiesel production by shifting from a batch production to a continuous production. The designed unit will also allow for methanol recovery. the students was aimed to achieve the reaction within 10minutes and to use a lower methanol to oil molar ratio of about 4 to 1. Furthermore, the design was highly effective to recover methanol. The unit was design to be very versatile: every component can be analyzed and understood separately. The feasibility of using such a system for continuous flow production can be assessed and consequent scale-up may occur The design is a scale up of the experimental set-up of a team from Idaho University, Moscow،Idaho. Its principle relies on the use of a reactive distillation reactor which allows for faster and more efficient biodiesel production. The lab-scale unit was worked under gravity only, which therefore allows for very small flows at a minimum cost.

1.5 Project Schedule

Table 1.1 Project time-schedule for first semester

Process	Week														
	1	2	3	٤	5	6	7	8	9	10	11	12	13	14	15
Collecting Data and Literature	▨	▨	▨	▨	▨										
Analyzing of data	▨	▨	▨	▨	▨	▨	▨	▨							
Design experimental prototype						▨	▨	▨	▨						
Statistical and Survey						▨	▨	▨	▨	▨					
process design and calculations								▨	▨	▨	▨	▨	▨	▨	
Writing The documentation												▨	▨	▨	▨

Table 1.2 Project time-schedule for second semester

Process	Week														
	1	2	3	٤	5	6	7	8	9	10	11	12	13	14	15
Design experimental prototype	■	■	■	■	■	■	■								
Process design and calculations								■	■	■	■				
Biodiesel Production and results and analysis									■	■	■	■			
Building the experimental prototype								■	■	■	■	■	■	■	■
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The work Stages

1. literature review during were the first two weeks, which started early and passed within eight weeks.
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5. Finally, writing the documentation research was started after finishing the previous steps.

1.6 Project Budget

The apparatus requirements are chemical materials (methanol, sodium hydroxide...), laboratory instrument, tanks, injector, condenser, piping and fittings, heater, valves, pumps, blender…..).

The budget of the project also includes printing costs and local study and survey. The following table shows the estimated cost of each one.

Table 1.3 Project budget

Element	Description	Availability	Students	DSR Grant
	Valves and fitting			250
	Mixer			300
	Piping			350
	Electric heater (1)			100
	Electric heater(2)			200
	condenser			150
	Electric centrifugal pump1			100
	Electric centrifugal pump2			100
	Electric gear pump1			1000
	Injector			170
	Reactor			1000
	Machining (Lathe and welding)	available		
	Methanol and NaOH			850
Experimentation	Chemistry Lab tools	Chemistry lab in PPU		
	Printing and preparing documentation			
	Visits to companies, shops		20	
Transportation			130	
Total cost (NIS)				4720

1.7 Report content

This chapter presents the general idea of the project and its importance, in addition the field of application and specialization also, in addition conduct the literature reviews of the previous studies about this project, this chapter also includes the time plan for all over the project, and the tools, equipments, materials that are used in the project, and finally the total cost.

Chapter two presents an introduction about biodiesel, historical perspective, the definition of biodiesel with the advantages of it, and also the disadvantage, then it describes how to overcome the disadvantages, in addition of that the emission of biodiesel and finally the impact of biodiesel on environment and health.

Chapter three discuss the process of biodiesel production including prototype design, and discussed its component in details, and biodiesel is analyzed in detail and calculation of each component.

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Chapter One

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Chapter Two

Biodiesel and its potential in Palestine

Content:

Chapter Two

Biodiesel and its potential in Palestine

2.1 Introduction

The industrial revolution in the recent years and the increase in population increases the demand for energy in a continuous manner, and as it is known, the main source of used energy nowadays in all aspects of daily life is restricted at most within petroleum, natural gas, coal, hydro and nuclear energy.

Petroleum diesel continues to be a major fuel world wide. The most of this is utilized in the transportation sector. The major disadvantage of using petroleum-based fuels is that, day by day, the fossil fuel reserves are decreasing. Another disadvantage is atmospheric pollution created by the use of petroleum diesel. Petroleum diesel combustion is a major source of greenhouse gas. Then many industrial countries began to search about alternatives of petroleum based fuel. They suggest using solar, wind, water, and biomass energy, as a result of several researches it was discovered that the vegetable oil can be used as fuel after converted to alkyl esters compounds by reacting with suitable alcohol mainly methanol and the final product was called Biodiesel.

2.2 Historical Perspective

In 1900, Rudolf Diesel demonstrated his compression ignition engine at the World's Exhibition in Paris. In that prototype engine he used peanut oil, the first biodiesel. Vegetable oils were used until the 1920's when an alteration was made to the engine enabling it to use a residue of petroleum diesel. Although the diesel engine gained worldwide acceptance, biodiesel did not. With superior price, availability, and government subsidies, petroleum diesel quickly became the fuel of choice for the diesel engine.

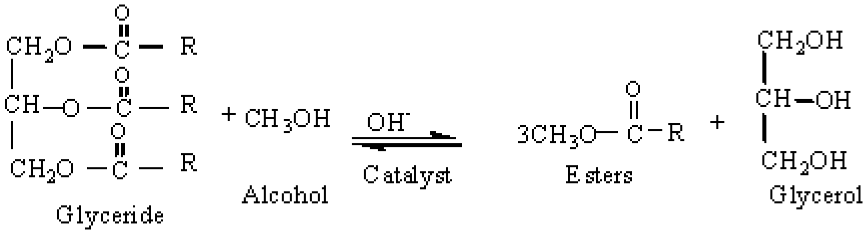
In the mid 1970s, fuel shortages revived interest in developing biodiesel as an alternative to petroleum diesel. However, as the petroleum market was increasingly subsidized, biodiesel was again relegated to a minority “alternative” status. This political and economic struggle continues to limit the impact of the biodiesel industry today.

Now, increasing concerns about the potential of global climate change, declining air and water quality, and serious human health concerns are inspiring the development of biodiesel, as a renewable, cleaner burning diesel alternative. Biodiesel is made from recycled animal fat and various feedstocks (biomass sources). As part of an active carbon cycle biodiesel feedstock production reduces the buildup of greenhouse gases, and in turn, global warming. [4]

2.3 What is Biodiesel?

Biodiesel is defined as the mono-alkyl esters of fatty acids derived from vegetable oils or animal fats. In simple terms, biodiesel is the product obtained when a vegetable oil or animal fat is chemically reacted with an alcohol to produce fatty acid alkyl esters. A catalyst such as sodium or potassium hydroxide is required. Glycerol is produced as a co product.

The simple reaction are



Glycerin which is the main byproduct has a numerous uses, including many applications as an ingredient or processing aid in cosmetics, toiletries, personal care, drugs, and food products [4].

Biodiesel can also be made from other feedstocks:

1. Other vegetable oils such as corn oil, canola (an edible variety of rapeseed) oil, cottonseed oil, mustard oil, palm oil, etc.
2. Restaurant waste oils such as frying oils
3. Animal fats such as beef tallow or lard
4. Trap grease (from restaurant grease traps), float grease (from waste water treatment Plants), etc.

2.4 Advantages of Biodiesel

Biodiesel can be used in several different ways. one can use 1% to 2% biodiesel as a lubricity additive, which could be especially important for Ultra Low Sulfur Diesel fuels (ULSD, less than 15 ppm sulfur), which may have poor lubricating properties. It can blend by 20% Biodiesel with 80% diesel fuel (B20) for use in most applications that use diesel fuel. Also it can be even use in its pure form (B100) if proper precautions are taken. The word biodiesel in this thesis refers to the pure fuel (B100) that meets the specific biodiesel definition and standards approved by ASTM International. The number following the “B” indicates the percentage of biodiesel in the volume fuel.

Today, B20 is the most common biodiesel blend in the world because it balances property differences with conventional diesel, performance, emission benefits, and costs. Higher blend levels, such as B50 or B100, require special handling and fuel management and may require equipment modifications such as the use of heaters or changing seals and gaskets that come in contact with the fuel to those compatible with high blends of biodiesel. The level of special care needed largely depends on the engine and vehicle manufacturer.

Biodiesel-fueled vehicles are called non-dedicated flexible fuel vehicles because biodiesel use does not require any significant modifications to the engine, so that the engine does not have to be dedicated for biodiesel use only. It is completely soluble in commercial petroleum-based diesel fuel, so **biodiesel can be used as a blend and one fuel tank can be used for storage of both fuels**. This makes the vehicle flexible. This is a unique advantage compared with most other alternative fuels, because this will give users the opportunity to use the alternative fuel where and when it is available without paying any extra money for engine modifications.

Given the fact that, Biodiesel is a renewable fuel manufactured from vegetable oils, animal fats, and recycled cooking oils. Biodiesel offers many advantages:

1. It is renewable.
2. It is energy efficient equivalent to petroleum diesel.
3. It potentially replaces petroleum derived diesel fuel.

4. It can be used in most diesel equipment with no or only minor modifications.
5. It can reduce global warming gas emissions because of the plant life cycle.
6. It can reduce tailpipe emissions, including air toxics.
7. It is nontoxic, biodegradable, and suitable for sensitive environment
8. Reduction in emissions of:
    a. Sulfur dioxide by 100%
    b. Soot emissions by 40-60%
    c. Carbon monoxide by 10-50%
    d. Hydrocarbons by 10-50%
    e. Nitrous oxide by 5-10%, depending on engine tuning and the age of the engine. Nitrous oxide emissions may increase in some instances.
9. Readily mixes with petroleum diesel fuel in any ratio
10. It has a higher flash point than petroleum diesel and thus helps prevent damaging fires. [5]
11. Biodiesel (B100) contains 11% oxygen by weight. The presence of fuel oxygen allows the fuel to burn more completely so fewer unburned fuel emissions result. [5]
12. Biodiesel has a higher cetane number than diesel fuel, which is provided easier starting, and quieter operation, better ignition quality, shorter ignition delay.

Most of the B100 made today that meets D6751 has a cetane number higher than 47. This is compared to the minimum of 40 for highway diesel fuel, whose national average is between 42 and 44. Therefore, biodiesel has a higher cetane number than most U.S. diesel fuel, which is believed to provide easier starting and quieter operation. Highly saturated B100, such as animal fats and used cooking oils, can have a cetane number of 70 or higher. Common polyunsaturated fuels that contain high levels of C18:2 and C18:3 fatty acids include soy, sunflower, corn, and canola (rapeseed) oils. These will be at the lower end of the scale, at 47 or slightly higher. Figure 2.1 shows the cetane number of various biodiesel samples. [5]

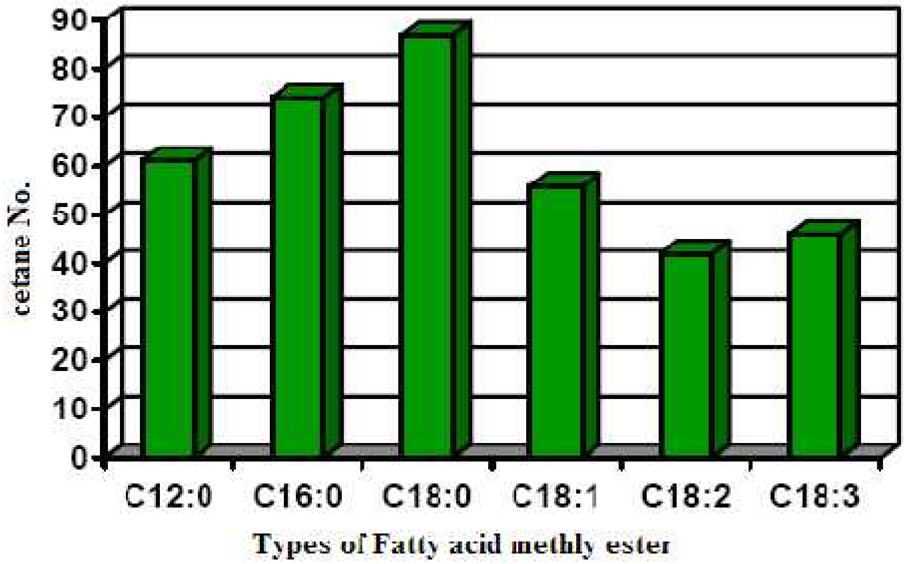


Figure2.1 Cetane number of fuels made from pure fatty acids

Table2.1 Fuel properties as a function of fuel composition in diesel engines

	Saturated	Monounsaturated	Polyunsaturated
Fatty acid	12:0,16:0 18:0,20:0, 22:0	16:1, 18:1, 20:1, 22:1	18:2, 18:3
Cetane Number	High	Medium	Low

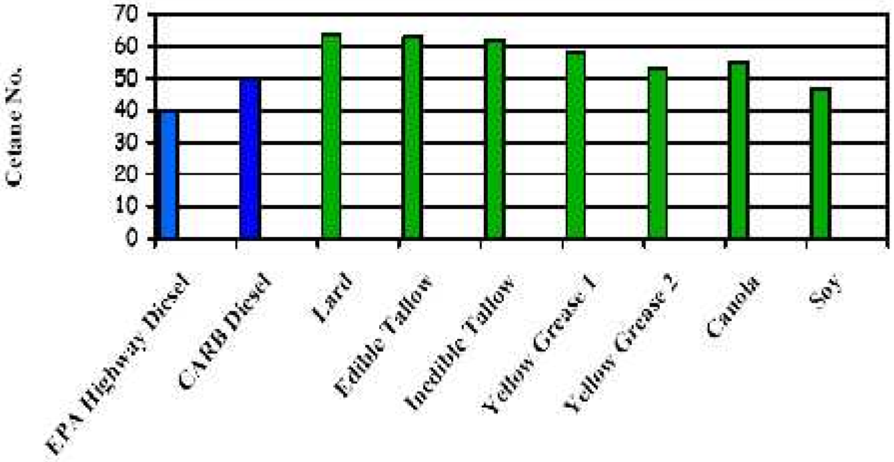


Figure2.2 Cetane number of fatty acid methyl esters, petroleum diesel and various biodiesel fuels

2.5 Biodiesel Disadvantages:

1. Biodiesel is a solvent that can be incompatible with the rubber seals and gaskets in the fuel systems of some types of diesel vehicles. If users have not taken measures to properly adapt their engines to run on biodiesel, dissolution of dirt and rubber can result in clogged engine and fuel lines. As such, pure B100 cannot be safely used as a stand-alone fuel in conventional vehicles.

2. The energy content of biodiesel is lower than that of petroleum diesel. As a result, vehicles running on any blend of biodiesel will experience a small reduction in fuel economy (miles per gallon). [6]

3. The use of biodiesel in cold weather presents certain challenges. All diesel fuel “clouds” at low temperatures. Clouding indicates the formation of wax crystals, which can inhibit proper flow of fuel to the engine and clog fuel lines or filters. Conventional petrodiesel begins to cloud at approximately 0° F, while B100 has a

clouding point of about 30° F .The higher clouding temperature is an important consideration for the use of biodiesel during cold winters. [6]

4. Nitrogen oxide emissions are increased for biodiesel combustion versus petrodiesel combustion.

2.6 Overcoming Disadvantages of Biodiesel Blends

Many of the disadvantages associated with neat biodiesel can be overcome by using Biodiesel blends, which consist of petrodiesel mixed with a specified quantity of biodiesel. Biodiesel blends are labeled BX, where X is a number that indicates the percentage of biodiesel in the blend. For example, B20 is a mixture of 80 percent petrodiesel and 20 percent biodiesel. Common blends include: B2, B5, B10, and B20. Biodiesel blends can overcome the inherent disadvantages of B100 in the following ways:

1. Blends up to a B20 (or even B35 in some cases) can be used with no alterations to a standard diesel engine.
2. The use of certain additives can prevent cold-weather clogging issues associated with biodiesel use in the winter months.
3. The addition of varying amounts of kerosene (depending on which biodiesel blend is used) has the ability to reduce nitrogen oxide emission.

2.7 Emissions of Biodiesel

Diesel engines always operate well on the lean side of stoichiometric, which means that CO emissions will be low, and regulations will easily be met. When one considers the chemistry of biodiesel, the CO emissions will be even lower. Because biodiesel is approximately 11% oxygen by weight, there will be extra oxygen to react with during the combustion process, allowing for more complete burning. In addition to reducing the amount of unburned hydrocarbons, this should reduce the emission of CO.

Furthermore, biodiesel has a lower carbon-to-hydrogen ratio than conventional petro diesel. It was found that biodiesel blends with the lowest carbon content formed the least CO, and all biodiesel emitted less CO than petroleum diesel. This makes intuitive sense, because, with less carbon in the fuel, there is a better chance that each carbon atom will find two oxygen atoms to bind. The decrease in CO emissions that was noticed with an increase in loading can also be simply explained. When the load on the engine is higher, the gas inside the cylinder will naturally be at a higher temperature. This speeds up the conversion rate of CO to CO_2, completing the combustion process and lowering CO emissions.

The oxygen content by weight of the biodiesel as a reason why NOx emissions increase. They reason that because the fuel itself contains oxygen, there will be more oxygen available to react with the nitrogen in the air. However, the increase in NOx is unexpected based on some of the biodiesel fuel properties, since a higher cetane number and lower energy content are usually associated with lower NOx.

Hydrocarbons are also a contributing factor in the creation of smog and ozone. Hydrocarbon emission, also called volatile organic compound (VOC) in atmospheric chemistry, is the main ingredient to the creation of photochemical smog. The oxidation reaction of the VOCs leads to the creation of ozone and aldehydes. The product ozone is also toxic. Ozone has poor solubility properties which, when taken into the lungs, can cause inflammation due to oxidization of lung tissue.

The consequences of local ozone formation also include detrimental effects on crop yields and the faster wearing of tires. When hydrocarbons are combined with NOx emissions, more volatile reactions resulting in ozone formation are possible. NOx emissions are an important emission of automobile exhaust. The reduction of hydrocarbons effectively means a reduction of many harmful consequences of hydrocarbon release into the environment.

The overall ozone (smog) forming potential of Biodiesel is less than Diesel fuel. The ozone forming potential of the speciated hydrocarbon emissions was nearly 50 percent less than that measured for Diesel fuel. Sulphur emissions are essentially eliminated with pure Biodiesel. The exhaust emissions of sulphur oxides and sulfates (major components of acid rain) from Biodiesel were essentially eliminated compared to sulphur oxides and sulphates from Diesel. [5]

Table2.3 provides the percentage changes in various emissions (relative to those from conventional petrodiesel) for various biodiesel blends. Generally, as the percentage of biodiesel blended with diesel increases, there is a concomitant reduction in harmful emissions. A notable exception is NOx emissions, which increase slightly with biodiesel use.[5]

Overall, however, biodiesel has the potential to reduce harmful emissions from current levels by up to 80 percent. This is equivalent to removing roughly.

Table 2.2 Percentage changes in emissions from various blends of Biodiesel relative to petro diesel.

% Biodiesel	PM	HC	CO	NOx	SOx	CO_2
1	-0.64	-1.11	-0.65	0.10	-1.00	-0.78
5	-3.14	-5.44	-3.23	0.49	-5.00	-3.92
10	-6.18	-10.59	-6.35	0.98	-10.00	-7.85
20	-11.99	-20.06	-12.30	1.98	-20.00	-15.69
30	-17.43	-28.53	-17.87	2.98	-30.00	-23.54
50	-27.33	-42.86	-27.97	5.02	-50.00	-39.23
80	-39.99	-59.16	-40.84	8.15	-80.00	-62.96
100	-47.19	-67.36	-48.11	10.29	-100.00	-78.45

These data are graphically illustrated in Figure 2.3

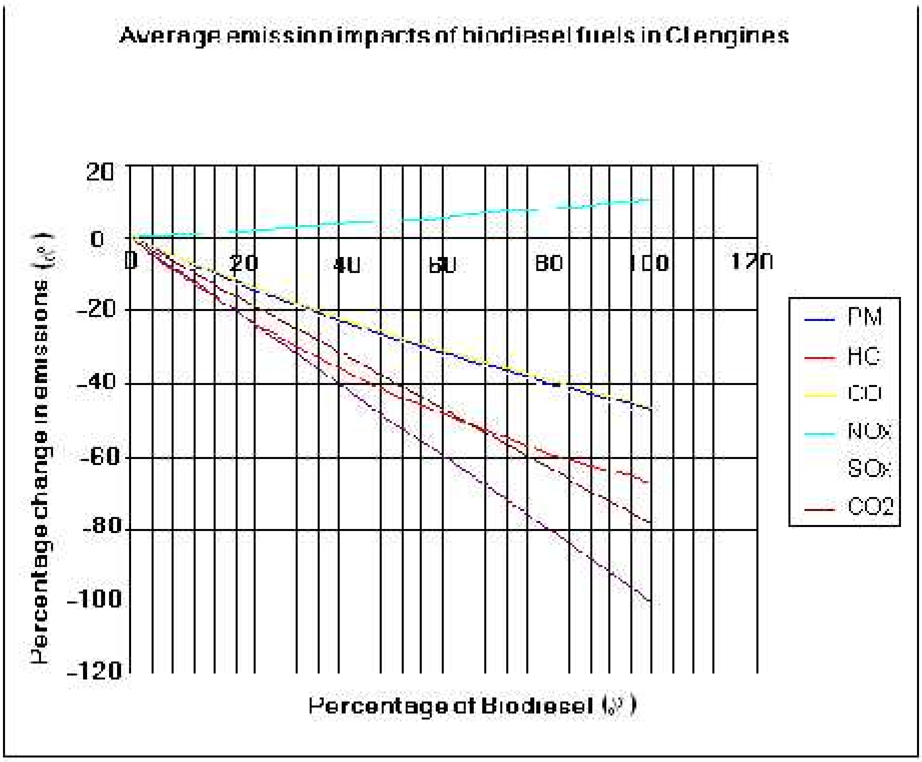


Figure 2.3 Average emission impacts of biodiesel fuels in CI engines

According to the previous figure carbon dioxide is one of the main greenhouse gases contributing to global warming. Neat Biodiesel (100% Biodiesel) reduces carbon dioxide emissions by more than 75% over petroleum Diesel. But using a blend of 20% Biodiesel reduces carbon dioxide emissions by 15%. Biodiesel also produces fewer particulate matter, carbon monoxide, and sulphur dioxide emissions.

The use of Biodiesel has significant benefit when it comes to supporting the environment. Biodiesel is the first and only alternative fuel to have a complete evaluation of emission results and potential health effects.

According to figure2.4 it can make a comparison of emission between diesel and Biodiesel.

1. Carbon Monoxide: The exhaust emissions of carbon monoxide (a poisonous gas) from Biodiesel were 50 percent lower than carbon monoxide emissions from Diesel.

2. Particulate Matter: Breathing particulate has been shown to be a human health hazard. The exhaust emissions of particulate matter from Biodiesel were 30 percent lower than overall particulate matter emissions from Diesel.

3. Hydrocarbons: The exhaust emissions of total hydrocarbons (a contributing factor in the localized formation of smog and ozone) were 93 percent lower for Biodiesel than Diesel fuel.

3. Sulphur oxides: Sulphur emissions are essentially eliminated with pure Biodiesel. The exhaust emissions of sulphur oxides and sulfates (major components of acid rain) from Biodiesel were essentially eliminated compared to sulphur oxides and sulphates from Diesel.

4. Nitrogen Oxides: NOx emissions from (100%) Biodiesel increased in this by 13 percent. However, Biodiesel’s lack of sulphur allows the use of NOx control technologies that cannot be used with conventional Diesel. So, Biodiesel NOx emissions can be effectively managed and efficiently eliminated as a concern of the fuel’s use.

2.7.1 How to solve the problem of NOx

The high level of NOx emissions is the major obstacle standing in the way of broad support for biodiesel, and much research has been devoted to its reduction, particularly in light of stringent exhaust emission regulations being imposed on diesel engines over the next few years. One popular method of reducing NOx emissions is exhaust gas recirculation (EGR). EGR reduces engine temperature by pumping a portion (10-25%) of exhaust gas back into the intake. Because the exhaust gas is nearly inert, it will not react in the combustion chamber and acts only as a heat sink. A small power loss is associated with EGR systems, but NOx emissions are decreased by up to 80%.

Another option to reduce NOx emissions is to install a catalytic converter. However, they work best at the stoichiometric ratio, so it will not be as effective on a diesel engine. They are also expensive and work better at high temperatures, while diesel exhaust is generally lower than gasoline exhaust. Selective noncatalytic reduction, diesel oxidation catalysts, water-fuel emulsions, and NOx and particulate traps have also been used to reduce NOx emissions on biodiesel engines. All of these methods, however, are only solving the problem of biodiesel NOx emissions indirectly, by removing the NOx after it are created.

Many studies of biodiesel combustion have found that the start of injection timing is advanced. This should result in a higher peak temperature inside the cylinder due to more premixed combustion, which will increase the rate of NOx production. This will also result in a longer residence time, allowing NOx production to continue for more time. In fact, It was found that a linear relationship between NOx emission and injection timing. The retard (delay) of injection timing lowered the NOx emission for all the biodiesel fuel blends. It has been pointed out that there was a NOx emission reduction of 35% to 43% for all biodiesel fuel blends at 3° retarded injection timing relative to the 3° advanced injection timing for the same fuel at the same load and speed condition.

2.8 Environmental Impacts of Biodiesel

The production and use of biodiesel creates 78% less carbon dioxide emissions than conventional diesel fuel. Carbon dioxide is a greenhouse gas that contributes to global warming by preventing some of the sun’s radiation from escaping the Earth. Burning biodiesel fuel also effectively eliminates sulfur oxide and sulfate emissions, which are major contributors to acid rain. That’s because, unlike petroleum-based diesel fuel, biodiesel is free of sulfur impurities. Combustion of biodiesel additionally provides a 56% reduction in hydrocarbon emissions and yields significant reductions in carbon monoxide and soot particles compared to petroleum based diesel fuel. Also, biodiesel can reduce the carcinogenic properties of diesel fuel by 94%. [7]

2.9 Statistical and Survey Analysis [1]

Another field visits had targeted meats and chicken shops, and also the concentrated on larger shops such as meats and chicken slaughterhouses to collect the amounts of animals fats and grease that can be obtained from Hebron district.

After the field visited department agriculture in Hebron district had been finished completely, there were main concluded information and data that had been studied carefully and analyzed with certain required calculations to attain the final shape of required data available. That is clearly shown in the following the amount of animal fats is 911 Ton's annually

Table2.3: Statistically fat extracted annually in the Hebron Governorate

Statistically fat extracted annually in the Hebron Governorate			
Type of fat	Number	loss quantity gr	Quantity in kg
Sheep	120000	1500	180000
Calves	37000	3000	111000
Camel	10000	2000	20000
White meat	3000000	200	600000
Total			911000

Must be indicated to the numbers inside table in continuously increasing.

Waste fats can be efficiently converted to biodiesel using a continues process. The estimated annual quantities of waste animal fat produced in Hebron district could produce around 0.93 million liter of Biodiesel from animal fats.

A Biodiesel blend provides a cleaner burning, more environmentally friendly substitute to ordinary diesel. No vehicle modifications are necessary.

Collecting waste oil and animal fats could create many jobs in Hebron district. The number of jobs could be increased by increasing of waste oil and animal fats. In addition, it will support Palestinian economy and increase national income.

Biodiesel is one of the most promising of the alternative fuels. It is produced from vegetable oil or animal fats using fairly simple chemistry .It is non-toxic and rapidly biodegrades. It can be produced from animal fats and offers good performance together with a number of environmental benefits compared to ordinary petroleum diesel. If all the estimated quantity of waste vegetable oil and animal fats were collected and converted to biodiesel up to 1.01 % of the total 94 million liter of petro diesel consumed in Hebron district annually could be replaced using the petro diesel fuel. This is a good and promising stand for reducing petroleum diesel usage.

Chapter Two

Biodiesel and its potential in Palestine

Content:

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2.1 Introduction

The industrial revolution in the recent years and the increase in population increases the demand for energy in a continuous manner, and as it is known, the main source of used energy nowadays in all aspects of daily life is restricted at most within petroleum, natural gas, coal, hydro and nuclear energy.

Petroleum diesel continues to be a major fuel world wide. The most of this is utilized in the transportation sector. The major disadvantage of using petroleum-based fuels is that, day by day, the fossil fuel reserves are decreasing. Another disadvantage is atmospheric pollution created by the use of petroleum diesel. Petroleum diesel combustion is a major source of greenhouse gas. Then many industrial countries began to search about alternatives of petroleum based fuel. They suggest using solar, wind, water, and biomass energy, as a result of several researches it was discovered that the vegetable oil can be used as fuel after converted to alkyl esters compounds by reacting with suitable alcohol mainly methanol and the final product was called Biodiesel.

2.2 Historical Perspective

In 1900, Rudolf Diesel demonstrated his compression ignition engine at the World's Exhibition in Paris. In that prototype engine he used peanut oil, the first biodiesel. Vegetable oils were used until the 1920's when an alteration was made to the engine enabling it to use a residue of petroleum diesel. Although the diesel engine gained worldwide acceptance, biodiesel did not. With superior price, availability, and government subsidies, petroleum diesel quickly became the fuel of choice for the diesel engine.

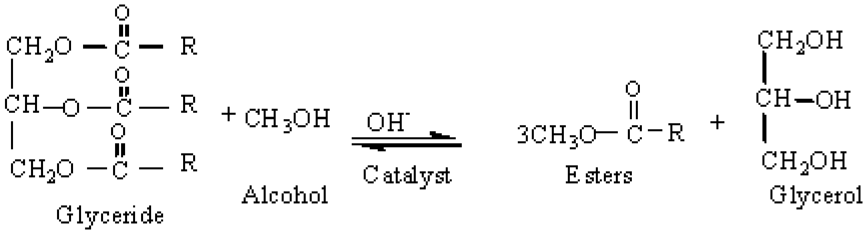
In the mid 1970s, fuel shortages revived interest in developing biodiesel as an alternative to petroleum diesel. However, as the petroleum market was increasingly subsidized, biodiesel was again relegated to a minority “alternative” status. This political and economic struggle continues to limit the impact of the biodiesel industry today.

Now, increasing concerns about the potential of global climate change, declining air and water quality, and serious human health concerns are inspiring the development of biodiesel, as a renewable, cleaner burning diesel alternative. Biodiesel is made from recycled animal fat and various feedstocks (biomass sources). As part of an active carbon cycle biodiesel feedstock production reduces the buildup of greenhouse gases, and in turn, global warming. [4]

2.3 What is Biodiesel?

Biodiesel is defined as the mono-alkyl esters of fatty acids derived from vegetable oils or animal fats. In simple terms, biodiesel is the product obtained when a vegetable oil or animal fat is chemically reacted with an alcohol to produce fatty acid alkyl esters. A catalyst such as sodium or potassium hydroxide is required. Glycerol is produced as a co product.

The simple reaction are



Glycerin which is the main byproduct has a numerous uses, including many applications as an ingredient or processing aid in cosmetics, toiletries, personal care, drugs, and food products [4].

Biodiesel can also be made from other feedstocks:

1. Other vegetable oils such as corn oil, canola (an edible variety of rapeseed) oil, cottonseed oil, mustard oil, palm oil, etc.
2. Restaurant waste oils such as frying oils
3. Animal fats such as beef tallow or lard
4. Trap grease (from restaurant grease traps), float grease (from waste water treatment Plants), etc.

2.4 Advantages of Biodiesel

Biodiesel can be used in several different ways. one can use 1% to 2% biodiesel as a lubricity additive, which could be especially important for Ultra Low Sulfur Diesel fuels (ULSD, less than 15 ppm sulfur), which may have poor lubricating properties. It can blend by 20% Biodiesel with 80% diesel fuel (B20) for use in most applications that use diesel fuel. Also it can be even use in its pure form (B100) if proper precautions are taken. The word biodiesel in this thesis refers to the pure fuel (B100) that meets the specific biodiesel definition and standards approved by ASTM International. The number following the “B” indicates the percentage of biodiesel in the volume fuel.

Today, B20 is the most common biodiesel blend in the world because it balances property differences with conventional diesel, performance, emission benefits, and costs. Higher blend levels, such as B50 or B100, require special handling and fuel management and may require equipment modifications such as the use of heaters or changing seals and gaskets that come in contact with the fuel to those compatible with high blends of biodiesel. The level of special care needed largely depends on the engine and vehicle manufacturer.

Biodiesel-fueled vehicles are called non-dedicated flexible fuel vehicles because biodiesel use does not require any significant modifications to the engine, so that the engine does not have to be dedicated for biodiesel use only. It is completely soluble in commercial petroleum-based diesel fuel, so **biodiesel can be used as a blend and one fuel tank can be used for storage of both fuels**. This makes the vehicle flexible. This is a unique advantage compared with most other alternative fuels, because this will give users the opportunity to use the alternative fuel where and when it is available without paying any extra money for engine modifications.

Given the fact that, Biodiesel is a renewable fuel manufactured from vegetable oils, animal fats, and recycled cooking oils. Biodiesel offers many advantages:

1. It is renewable.
2. It is energy efficient equivalent to petroleum diesel.
3. It potentially replaces petroleum derived diesel fuel.

4. It can be used in most diesel equipment with no or only minor modifications.
5. It can reduce global warming gas emissions because of the plant life cycle.
6. It can reduce tailpipe emissions, including air toxics.
7. It is nontoxic, biodegradable, and suitable for sensitive environment
8. Reduction in emissions of:
    a. Sulfur dioxide by 100%
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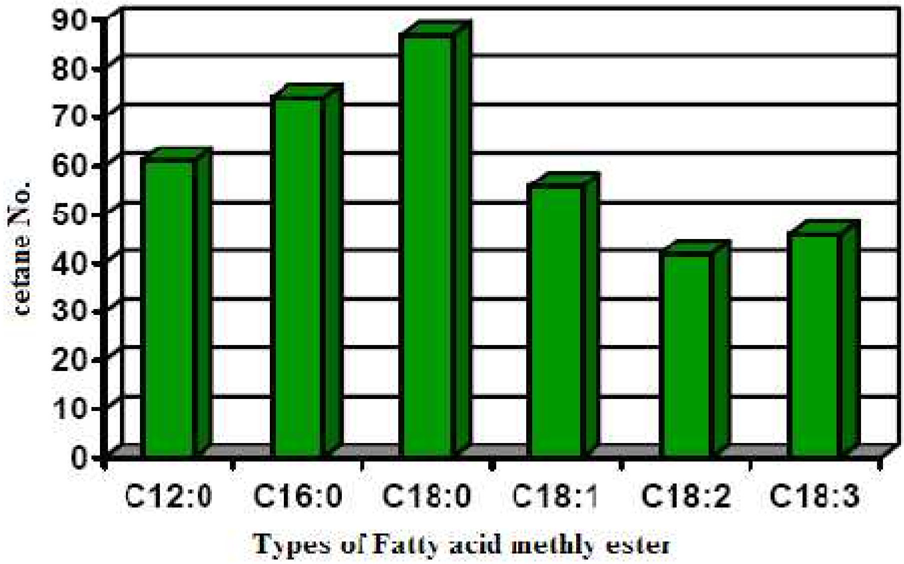
9. Readily mixes with petroleum diesel fuel in any ratio
10. It has a higher flash point than petroleum diesel and thus helps prevent damaging fires. [5]
11. Biodiesel (B100) contains 11% oxygen by weight. The presence of fuel oxygen allows the fuel to burn more completely so fewer unburned fuel emissions result. [5]
12. Biodiesel has a higher cetane number than diesel fuel, which is provided easier starting, and quieter operation, better ignition quality, shorter ignition delay.

Most of the B100 made today that meets D6751 has a cetane number higher than 47. This is compared to the minimum of 40 for highway diesel fuel, whose national average is between 42 and 44. Therefore, biodiesel has a higher cetane number than most U.S. diesel fuel, which is believed to provide easier starting and quieter operation. Highly saturated B100, such as animal fats and used cooking oils, can have a cetane number of 70 or higher. Common polyunsaturated fuels that contain high levels of C18:2 and C18:3 fatty acids include soy, sunflower, corn, and canola (rapeseed) oils. These will be at the lower end of the scale, at 47 or slightly higher. Figure 2.1 shows the cetane number of various biodiesel samples. [5]



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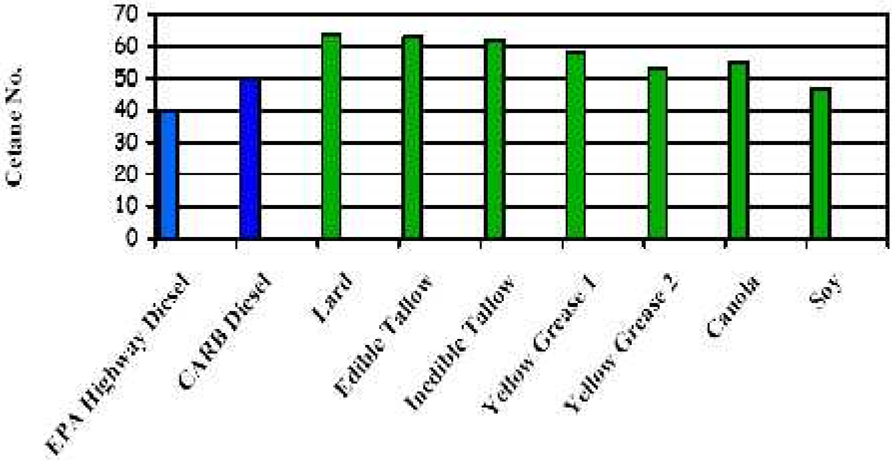

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2. The energy content of biodiesel is lower than that of petroleum diesel. As a result, vehicles running on any blend of biodiesel will experience a small reduction in fuel economy (miles per gallon). [6]

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Many of the disadvantages associated with neat biodiesel can be overcome by using Biodiesel blends, which consist of petrodiesel mixed with a specified quantity of biodiesel. Biodiesel blends are labeled BX, where X is a number that indicates the percentage of biodiesel in the blend. For example, B20 is a mixture of 80 percent petrodiesel and 20 percent biodiesel. Common blends include: B2, B5, B10, and B20. Biodiesel blends can overcome the inherent disadvantages of B100 in the following ways:

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20	-11.99	-20.06	-12.30	1.98	-20.00	-15.69
30	-17.43	-28.53	-17.87	2.98	-30.00	-23.54
50	-27.33	-42.86	-27.97	5.02	-50.00	-39.23
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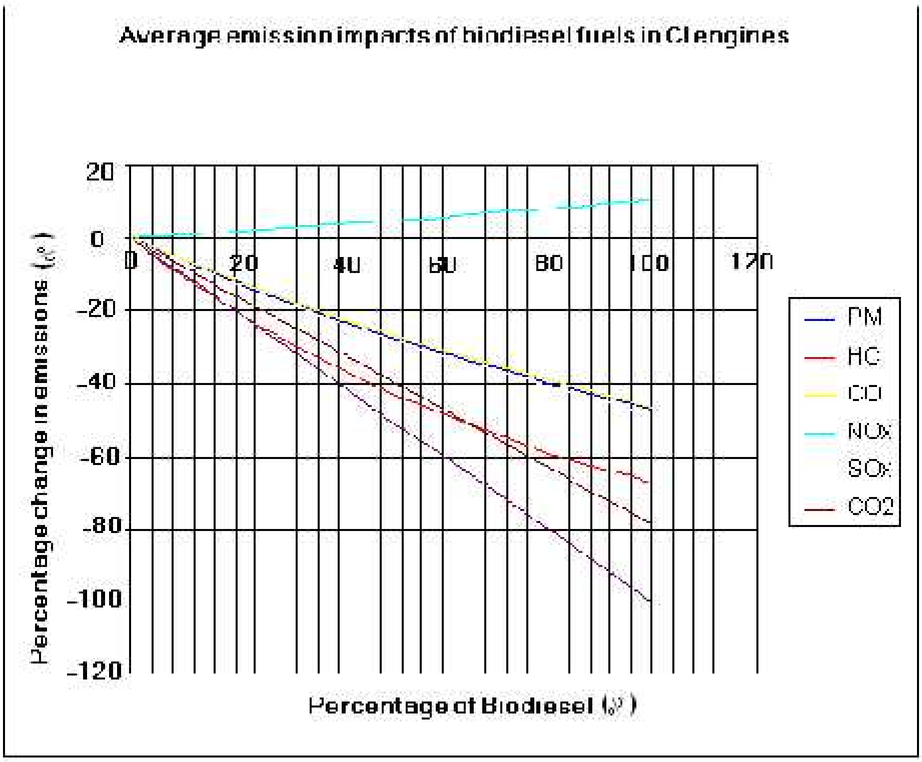

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4. Nitrogen Oxides: NOx emissions from (100%) Biodiesel increased in this by 13 percent. However, Biodiesel’s lack of sulphur allows the use of NOx control technologies that cannot be used with conventional Diesel. So, Biodiesel NOx emissions can be effectively managed and efficiently eliminated as a concern of the fuel’s use.

2.7.1 How to solve the problem of NOx

The high level of NOx emissions is the major obstacle standing in the way of broad support for biodiesel, and much research has been devoted to its reduction, particularly in light of stringent exhaust emission regulations being imposed on diesel engines over the next few years. One popular method of reducing NOx emissions is exhaust gas recirculation (EGR). EGR reduces engine temperature by pumping a portion (10-25%) of exhaust gas back into the intake. Because the exhaust gas is nearly inert, it will not react in the combustion chamber and acts only as a heat sink. A small power loss is associated with EGR systems, but NOx emissions are decreased by up to 80%.

Another option to reduce NOx emissions is to install a catalytic converter. However, they work best at the stoichiometric ratio, so it will not be as effective on a diesel engine. They are also expensive and work better at high temperatures, while diesel exhaust is generally lower than gasoline exhaust. Selective noncatalytic reduction, diesel oxidation catalysts, water-fuel emulsions, and NOx and particulate traps have also been used to reduce NOx emissions on biodiesel engines. All of these methods, however, are only solving the problem of biodiesel NOx emissions indirectly, by removing the NOx after it are created.

Many studies of biodiesel combustion have found that the start of injection timing is advanced. This should result in a higher peak temperature inside the cylinder due to more premixed combustion, which will increase the rate of NOx production. This will also result in a longer residence time, allowing NOx production to continue for more time. In fact, It was found that a linear relationship between NOx emission and injection timing. The retard (delay) of injection timing lowered the NOx emission for all the biodiesel fuel blends. It has been pointed out that there was a NOx emission reduction of 35% to 43% for all biodiesel fuel blends at 3° retarded injection timing relative to the 3° advanced injection timing for the same fuel at the same load and speed condition.

2.8 Environmental Impacts of Biodiesel

The production and use of biodiesel creates 78% less carbon dioxide emissions than conventional diesel fuel. Carbon dioxide is a greenhouse gas that contributes to global warming by preventing some of the sun’s radiation from escaping the Earth. Burning biodiesel fuel also effectively eliminates sulfur oxide and sulfate emissions, which are major contributors to acid rain. That’s because, unlike petroleum-based diesel fuel, biodiesel is free of sulfur impurities. Combustion of biodiesel additionally provides a 56% reduction in hydrocarbon emissions and yields significant reductions in carbon monoxide and soot particles compared to petroleum based diesel fuel. Also, biodiesel can reduce the carcinogenic properties of diesel fuel by 94%. [7]

2.9 Statistical and Survey Analysis [1]

Another field visits had targeted meats and chicken shops, and also the concentrated on larger shops such as meats and chicken slaughterhouses to collect the amounts of animals fats and grease that can be obtained from Hebron district.

After the field visited department agriculture in Hebron district had been finished completely, there were main concluded information and data that had been studied carefully and analyzed with certain required calculations to attain the final shape of required data available. That is clearly shown in the following the amount of animal fats is 911 Ton's annually

Table2.3: Statistically fat extracted annually in the Hebron Governorate

Statistically fat extracted annually in the Hebron Governorate			
Type of fat	Number	loss quantity gr	Quantity in kg
Sheep	120000	1500	180000
Calves	37000	3000	111000
Camel	10000	2000	20000
White meat	3000000	200	600000
Total			911000

Must be indicated to the numbers inside table in continuously increasing.

Waste fats can be efficiently converted to biodiesel using a continues process. The estimated annual quantities of waste animal fat produced in Hebron district could produce around 0.93 million liter of Biodiesel from animal fats.

A Biodiesel blend provides a cleaner burning, more environmentally friendly substitute to ordinary diesel. No vehicle modifications are necessary.

Collecting waste oil and animal fats could create many jobs in Hebron district. The number of jobs could be increased by increasing of waste oil and animal fats. In addition, it will support Palestinian economy and increase national income.

Biodiesel is one of the most promising of the alternative fuels. It is produced from vegetable oil or animal fats using fairly simple chemistry .It is non-toxic and rapidly biodegrades. It can be produced from animal fats and offers good performance together with a number of environmental benefits compared to ordinary petroleum diesel. If all the estimated quantity of waste vegetable oil and animal fats were collected and converted to biodiesel up to 1.01 % of the total 94 million liter of petro diesel consumed in Hebron district annually could be replaced using the petro diesel fuel. This is a good and promising stand for reducing petroleum diesel usage.

Chapter Three

Biodiesel Production Process Design

Content:

3.1 Introduction

Biodiesel is a fuel derived from the transesterification of fats and oils (refer to Fig.3.1). This fuel has similar properties to that of diesel produced from crude oil and can be used directly to run existing diesel engines or as a mixture with crude oil diesel.. Biodiesel is generally manufactured using batch reactors. However, this trend is changing and more continuous processes have been examined and used either in a laboratory or industrial scale due to the increase in biodiesel demand.

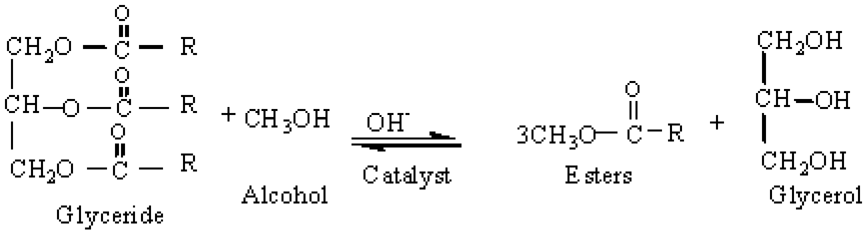

Figure 3.1 Chemistry Transesterification Reaction

3.2 Available methods to produce biodiesel from animal fats

1. Non-Catalyzed Systems – Supercritical Process

When a fluid or gas is subjected to temperatures and pressures in excess of its critical point, there are a number of unusual properties exhibited. There no longer is a distinct liquid and vapor phase, but a single, fluid phase present. Solvents containing a hydroxyl (OH) group, such as water or primary alcohols, take on the properties of super-acids. A non-catalytic approach is the use of a high (42:1) alcohol to oil ratio. Under supercritical conditions (350 to 400 °C and > 80 atm or 1200 psi) the reaction is complete in about four minutes[8]. Capital and operating costs can be more expensive, and energy consumption higher. An intriguing example of this process has been demonstrated in Japan, where oils in a very large excess of methanol have been subjected to very high temperatures and pressures for a short period of time.

The result is a very fast (3 to 5 minute) reaction to form esters and glycerol. The reaction must be quenched very rapidly so that the products do not decompose. The efficiency in this process equal 96%. [8]

This method is very expensive and not available equipment locally

2. Enzymatic Conversion

There is interest in using lipases for enzymatic catalysis of oils for biodiesel production. The enzymes can be used in solution or immobilized onto a support material, which allows the use of fixed-bed reactors. The reaction can be performed at 35 to 45 degrees Celsius. However, the reaction is very slow, requiring from four to 40 hours. Because of the high cost of the enzymes, this process is not economically feasible for biodiesel production at this time. [9]

This method is not available due to the monopoly of the enzyme for the industrialized countries

3. Using sulfuric acid Catalysis

This technique uses a strong acid. Soap formation is not a problem because there are no alkali metals in the reaction medium. Acid catalysts can be used for transesterification of the triglycerides, but the reaction might take several days to complete. This is too slow for industrial processing.Acid catalysis requires a high alcohol to free fatty acid ratio (20:1 or 40:1 mole ratio) and large amount of catalyst (5-25 percent). Sulfuric acid and phosphoric acid are the most common acid catalysts. The feedstock is sometimes dried to 0.4 percent water and filtered before the reaction. Then, an acid and methanol mixture is added to the feedstock. Once the conversion of the fatty acids to methyl esters has reached equilibrium, the methanol, water and acid mixture is removed by settling or centrifugation. Fresh methanol and base catalyst are added into the remaining oil for transesterification. The rest of the process is the same as base catalysis. Reaction times of 10 minutes to 2 hours have been reported. [8]

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5. Liquid - gas reaction

This method investigating the transesterification of fats and oil with methanol was performed to improve the economic viability of the production process for biodiesel from oil and fats . The key feature of the new process developed in this work is its ability to operate continuously with a high reaction rate, potentially requiring less post reaction cleaning and product/reactant separation than currently established processes. This was achieved by atomizing the heated oil/fat and then spraying it into a reaction chamber filled with methanol vapor in a counter current flow arrangement. Therefore, this particular process has a primary advantage over conventional processes, in that it can produce biodiesel more efficiently with a potential saving of both time and capital. The overall conversion based on a single cycle of this process has been between 60 to 96% of the feed stock materials . Maximum conversion of 96% was achieved while operating with 5-7g of sodium methoxide/kg of methanol at methanol flow rate of 17.2 kg/hr and oil flow rate of 10 kg/hr. Additional variations in the reactant stoichiometry (i.e. reactant flow rates), catalyst type/concentration, Injection pressure, and reaction temperature on the overall product conversion are obtainable using economically available components. In this project the use of a gas-liquid reactor to produce biodiesel was adopted. The hot oil was sprayed as fine droplets into an atmosphere of vapor methanol in a counter current flow arrangement. The effect of operating temperature, catalyst and the methanol concentrations were studied in literature [2]

This method is available and can be applied and all items can be purchased Applied there for this method is adopted in this project.

3.3 Operation principle process of liquid – gas reactor

Animal fat and methanol will be used in this project as the feedstock while sodium methoxide or sodium hydroxide was used as catalysts. Technical grade methanol that is available will be use as the alcohol source in the project . The methanol was premixed with sodium hydroxide (NaOH) in the range of 0-10 g NaOH/ kg methanol before being pumped into the reactor. Pre-mixing the sodium hydroxide with methanol allows the formation of sodium methoxide needed to catalyses the reaction. Higher pressure pump would be a suitable unit for generating small micro sized droplets of high surface area. The surface area generated in this process is an order of magnitude higher than the contact area in any standard mixing processes currently employed in biodiesel processes based on liquid-liquid reaction. This simplified the geometry of the unit and allowed the reaction to be carried out in a spray like reactor unit. Methanol circulation as illustrated in Figure 3.2 was also a key design parameter.

The reaction will be carried out in a 1.66 m high x 0.344m diameter stainless steel tank as shown in Figure 3.2 The oil atomization is carried out using a high pressure diesel injection pump while methanol is pumped using a centrifugal pump. The process operates by injecting oil and fat through a high pressure nozzle into a reactor filled with methanol vapor carrying the catalyst and moving in counter current flow direction. This allows direct contact between the two phases with large contact area thereby promoting more heat and mass transfer. The high pressure nozzles in the system atomize the liquefied animal fats into small droplets in the range of 100 to 200μm diameter, thus significantly increasing the contact surface area of the methanol/fats. The desired reaction temperature is achieved by heating the reactor using a steam jacket and preheating the reactants before being fed to the reactor. Since the process operates at temperatures well above the alcohol boiling point, a higher rate of reaction was achieved . This process can operate at any temperature below the degradation temperature of fat and oil (i.e. ≤ 200 °C) . To increase the reaction rate, a high methanol to oil ratio was used as in any other transesterifcation process. In this reactor, the methanol is condensed , mixed with fresh liquid methanol and recycled to the reactor. However, this is unnecessary in the industrial scale reactor as the methanol vapor could be recycled in the vapor phase To improve reaction rate the reactants will be pre-heated using a combination of steam and electrical heating. The oil will be injected into the reactor at 100 - 120 °C because obtain best atomizing for oil while methanol will be injected, at 85 - 95 °C because avoid reach dissociation degree for sodium methoxide . This reactor will be not designed as a pressure vessel and hence was heated using saturated steam of 1 bar. This limited the operating temperature to a maximum of 100 °C. Based on this technology and with suitable method of heating, industrial reactors may operate at any temperature below the degradation temperature of oil.

Once the reaction is complete, two major products exist: Glycerin and Biodiesel. The reacted mixture is sometimes neutralized at this step if needed. The Glycerin phase is much denser than Biodiesel phase and the two can be gravity separated with Glycerin simply drawn off the bottom of the settling vessel. In some cases, a centrifuge is used to separate the two materials faster.

Once separated from the Glycerin, the Biodiesel is sometimes purified by washing gently with worm water to remove residual catalyst or soaps, dried and sent to storage. In some processes this step is unnecessary. This is normally the end of the production process resulting in a clear amber-yellow liquid with a viscosity similar to petro diesel. In some systems the Biodiesel is distilled in an additional step to remove small amounts of color bodies to produce a colorless Biodiesel.

3.4 Reaction influencing factors

3.4.1. Catalyst Concentration and Methanol Flow Rate

The conversion of triglyceride is dependent on both the catalyst concentration and methanol flow rate. At a high methanol to oil ratio a much higher conversion was achieved, were the highest conversion was achieved at an oil flow rate of 0.094 kg/min and methanol flow rate of 0.188 kg / min. These flow rates equate to a mol ratio of 1:2 (oil: methanol). The reduction in methanol flow rate reduced the overall conversion by ≈ 10%. Similar to conventional processes, sodium methoxide will be used as the catalyst of choice. This has been in the form of anhydrous sodium methoxide or sodium hydroxide dissolved in methanol prior to the start of the reaction. However, the reaction of sodium hydroxide with methanol forms water, which is undesirable and enhances the saponification reaction, which ascertained the minimum amount of catalyst required to initiate the reaction a catalyst concentration of 5 to 9 g NaOH/kg of methanol will be the highest overall conversion. The overall conversion decreased as the catalyst concentration increased above 9g catalyst/kg of methanol. This is assumed to have been caused by the formation of sodium soaps. The sodium hydroxide as a catalyst, high yield losses are experienced due to triglyceride saponification and methyl ester dissolution in the glycerol phase. The formation of sodium soaps increases with catalyst concentration. The suggest that a catalyst concentration of 5 to 7 g sodium hydroxide/kg of methanol is optimal for high yields of biodiesel . The using 5 to 7 g sodium hydroxide or sodium methoxide/kg of methanol, at various oil and methanol flow rates.

$$\mathrm{NaOH + CH3OH \leftrightarrow (CH3O+\ Na-) + H2O}$$

Equation Sodium methoxide formation

To minimize the affect of saponification and biodiesel solubility in the glycerol phase, pure sodium methoxide was used as the catalyst. When using oil flow rate of 0.094 kg/min and a methanol flow rate of 0.188 kg / min, at a catalyst concentration of 5 to 7 g sodium methoxide/kg of methanol. As these are control experiments for optimization, to minimize the formation of soap due to FFA and water. In general vegetable oils have longer shelf life and contain less FFA and moisture than animal fats. It should be noted that this change had no effect on the overall reaction mechanism. As expected the conversion of biodiesel had increased with the introduction of this catalyst Based on analsisys, subsequent experiments were then performed using 5 to 7 g sodium methoxide /kg of methanol, at various methanol flow rates.

Change in methanol concentration had a significant effect on biodiesel conversion. Therefore, additional experiments were conducted at oil flow rate of 0.094 kg/min, methanol flow rate of 0.188 kg / min, and catalyst concentration of 5 to 7 g sodium methoxide/kg of methanol. a significant increase in the conversion to methyl ester when methanol flow rate was increased. As discussed earlier the increase in methanol concentration allows the reaction equilibrium to be pushed forward. [2]

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The conversion could be higher at central part of the reactor compared to locations near the wall. This is caused by the coalescence of the droplets into a liquid film on the reactor wall. Formation of this film decreases the contact surface area between the two reactants. It also reduces the heat and mass transfer that is vital for a rapid reaction. This effect could be reduced through the use of a larger diameter reactor or a smaller injection angle. The conversion of methyl ester could be found to increase as the droplets moved further away from the injection point. [2]

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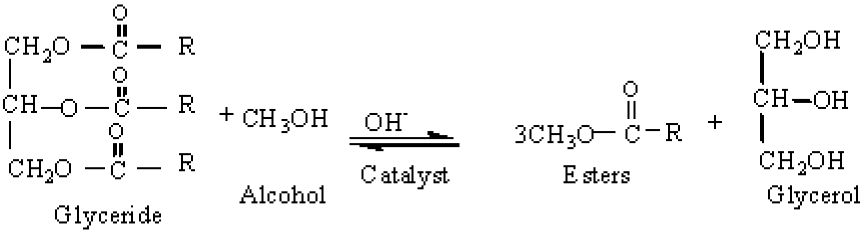

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Chapter Four

Process component and Design

Content:

4.2 Methanol quantity

Choosing quantity of methanol based on power of electricity available in laboratory at ppu.

Power = I * V

Where

I current (A)

V volte (V)

Power = I * V

= 16 A * 240 V

= 3840 watt

= 3840 watt * 60 s

= 230.4 kJ

When

h_{fg} = 1101.8 kJ/kg (latent heat for methanol at 0.9 bar and 61.5°C)

m mass (kg)

$Cp_{\text{liquid methanol}}$ = 2.55 kJ/kg. °C [1]

$Cp_{\text{vapor methanol}}$ = 1.86 kJ/kg. °C [3]

ρ density of methanol (786.75 kg / m³) at 25 °C

Q Total heat transfer (kJ)

ΔT temperature difference

T time (s)

Methanol will be heated from 25°C to 80°C in the process and the rest will depend on this quantity.

$Q = Q_{\text{liquid phase}} + Q_{\text{phase change}} + Q_{\text{vapor phase}}$

230.4 kj = $[m_{\text{methanol}}/\text{min} * Cp_{\text{liquid methanol}} * (\Delta T)]_{\text{liquid phase}}$

$+ [\ m/\text{min}*(\ hfg\ )]_{\text{change phase}}$

$+ [m_{\text{methanol}}/\text{min} * Cp_{\text{vapor methanol}} * (\Delta T)]_{\text{vapor phase}}$

Q = m kg/min * 2.55 kJ/kg * (61.5 – 25) ℃

+ m kg/min * 1101.8 kJ/kg

+ m kg/min * 1.86 kJ/kg. ℃ * (80- 61.5) ℃

= 230.4 kJ

→ m/min = 0.188 kg/min

m kg = ρ kg / m³ * V m³ → ρ kg / m³ = m kg / V m³

= 0.188 kg / 786.75 kg / m³

= 0.000244 m³

= 0.244 L

→ m/min = 0.244 L/min

= 244 mL / min(0.188 kg / min)

When more power available it can be increasing the quantity of methanol the system capacity.

4.3 Heated methanol H3

In order to heat the methanol heat in system is designed in which the liquid methanol it passed through pipe submersed in hot oil, and used temperature sensor type(WY 138-11s 0804) to adopted the temperature of oil at 138℃,The temperature sensor connected with heater.

The length of pipe to obtain vapor methanol based equation:

$$Qconduction = \frac{2*\pi*k\frac{w}{m}.c°*L\ m*\Delta Tc°}{\ln(ro/ri)} \quad [13]$$

Where

K thermal conductivity (copper = 120 w/m. °C)

L length of pipe (m)

r_o outer radius of pipe (m)

r_i inner radius of pipe (m)

$\Delta T = 1$ °C

Q conduction = 3840 watt

The available pipe diameter (1/4 inch, 1/2 inch, 1 inch)

→ When

r_o = 1/4 inch = 0.00635 m

r_i = 1/4 inch = 0.00535 m

→ $\ln(r_o/r_i) = 0.171$

$$From \ldots Qconduction = \frac{2 * \pi * k \frac{w}{m} . c° * L\ m * \Delta T c°}{\ln(ro/ri)}$$

3840 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.171

→ L = 0.88 m = 88 cm

→ When

r_o = 1/2 inch = 0.0127 m

r_i = 1/2 inch = 0.0117 m

→ $\ln(r_o/r_i) = 0.082$

$$From \ldots Qconduction = \frac{2 * \pi * k \frac{w}{m} . c° * L\ m * \Delta T c°}{\ln(ro/ri)}$$

3840 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.082

→ L = 0.42 m = 42 cm

→ When

r_o = 1inch = 0.0254 m

r_i = 1inch = 0.0244 m

→ $\ln(r_o/r_i) = 0.04$

$$From \ldots Qconduction = \frac{2*\pi*k\frac{w}{m}.c°*L\ m*\Delta Tc°}{\ln(ro/ri)}$$

3840 w = 2 * 3.14 *120 w/m. ℃ * L m * 1℃ / 0.04

→ L = 0.20 m = 20 cm

The best is 1/4 inch which ensure the total evaporator of methanol

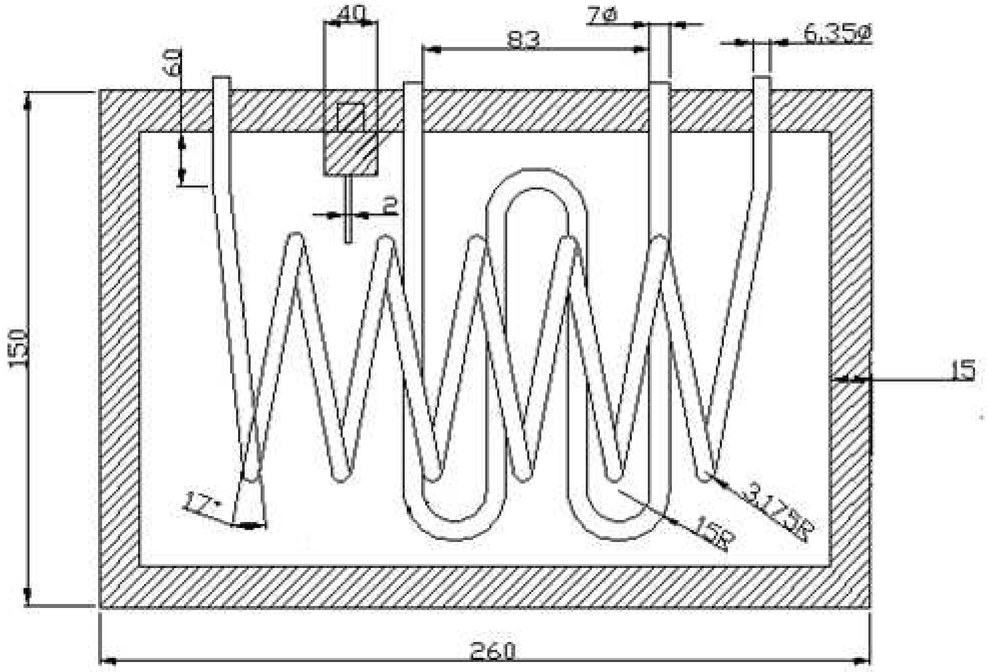


Figure 4.2 Methanol evaporator(All dimensions in millimeter)

$$Vpipe = \frac{\pi * d^2}{4} * L$$

$= 3.14 * 0.002675^2 m^2/4 * 1.2\ m$

$= 0.00000671\ m^3$

$$Vheater = \frac{\pi * d^2}{4} * L$$

$= 3.14 * 0.007^2 m^2/4 * 0.6\ m$

$= 0.000023\ m^3$

$$Vcylinder = \frac{\pi * d^2}{4} * L$$

$= 3.14 * 0.23^2 m^2/4 * 0.12\ m$

$= 0.00498\ m^3$

$V\ oil = V_{cylinder} - V_{heater} - V_{pipe}$

$= 0.00498\ m^3 - 0.000023\ m^3 - 0.00000671\ m^3$

$= 4.95\ L$

$moil\ kg = \rho\ kg / m^3 * V\ m^3$

$= 850 kg /m^3 * 0.00495\ m^3$

$= 4.2\ kg$

→ $Q = [m_{oil}/t\ min * Cp_{oil} * (\Delta T)]$

$230.4\ kJ = 4.2\ kg/t\ min * 1.67\ kJ/kg.\ °C * (138-25)\ °C$

→ → $t = 3.44$ min until reach $\Delta T = 1\ °C$(until the pipe reached the system temperature)

There for must be waited four minutes before pumped liquid methanol until the pipe reached the system temperature.

4.4 Condensating returned methanol C1

I assume the efficiency of reactor 60 % such that assumed the quantity of returned methanol equal (0.4 * 0.188 kg) .

$Q = Q_{\text{vapor phase}} + Q_{\text{phase change}} + Q_{\text{liquid phase}}$

$Q = [m_{\text{methanol}} * Cp_{\text{vapor methanol}} * (\Delta T)]_{\text{vapor phase}}$

$+ [\ m*(\ hfg\ )]_{\text{change phase}}$

$+ [m_{\text{methanol}} * Cp_{\text{liquid methanol}} * (\Delta T)]_{\text{liquid phase}}$

Q = 0.4 * 0.188 kg * 2.55 kJ/kg * (80- 61.5) °C

+ 0.4*0.188 kg * 1101.8 kJ/kg

+ 0.4 kg*0.188 * 1.86 kJ/kg. °C * (61.5 – 25) °C

= 91.55kJ

= 1525.84 watt

→ Calculate the length of pipe to obtain liquid methanol based equation:

$$Qconduction = \frac{2*\pi*k\frac{w}{m}.c°*L\ m*\Delta Tc°}{\ln(ro/ri)} \qquad [13]$$

Where

K thermal conductivity (copper = 120 w/m. °C)

L length of pipe (m)

ro outer radius of pipe (m)

ri inner radius of pipe (m)

$\Delta T = 1$ °C

Q conduction = 1525.84 watt.

→ When

ro = 1/4 inch = 0.00635 m

ri = 1/4 inch = 0.00535 m

→ ln(ro/ri) = 0.171

$$From \ldots Qconduction = \frac{2*\pi*k\frac{w}{m}.c^{\circ}*L\ m*\Delta Tc^{\circ}}{\ln(ro/ri)}$$

1525.84 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.171

→ L = 0.35 m = 35 cm

→When

ro = 1/2 inch = 0.0127 m

ri = 1/2 inch = 0.0117 m

→ ln(ro/ri) = 0.082

$$From \ldots Qconduction = \frac{2*\pi*k\frac{w}{m}.c^{\circ}*L\ m*\Delta Tc^{\circ}}{\ln(ro/ri)}$$

1525.84 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.082

→ L = 0.17 m = 17 cm

→ When

ro = 1inch = 0.0254 m

ri = 1inch = 0.0244 m

→ ln(ro/ri) = 0.04

$$From \ldots Qconduction = \frac{2*\pi*k\frac{w}{m}.c^{\circ}*L\ m*\Delta Tc^{\circ}}{\ln(ro/ri)}$$

1525.84 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.04

→ L = 0.08 m = 8 cm

The best is 1/4 inch which ensure the total methanol returned was condensate

→ the length of pipe to condensate returned methanol → L = 0.35 m = 35 cm

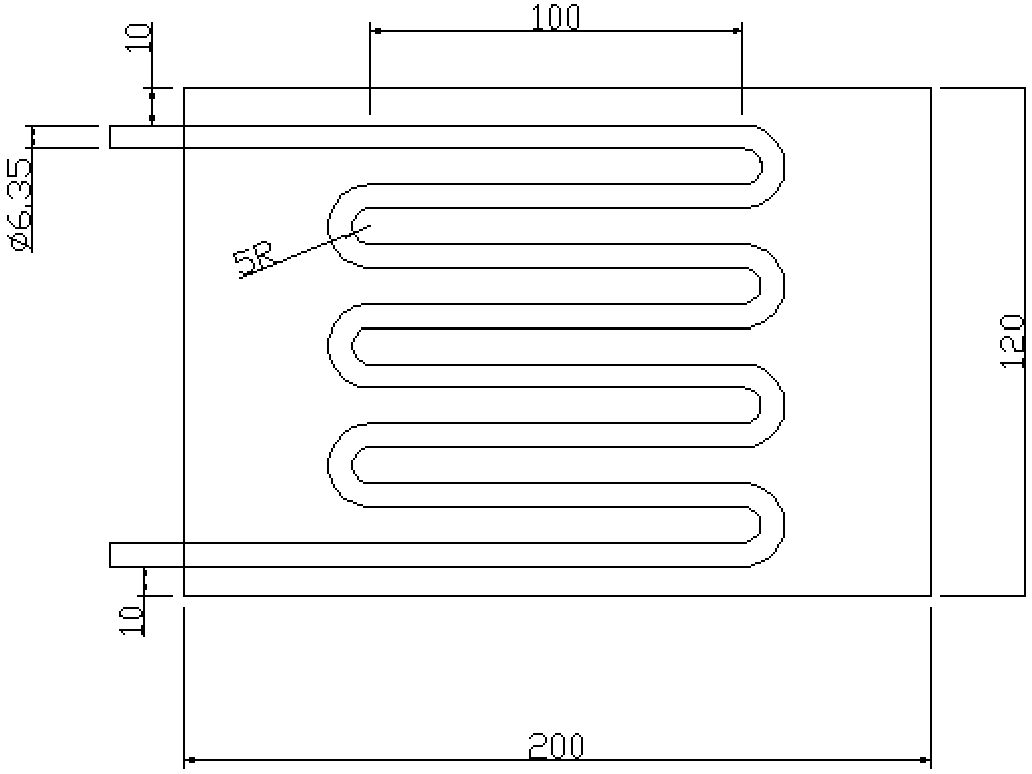


Figure 4.3 Methanol condenser(All dimensions in millimeter)

4.5 Electrical heater into convert fat to oil H1

The fat convert into oil at temperature 50 °C.

Q = [m $_{fat}$* Cp $_{fat}$* (ΔT)] + [m $_{fat}$ * latent heat]

Q = 0.094 kg/min * 2.11kJ/kg. °C *(50-25) °C + [0.094 kg / min * 883.8 kJ/kg

Q = 88.03 kJ/min

Q = 1467.17 watt

4.6 Electrical heater for increase temperature oil H2

At a high methanol to oil ratio a much higher conversion was achieved, were the highest conversion was achieved at an oil flow rate of 0.094 kg /min and methanol flow rate of 0.188 kg(0.244 L/min) to investigated ratio of 1:2 (oil: methanol).

$Q = [m_{oil} * Cp_{oil} * (\Delta T)]$

$Q = 0.094 \text{ kg/min} * 1.67 \text{ kJ/kg.}°\text{C} *(120-50) °\text{C}$

$= 10.99 \text{ kJ/min}$

$= 183.17 \text{ watt}$

4.7 Design the pumps

We Will use two pumps in the system ,the first pump is a gear pump because the liquefied fats is high viscosity and have needed high pressure to atomized liquefied fats will became oil, The second pump is a centrifugal pump for pumping methanol into reactor after heated.

So that is needed to calculated main parameters of the pumps to choose the appropriate pump Such parameters are as follows:

- Flow rate
- Total head
- Power required

We need in experimental prototype methanol quantity double oil quantity until reach obtain high efficiency , we assume that quantity :

1. 0.094 kg_{oil} / min .
2. 0.188 $kg_{methanol}$ / min.

There is a simple calculation for computing the total head and the flow rate in order to select the suitable pump for this purpose.

1. Head

$$\text{Total head} = \text{Head loss due to friction} + \text{static head}$$

$f = 64 / Re$ for laminar flow.

Where:

f: Friction factor for laminar flow.

Re: Reynolds number.

$V_{oil} = m / \rho$

$= (0.094\ kg/min) / (801 kg/m^3)$

$= 0.00012\ m^3/min$

$V_{methanol} = m / \rho$

$= (0.188\ kg/min) / (768.75\ kg/m^3)$

$= 0.00024\ m^3/min$

Where:

m mass flow rat (kg / min)

ρ density of fluid (kg / m^3)

The velocity $_{oil} = Q / A$.

$= (0.00012\ m^3/min) / (\pi D^2 / 4)$

$= (0.00012\ m^3/min) / (\pi\ 0.00535^2 / 4)$

$= 5.34\ m/min$

The velocity $_{methanol} = Q / A$.

$= (0.00024\ m^3/min) / (\pi D^2 / 4)$

$= (0.00024\ m^3/min) / (\pi\ 0.00535^2 / 4)$

$= 10.7\ m/min$

Where:

Q: Flow (m^3/s).

A: Pipe area (m^2).

$Re_{methanol} = (V * \rho * D) / \mu$

$= (10.7/60) * 786.75 * 0.00535 / 0.000544$

$= 1379.8$ Re < 2000 laminar

$Re_{oil} = (V * \rho * D) / \mu$

$= (5.34/60) * 801 * 0.00535 / 0.0346$

$= 10.7$ Re < 2000 laminar

Where:

V: Fluid velocity (m/s).

D: Pipe diameter (m).

μ: dynamic viscosity of fluid(mm^2/s or pa.s))

ρ : density of fluid (kg/m^3)

$f = 64 / Re$

$f_{methanol} = 64 / 1379.8 = 0.047$

$f_{oil} = 64 / 10.7 = 5.98$

Where:

f: Friction factor for laminar flow.

Re: Reynolds number.

$Le = (KL * D) / f$

$Le_{oil} = 0.8 * 0.00535 / 5.98 = 0.0007$ neglected

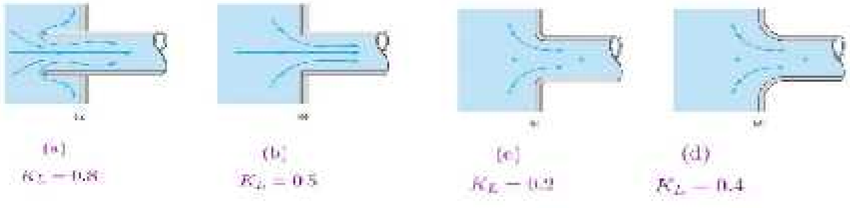
$Le_{methanol} = 0.8 * 0.00535 / 0.047 = 0.09$ neglected

Where:

D: Pipe diameter (m).

Le The equivelent length

$H1 = \{ (f * (L/D) * (V^2 / 2 g) \}+ \{ KL *(V^2 / 2 g) \}$



(a) $K_L = 0.8$

(b) $K_L = 0.5$

(c) $K_L = 0.2$

(d) $K_L = 0.4$

$H1_{oil} = \{5.98 * (2.5 \ / \ 0.00535) * (0.089^2 \ / \ 2*9.81) + (0.8 * (0.089^2 \ / \ 2*9.81))\}$

$= 1.13 m$

$H1_{methanol} = \{0.047 * (2.5 \ / \ 0.00535) * (0.18^2 \ / \ 2*9.81) + (0.8 * (0.18^2 \ / \ 2*9.81))\}$

$= 0.038 \ m$

Where:

KL: Factor of fitting.

H_1: Kinematics' head (m).

$(\text{Total head} = \text{Head loss due to friction} + \text{static head})_{oil}$

$= 1.13 + 2$

$= 3.13 \ m$

$(\text{Total head} = \text{Head loss due to friction} + \text{static head})_{methanol}$

$= 0.038 + 0.5$

$= 0.538 \ m$

2. Power

$P = Q \cdot \rho \cdot H \cdot 9.81_{\ oil}$

$= 0.094 \ kg/min * 801 kg/m^3 * 3.13 m * 9.81$

$= 2311.9$ watt

$P = Q \cdot \rho \cdot H \cdot 9.81_{\ methanol}$

$= 0.188 \ kg/min * 786.75 \ kg/m^3 * 0.538 \ m * 9.81$

$= 780.7$ watt

Where :

P = Power transmitted to the fluid by the pump in Watt.

Q = Flow in kg/min.

p = Density of the fluid in kg/m³

H = height in meter.

9.81 = gravity

A pump is required, having the following characteristics:

For pump P2

H methanol =0.538 m, Q methanol =0.188kg /min, Power methanol = 780.7watt

and using pressure equal 1bar (pressure of reactor).

For pump P1

H oil = 3.6 m, Qoil = 0.094 kg /min. Power oil = 2660.4 watt

and using pressure 70 bar – 100 bar (high pressure to atomized liquefied fats) Basely previous specification I will be choose pumps type (W9A1- 04) Typical levels at 200 bar and 2300 rpm using mineral oil with viscosity of 40 mm2/s and at temperature of 60°C.

Figure 4.4 Gear pump and electrical motor

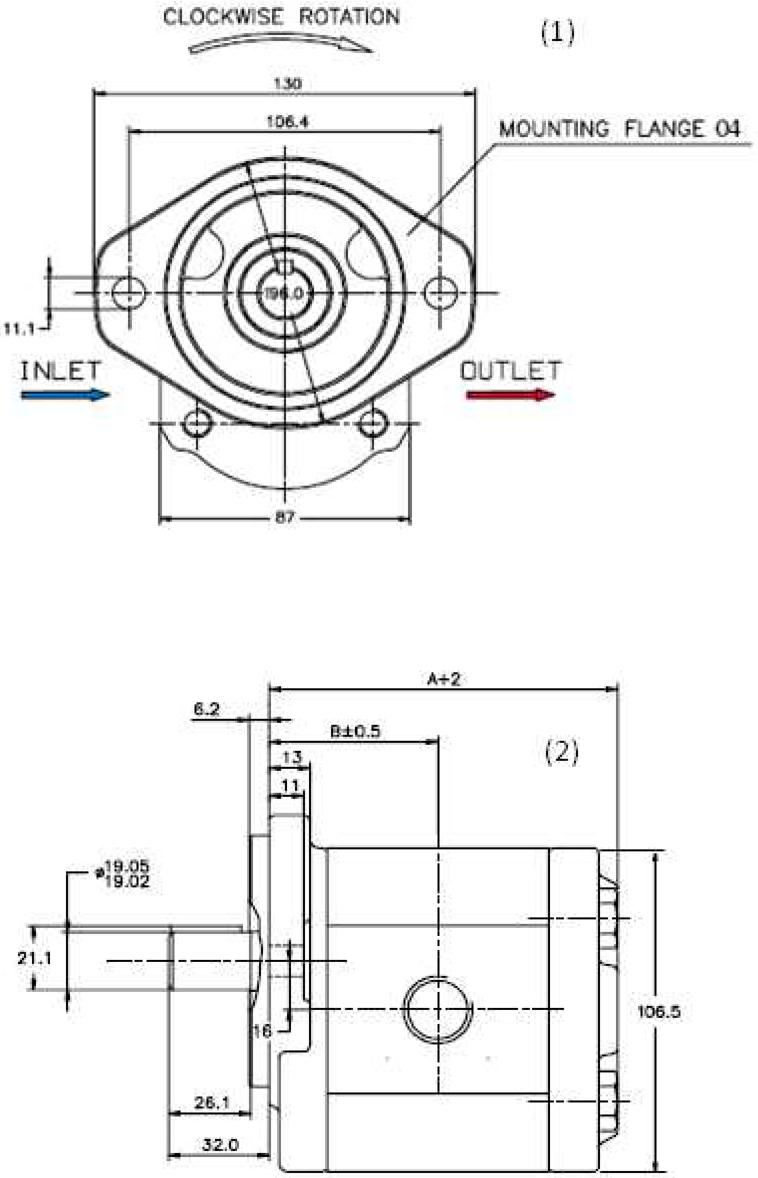


Figure 4.5 (1) and (2) Dimension of the Gear pump in millimeter, A=90mm,B=1 43mm.

4.8 Design the Reactor

Design the reactor dependent of geometry of spray of injector.

4.8.1 Design nozzle hole diameter of the injector

Basally equation and data that described the spray tip penetration can be choose the nozzle hole diameter of injector (dn) based on the time of transferred droplet in reactor by using equation (1) and equation (2)

$S = 0.39 \times (\Delta p / \rho l)^{1/2} \times t$ ……. (1) before break up the oil [17]

When $(0 < t < t_{break\ up})$

$S = 2.95 \times (\Delta p / \rho m)^{1/4} \times (dn \times t)^{1/2}$ …..(2) After break up the oil [17]

When $(t \geq t_{break\ up})$

$tb = (29 \times \rho l \times dn) / (\rho m \times \Delta p)^{1/2}$ ………..(3) [17]

Where

S spray penetration (m)

Δp pressure drop through the nozzle hole (Pascal)

$\rho\ l$ density of oil (kg / m^3)

$\rho\ m$ density of methanol (kg / m^3)

t time transfer the droplet through the reactor (second)

dn nozzle hole diameter of injector (mm)

tb break up the oil (second)

ρ density of MeOH vapor(kg / m^3) = 4 kg / m^3

ρ density of oil(kg / m^3) =801kg / m^3

Injection pressure (kPa) 100

Maximum distance before break up and after break up the oil through reactor

equal $S = 1.5$ m [19] (Eighth International Conference on Liquid Atomization and Spray System Pasadena CA.USA.July2000)

When you are in the resulting from atomized exposed to contact with methanol vapor which carries a catalyst for reaction depends on the nozzle hole diameter of injector (dn) ,The more time that the droplet is exposed to the possibility of interaction increased biodiesel production more and accordingly we will choose the appropriate injector.

→ When dn = 0.254 mm

tb =(29 x ρl x dn) / (ρm x Δp) ½

= (29 x 801kg /m³ x 0.254 mm) / (8 kg /m³ x 100 kPa)

= 0.00092164 s

From equation .... (1)

S = 0.39 x (Δp / ρl) ½ x t

= 0.39 x (100 kPa / 801kg /m³) ½ x 0.00092164 s

= 0.0402m

The value sub equation ....(2) = 1.5 m - 0.0402m

= 1.4598 m

The (1.4598 m) sub equation ....(2)

→ t = 0.6097 s

→ t total = t + t break up

= 0.6097 s + 0.00092164 s

= 0.61062164 s this total time when the droplet transferred in reactor maximum distance to1.5 m when used injector with nozzle hole diameter dn = 0.254 mm

→ When dn = 0.343 mm

$t_b = (29 \times \rho_l \times d_n) / (\rho_m \times \Delta p)^{1/2}$

$= (29 \times 801\text{kg}/\text{m}^3 \times 0.343\text{ mm}) / (8\text{ kg}/\text{m}^3 \times 100\text{ kPa})$

$= 0.0012\text{ s}$

From equation …….. (1)

$S = 0.39 \times (\Delta p / \rho_l)^{1/2} \times t$

$= 0.39 \times (100\text{ kPa} / 801\text{kg}/\text{m}^3)^{1/2} \times 0.0012\text{ s}$

$= 0.0523\text{m}$

The value sub equation ….(2) = 1.5 m - 0.0523m

= 1.4477m

The (1.4477m) sub equation ….(2)

→ t = 0.4441s

→ t total = t + t break up

= 0.4441s + 0.0012 s

= 0.4453 s this total time when the droplet transferred in reactor maximum distance to1.5 m when used injector with nozzle hole diameter dn = 0.343 mm

→ When dn = 0.61 mm

$t_b = (29 \times \rho_l \times d_n) / (\rho_m \times \Delta p)^{1/2}$

$= (29 \times 801\text{kg}/\text{m}^3 \times 0.61\text{ mm}) / (8\text{ kg}/\text{m}^3 \times 100\text{ kPa})$

$= 0.0022\text{ s}$

From equation …….. (1)

$S = 0.39 \times (\Delta p / \rho l)^{1/2} \times t$

$= 0.39 \times (100\ kPa / 801 kg/m^3)^{1/2} \times 0.0061 s$

$= 0.0959\ m$

The value sub equation ….(2) = 1.5 m - 0.0959 m

= 1.4041m

The (1.4041m) sub equation ….(2)

→ t = 0.2349s

→ t total = t + t break up

= 0.2349s + 0. 0022 s

= 0.2371 s this total time when the droplet transferred in reactor maximum distance to1.5 m when used injector with nozzle hole diameter dn = 0.61 mm

Table 4.1 Standard (Nozzle orifices diameter) versus Time when the droplet transferred in reactor max distance (1.5 m)

dn standard (Nozzle orifices diameter) (John .B Heywood)	Time when the droplet transferred in reactor max distance (1.5 m)
0.254 mm	0.61062164 s
0.343 mm	0.4453 s
0.61 mm	0.2371 s

Choosing dn = 0.254 mm because this longest time (0.61062164 s) occurred had the droplet exposed for interaction with methanol to produce biodiesel.

4.8.2 Design the diameter of the reactor

Basally equation (4) and equation (5) and data that describe the angle of spray inside reactor can be calculated the diameter of reactor

$A = 3 + (0.28 \times (ln / dn))$ ………(4) [17]

$\tan(\theta/2) = (1/A) \times 4 \times \prod \times (\rho m / \rho l)^{½} \times (\sqrt{3} \times 6)$ ……..(5) [17]

where

l_n (Hole length) mm

d_n (Hole diameter)) mm

→ when ratio $l_n/d_n = 4$ [17]

$A = 3 + (0.28 \times (4))$

$A = 4.12$

Sub (A) in equation …..(5)

$\tan(\theta/2) = (1/A) \times 4 \times \prod \times (\rho m / \rho l)^{½} \times (\sqrt{3} \times 6)$

$= (1 / 4.12) \times 4 \times 3.14 \times (4\ kg/m^3 / 801 kg/m^3)^{½} \times (\sqrt{3} \times 6)$

→ $\theta/2 = 3.56$

→ when ratio $l_n/d_n = 2.1$ [17]

$A = 3 + (0.28 \times (2.1))$

$A = 3.588$

Sub (A) in equation …..(5)

$\tan(\theta/2) = (1/A) \times 4 \times \prod \times (\rho m / \rho l)^{½} \times (\sqrt{3} \times 6)$

$= (1 / 3.588) \times 4 \times 3.14 \times (4\ kg/m^3 / 801 kg/m^3)^{½} \times (\sqrt{3} \times 6)$

→ $\theta/2 = 4.09$

→ when ratio $l_n/d_n = 0.5$ [17]

$A = 3 + (0.28 \times (0.5))$

$A = 3.14$

Sub (A) in equation .....(5)

$\tan(\theta/2) = (1/A) \times 4 \times \pi \times (\rho m / \rho l)^{½} \times (\sqrt{3} \times 6)$

$= (1/3.14) \times 4 \times 3.14 \times (4\ kg/m^3 / 801kg/m^3)^{½} \times (\sqrt{3} \times 6)$

→ $\theta/2 = 4.67$

Table 4.2 Ratio between (ln (Hole length) /dn (Hole diameter)) versus Angle of spray jet

Ratio (ln / dn) standard value[11]	Angle of spray jet θ/2
4	3.56
2.1	4.09
0.5	4.67

Design the diameter of reactor while occur maximum angle spray When minimum ratio between (l_n (Hole length) /d_n (Hole diameter)), Choosing ratio $l_n/d_n = 0.5$

Maximum distance before break up and after break up the liquefied fats droplet through reactor equal S=1.5 m [19]

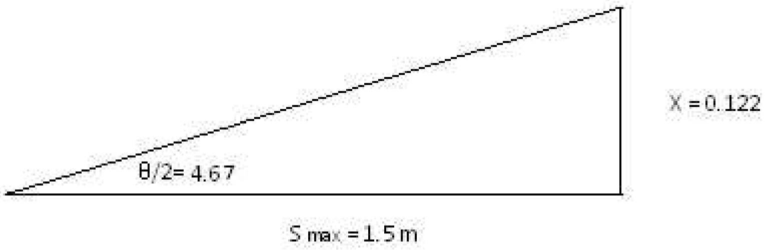


Figure 4.6 Geometry of the jet 1

θ/2 = 4.67 → θ = 9.34

width of the jet = 2 x 0.122 m = 24.4 cm

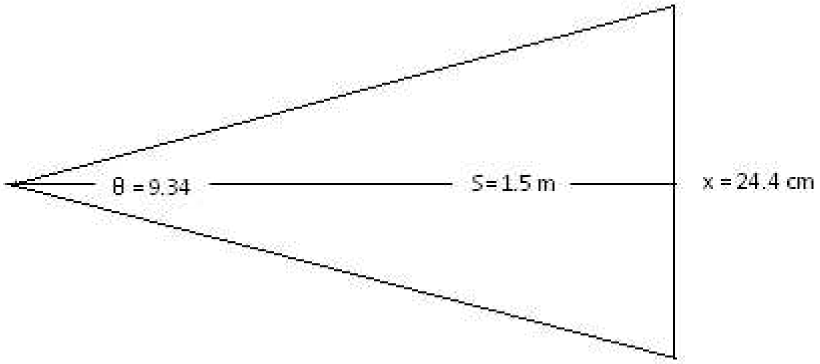


Figure4.7 Geometry of the jet 2

→ Design of diameter = 24.4 cm + 10 cm safety = 34.4 cm

→ The length of reactor maximum distance through reactor equal

L = 1.5 m + 0.16 m safety = 1.66 m

Design the reactor dependent of geometry of spray

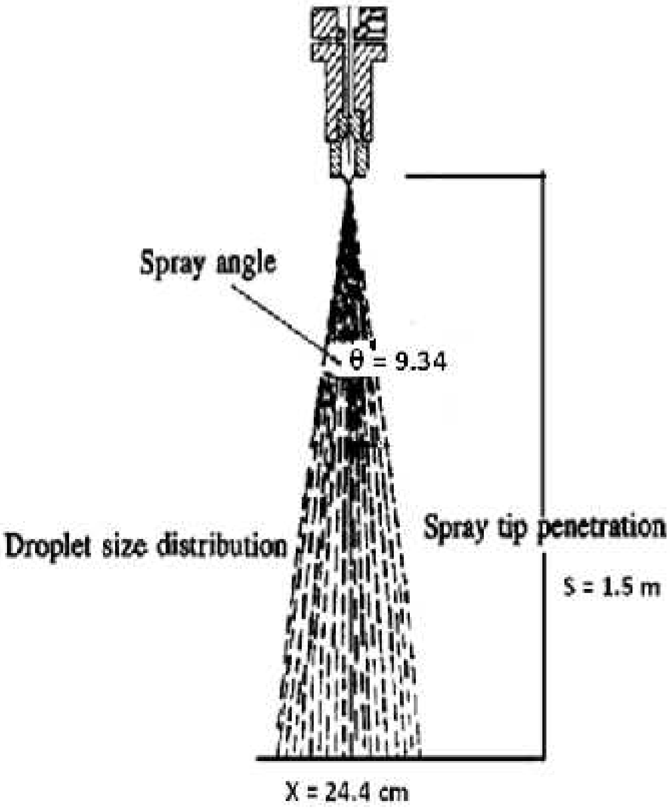


Figure 4.8 Schematic of spray defining its major parameters

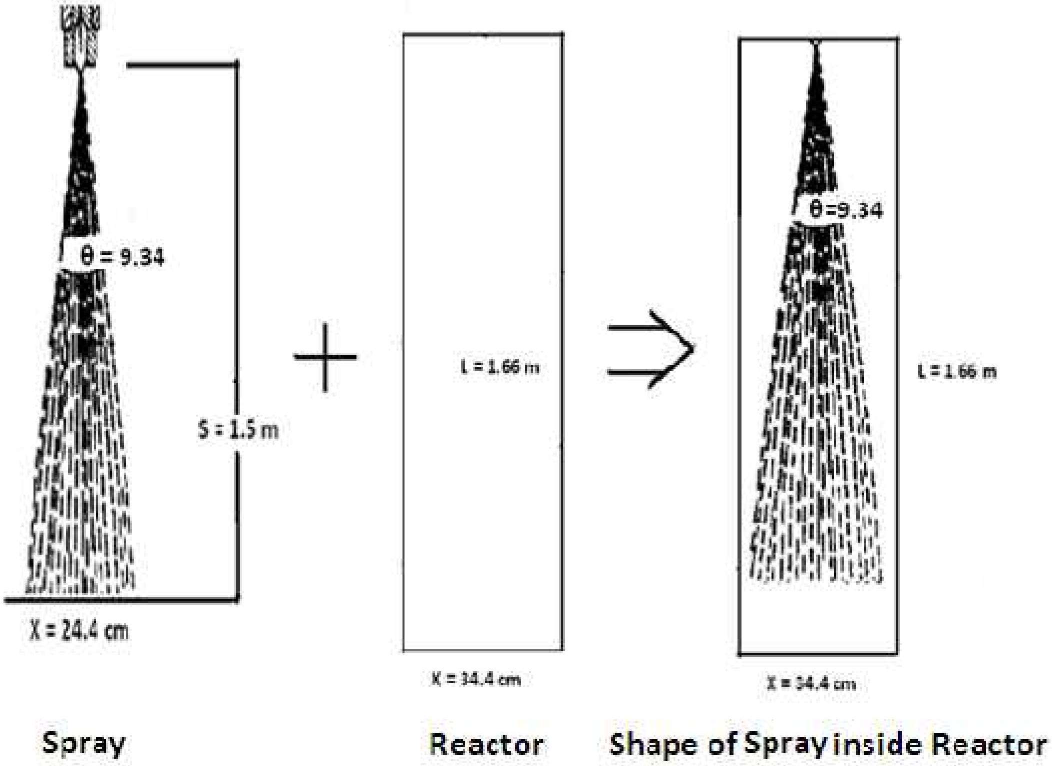


Figure 4.9 Design reactor based on geometry of the spray

The diameter of the reactor 38 cm is available in the market

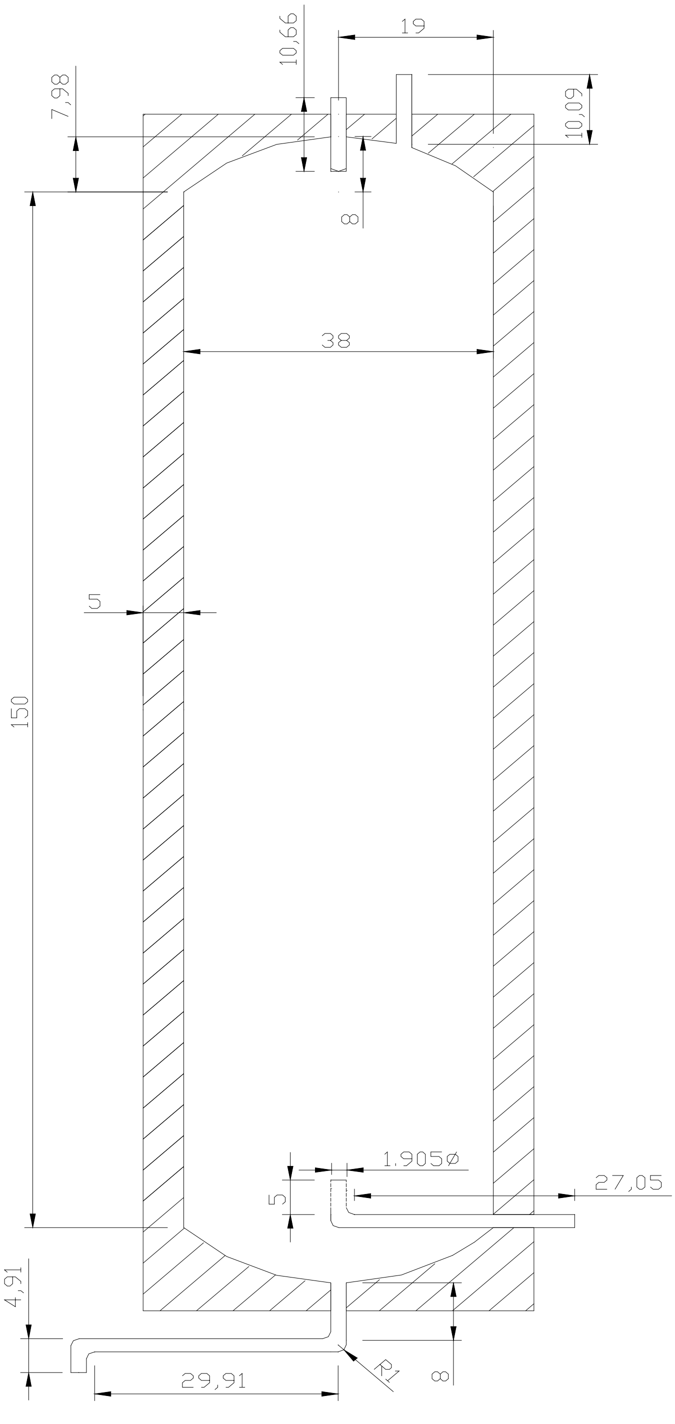


Figure 4.10 Dimensions of the reactor (in millimeter)

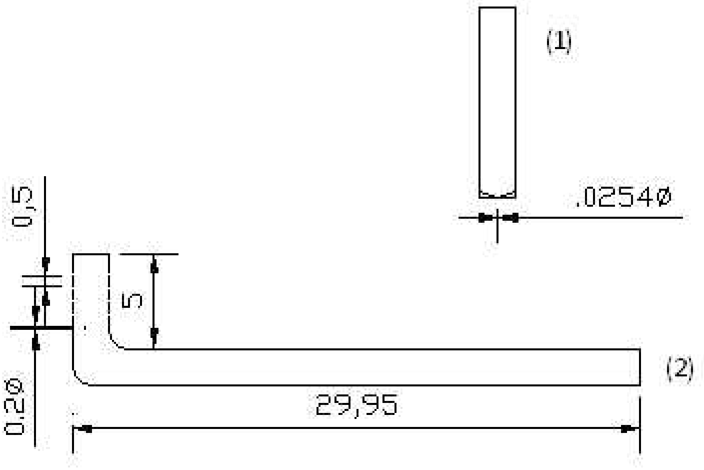


Figure 4.11 (1) Dimensions of injector (in millimeter) (2) Dimensions of pipe inside reactor to get out vapor methanol (in millimeter)

Figure 4.12 Final Shape of reactor

4.9 Design of tanks [1]

4.9.1 Settling Tank Design

As before, it's made of a galvanized steel material, this tank is used for separating biodiesel from glycerin. The tank is conic shaped from the bottom side. For ideal process, it is recommended that the time of settling operation is to be between 8 and 12 hours.

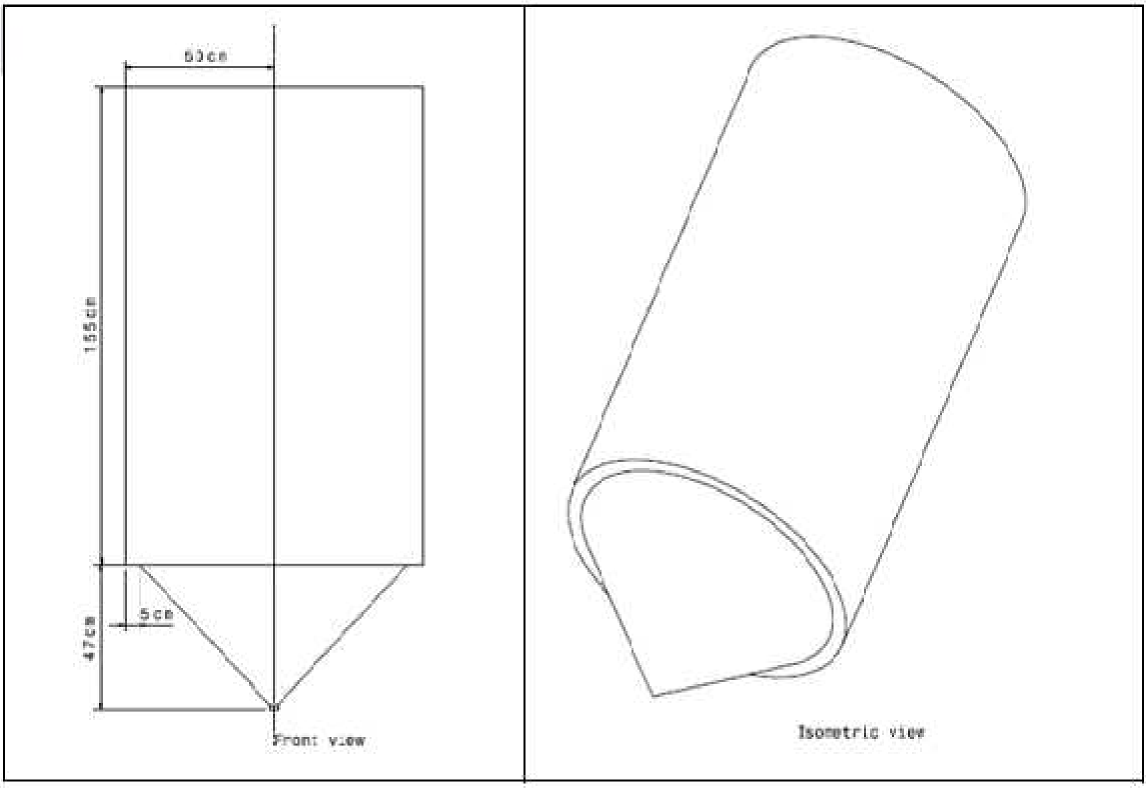


Figure 4.13 Projections of settling tank

The bottom of this tank is provided with a valve for the removal operation of glycerin, also there is another valve located at the top of the conic part of the same tank, which is used for the absorption of biodiesel towards the washing tank.

4.9.2 Washing Tank

Its design has the same designing dimensions of the settling tank, there is a metal pipe which is concentric within the tank, and it is connected to a pump for absorbing water and biodiesel from the opened top of the same pipe.

For ideal process, it is recommended that the time of washing operation is to be between 1 and 1.5 hours, and then, the settling process is to be between 8 and 10 hours.

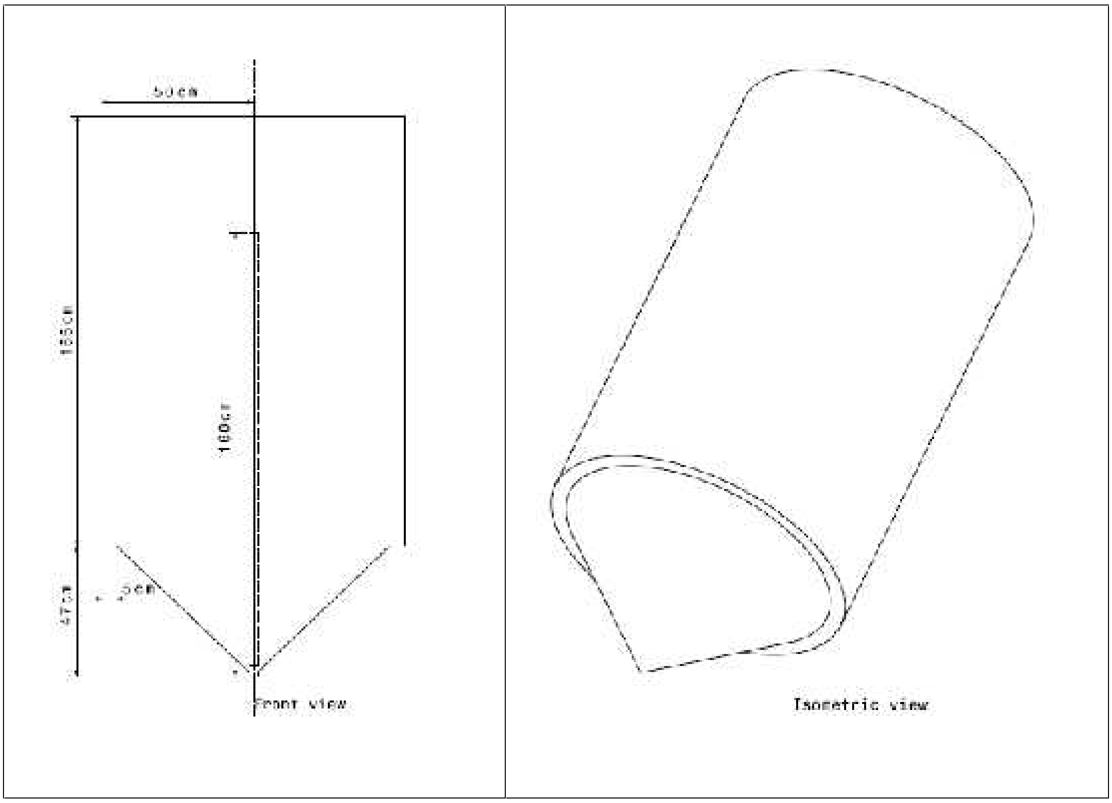


Figure 4.14 Projections of washing tank

The water is added to the tank after the tank is fulfilled with biodiesel. The bottom of this tank is provided with a valve for the removal operation of water, also there is another valve located at the top of the conic part of the same tank, which is used for the absorption of biodiesel towards the storage tank.

The washing process implies absorption of biodiesel and water, and then they will return back to the same tank, it is connected after the top valve. Air can be used for the decomposition of bonds and soap. This process lasts until it is assured that the entire amount is mixed very well completely.

Chapter Five

Conclusions and Recommendations

Content:

5.1 Conclusion

1. The dimension of the reactor based geometry of the spray ,the diameter of the reactor equal thirty four centimeter and the length of the reactor equal one and half meter .

2. Maximum time of the reaction occurred while used smallest nozzle orifices diameter of injector possible.

3. Can be increase the reaction by create wider umbrella from droplets downward which allowed better mix between droplets oil and vapor methanol which can be achieved by choose minimum ratio between hole length of injector and hole diameter injector .

4. The use of higher reaction temperatures. This process can operate at any temperature below the degradation temperature of fat and oil (i.e. ≤ 200 °C) and is not limited to the boiling point of the methanol, which is 61.5 °C.

5. The use of atomized oil/fat. The atomization process increases the oil/methanol contact area by producing small sized droplets and therefore increasing the heat and mass transfer that is vital for a rapid reaction.

6. The process allows the use of excess methanol vapor can be recycled back to the reactor without the need for expensive separation processes.

5.2 Recommendations

1. The NaOH could be deposited and accordingly recommend using sodium as a catalyst sodium methoxide

2. Accounts for and a description of the dynamics of interaction within the reactor

3. Study how to increase the proportion of interaction

Chapter Four

Process component and Design

Content:

4.2 Methanol quantity

Choosing quantity of methanol based on power of electricity available in laboratory at ppu.

Power = I * V

Where

I current (A)

V volte (V)

Power = I * V

= 16 A * 240 V

= 3840 watt

= 3840 watt * 60 s

= 230.4 kJ

When

h_{fg} = 1101.8 kJ/kg (latent heat for methanol at 0.9 bar and 61.5°C)

m mass (kg)

$Cp_{\text{liquid methanol}}$ = 2.55 kJ/kg. °C [1]

$Cp_{\text{vapor methanol}}$ = 1.86 kJ/kg. °C [3]

ρ density of methanol (786.75 kg / m^3) at 25 °C

Q Total heat transfer (kJ)

ΔT temperature difference

T time (s)

Methanol will be heated from 25°C to 80°C in the process and the rest will depend on this quantity.

$Q = Q_{\text{liquid phase}} + Q_{\text{phase change}} + Q_{\text{vapor phase}}$

230.4 kj = [m $_{\text{methanol}}$/min* Cp $_{\text{liquid methanol}}$* (ΔT)] $_{\text{liquid phase}}$

+ [m/min*(hfg)] $_{\text{change phase}}$

+ [m $_{\text{methanol}}$/min* Cp $_{\text{vapor methanol}}$* (ΔT)] $_{\text{vapor phase}}$

Q = m kg/min * 2.55 kJ/kg * (61.5 – 25) °C

+ m kg/min * 1101.8 kJ/kg

+ m kg/min * 1.86 kJ/kg. °C * (80- 61.5) °C

= 230.4 kJ

→ m/min = 0.188 kg/min

m kg = ρ kg / m³ * V m³ → ρ kg / m³ = m kg / V m³

= 0.188 kg / 786.75 kg / m³

= 0.000244 m³

= 0.244 L

→ m/min = 0.244 L/min

= 244 mL / min(0.188 kg / min)

When more power available it can be increasing the quantity of methanol the system capacity.

4.3 Heated methanol H3

In order to heat the methanol heat in system is designed in which the liquid methanol it passed through pipe submersed in hot oil, and used temperature sensor type(WY 138-11s 0804) to adopted the temperature of oil at 138°C,The temperature sensor connected with heater.

The length of pipe to obtain vapor methanol based equation:

$$Qconduction = \frac{2*\pi*k\frac{w}{m}.c°*L\ m*\Delta Tc°}{\ln(ro/ri)} \quad [13]$$

Where

K thermal conductivity (copper = 120 w/m. °C)

L length of pipe (m)

ro outer radius of pipe (m)

ri inner radius of pipe (m)

ΔT= 1 °C

Q conduction = 3840 watt

The available pipe diameter (1/4 inch, 1/2 inch, 1 inch)

→ When

ro = 1/4 inch = 0.00635 m

ri = 1/4 inch = 0.00535 m

→ ln(ro/ri) = 0.171

$$From \ldots Qconduction = \frac{2*\pi*k\frac{w}{m}.c°*L\ m*\Delta Tc°}{\ln(ro/ri)}$$

3840 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.171

→ L = 0.88 m = 88 cm

→ When

ro = 1/2 inch = 0.0127 m

ri = 1/2 inch = 0.0117 m

→ ln(ro/ri) = 0.082

$$From \ldots Qconduction = \frac{2*\pi*k\frac{w}{m}.c°*L\ m*\Delta Tc°}{\ln(ro/ri)}$$

3840 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.082

→ L = 0.42 m = 42 cm

→ When

r_o = 1inch = 0.0254 m

r_i = 1inch = 0.0244 m

→ $\ln(r_o/r_i)$ = 0.04

$$From \ldots Qconduction = \frac{2*\pi*k\frac{w}{m}.c°*L\ m*\Delta Tc°}{\ln(ro/ri)}$$

3840 w = 2 * 3.14 *120 w/m. ℃ * L m * 1℃ / 0.04

→ L = 0.20 m = 20 cm

<u>The best is 1/4 inch which ensure the total evaporator of methanol</u>

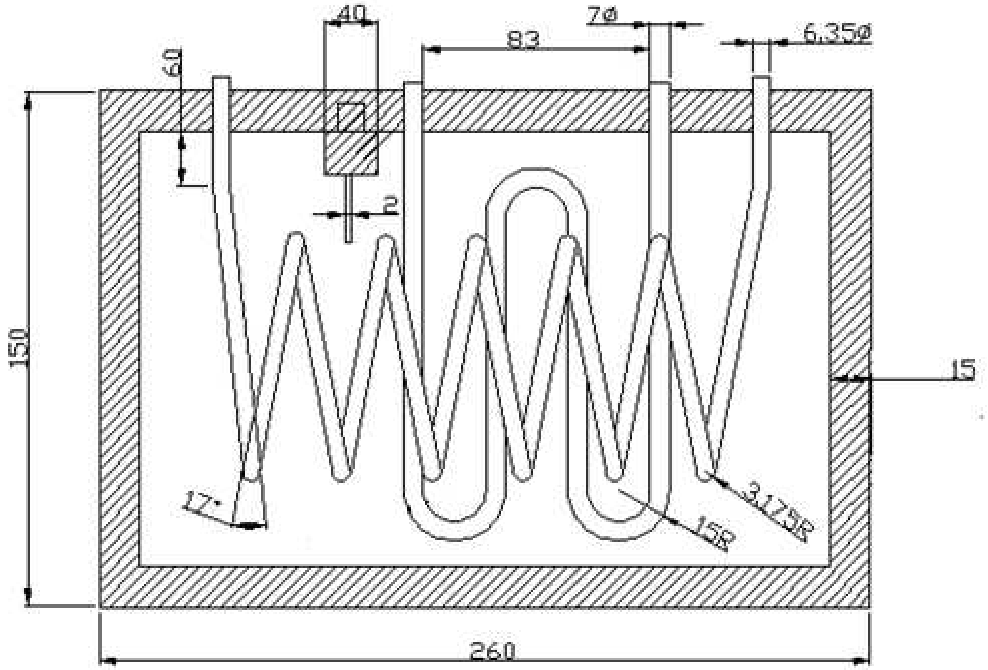


Figure 4.2 Methanol evaporator(All dimensions in millimeter)

$$Vpipe = \frac{\pi * d^2}{4} * L$$

$= 3.14 * 0.002675^2 m^2/4 * 1.2\ m$

$= 0.00000671\ m^3$

$$Vheater = \frac{\pi * d^2}{4} * L$$

$= 3.14 * 0.007^2 m^2/4 * 0.6\ m$

$= 0.000023\ m^3$

$$Vcylinder = \frac{\pi * d^2}{4} * L$$

$= 3.14 * 0.23^2 m^2/4 * 0.12\ m$

$= 0.00498\ m^3$

$V\ oil = V_{cylinder} - V_{heater} - V_{pipe}$

$= 0.00498\ m^3 - 0.000023\ m^3 - 0.00000671\ m^3$

$= 4.95\ L$

$m_{oil}\ kg = \rho\ kg / m^3 * V\ m^3$

$= 850 kg/m^3 * 0.00495\ m^3$

$= 4.2\ kg$

→ $Q = [m_{oil}/t\ min * Cp_{oil} * (\Delta T)]$

$230.4\ kJ = 4.2\ kg/t\ min * 1.67\ kJ/kg.\ ^\circ C * (138-25)\ ^\circ C$

→ → $t = 3.44$ min until reach $\Delta T = 1\ ^\circ C$(until the pipe reached the system temperature)

There for must be waited four minutes before pumped liquid methanol until the pipe reached the system temperature.

4.4 Condensating returned methanol C1

I assume the efficiency of reactor 60 % such that assumed the quantity of returned methanol equal (0.4 * 0.188 kg) .

$Q = Q_{\text{vapor phase}} + Q_{\text{phase change}} + Q_{\text{liquid phase}}$

$Q = [m_{\text{methanol}} * Cp_{\text{vapor methanol}} * (\Delta T)]_{\text{vapor phase}}$

$+ [\, m*(\, hfg\,)]_{\text{change phase}}$

$+ [m_{\text{methanol}} * Cp_{\text{liquid methanol}} * (\Delta T)]_{\text{liquid phase}}$

Q = 0.4 * 0.188 kg * 2.55 kJ/kg * (80- 61.5) °C

+ 0.4*0.188 kg * 1101.8 kJ/kg

+ 0.4 kg*0.188 * 1.86 kJ/kg. °C * (61.5 – 25) °C

= 91.55kJ

= 1525.84 watt

→ Calculate the length of pipe to obtain liquid methanol based equation:

$$Qconduction = \frac{2*\pi*k\frac{w}{m}.c°*L\ m*\Delta Tc°}{\ln(ro/ri)} \qquad [13]$$

Where

K thermal conductivity (copper = 120 w/m. °C)

L length of pipe (m)

r_o outer radius of pipe (m)

r_i inner radius of pipe (m)

$\Delta T = 1$ °C

Q conduction = 1525.84 watt.

→ When

r_o = 1/4 inch = 0.00635 m

r_i = 1/4 inch = 0.00535 m

→ $\ln(r_o/r_i) = 0.171$

$$From \dots Qconduction = \frac{2*\pi*k\frac{w}{m}.c^{\circ}*L\ m*\Delta Tc^{\circ}}{\ln(ro/ri)}$$

1525.84 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.171

→ L = 0.35 m = 35 cm

→ When

ro = 1/2 inch = 0.0127 m

ri = 1/2 inch = 0.0117 m

→ ln(ro/ri) = 0.082

$$From \dots Qconduction = \frac{2*\pi*k\frac{w}{m}.c^{\circ}*L\ m*\Delta Tc^{\circ}}{\ln(ro/ri)}$$

1525.84 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.082

→ L = 0.17 m = 17 cm

→ When

ro = 1inch = 0.0254 m

ri = 1inch = 0.0244 m

→ ln(ro/ri) = 0.04

$$From \dots Qconduction = \frac{2*\pi*k\frac{w}{m}.c^{\circ}*L\ m*\Delta Tc^{\circ}}{\ln(ro/ri)}$$

1525.84 w = 2 * 3.14 *120 w/m. °C * L m * 1°C / 0.04

→ L = 0.08 m = 8 cm

The best is 1/4 inch which ensure the total methanol returned was condensate

→ the length of pipe to condensate returned methanol → L = 0.35 m = 35 cm

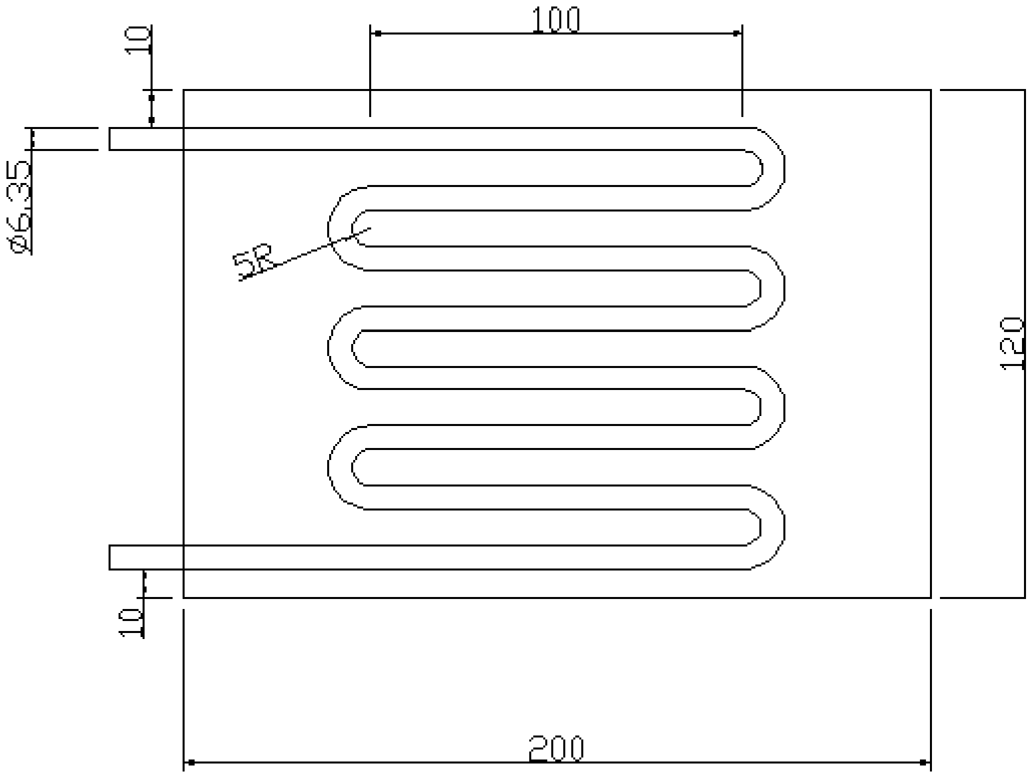


Figure 4.3 Methanol condenser(All dimensions in millimeter)

4.5 Electrical heater into convert fat to oil H1

The fat convert into oil at temperature 50 °C.

$Q = [m_{fat} * Cp_{fat} * (\Delta T)] + [m_{fat} * \text{latent heat}]$

$Q = 0.094 \text{ kg/min} * 2.11 \text{kJ/kg.}°C * (50-25) °C + [0.094 \text{ kg / min} * 883.8 \text{ kJ/kg}$

$Q = 88.03 \text{ kJ/min}$

Q = 1467.17 watt

4.6 Electrical heater for increase temperature oil H2

At a high methanol to oil ratio a much higher conversion was achieved, were the highest conversion was achieved at an oil flow rate of 0.094 kg /min and methanol flow rate of 0.188 kg(0.244 L/min) to investigated ratio of 1:2 (oil: methanol).

$Q = [m_{oil} * Cp_{oil} * (\Delta T)]$

$Q = 0.094$ kg/min * 1.67 kJ/kg. °C *(120-50) °C

= 10.99 kJ/min

= 183.17 watt

4.7 Design the pumps

We Will use two pumps in the system ,the first pump is a gear pump because the liquefied fats is high viscosity and have needed high pressure to atomized liquefied fats will became oil, The second pump is a centrifugal pump for pumping methanol into reactor after heated.

So that is needed to calculated main parameters of the pumps to choose the appropriate pump Such parameters are as follows:

- Flow rate
- Total head
- Power required

We need in experimental prototype methanol quantity double oil quantity until reach obtain high efficiency , we assume that quantity :

1. 0.094 kg_{oil} / min .
2. 0.188 $kg_{methanol}$ / min.

There is a simple calculation for computing the total head and the flow rate in order to select the suitable pump for this purpose.

1. Head

$$\text{Total head} = \text{Head loss due to friction} + \text{static head}$$

f = 64 / Re for laminar flow.

Where:

f: Friction factor for laminar flow.

Re: Reynolds number.

$V_{oil} = m / \rho$

$= (0.094\ kg/min) / (801 kg/m^3)$

$= 0.00012\ m^3/min$

$V_{methanol} = m / \rho$

$= (0.188\ kg/min) / (768.75\ kg/m^3)$

$= 0.00024\ m^3/min$

Where:

m mass flow rat (kg / min)

ρ density of fluid (kg / m^3)

The velocity $_{oil} = Q / A$.

$= (0.00012\ m^3/min) / (\pi D^2 / 4)$

$= (0.00012\ m^3/min) / (\pi\ 0.00535^2 / 4)$

$= 5.34\ m/min$

The velocity $_{methanol} = Q / A$.

$= (0.00024\ m^3/min) / (\pi D^2 / 4)$

$= (0.00024\ m^3/min) / (\pi\ 0.00535^2 / 4)$

$= 10.7\ m/min$

Where:

Q: Flow (m^3/s).

A: Pipe area (m^2).

$Re_{methanol} = (V * \rho * D) / \mu$

$= (10.7/60) * 786.75 * 0.00535 / 0.000544$

$= 1379.8$ Re < 2000 laminar

$Re_{oil} = (V * \rho * D) / \mu$

$= (5.34/60) * 801 * 0.00535 / 0.0346$

$= 10.7$ Re < 2000 laminar

Where:

V: Fluid velocity (m/s).

D: Pipe diameter (m).

μ: dynamic viscosity of fluid(mm^2/s or pa.s))

ρ : density of fluid (kg/m^3)

$f = 64 / Re$

$f_{methanol} = 64 / 1379.8 = 0.047$

$f_{oil} = 64 / 10.7 = 5.98$

Where:

f: Friction factor for laminar flow.

Re: Reynolds number.

Le = (KL * D) / f

Le_{oil} = 0.8 * 0.00535 / 5.98 = 0.0007 neglected

$Le_{methanol}$ = 0.8 * 0.00535 / 0.047 = 0.09 neglected

Where:

D: Pipe diameter (m).

Le The equivelent length

$H1 = \{ (f * (L/D) * (V^2 / 2 g) \} + \{ KL * (V^2 / 2 g) \}$

(a) $K_L = 0.8$ (b) $K_L = 0.5$ (c) $K_L = 0.2$ (d) $K_L = 0.4$

$H1_{oil} = \{5.98 * (2.5 / 0.00535) * (0.089^2 / 2*9.81) + (0.8 * (0.089^2 / 2*9.81))\}$

$= 1.13 m$

$H1_{methanol} = \{0.047 * (2.5 / 0.00535) * (0.18^2 / 2*9.81) + (0.8 * (0.18^2 / 2*9.81))\}$

$= 0.038 m$

Where:

KL: Factor of fitting.

H_1: Kinematics' head (m).

$(\text{Total head} = \text{Head loss due to friction} + \text{static head})_{oil}$

$= 1.13 + 2$

$= 3.13 m$

$(\text{Total head} = \text{Head loss due to friction} + \text{static head})_{methanol}$

$= 0.038 + 0.5$

$= 0.538 m$

2. Power

$P = Q \cdot \rho \cdot H \cdot 9.81_{oil}$

$= 0.094 kg/min * 801 kg/m^3 * 3.13 m * 9.81$

$= 2311.9$ watt

$P = Q \cdot \rho \cdot H \cdot 9.81_{methanol}$

$= 0.188 kg/min * 786.75 kg/m^3 * 0.538 m * 9.81$

$= 780.7$ watt

Where :

P = Power transmitted to the fluid by the pump in Watt.

Q = Flow in kg/min.

p = Density of the fluid in kg/m³

H = height in meter.

9.81 = gravity

A pump is required, having the following characteristics:

For pump P2

H methanol =0.538 m, Q methanol =0.188kg /min, Power methanol = 780.7watt and using pressure equal 1bar (pressure of reactor).

For pump P1

H oil = 3.6 m, Qoil = 0.094 kg /min. Power oil = 2660.4 watt and using pressure 70 bar – 100 bar (high pressure to atomized liquefied fats) Basely previous specification I will be choose pumps type (W9A1- 04) Typical levels at 200 bar and 2300 rpm using mineral oil with viscosity of 40 mm2/s and at temperature of 60°C.

Figure 4.4 Gear pump and electrical motor

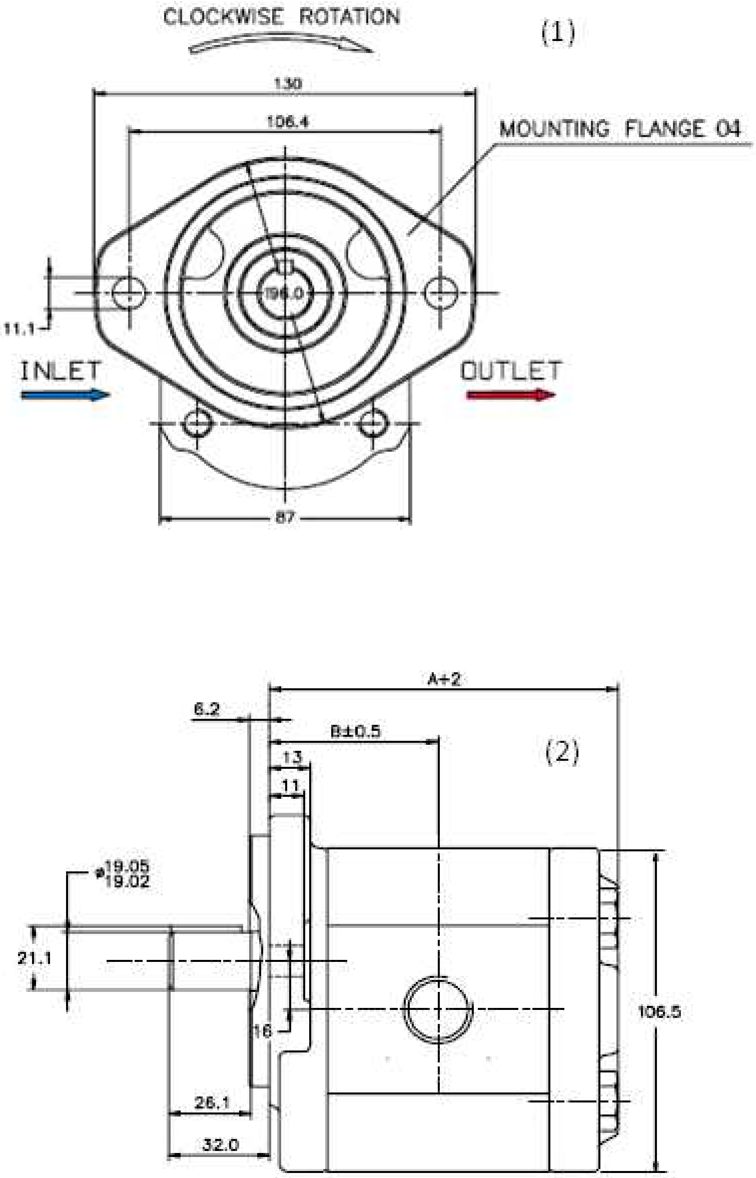


Figure 4.5 (1) and (2) Dimension of the Gear pump in millimeter, A=90mm,B=1 43mm.

4.8 Design the Reactor

Design the reactor dependent of geometry of spray of injector.

4.8.1 Design nozzle hole diameter of the injector

Basally equation and data that described the spray tip penetration can be choose the nozzle hole diameter of injector (dn) based on the time of transferred droplet in reactor by using equation (1) and equation (2)

$S = 0.39 \times (\Delta p / \rho l)^{1/2} \times t$ ……. (1) before break up the oil [17]

When $(0 < t < t_{\text{break up}})$

$S = 2.95 \times (\Delta p / \rho m)^{1/4} \times (dn \times t)^{1/2}$ …..(2) After break up the oil [17]

When $(t \geq t_{\text{break up}})$

$tb = (29 \times \rho l \times dn) / (\rho m \times \Delta p)^{1/2}$ ………..(3) [17]

Where

S spray penetration (m)

Δp pressure drop through the nozzle hole (Pascal)

ρ l density of oil (kg / m³)

ρ m density of methanol (kg / m³)

t time transfer the droplet through the reactor (second)

dn nozzle hole diameter of injector (mm)

tb break up the oil (second)

ρ density of MeOH vapor(kg / m³) = 4 kg /m³

ρ density of oil(kg / m³) =801kg /m³

Injection pressure (kPa) 100

Maximum distance before break up and after break up the oil through reactor

equal S = 1.5 m [19] (Eighth International Conference on Liquid Atomization and Spray System Pasadena CA.USA.July2000)

When you are in the resulting from atomized exposed to contact with methanol vapor which carries a catalyst for reaction depends on the nozzle hole diameter of injector (dn) ,The more time that the droplet is exposed to the possibility of interaction increased biodiesel production more and accordingly we will choose the appropriate injector.

→ When dn = 0.254 mm

tb =(29 x ρl x dn) / (ρm x Δp) ½

= (29 x 801kg /m³ x 0.254 mm) / (8 kg /m³ x 100 kPa)

= 0.00092164 s

From equation …….. (1)

S = 0.39 x (Δp / ρl) ½ x t

= 0.39 x (100 kPa / 801kg /m³) ½ x 0.00092164 s

= 0.0402m

The value sub equation ….(2) = 1.5 m - 0.0402m

= 1.4598 m

The (1.4598 m) sub equation ….(2)

→ t = 0.6097 s

→ t total = t + t break up

= 0.6097 s + 0.00092164 s

= 0.61062164 s this total time when the droplet transferred in reactor maximum distance to1.5 m when used injector with nozzle hole diameter dn = 0.254 mm

→ When dn = 0.343 mm

tb =(29 x ρl x dn) / (ρm x Δp) ½

= (29 x 801kg /m³ x 0.343 mm) / (8 kg /m³ x 100 kPa)

= 0.0012 s

From equation …….. (1)

S = 0.39 x (Δp / ρl) ½ x t

= 0.39 x (100 kPa / 801kg /m³) ½ x 0.0012 s

= 0.0523m

The value sub equation ….(2) = 1.5 m - 0.0523m

= 1.4477m

The (1.4477m) sub equation ….(2)

→ t = 0.4441s

→ t total = t + t break up

= 0.4441s + 0.0012 s

= 0.4453 s this total time when the droplet transferred in reactor maximum distance to1.5 m when used injector with nozzle hole diameter dn = 0.343 mm

→ When dn = 0.61 mm

tb =(29 x ρl x dn) / (ρm x Δp) ½

= (29 x 801kg /m³ x 0. 61 mm) / (8 kg /m³ x 100 kPa)

= 0.0022 s

From equation …….. (1)

$S = 0.39 \times (\Delta p / \rho l)^{1/2} \times t$

$= 0.39 \times (100\ kPa / 801 kg/m^3)^{1/2} \times 0.0061 s$

$= 0.0959\ m$

The value sub equation ….(2) = 1.5 m - 0.0959 m

= 1.4041m

The (1.4041m) sub equation ….(2)

→ t = 0.2349s

→ t total = t + t break up

= 0.2349s + 0. 0022 s

= 0.2371 s this total time when the droplet transferred in reactor maximum distance to1.5 m when used injector with nozzle hole diameter dn = 0.61 mm

Table 4.1 Standard (Nozzle orifices diameter) versus Time when the droplet transferred in reactor max distance (1.5 m)

dn standard (Nozzle orifices diameter) (John .B Heywood)	Time when the droplet transferred in reactor max distance (1.5 m)
0.254 mm	0.61062164 s
0.343 mm	0.4453 s
0.61 mm	0.2371 s

Choosing dn = 0.254 mm because this longest time (0.61062164 s) occurred had the droplet exposed for interaction with methanol to produce biodiesel.

4.8.2 Design the diameter of the reactor

Basally equation (4) and equation (5) and data that describe the angle of spray inside reactor can be calculated the diameter of reactor

$A = 3 + (0.28 \times (l_n / d_n))$ ………(4) [17]

$\tan(\theta/2) = (1 / A) \times 4 \times \prod \times (\rho_m / \rho_l)^{½} \times (\sqrt{3} \times 6)$ ……..(5) [17]

where

l_n (Hole length) mm

d_n (Hole diameter)) mm

→ when ratio $l_n/d_n = 4$ [17]

$A = 3 + (0.28 \times (4))$

$A = 4.12$

Sub (A) in equation …..(5)

$\tan(\theta/2) = (1 / A) \times 4 \times \prod \times (\rho_m / \rho_l)^{½} \times (\sqrt{3} \times 6)$

$= (1 / 4.12) \times 4 \times 3.14 \times (4\ kg/m^3 / 801 kg/m^3)^{½} \times (\sqrt{3} \times 6)$

→ $\theta/2 = 3.56$

→ when ratio $l_n/d_n = 2.1$ [17]

$A = 3 + (0.28 \times (2.1))$

$A = 3.588$

Sub (A) in equation …..(5)

$\tan(\theta/2) = (1 / A) \times 4 \times \prod \times (\rho_m / \rho_l)^{½} \times (\sqrt{3} \times 6)$

$= (1 / 3.588) \times 4 \times 3.14 \times (4\ kg/m^3 / 801 kg/m^3)^{½} \times (\sqrt{3} \times 6)$

→ $\theta/2 = 4.09$

→ when ratio $l_n/d_n = 0.5$ [17]

$A = 3 + (0.28 \times (0.5))$

$A = 3.14$

Sub (A) in equation .....(5)

$\tan(\theta/2) = (1 / A) \times 4 \times \Pi \times (\rho m / \rho l)^{1/2} \times (\sqrt{3} \times 6)$

$= (1 / 3.14) \times 4 \times 3.14 \times (4\ kg/m^3 / 801 kg/m^3)^{1/2} \times (\sqrt{3} \times 6)$

→ $\theta/2 = 4.67$

Table 4.2 Ratio between (ln (Hole length) /dn (Hole diameter)) versus Angle of spray jet

Ratio (ln / dn) standard value[11]	Angle of spray jet θ/2
4	3.56
2.1	4.09
0.5	4.67

Design the diameter of reactor while occur maximum angle spray When minimum ratio between (l_n (Hole length) /d_n (Hole diameter)), Choosing ratio $l_n/d_n = 0.5$

Maximum distance before break up and after break up the liquefied fats droplet through reactor equal S=1.5 m [19]

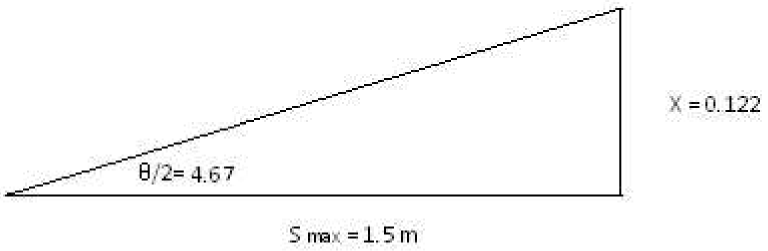


Figure 4.6 Geometry of the jet 1

θ/2 = 4.67 → θ = 9.34

width of the jet = 2 x 0.122 m = 24.4 cm

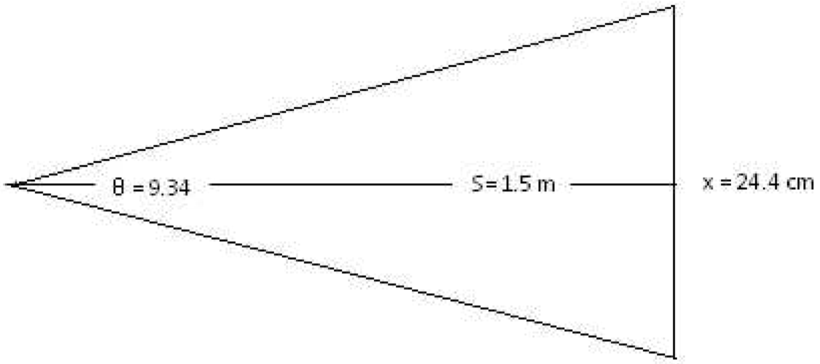


Figure4.7 Geometry of the jet 2

→ Design of diameter = 24.4 cm + 10 cm safety = 34.4 cm

→ The length of reactor maximum distance through reactor equal

L = 1.5 m + 0.16 m safety = 1.66 m

Design the reactor dependent of geometry of spray

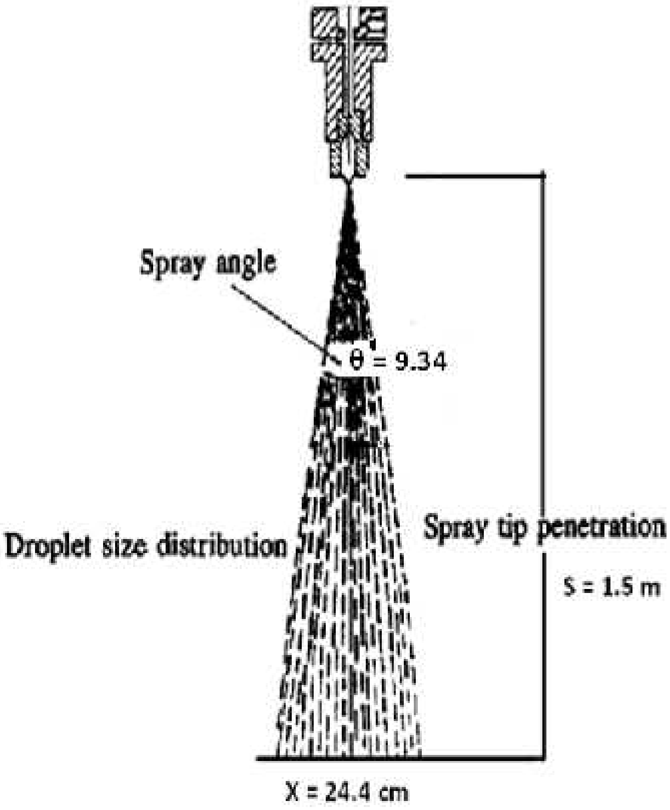


Figure 4.8 Schematic of spray defining its major parameters

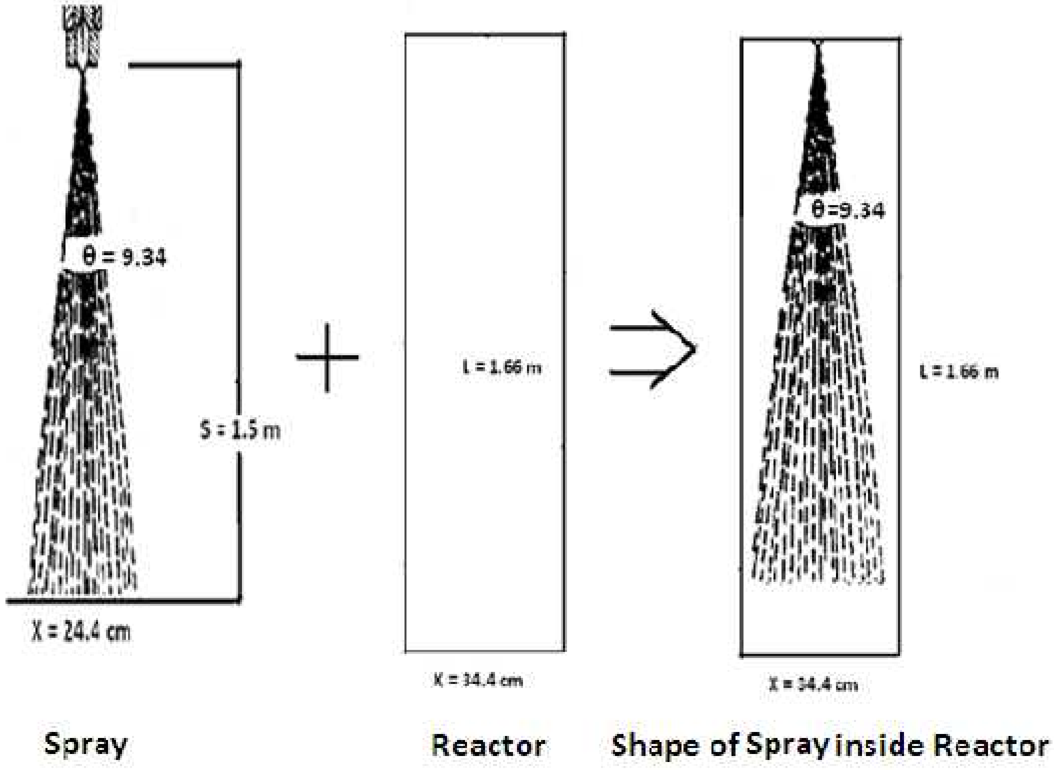


Figure 4.9 Design reactor based on geometry of the spray

The diameter of the reactor <u>38 cm </u>is available in the market

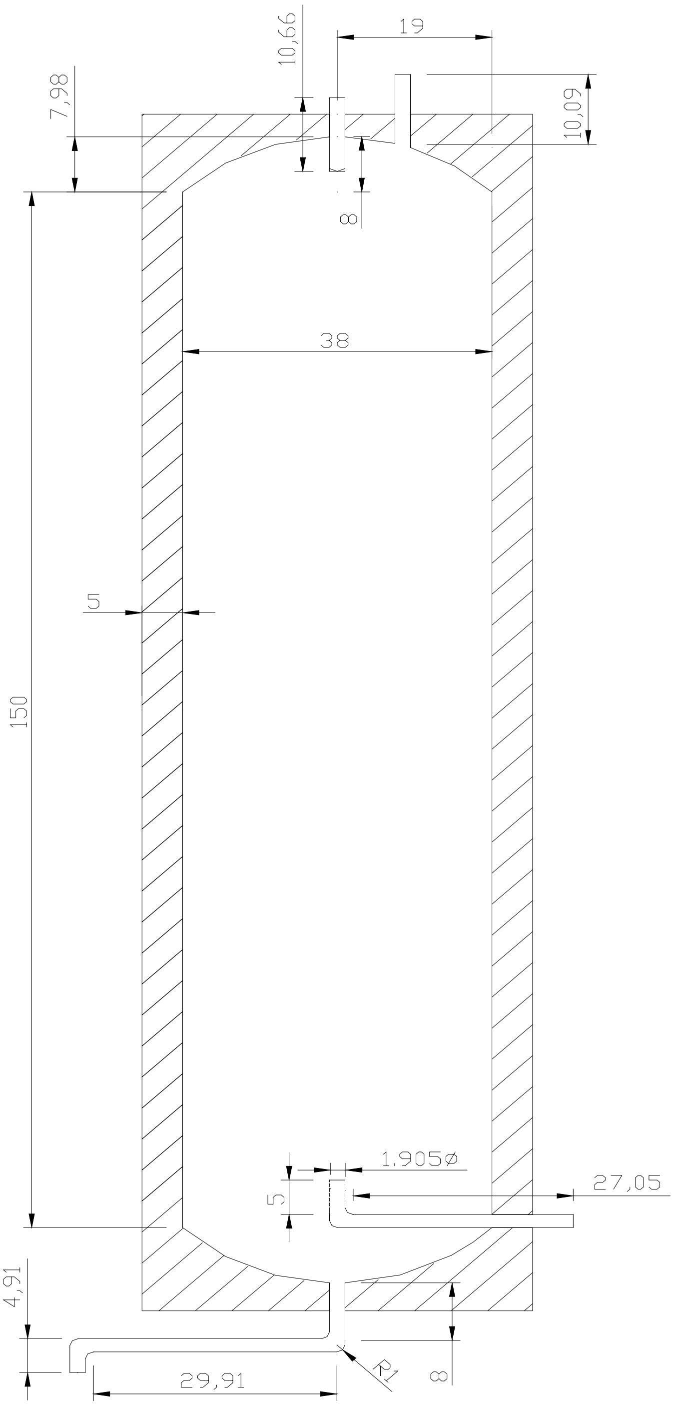


Figure 4.10 Dimensions of the reactor (in millimeter)

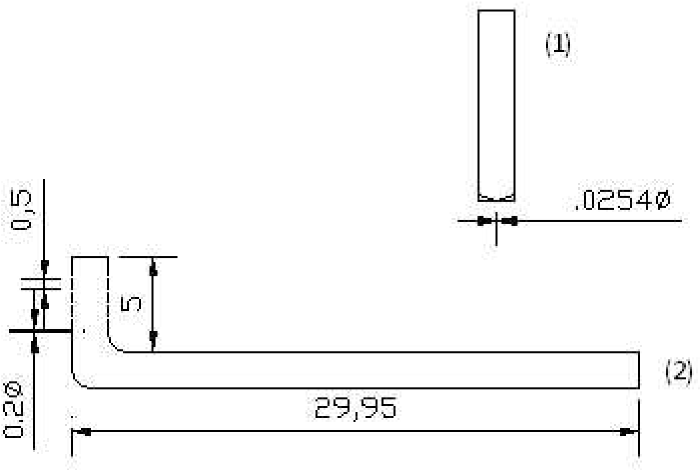


Figure 4.11 (1) Dimensions of injector (in millimeter) (2) Dimensions of pipe inside reactor to get out vapor methanol (in millimeter)

Figure 4.12 Final Shape of reactor

4.9 Design of tanks [1]

4.9.1 Settling Tank Design

As before, it's made of a galvanized steel material, this tank is used for separating biodiesel from glycerin. The tank is conic shaped from the bottom side. For ideal process, it is recommended that the time of settling operation is to be between 8 and 12 hours.

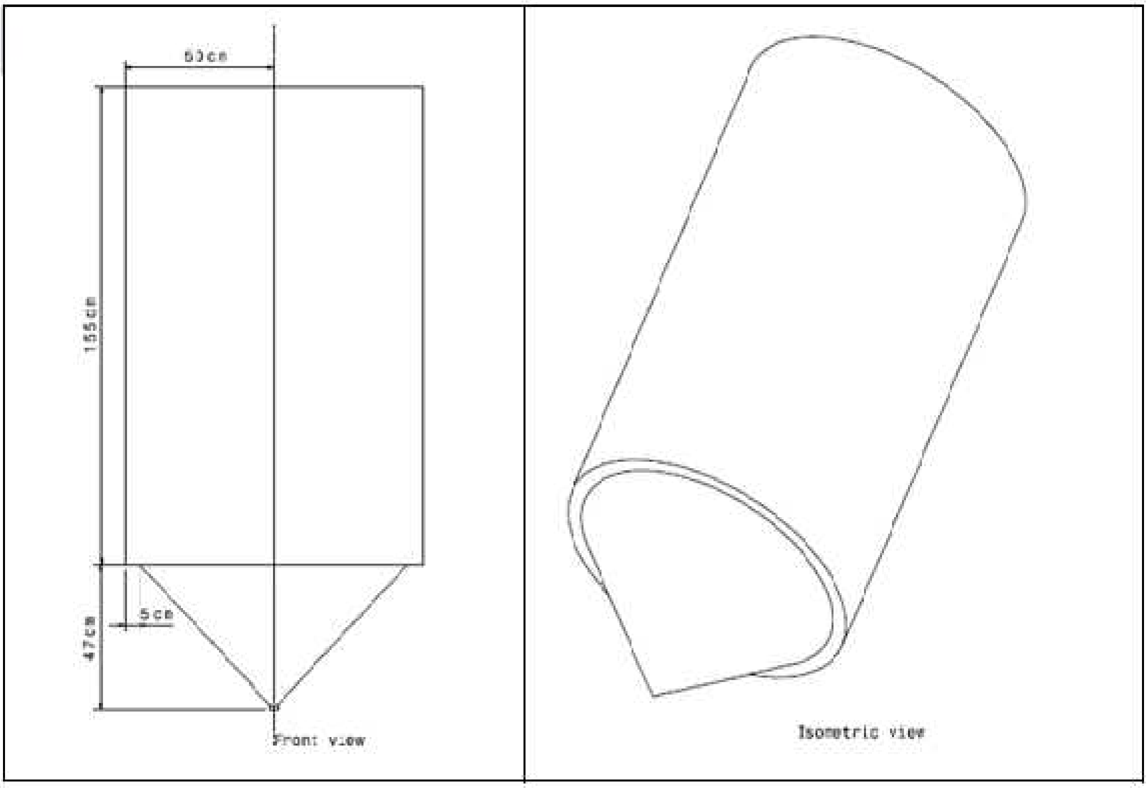


Figure 4.13 Projections of settling tank

The bottom of this tank is provided with a valve for the removal operation of glycerin, also there is another valve located at the top of the conic part of the same tank, which is used for the absorption of biodiesel towards the washing tank.

4.9.2 Washing Tank

Its design has the same designing dimensions of the settling tank, there is a metal pipe which is concentric within the tank, and it is connected to a pump for absorbing water and biodiesel from the opened top of the same pipe.

For ideal process, it is recommended that the time of washing operation is to be between 1 and 1.5 hours, and then, the settling process is to be between 8 and 10 hours.

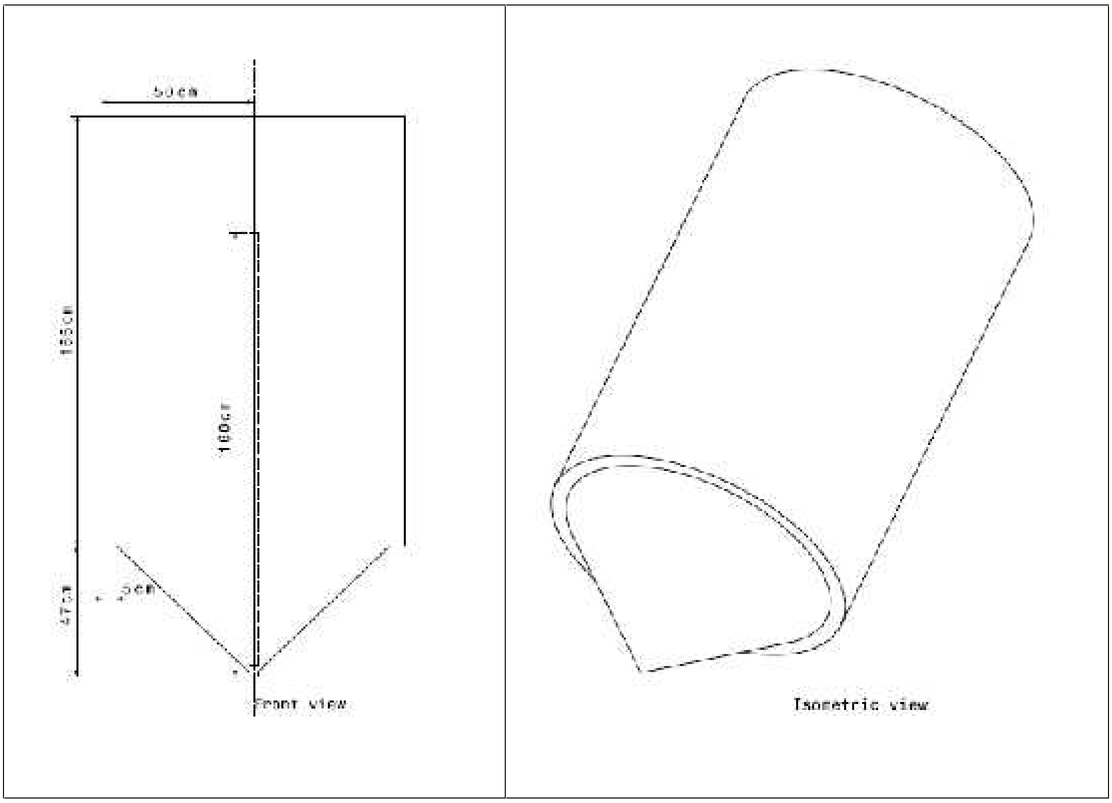


Figure 4.14 Projections of washing tank

The water is added to the tank after the tank is fulfilled with biodiesel. The bottom of this tank is provided with a valve for the removal operation of water, also there is another valve located at the top of the conic part of the same tank, which is used for the absorption of biodiesel towards the storage tank.

The washing process implies absorption of biodiesel and water, and then they will return back to the same tank, it is connected after the top valve. Air can be used for the decomposition of bonds and soap. This process lasts until it is assured that the entire amount is mixed very well completely.

Chapter Five

Conclusions and Recommendations

Content:

5.1 Conclusion

1. The dimension of the reactor based geometry of the spray ,the diameter of the reactor equal thirty four centimeter and the length of the reactor equal one and half meter .

2. Maximum time of the reaction occurred while used smallest nozzle orifices diameter of injector possible.

3. Can be increase the reaction by create wider umbrella from droplets downward which allowed better mix between droplets oil and vapor methanol which can be achieved by choose minimum ratio between hole length of injector and hole diameter injector .

4. The use of higher reaction temperatures. This process can operate at any temperature below the degradation temperature of fat and oil (i.e. ≤ 200 °C) and is not limited to the boiling point of the methanol, which is 61.5 °C.

5. The use of atomized oil/fat. The atomization process increases the oil/methanol contact area by producing small sized droplets and therefore increasing the heat and mass transfer that is vital for a rapid reaction.

6. The process allows the use of excess methanol vapor can be recycled back to the reactor without the need for expensive separation processes.

5.2 Recommendations

1. The NaOH could be deposited and accordingly recommend using sodium as a catalyst sodium methoxide

2. Accounts for and a description of the dynamics of interaction within the reactor

3. Study how to increase the proportion of interaction

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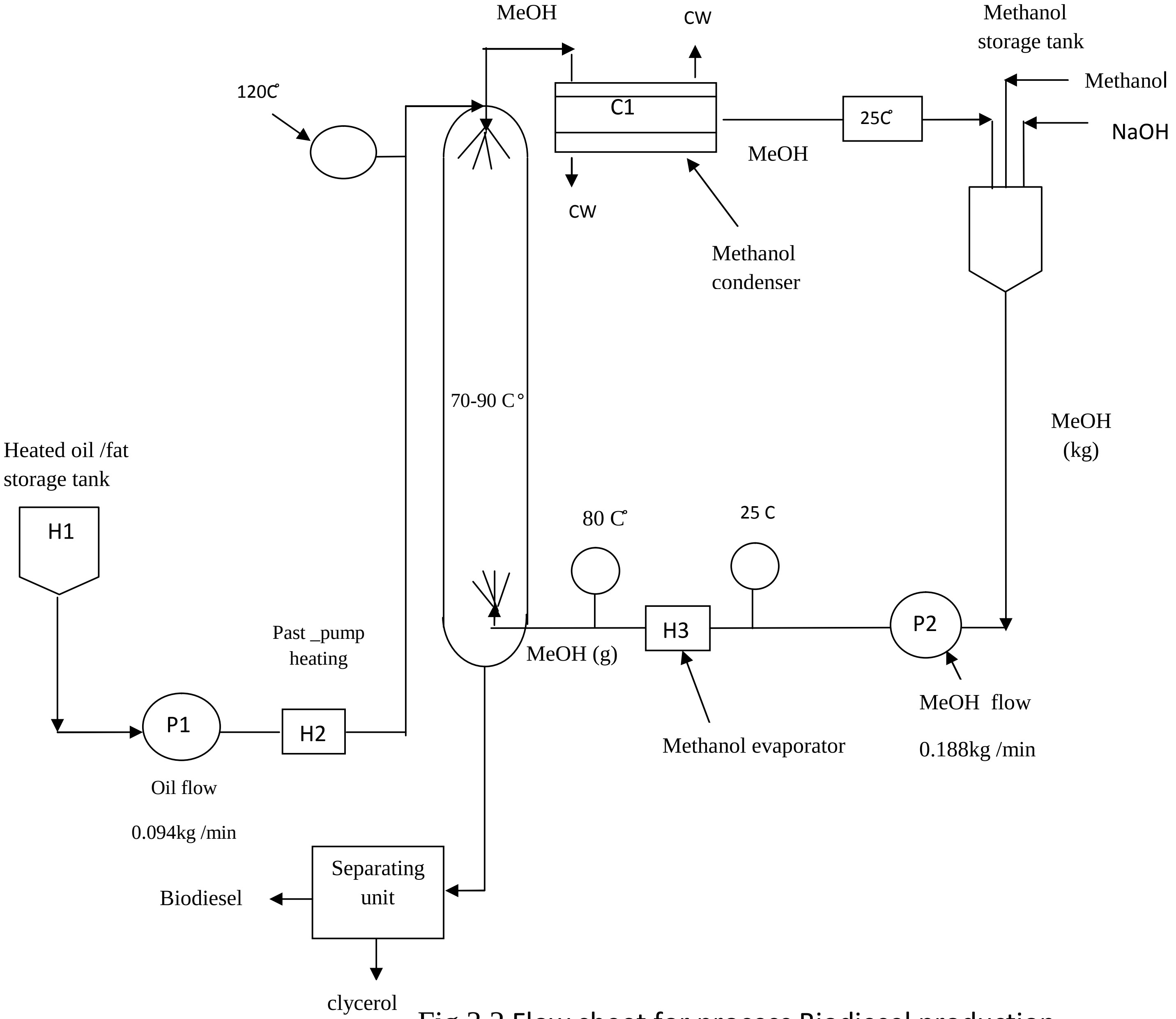

Fig.3.2 Flow sheet for process Biodiesel production

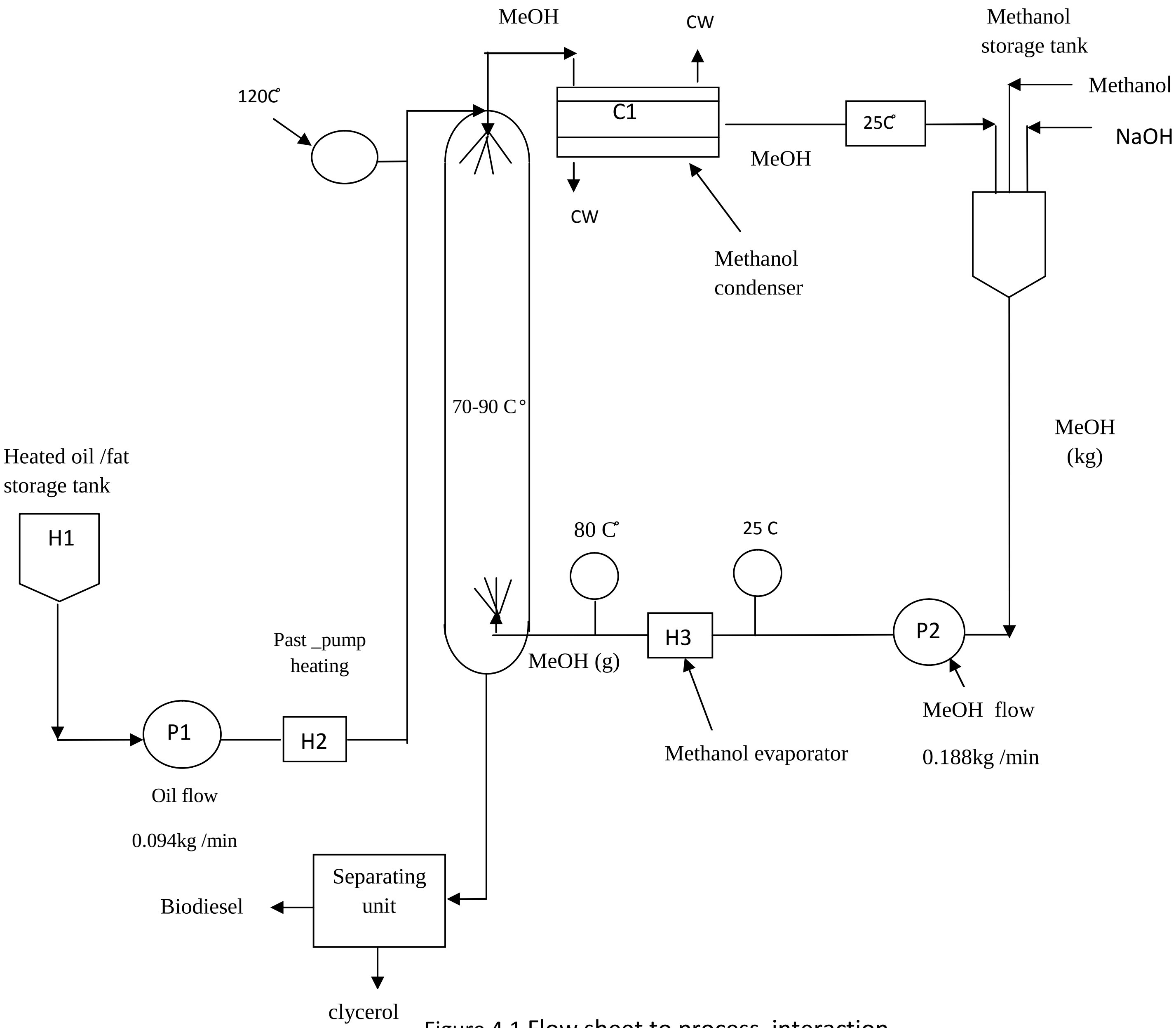

Figure 4.1 Flow sheet to process interaction

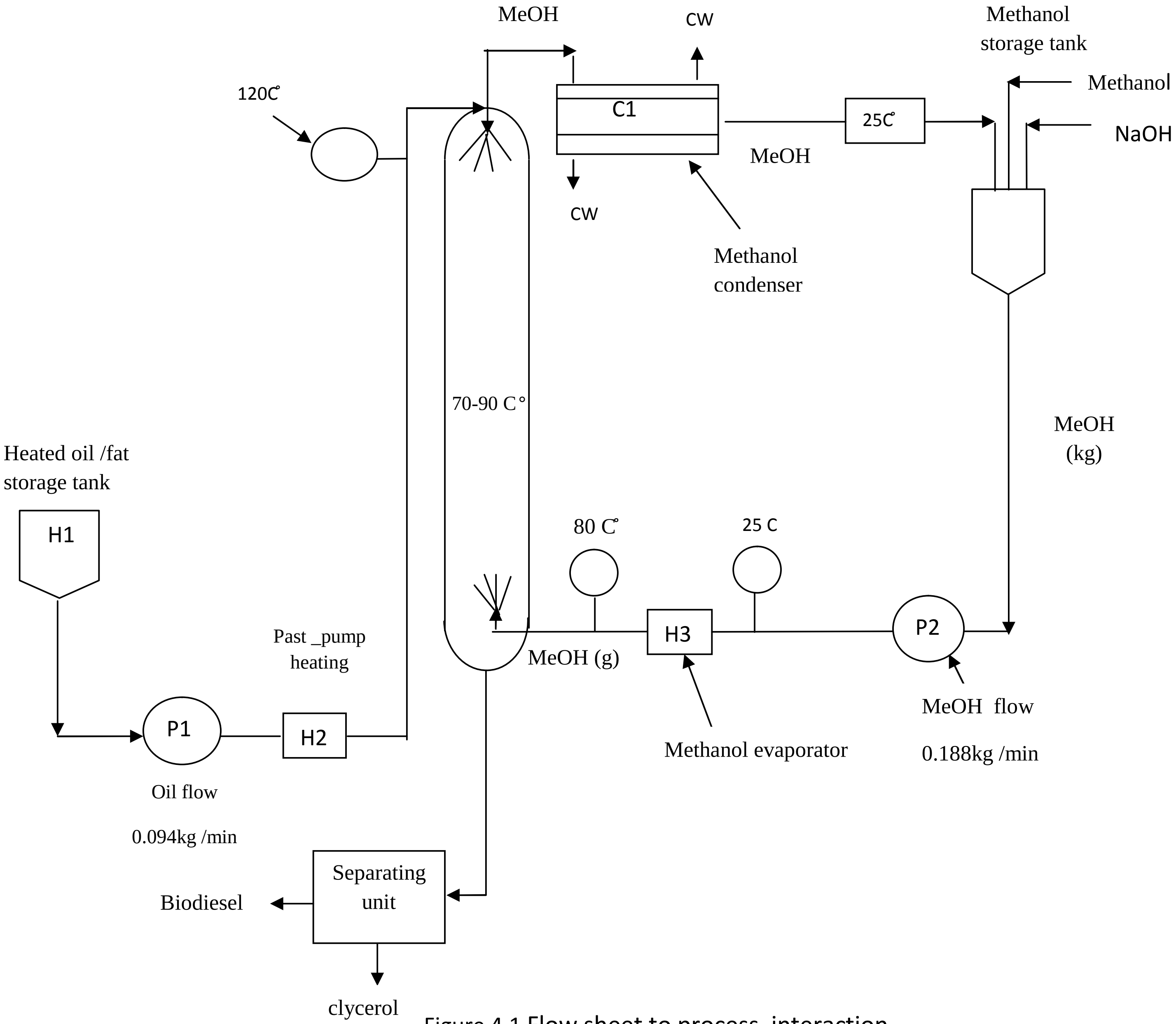

Figure 4.1 Flow sheet to process interaction

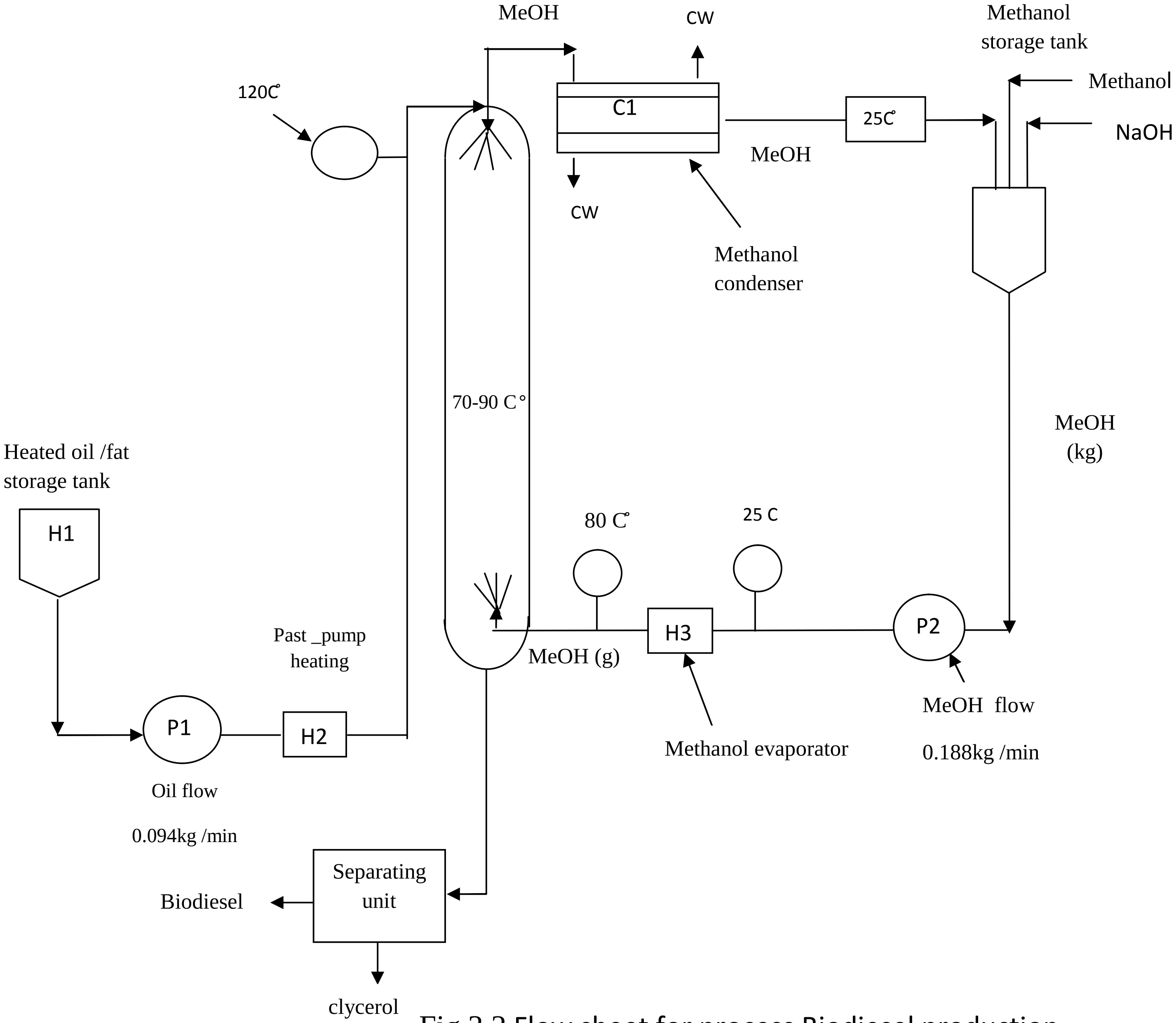

Fig.3.2 Flow sheet for process Biodiesel production