IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 5 Ver. VI (Sep. - Oct. 2016), PP 105-111
www.iosrjournals.org

Taguchi Methods for Study of Characteristic of Water Emulsion Fuel

Agung Sudrajad
Department of Mechanical Engineering, University of Sultan AgengTirtayasa- Indonesia

Abstract: *The study is aims to identify the characteristics of the water emulsion fuel.This study using Taguchi experimental design method and determine the characteristics of the water emulsion fuel through testing Thermal Gravimetric Analysis (TGA) and Gas Chromatography-Mass Spectrometry (GCMS). From the test results it can be seen pure diesel fuel MDO begin to decompose at temperatures of 230°C, whereas all samples of diesel emulsion water averaged compose at a temperature of 110°C.In Thermal Gravimetric Analysis (TGA) testing sample numbers II is the best sample, whereas in the test Gas Chromatography-Mass Spectrometry (GCMS) sample number I is the best sample. From both these tests it can be concluded that the sample numbers II is the best sample in this study.*
Keywords*: emulsion fuel, diesel fuel, Taguchi method, TGA, GCMS*

I. Introduction

The fuel that we use for our industrial plant contain components of air pollutants. To overcome these problems a lot of engineers to create a way for the fuel used was clean and friendly environment. One method used is a water emulsion.Water Emulsion Fuel is a potential solution to overcome the problems associated with a clean environment and effective utilization of energy. Besides, the availability of fossil fuels is depleted also be a factor pushing people to think how to reduce the fuel consumption.Recently, the research has been done on making fuel water emulsion is often not all can achieve a predefined quality standard. This can occur due to many factors, one of which influence fuel composition is not suitable water emulsion. Therefore, the quality of the water emulsion fuel production must be considered, the other word the control every material and equipment used, and doing trial mix to obtain appropriate quality.The research study is using Taguchi Method attempt to get the standard composition of additive-water-fuel for optimum quality of emulsion fuel.

II. Research References

Orthogonal Array

Orthogonal array is a matrix of factors and levels are structured such that the influence of a factor and does not mingle with the factor level and other levels. Matrix elements arranged in rows and columns. Line is a factor state, while the column is a factor that can be changed in the experiment. Orthogonal array notation is :

$L_n(l^f)$………………………. (1)

where :
f = factors (columns)
l = levels
n = number of observations (lines)
L = square design

The following are some examples of tables Orthogonal Array in Taguchi experimental design is show in table 1.

Table 1. Ortogonal Array $L_9(3^4)$

	Factor			
EXP	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Degree of Freedom

Degrees of freedom that exist in the orthogonal matrix associated with the number of levels in the number of columns. To calculate the total degrees of freedom in the whole matrix we can take advantage of the nominal sort order to explain each matrix. As the degrees of freedom in the same column with the number of levels in the minus one column, the total degrees of freedom for the entire matrix of degrees of freedom equal to the number of individuals for each column.

$L_n(l^f) = f\ x\ (l-1)$…………….. (2)

where :

f = factor (columns)

l =levels

n = number of observations (lines)

L = square design

Emulsion Fuel

Emulsions are mixtures of two or more liquids that are usually mixed either by itself or in a way in blender.Emulsion fuel is fuel that is updated with a variety of substances that are on earth, for example water, coconut oil, castor oil, and so forth. The types of emulsion fuel are water in oil W/O and oil in water O/W. This research attempt to try experiment of W/O test by TGA and GCMS.

III. Research Methodology

The methodology of research is experimental method with preliminary design of experiment by using Taguchi Method.

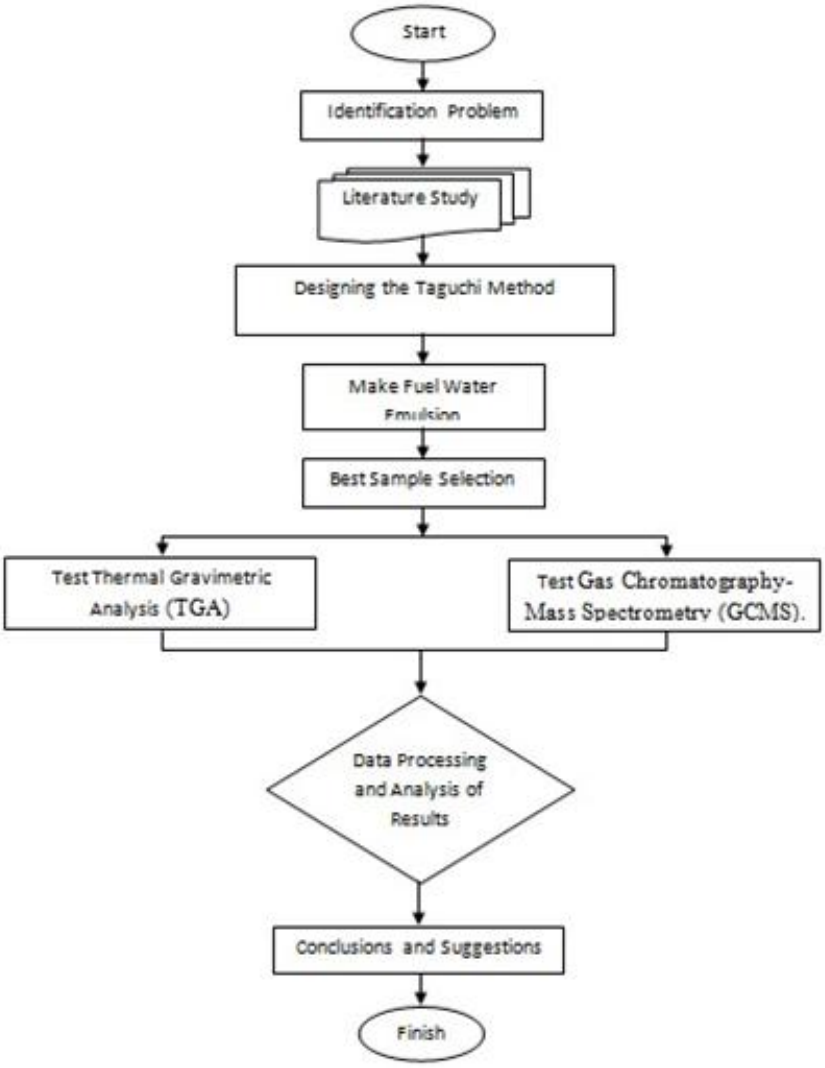

Figure 1. Research Methodology

Determination of Number Level and Level Value Factor

Selection of the number of levels is important for the precision of the experiment and the cost of implementation of the experiment.The more levels studied, the experimental results will be more accurate because more data is obtained,but the number of levels will increase the number of observations thus raise the cost of the experiment.Table 2 show the data of value level determination factors will be examined.

Table 2. Determination of the number of levels and the level values of factors experiment I

Code	Control Factor	Level 1	Level 2	Level 3
A	**Surfactant**	15 mL	20 mL	25 mL
B	**Water**	20 mL	25 mL	30 mL

Table 3. Determination of the number of levels and the level values of factors experiment II

Code	Control Factor	Level 1	Level 2	Level 3
A	**Surfactant**	10 mL	15 mL	20 mL
B	**Water**	20 mL	25 mL	30 mL

IV. Results and Discussions

The following is an orthogonal matrix which is used in the design of the Taguchi method.

Table4. Matrix orthogonal $L_9(3^4)$

Matrix Orthogonal L_9 (3^4)		
Experiment	**Column/Factor**	
	A	**B**
1	1	1
2	1	2
3	1	3
4	2	1
5	2	2
6	2	3
7	3	1
8	3	2
9	3	3

In the orthogonal matrix contained nine times the experiment or sample preparation, and there are two factors that control the reference of the study, the two factors that control each have a three-level factors.In the calculation of the degrees of freedom states that research design has three levels will result in a total of eight degrees of freedom, therefore the chosen design $L_9(3^4)$which will produce nine times the experiment.The design of the Taguchi method is generated through orthogonal matrix, then we can make water emulsion composition that has been planned.

Table 5. The Composition of Emulsion FuelBased on Orthogonal Concept

Design I						
Experiment	**Composition**					
	Oil		**Surfactant**		**Water**	
	(ml)	**(%)**	**(ml)**	**(%)**	**(ml)**	**(%)**
1	70	66,667	15	14,285	20	19,047
2	70	63,636	15	13,636	25	22,727
3	70	60,869	15	13,043	30	26,086
4	70	63,636	20	18,181	20	18,181
5	70	60,869	20	17,391	25	21,739
6	70	58,333	20	16,667	30	25
7	70	60,869	25	21,739	20	17,391
8	70	58,333	25	20,833	25	20,833
9	70	56	25	20	30	24

After the manufacture of fuel water emulsion samples of the planning that has been made and the samples were selected based on:

1. Using the surfactant / emulsifier composition fewer than the other samples,
2. Physical changes are not much different from pure diesel with the design.

A sample that has been selected from the first design and the second design of the Taguchi experimental design method is shown in Table 6 bellow.

Table6. The results of the sample selection

Design I							Sample
Experiment	Composition						
	Oil		Surfactant		Water		
	(ml)	(%)	(ml)	(%)	(ml)	(%)	
2	70	63.636	15	13.636	25	22.727	I
3	70	60.869	15	13.043	30	26.086	II
5	70	60.869	20	17.391	25	21.739	III
6	70	58.333	20	16.667	30	25	IV
Design II							Sample
Experiment	Composition						
	Oil		Surfactant		Water		
	(ml)	(%)	(ml)	(%)	(ml)	(%)	
4	60	63.157	15	15.789	20	21.052	V

Design II						
Experiment	Composition					
	Oil		Surfactant		Water	
	(ml)	(%)	(ml)	(%)	(ml)	(%)
1	60	66,667	10	11,111	20	22,22
2	60	63,157	10	10,526	25	26,315
3	60	60	10	10	30	30
4	60	63,157	15	15,789	20	21,052
5	60	60	15	15	25	25
6	60	57,142	15	14,285	30	28,571
7	60	60	20	20	20	20
8	60	57,142	20	19,047	25	23,809
9	60	54,545	20	18,181	30	27,272

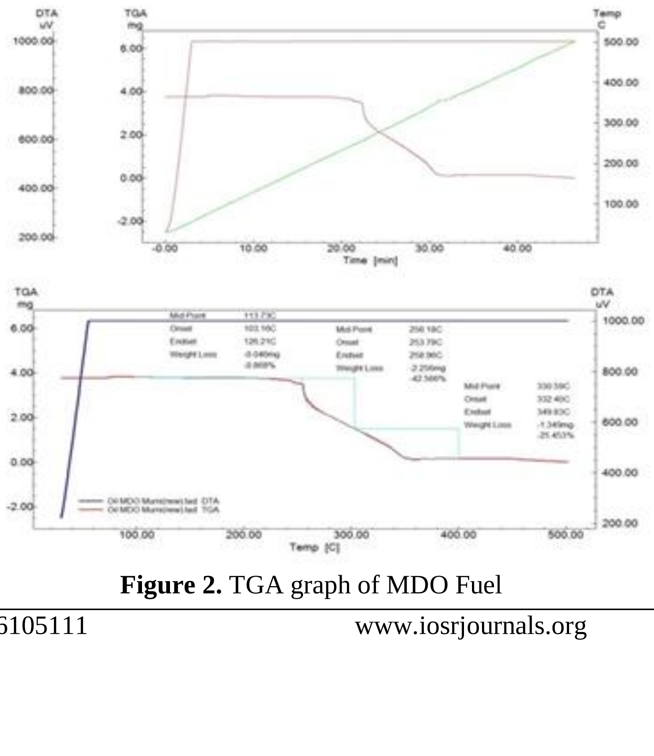

Figure 2. TGA graph of MDO Fuel

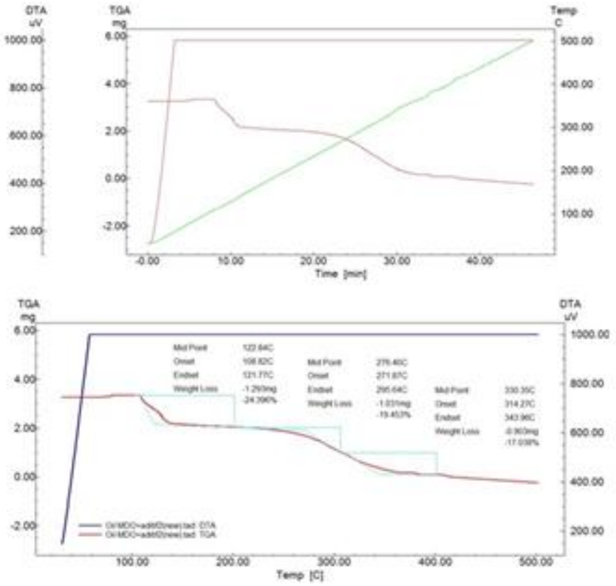

Figure 3. TGA graph MDO + Fuel Sample Composition II

The comparison of the two samples can be seen that pure diesel fuel MDO has resistance to a higher temperature than diesel fuel MDO design water emulsion composition II, it is seen from the point of beginning (onset) of these compounds lose weight, but pure diesel fuel MDO faster loss of compound or severe, it is evident on the test results up to 30 minutes until the weight disappear when no longer remaining the pure diesel fuel MDO begin to decompose at temperatures of 240 ° C while the MDO design fuel composition II began to decompose at a temperature of 110 ° C. Here are is the result of the analysis of all samples are done testing.

Table7. Thermal Test Results Gravimetric Analysis (TGA)

	Pure Oil MDO	Sample I	Sample II	Sample III	Sample IV	Sample V
Zone I						
• Mid Point	113,73°C	131,40°C	122,84°C	108,65°C	118,24°C	124,99°C
• Onset	103,16°C	130,26°C	108,82°C	103,26°C	120,00°C	108,85°C
• Endset	126,21°C	139,73°C	121,77°C	109,13°C	139,94°C	137,15°C
• %Weight	0,868%	30,453%	24,396%	53,415%	44,509%	62,240%
Zone II						
• Mid Point	256,18°C	280,59°C	276,40°C	273,79°C	268,60°C	274,36°C
• Onset	253,78°C	273,07°C	271,87°C	287,49°C	296,12°C	296,80°C
• Endset	258,96°C	302,27°C	295,64°C	290,65°C	293,66°C	299,54°C
• %Weight	42,566%	24,585%	19,453%	15,113%	12,000%	17,060%
Zone III						
• Mid Point	330,59°C	326,60°C	330,35°C	333,86°C	319,53°C	307,45°C
• Onset	332,40°C	415,75°C	314,27°C	369,71°C	311,92°C	358,60°C
• Endset	349,83°C	380,06°C	343,96°C	362,31°C	320,93°C	348,70°C
• %Weight	25,453%	28,321%	17,038%	18,566%	23,340%	18,840%

Description:

- Zone 1 = temperature 100-200°C
- Zone 2 = temperature 200-300°C
- Zone 3 = temperature 300-400°C

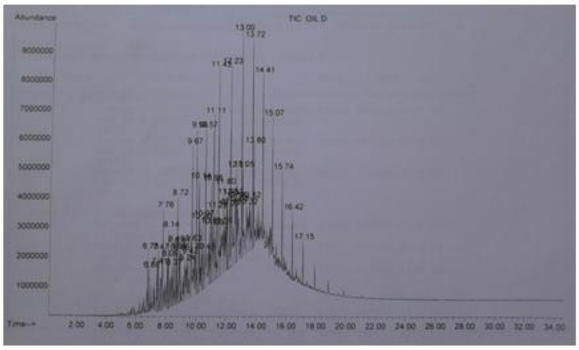

Figure 4.*Gas Chromatography-Mass Spectrometry* (GCMS) Graph

The figure 4 and 5 shows the percentage of weight lost on the compound that causes the temperature combustion.At temperatures up to 100 ° C all samples showed no weight loss (weight loss), this is because the fuel has a temperature resistance exceeds this temperature.In a sample of pure diesel fuel MDO weight loss (weight loss) occurred significantly compound at a temperature of 300 ° C, whereas all samples of water diesel emulsion decreased weight of the compound at a temperature of 200 ° C, this happens because of the addition of surfactant and water having a boiling point temperature which is different from the solar MDO. In sample III - V samples the weight loss is very high, this is because the amount of surfactant composition contained in the water emulsion diesel samples, in contrast to sample I and sample II which only has a composition of 13% surfactant.At temperatures of 500 ° C the weight loss (weight loss) does not happen again because of all the fuel samples had reached the point of maximum weight loss / decomposition. Thermal Gravimetric Analysis of testing (TGA) has done the second sample showed the best results of all the samples tested, it can be seen from the graph that shows the weight loss (weight loss) is continuously compared to other samples.

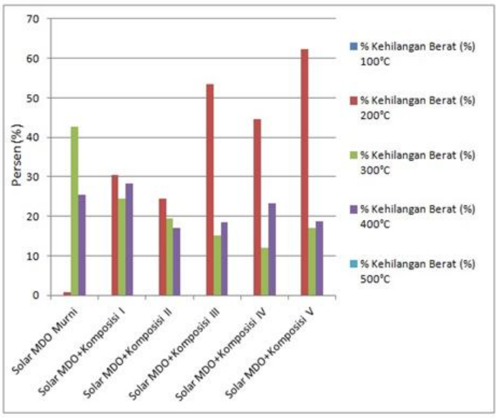

Figure 5. Weight Loss Graph

Table 8. Result of Gas Chromtography - Mass Spectrometry (GCMS)

No.	Time (min)	Compound	Molecul Formula	% Oil Area										
				Pure	Sample 1		Sampel II		Sample III		Sample IV		Sample V	
					I	Dif	II	Dif	III	Dif	IV	Dif	V	Dif
1	9.67	Tridecane	$C_{13}H_{28}$	2,85	4,69	1,84	2,60	0,25	1,79	1,06	4,71	1,86	3,21	0,36
2	9.96	Napthalene	$C_{10}H_8$	2,85	3,10	0,25	2,64	0,21	1,79	1,06	3,10	0,25	3,36	0,51
3	10.57	Tetradecane	$C_{14}H_{30}$	3,34	3,56	0,22	2,99	0,35	2,27	1,07	3,65	0,31	3,93	0,59
4	11.11	Napthalene	$C_{10}H_8$	5,73	6,10	0,37	5,19	0,54	3,86	1,87	2,91	2,82	6,74	1,01
5	11.43	Pentadecan	$C_{16}H_{32}$	4,64	4,91	0,27	4,16	0,48	3,10	1,54	5,08	0,44	5,44	0,8
6	12.23	Hexadecane	$C_{16}H_{34}$	4,14	4,30	0,16	3,63	0,51	2,97	1,17	4,33	0,19	12,2	8,06
7	13.00	Heptadecan	$C_{17}H_{36}$	4,44	4,53	0,09	3,78	0,66	3,47	0,97	4,33	0,11	4,92	0,48
8	13.72	Octadecane	$C_{18}H_{38}$	4,07	4,08	0,01	3,37	0,7	3,44	0,63	3,60	0,47	4,34	0,27
9	14.41	Nonadecan	$C_{19}H_{40}$	2,58	2,56	0,02	2,10	0,48	2,45	0,13	2,72	0,14	2,63	0,05
10	15.07	Eicosane	$C_{20}H_{42}$	1,97	2,31	0,34	1,42	0,55	2,36	0,39	1,81	0,16	1,86	0,11
Total						3,57		4,73		9,89		6,75		12,24

The table 8 shows tested by Gas Chromatography-Mass Spectrometry (GCMS), The results of the comparison area the percentage difference between pure diesel fuel MDO with all water emulsion samples can be determined by identifying compounds that arise and areas that arise.From the analysis of samples of water emulsified diesel fuel number I have a difference that is not much different from or closer to the comparison sample of pure diesel fuel MDO, therefore water emulsion sample numbers I have a test result Gas Chromatography-Mass Spectrometry (GCMS) best.

V. Conclusion

The experiment on emulsion fuel was done. Taguchi method was success to generated through orthogonal matrix, that we can produce a good water emulsion fuel composition for the experiment. Thermal Gravimetric Analysis (TGA) where analyse of thermal characteristic of emulsion fuel shown the sample II was the best results among the other samples.Gas Chromatography-Mass Spectrometry (GC-MS) where analyse the characteristic of fuel component shows the best result onsamples of emulsion number I.

References

[1] Directorate of Mineral and Gas , Republic of Indonesia

[2] Gideon H. , Cahyono H, Dedy. (1999).*"Quality Control of Process and Production of Spun-Pile with Taguchi Method"*,Dimensi Teknik Sipil vol. 1, No. 2, pp : 59-64

[3] Didik. W, Gan. SS, Yohan. P (2001). *"Optimization Process of Injection by Taguchi Method".* Jurusan Teknik Industri, Universitas Kristen Petra, Indonesia

[4] Ishak. A (2002). *"Quality Engineering".* Jurusan Teknik Industri, Fakultas Teknik, Universitas Sumatra Utara

[5] Agung Sudrajad, N.Osami, H.Fujita, W.Harano, (2002). "*Exhaust Emissions of Diesel N_2O by Various Fuel Oil Condition*", *Proceeding of Techno Ocean*, Kobe

[6] Park J.W, Huh K.Y, Park K.H, (2000). "*Experimental study on combustion of emulsified diesel in a RCEM*", *World Automotive Congress 2000*, F 2000A073, Korea

[7] Irwan Soejanto (2009). *"Design Experiment by Taguchi Method"*.Penerbit Graha Ilmu, Jakarta

[8] Samec N, Dibble RW, Chen JY, Pagon A. (2000). "*Reduction of NOx andsoot emission by water injection during combustion in a diesel engine*".*ProceedingofFISITA2000*, Seoul, Korea

[9] Samec N, Dibble RW. (2000). "*The strategies for reducing emission from Heavydutydieselvehicles*".*Proceeding ofUrbanTransport 2000*, Cambridge,UK