SIMULATION OF BIODIESEL PRODUCTION FROM USED FRYING OIL (UFO) USING ALKALINE - BASED CATALYSTS

TAY YON YON

This report is presented in
partial fulfilment of the requirements for the
Degree of Bachelor of Mechanical Engineering (Thermal Fluid)

Faculty of Mechanical Engineering
University Technical Malaysia Melaka

MAY 2010

VERIFICATION

I have read this thesis
and from my opinion the thesis
is sufficient in aspects of scope and quality for awarding
Bachelor of Mechanical Engineering (Thermal Fluid)

Signature : ……………………………
Name of Supervisor : MAHANUM MOHD ZAMBERI
Date : 20 MAY 2010

DECLARATION

"I hereby, declare this thesis is the result of my own research except at cited in the reference"

Signature : ....

Author's Name : TAY YON YON

Date : 19/5/2010

PENGAKUAN

"Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya telah jelaskan sumbernya"

Tandatangan : ....

Nama Penulis : TAY YON YON

Tarikh : 19/5/2010

DEDICATION

To

My Beloved Family & Friends

ACKNOWLEDGEMENT

Special thanks to my project supervisor Ms. Mahanum Mohd Zamberi, for always willing to spend her precious time giving advices, guidance and sharing the knowledge throughout this work, and being an inspiring teacher for me.

I would like to thanks to Dr. Yusmady Mohamed Arifin as my project second examiner. Thanks for willing to spend his precious time examine my work. I would like to express my most sincere thanks to Dr. Hady Effendy for guiding my work and invaluable suggestion and advice

Last but not least, my deepest gratitude to all my friends and teammates most of my time with -who did not fed up with my endless ”Wh” question and endless their support.

ABSTRAK

Sumber bahan api fosil kini menghadapi penyusutan dengan cepat. Untuk mengatasi masalah ini, biodiesel adalah penting untuk dijadikan salah satu bahan api alternatif. Kajian ini adalah untuk melaksanakan simulasi dengan menggunakan HYSYS 3.2 keatas penghasilan biodiesel daripada minyak penggorengan terpakai (UFO) dengan menggunakan pemangkin beralkali, (i.e. natrium hidroksida, kalium hidroksida, natrium metosida, campuran natrium hidroksida dengan kalium hidroksida dan campuran natrium hidroksida dengan kalium hidroksida, serta campuran natrium hidroksida dengan natrium metosida). Berasaskan beberapa kajian ilmiah, hasil penyelidikan yang dirujuk menunjukkan bahawa jenis dan kuantiti pemangkin yang berbeza akan memberikan hasilan biodiesel yang berbeza. Kaedah proses simulasi dalam penyelidikan ini, melibatkan pentakrifan komponen-komponen kimia, pemilihan model termodinamik, pemilihan unit beroperasi dan keadaan input yang sesuai dan pelaksanaan keadaan mantap simulasi. Jenis mangkin yang berbeza akan memberi hasil yang berbeza dan matrik hasil biodiesel yang berbeza untuk pengujian yang sebenar. Tetapi, matrik hasil biodiesel untuk kaedah simulasi tidak menunjukkan perbezaan yang besar apabila pemangkin yang berbeza dipakai, ini adalah mungkin disebabkan kaedah simulasi adalah lebih ideal jika dibandingkan dengan pengujian yang sebenar.

ABSTRACT

Fossil fuel resource is now facing fast depletion. As to overcome this situation, biodiesel is gaining more and more importance as an alternative fuel. This thesis is concern about the simulation of biodiesel production from used frying oil (UFO) using alkaline-based catalysts, (i.e. sodium hydroxide, potassium hydroxide, sodium methoxide, mixture of sodium hydroxide with potassium hydroxide and mixture of sodium hydroxide with sodium methoxide) and the yield of biodiesel is simulated by HYSYS 3.2 analytical software. Based upon several literature reviews, the result gained by these researches show different types and amount of catalysts give different yield of biodiesel. The method of process simulation in this research, mainly involve defining chemical components, selecting thermodynamic model, choosing proper operating unit and input condition and execute the steady state simulation. Different type of catalysts gives different values of biodiesel yield production in laboratory experiment. Yet by using simulation, the difference between the yield productions for different types of catalysts did not show significant different, this maybe cause by the idealness of simulation environment.

CONTENT

CHAPTER	TITLE		PAGE NO.
	ACKNOWLEDGEMENT		ii
	ABSTRAK		iii
	ABSTRACT		iv
	CONTENT		v
	LIST OF TABLE		ix
	LIST OF FIGURE		xi
CHAPTER1	INTRODUCTION		1
	1.1	Background	1
	1.2	Objectives	3
	1.3	Scope	3
	1.4	Problem Statement	4
CHAPTER 2	LITERATURE REVIEW		5
	2.1	Theory	6
	2.2	Molar Ratio of Alcohol to Oil	6
	2.3	Type and Quantity of Catalysts Used	7
	2.4	Reaction Temperature	8
	2.5	Reaction Time	9
	2.6	General Biodiesel Process	12
	2.6.1	Pre-processing Process	12
	2.6.2	Transesterification	12

	2.6.3	Washing Process	13
	2.6.4	Drying	13
	2.7	Batch Processing	14
CHAPTER 3	METHODOLOGY		16
	3.1	Research Tool	16
	3.2	Aspen HYSYS 3.2	16
	3.3	HYSYS Simulation Parts	17
	3.4	Defining Chemical Component	19
	3.5	Selecting Thermodynamic Model	19
	3.6	Choosing Proper Operation Unit	20
	3.6.1	Reactor	20
	3.6.2	Pump	22
	3.6.3	Mixer	24
	3.6.4	Heater	24
	3.6.5	Distillation Column	25
	3.6.6	Liquid-Liquid Extractor	26
	3.6.7	Extractor	27
	3.7	Steady-State Simulation	28
	3.8	Proposed Biodiesel Production Apparatus	29
	3.9	Types of Raw Material and Parameters Set For Simulation of Biodiesel Production	30
CHAPTER4	SIMULATION AND OPTIMAZATION OF BIODIESEL PRODUCTION PLANT		31
	4.1	Process Description of Biodiesel Production from Used Frying Oil	31

	4.2	Modeling and Simulation of Biodiesel Production from Waste Cooking Oil	32
	4.3	Fluid Package Used	34
	4.4	Physical Properties	34
	4.5	Optimization of Simulation Condition in Each Operation Unit	35
	4.5.1	Conversion Reactor	35
	4.5.2	Methanol Distillation Column	37
	4.5.3	Extractor	37
	4.5.4	Liquid- Liquid Extractor	38
	4.5.5	Distillation Column	39
CHAPTER 5	RESULT AN DISCUSSION		40
	5.1	Simulation of Biodiesel Process Using NaOH As Catalyst	40
	5.1.1	Result for Conversion Reactor	40
	5.1.2	Result for Methanol Distillation Column	41
	5.1.3	Result for Extractor	41
	5.1.4	Result for Liquid-Liquid Extractor	42
	5.1.5	Result for Distillation Column	42
	5.1.6	Summary of Result and Process Condition For Simulation of Biodiesel Process Using NaOH as Catalyst	43
	5.2	Simulation of Biodiesel Process Using KOH As Catalyst	45
	5.2.1	Result for Conversion Reactor	45
	5.2.2	Result for Methanol Distillation Column	45
	5.2.3	Result for Extractor	46
	5.2.4	Result for Liquid-Liquid Extractor	46

	5.2.5	Result for Distillation Column	47
	5.2.6	Summary of Result and Process Condition For Simulation of Biodiesel Process Using KOH as Catalyst	48
	5.3	Simulation of Biodiesel Process Using $NaOCH_3$ as Catalyst	50
	5.3.1	Result for Conversion Reactor	50
	5.3.2	Result for Methanol Distillation Column	50
	5.3.3	Result for Extractor	51
	5.3.4	Result for Liquid-Liquid Extractor	51
	5.3.5	Result for Distillation Column	52
	5.3.6	Summary of Result and Process Condition For Simulation of Biodiesel Using $NaOCH_3$	52
	5.4	Comparison of the Conversion Rate and Condition of Reaction of Biodiesel Production For Different Catalysts	54
CHAPTER 6	CONCLUSION AND RECOMMENDATION		55
	REFERENCES		58
	APPENDIX		61

LIST OF TABLE

TABLE NO.	TITLE	PAGE NO.
2.1	Comparison of Different Yield Biodiesel Production with Different Researches.	11 - 12
3.6.0	Information Needed for Equilibrium Reaction. (HYPROTECH, 2003)	22
3.6.1	Stream Properties for Input and Output (Reactor)	22
3.6.2	Stream Properties for Input and Output (Pump)	23
3.9	Types of Raw Material and Parameters Set for Simulation of Biodiesel Production	30
4.4	Physical Properties of Components	35
5.1	Summary of Result and Process Condition for Simulation of Biodiesel Process Using NaOH as Catalyst	44

5.2	Summary of Result and Process Condition for Simulation of Biodiesel Process Using KOH as Catalyst	49
5.3	Summary of Result and Process Condition for Simulation of Biodiesel Process Using $NaOCH_3$ as Catalyst	53
5.4	Comparison of Data Obtained In Stream 106 For Different Catalysts	54

LIST OF FIGURE

FIGURE NO.	TITLE	PAGE NO.
1.0	Transesterification Reaction	2
2.6.2	Settling Process after Transesterification (Retrieved from www.journeytoforever. org/biodiesel_make2.html)	13
2.6.3	Settling or Filtration after Washing (Shailendra Shina et.al, 2008)	14
2.7	Batch Reaction Process (J.Van Gerpen et.al, 2002-2004)	16
3.0	HYSYS Simulation Environment	17
3.1	Flowchart of Methodology	18
3.3	Component List View	19
3.5	Selecting Thermodynamic Model	20
3.6.0	Pump Window Properties	23

3.6.1	Changing Pump Efficiency	23
3.6.3	Mixer	24
3.6.4	Heater	25
3.6.5	Distillation Column	26
3.6.6	Liquid-Liquid Extractor	26
3.6.7	Extractor	27
3.8	Proposed Biodiesel Production Apparatus	29
4.1	The Whole Biodiesel Plant from Aspen HYSYS	33
4.5.1	Conversion Reactor (CRV-100)	36
4.5.2	Distillation Column (T-100)	37
4.5.3	Extractor (X-100)	38
4.5.4	Liquid-Liquid Extractor (T-101)	38
4.5.5	Distillation Column (T-102)	39
5.1.1	Worksheet for Conversion Reactor	40
5.1.2	Worksheet for Distillation Column	41
5.1.3	Worksheet for Extractor	41

5.1.4	Worksheet for Liquid-Liquid Extractor	42
5.1.5	Worksheet for Distillation Column	43
5.2.1	Worksheet for Conversion Reactor	45
5.2.2	Worksheet for Distillation Column	46
5.2.3	Worksheet for Extractor	46
5.2.4	Worksheet for Liquid-Liquid Extractor	47
5.2.5	Worksheet for Distillation Column	47
5.3.1	Worksheet for Conversion Reactor	50
5.3.2	Worksheet for Distillation Column	50
5.3.3	Worksheet for Extractor	51
5.3.4	Worksheet for Liquid-Liquid Extractor	51
5.3.5	Worksheet for Distillation Column	52

CHAPTER 1

INTRODUCTION

1.1 Background

Today, energy requirement is critically important for any development of economy. Most of the energy we use is come from the fossil fuel: petroleum, coal and natural gas. The fossil fuel is non renewable as they are being consumed more rapidly than they are being produced, and this lead to fast depletion of fuel resource coupled with environmental issues. To overcome this situation, development of alternative fuels-biodiesel for diesel engine is concern. Biodiesel is produced by renewable resources such as vegetable oil, animal fats and as well as non edible oil make biodiesel biodegradable and non toxic, as well as contribute to low emission of carbon dioxide, because it content close carbon cycle (Van Gerpen ,2005).

Malaysia has large and growing palm oil industry; these vast agricultural products can be turn into biodiesel. Hence, the Malaysia Federal Government developed ambitious biodiesel policies in 2005 to help country's agricultural product, palm oil, could profitably transformed into biodiesel as to improve energy security and create new export industry. However, since late 2007, the price of crude palm oil increases dramatically and caused many biodiesel producers to suspend operation. As of September 2008, there were only eight plant were in production out of 14 functional biodiesel plant in Malaysia due to high feedstock prices, closed or cancelled plans and shifting operation.(Gregore Pio Lopez, 2008)

Biodiesel can also produced by waste frying oil. Regarding the situation mentioned, biodiesel produced using waste frying oil should be concerned. Waste frying oil are usually cheaper than crude palm oil; moreover, by using waste frying oil, which does not compete with the food market could gain two major advantages: (i) recycling waste material; and (ii) reducing cost of biodiesel production.

Biodiesel can be produced by transesterification reaction, which the feedstock (vegetable, waste frying oil or animal fats) is reacted in the present of catalyst with an alcohol to give corresponding alkyl esters of the fatty acid mixture found in the parent oil. The process of transesterification has been widely used to reduce the high viscosity of triglycerides. The overall reaction is shown at Figure 1.0. Parameters which greatly influence the transesterification reaction is: temperature, methanol:oil molar ratio, mixing rate, catalyst type and amount of catalyst.

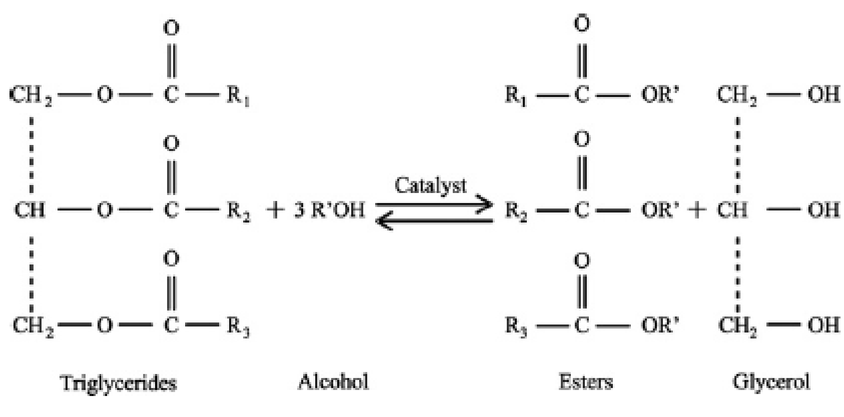

Figure 1.0 Transesterification Reaction

The biodiesel processes can be designed and simulated in analytical software. HYSYS is a powerful engineering simulation tool with vast component libraries, comprehensive thermodynamics packages and advances computational methods. With all the technology feasibility obtain in this software; an economical and complete process simulation of biodiesel can be performed.

1.2 Objectives

This project is to simulate the production of biodiesel from Used Frying Oil (UFO) Using Alkaline-Based Catalysts. The simulation of the biodiesel production is done by HYSYS. The main objectives of this Final Year Project are as following:

- To study the biodiesel production model, process criticality and constrain parameters.
- To design the virtual experimental model of biodiesel production for simulation purpose using analytical software.
- To simulate the yields of UFO biodiesel produced by varies the catalysts used during the production. Furthermore; this data will be compare to actual production of biodiesel for existing project.

1.3 Scope

This project will involve the simulation of biodiesel produced using different alkaline-based catalysts. The scopes that cover in this project are as following:

- To summarize the current build of transesterification reactor, inclusive of its process criticality, constrain parameters and raw material used of each model in order to develop comprehensive overview of biodiesel production related-matter

- From the comprehensive overview, this study is extend to designing the virtual experimental model of biodiesel reactor inclusive of raw material mixing ratio, homogeneous mixing method, selection of heating method and so on. This model will be build up by using HYSYS 3.2 software.
- To establish the yield matrix of UFO biodiesel using the simulation. Data captured will be comparing to actual production of biodiesel and the study will be extended to gap analysis.

1.4 Problem Statement

There are several types of transesterification designs and ways used to produce biodiesel such as the batch and continuous process. Different designs works in different way and as well different optimum parameters are needed to ensure the reactor to function well. The problem statement of this project includes:

- Various studies on the reactors and parameters are important as reference on designing a good experimental model for biodiesel production.
- The production of biodiesel includes many process steps; therefore, proper design of a complete process and complete simulation must carry out first by using suitable software to avoid any unnecessary cost wastage.
- There is lack of study of supporting information regarding the comparison of the performance specific raw material- waste frying oil with catalysts and with the mixture of different base catalysts.
- There will be some expected differences between a process simulation and real life operation. Comparison of the real life operation yield matrix and the simulation result need to be done to verify the difference between real life operation results with the simulation result.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory

The purpose of the transesterification process of vegetable oils is to reduce the high viscosity of oil to enable their use in common diesel engine. There are four basic routes to biodiesel production by using transesterification process; base-catalyzed transesterification; direct acid-catalyzed transesterification; enzyme catalytic conversion of oil into fatty acid and then into biodiesel, and non-catalytic transesterification using methanol.

Among the four methods of biodiesel production, alkali base-catalyzed transesterification also known as alkaline methanolysis of oil or fat with simple alcohol is the preferred method for producing biodiesel as this process can achieved high purity and yield of biodiesel production in a short time. However, only oil with 0.5 wt% of free fatty acid can be used as the reactant in the based-catalyzed transesterification. (Ayhan Demirbas, 2009)

For every biodiesel production, parameters give significant effects in the production. The main factors that affect the transesterification of used frying oil are: the molar ratio of oil to alcohol, the type and quantity of catalyst used, reaction temperature and reaction time.

2.2 Molar Ratio of Alcohol to Oil

The most frequent molar ratio of alcohol to triglycerides used by researchers is 6:1. Though the higher alcohol to triglyceride ratio used will help to faster the conversion process, it will also result in excess alcohol accumulating in the biodiesel product. As a result, the biodiesel is washed with water to remove the excess alcohol as well as other impurities such as traces of soap and catalyst (Tickle, 2000).

According to Xiangmei Meng et.al (2008), on the study of biodiesel production from waste cooking oil via alkali catalyst, the molar ratio of alcohol to oil used was 6:1 and this produced a good yield of biodiesel which is in the range of 65%- 88.90% with different amount of catalysts used.

According to Umer Rashid, et.al (2008), of the research on the production of Sunflower oil methyl esters by alkali-catalyzed methanolysis, the best result of yield is 97.1% under the condition of 6:1 molar ratio of alcohol to oil used. This shown that, one of the optimum conditions needed by good yield of biodiesel is the 6:1 molar ratio of alcohol to oil.

As for research done by J.M Encinar, et .al (2007) .12:1 of ethanol to oil gave the highest yield biodiesel which is 72.5%. Yet, a later increased of molar ratio to 15:1does not increase in yield, since a lower value is obtained 66.2%. This is because, for higher molar ratio the separation of glycerol was difficult, since the excess ethanol will hinders the decantation by gravity so that the apparent yield of esters decreases since part of the glycerol remains in the biodiesel phase. These results are similar to those obtained by Feuge and Gros (1949) in the ethanolysis of peanut oil.

Therefore, the alcohol to oil molar ratio is one of the most important variables affecting the esters yield. Although the stoichiometric ratio for transesterification requires 3 mol of alcohol and 1 mol of triglyceride, an excess of alcohol is used in the practice. Hence, the alcohol molar: oil ratio is a variable that must be always optimized.

2.3 Type and Quantity of Catalysts Used

In catalytic transesterification process, catalysts play the role of an agent used to speed up a chemical reaction by lowering the activation energy. A catalyst is used in the transesterification reaction to break the chemical bonds between the glycerine molecule and each of the three esters attached to it (Tickle, 2000). Optimum amount of catalyst is needed to be determined to allow optimum production of biodiesel.

The most common alkali-based catalysts used are the sodium hydroxide (NaOH), potassium hydroxide (KOH) and alkoxide such as sodium alkoxide (NaOCH3) and potassium alkoxide ($KOCH_3$). According to Xiangmei Meng et.al (2008), types of catalyst used in the biodiesel production is sodium hydroxide, in different quantity, 1.00 wt% of sodium hydroxide gives the highest yield of biodiesel.

Umer Rashid, et. al (2008) in his study state the result that; with 1wt% of sodium hydroxide gave the best yield biodiesel production which is 97.1%. Yet, higher catalysts concentrations such as 1.25% and 1.50% used in production decreased the yield of biodiesel. The sodium hydroxide catalysts give better yield compare to potassium hydroxide, sodium alkoxide and potassium alkoxide.

According to O.J Alamu et. al (2006) on the study of biodiesel production from the Nigerian palm kernel oil effect of KOH concentration on yield, the result of the study shows that 1.0% of KOH catalyst gave the best yield, which is 95.80%. This is same as the research done by J.M Encinar.et.al (2006) on ethanolysis of used frying oil. Biodiesel preparation and characterization, with 1% of KOH give the highest yield.

The addition of an excessive amount of catalyst, will gives rise to the formation of an emulsion, which increases the viscosity and leads to the formation of gels. These deter the glycerol separation and, hence, reduce the apparent ester yield. In addition, further increases in catalyst concentration not only did not increase the conversion and yet lead to extra costs because it was necessary to remove it from the reaction medium at the end of process. (J.M Encinar.et.al 2006).