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Determining design parameter for fuel magnetizer using factorial design method

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Abstract. Fuel magnetizer is a magnetic device that can improve the combustion efficiency on vehicles or other combustion systems. Many studies have been studied about the effect of fuel magnetizer on fuel viscosity or combustion efficiency, fuel savings, and emissions reductions. This study aims to identify the main factors that can influence on the performance of fuel magnetizer and optimal fuel magnetizer parameters in gasoline generator set and LPG gas stove using Factorial Design method. This study used three factors with each factor consist of two levels. The result shows that the optimal parameters of fuel magnetizer in generator set are fuel magnetizer with Ferrite C8 magnet type, polarity repel each other with the liquid flows parallel to the lines of force in the magnetic field (mono-polar) with one magnet pair installed on the fuel pipe. It can increase 10.05% duration of fuel consumption. While optimal parameters of fuel magnetizer in LPG gas stove are used fuel Ferrite C8 magnet type, mono-polar polarity, and use two of magnet pairs installed on fuel pipe. It decrease 7.69% of water heating time.

1. Introduction

Fossil energy such as petroleum and natural gas is widely processed as fuel which is one source of energy for human life. Fuel oil and gas are used for household needs, transportation, and the industry. The amount of energy consumption increase time by time. Increasing of energy consumption can cause in depleted energy reserves. Facing the challenges of limitation of energy sources, saving energy is one effort that can be done. Efforts to save fuel oil not only can save energy supplies, but also can improve fuel economy, because fuel prices increase time by time, according to increasing of the demand of the fuel. The effects of fuel consumptions are not only about depletion of supplies and fuel prices, but also emissions resulting from the combustion process using these fuels can create health and environmental problems.

Based on several studies, a strong magnetic field can make better combustion, increase combustion efficiency, fuel savings and reduce emission. In an experiment conducted by Jalali et al. shows that magnetic fields can increase the kinetic energy of hydrocarbon molecules in fuel oil resulting in increased thermal efficiency in the combustion systems [1]. In para-hydrogen molecule, which occupies the anti-parallel rotation, the spin state of one atom relative to another is in the opposite direction, therefore it is diamagnetic. In the ortho molecule, which occupies the parallel rotational levels, the spin state of one atom relative to another is in the same direction, therefore, it is paramagnetic. When it happened, hydrogen attracts and bonds with more of the oxygen for complete combustion [2]. Figure 1 is an illustration of changes in the shape of a fuel molecule before and after the magnetic field is applied.

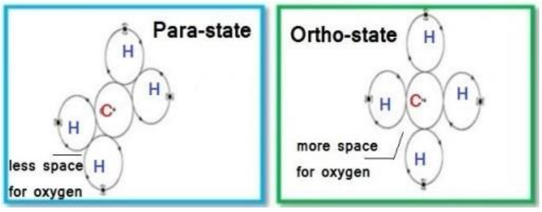

Figure 1. State of Para-hydrogen and Ortho-hydrogen [3]

Factors that can affect magnetic performance to produce fuel efficiency and reduce emissions are installation position, magnetic polarity, diameter, length, magnetic flux, magnet type, and magnetic force [4]. Some experiments have been conducted using various parameters of the fuel magnetizer used to save fuel with the different benefit that have been obtained. Design of Experiment (DOE) or experimental design is a systematic route that can be followed to find solutions to industrial process problems with greater objectivity using experimental and statistical techniques [5]. It can identify the parameter setting of the product or the process that finally gets the standardization of the optimal product or process parameters.

A company that manufactures fuel magnetizer, claims that by applying a magnet with a polarity configuration repelling each other will produce a larger magnet flux so that it can maximally fuel molecules. Another experiment said that the most important factors in the magnetizer technology are the magnetic field intensity and the magnetic lines flux [2]. The magnet direction must be parallel to the direction of the fuel flow which states that in order for maximum efficiency. It indicates that the magnetic pole configuration may affect the performance of the fuel magnetizer [6].

Table 1. Combustion Efficiency by Type and Magnet Intensity

Author	Engine Type	Magnet Parameter		Combustion Efficiency					
		Type of Magnet	Magnetic Strength (Gauss)	Reduction of Emission (%)				Break Thermal Efficiency (%)	Fuel Saving (%)
				CO	HC	NO_X	CO_2		
Patel, Rathod, Patel [7]	Single cylinder, four stroke, water cooled, C.I. Engine (Diesel)	Ferrite	2000	0.01	30	27	9.72	2	8
Tipole et al. [8]	Three cylinder four stroke S.I. Engine (Gasoline)	Neodymium (3;4;5 pairs)	3000	17.5	18.1	-	1.1	-	-
Kumar, Patro & Pudi [9]	Single cylinder, four stroke, water cooled, C.I. Engine (Diesel)	Neodymium	13000	-	-	-	-	2	-

Table 1. Combustion Efficiency by Type and Magnet Intensity (cont')

Author	Engine Type	Magnet Parameter		Combustion Efficiency					
		Type of Magnet	Magnetic Strength (Gauss)	Reduction of Emission (%)				Break Thermal Efficiency (%)	Fuel Saving (%)
				CO	HC	NOx	CO_2		
Al Rawaf [10]	Four cylinder, four stroke, S.I. Engine (Gasoline)	Neodymium (1;2 pairs)	1000	3.7	4.1	-	3.43	4.7	2.19
				6.9	9.1	-	9.94	13.5	5.49
Faris et al. [11]	Two stroke, S.I. Engine (Gasoline)	Neodymium	2000 to 9000	30	40	-	10	14	9-14
Ugare et al. [12]	Single cylinder, four stroke, S.I. Engine (Diesel)	Neodymium	5000	11	27	-	-	14	12
Attar et al. [13]	Single cylinder, four stroke, S.I. Engine (Diesel)	Neodymium	2000 4000 6000	-	-	-	-	-	19.07 26.8 15.46

2. Method

2.1. Experiment setup

In DOE there are several methods, namely factorial design, Taguchi method, response surface method, and mixture design. To produce more objective experiments are usually used factorial design methods. The working principle of factorial design is to investigate every possible combination of all factors and levels in the experiment. The effect of a factor is defined as the response resulting from the change of that level and factor. The data collection stage in this study was conducted by experiment with 64 of total treatments that use 3 factors, each at two levels and 8 replications are used for each treatment. Factors and levels in this study obtained based on interviews conducted with the expert, which can be seen in Table 2.

Table 2. Factors and Levels

Factors	Levels	
	1	2
Type of Magnet	Ferrite C8	Neodymium N45
Polarity	Bipolar	Monopolar
Number of Magnet Pair	1 pair	2 pairs

The type of magnet used is Ferrite C8 with a magnetic intensity of 3850 Gauss and Neodymium N45 which has a magnetic intensity of 13200 Gauss. Ferrite magnet has black color, while Neodymium is usually coated with a silver coating as shown in Figure3. The polarity consists of two types. Monopolar means repelling each other and the flow of magnetic field parallel with fuel flow. While bipolar polarity means attract each other of magnet configuration. The experiments were carried out using two objects, these are the Excell SF2900DX generator set with gasoline engine with a maximum capacity of 2500 watt type forced water cooled 4 stroke and LPG gas stove 3 kg.

The response variable in this experiment is the duration of fuel consumption for 250 ml of gasoline. While in the experiment on the gas stove the response variable is water heating time to 1000 ml of water from the temperature of 40°C-100°C. Figure 1 and 2 are a setup of both experiments performed. Experiment setting was done such as the experiments with the generator set given a load of 1100 watts and carried out blocking of the type of gasoline. While in experiments with gas stoves, room temperature is kept stable at 25°C. The run order experiment was done randomly.

(a)

(b)

Figure 2. Permanent Magnet (a) Ferrite Magnet (b) Neodymium Magnet

(a)

(b)

Figure 3. Object of Experiment (a) Gas Stove (b) Generator Set

2.2. Data processing

2.2.1. Analysis of Variance

Data processing was done with the help of statistical software like Minitab and SPSS. The Analysis of Variance (ANOVA) test can be conducted, as shown in table 3. If the significance value is below 0.05., there is a statistically significant difference in the mean factors to response variable.

Table 3. ANOVA Test

Term	p-value	
	Generator Set Experiment	Gas Stove Experiment
Type of Magnet	0.775	0.039
Polarity	0.000	0.000
Number of Magnet Pair	0.883	0.494
Type of Magnet*Polarity	0.237	0.784
Type of Magnet*Number of Magnet Pair	0.775	0.296
Polarity*Number of Magnet Pair	0.037	0.220

2.2.2. Main Effect

In the main effect, if the line for a particular parameter is near horizontal, then the parameter has no significant effect. Figure 3 shows the main effect plots for the product parameters of two experiments. In the generator set experiment, the factor or parameter that has significant effect is polarity at monopolar level for maximum fuel consumption. While, in the gas stove experiment, the factor that has significant effect to the water heating time are polarity at monopolar level and type of magnet at Ferrite C8 level for minimum of water heating time.

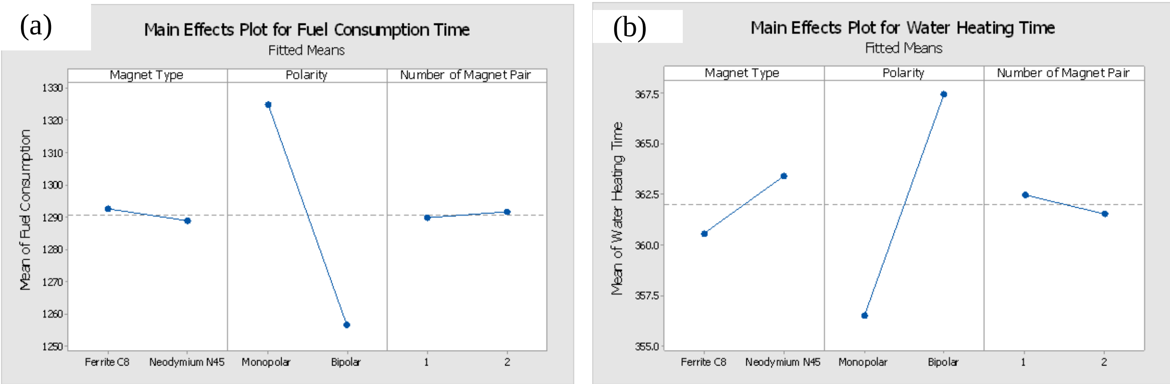

Figure 4. Main effect plot (a) fuel consumption time on generator set experiment using permanent magnet (b) water heating time on gas stove experiment using permanent magnet

2.2.3. Interaction Effect

If the interaction effects are significant, it cannot be interpreted the main effects without considering the interaction effects. The interaction plot to evaluate the interactions affect the relationship between the factors and the response, as shown in figure 4. The more lines are not parallel, the greater the strength of the interaction**.** In this interaction plots, only the polarity and number of magnet pair of the generator set experiment that has non parallel line. It indicates that the relationship between polarity and fuel consumption time depends on the value of number of magnet pair. The optimal result is produced by polarity at monopolar level and number of magnet pair is one. While in the gas stove experiment, the interaction between factors has not significant influence to the response.

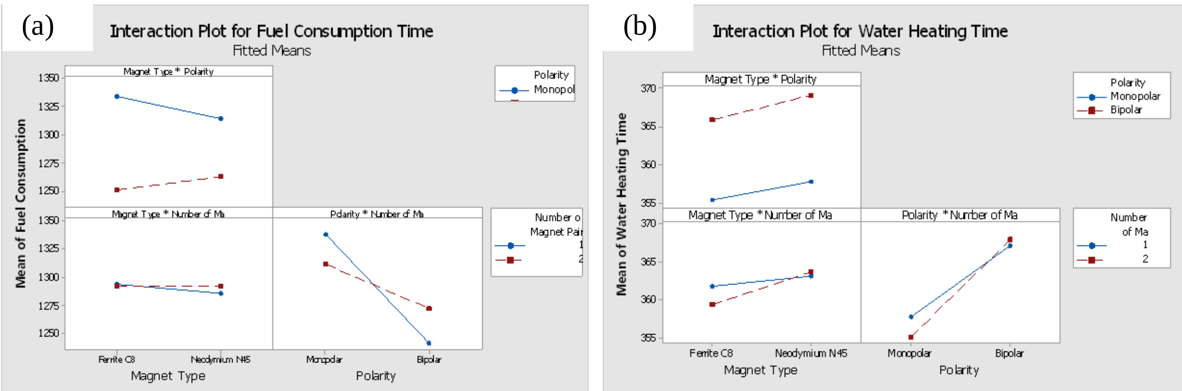

Figure 5. Interaction plot (a) fuel consumption time on generator set experiment using permanent magnet (b) water heating time on gas stove experiment using permanent magnet

In this interaction plots, only the polarity and number of magnet pair of the generator set experiment that has non parallel line. It indicates that the relationship between polarity and fuel consumption time depends on the value of number of magnet pair. The optimal result is produced by polarity at monopolar level and number of magnet pair is one. While in the gas stove experiment, the interaction between factors has not significant influence to the response.

2.2.4. Multiple Comparison Test
This study also conducted to compare treatments groups to a control group with *Dunnett* multiple comparison test. Local control group is result of fuel consumption time measurement without apply magnetizer, while the treatment groups is combination level factor of the experiment, as shown in Table 4. The result of *Dunnett* test is shown in Table 5.

Tabel 4. Multiple Groups of Treatment

Group of Treatment	Magnet Type	Polarity	Number of Magnet
1	Ferrite	Bipolar	1
2	Neodymium	Bipolar	1
3	Ferrite	Monopolar	1
4	Neodymium	Monopolar	1
5	Ferrite	Bipolar	2
6	Neodymium	Bipolar	2
7	Ferrite	Monopolar	2
8	Neodymium	Monopolar	2
9	Without Magnet		

Table 5. *Dunnett Test* for Generator Set Experiment

(I) Treatment Group	(J) Treatment Group	Generator Set		Gas Stove	
		Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.
1	9	-13.25	.965	-16.250*	.000
2	9	25.00	.546	-10.500*	.001
3	9	129.13*	.000	-21.250*	.000
4	9	75.50*	.025	-24.125*	.000
5	9	43.38	.251	-13.000*	.000
6	9	29.37	.471	-12.250*	.000
7	9	68.75*	.045	-29.250*	.000
8	9	82.75*	.013	-21.375*	.000

In Table 5, it is found that treatment groups that had significantly different results with group control were treatment group number 3, 4, 7, and 8, with a significance value of less than 0.05. However, the greatest mean difference was treatment group number 3. It means that by using fuel magnetizer, fuel consumption time longer 129.13 seconds or increase 10.05% of fuel consumption time than the normal condition. Meanwhile, on the gas stove experiment, it is found that all treatment groups had significantly mean difference to the control group, with a significance value of less than 0.05. However, the largest mean difference is treatment group number 7 with a time difference of 29.250 seconds. This means that by using a magnet, the time for water heating faster 29.250 seconds or

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decrease 7.69% of water heating time for 380.50 seconds of water heating time of normal condition (without magnet).

3. Result and Discussion

Based on the results of the whole processing of these two experiments, the similarities and differences in results are obtained. The similarity between these two experiments is the polarity factor being a significant factor to the performance of the fuel magnetizer, with the optimal level being monopolar or rejecting in the direction of the magnetic force in the direction of the fuel flow. Factors that are also predicted to affect the performance of fuel magnetizer is a type of magnet with a much different magnetic intensity.

Some study said that the greater intensity of the magnetic field will produce the greater the combustion efficiency, although not all literature says the same thing. However, in this experiment obtained results indicate that by using Ferrite C8 magnet with a smaller magnetic intensity. However, to determine the fuel magnetizer performance characteristics based on the intensity of the magnetic field, more levels are needed to obtain more accurate and precise. The different result also occurred on response to the number of magnet pair. If the gas stove required two pairs of magnets to produce optimal performance, the generator set required only one pair of fuel magnetizer. Differences are also found in the percentage of time efficiency produced. Larger results obtained on the use of fuel magnetizer in the generator set, which amounted to 10.05%, while the gas stove 7.69%.

Differences in the results obtained can be influenced by several things, such as the molecule structure of fuel difference, the viscosity of the fuel, and the absorption of energy obtained from the magnetic field. Abdul-Wahab et al. compared between types of engines (decreasing fuel consumption 56% in gasoline engine and 44% in diesel engine) and change in some properties of the fuel (density, internal energy, etc.) by the magnetic field in gasoline fuel compared with diesel fuel, it let to achieve reduction of emissions in gasoline engines with higher ranges from diesel engine [14].

Basically the LPG hydrocarbon molecule is lighter and has a lower viscosity, so the effect of magnets in solving hydrocarbon molecules into smaller particles is not as much as the effects of magnets on gasoline hydrocarbon molecules that have more complex molecular hydrocarbon structures and have higher viscosity. The magnetic field will affect the hydrocarbon molecule, but the absorption rate is different depending on the fuel material used, because the energy absorption of each material or type of fuel to the magnetic field will be different [1]. Therefore, a further research to investigate the chemical and physical characteristics of magnetic field effects on different fuel materials is required. Another factor can be due to the gas molecule passing through the magnetic field at high speed. With high speed, gas hydrocarbon molecules pass faster through magnets, resulting in less magnetic effects. The faster the flow of molecules, the weaker the magnetic effects [15].

4. Conclusion

1. Optimal fuel magnetizer parameter of these two different object are:
    a) With the efficiency 10.05% of fuel consumption time, the optimal fuel magnetizer parameters of the gasoline generator set are the Ferrrite C8 magnet type, monopolar, and numbered one of magnet pair.
    b) The optimal fuel magnetizer parameters on LPG gas stove are use Ferrite C8, monopolar, and numbered two magnet pairs that can increase 7.69% of water heating time.
2. With the same treatment, there is a difference of results obtained between experiments on a gasoline generator set with LPG gas stoves, i.e. in the case of the experimental unit reaction to factors that could be caused by molecular structure, viscosity, fuel flow rate, and parameter of burner machine itself, so it need to make differrent parameter of the fuel magnetizer parameters for each different application.

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