ANALYSIS ON DIMETHYL ETHER (DME) CHARACTERISTICS AS A LIQUID PETROLEUM GAS (LPG) FUEL SUBSTITUTION FOR HOUSEHOLD STOVE

ANALISIS KARAKTERISTIK DIMETIL ETER (DME) SEBAGAI PENGGANTI BAHAN BAKAR LPG UNTUK KOMPOR RUMAH TANGGA

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ABSTRAK

Meningkatnya populasi penduduk akan menyebabkan meningkat pula kebutuhan energi, oleh sebab itu sangat penting untuk menemukan energi alternatif selain bahan bakar fosil. Saat ini, energi yang ada di Indonesia pada umumnya berasal dari minyak dan gas bumi seperti LPG. Sejak tahun 2008, salah satu masalah utama LPG adalah meningkatnya kebutuhan LPG yang sangat tinggi untuk kebutuhan rumah tangga dan industri kecil sebagai akibat adanya kebijakan pemerintah mengkonversi minyak tanah ke LPG. Untuk memenuhi kebutuhan LPG tersebut, pemerintah harus mengimpor sampai dengan 2 juta ton LPG per tahun. Salah satu cara untuk mengatasi krisis LPG adalah perlu dikembangkannya energi alternatif yang tidak mengubah sistem distribusi, teknis ataupun sisi komersilnya, dan salah satu pilihannya adalah Dimetil Eter (DME) yang berasal dari gasifikasi batubara muda. Pada penelitian ini dilakukan analisis DME dibandingkan dengan LPG (sebagai bahan bakar reference) menggunakan metode uji berdasarkan spesifikasi LPG dari Dirjen Migas. Dari hasil penelitian, dapat disimpulkan bahwa karakteristik fisika dan kimia pencampuran bahan bakar LPG dan DME 20% dan 50% menunjukkan hasil yang bagus, stabil dan homogen. Oleh sebab itu, campuran DME 20% dan 50% pada LPG dapat digunakan sebagai bahan bakar pengganti LPG untuk kompor rumah tangga.

Kata kunci: Energi, bahan bakar fosil, DME, kompor rumah tangga, LPG

ABSTRACTS

Increasing growth of population will lead to increasing energy needs; therefore it is necessary to find alternative energy other than fossil fuel. Currently, energy sources in Indonesia are mainly derived from oil and natural gas such as LPG. Starting from 2008, LPG demand increased significantly for households and small industries as a result of government policy on conversion of kerosene to LPG. To meet this demand, the government imports LPG up to 2 million tons per year. In order to overcome LPG crisis, an alternative energy is required to be developed without changing either the distribution system, technical or commercial used. An option among others is dimethyl ether (DME) derived from low calori's coal gasification. In this research analysis characteristics of DME is compared to LPG (as fuel reference) used. The test methods carried out refers to the specification of LPG issued by Directorate General of Oil and Gas. Based on the results, it shows that the characteristics of the fuel LPG mixed with DME 20% and 50% have some good results particularly on physical and chemical properties, stability and homogeneous of gas. Hence, LPG mixed DME 20% and 50% can be used as a substitute fuel for household stove.

Keyword: *Energy, fossil fuel, DME, household stove, LPG*

I. INTRODUCTION

Energy diversification can be made by optimizing the use of all available energy sources, where in Indonesia the government brought about a cooking-fuels shift from kerosene to LPG in more than 50 million households in approximately four years (Foell, *et al*, 2011). This policy of kerosene to LPG conversion had caused the increasing of LPG demand significantly. Total LPG consumption in 2008 reached 1.85 million tons with 600,000 tons of these are caused by the kerosene conversion program (Pertamina, 2009). At 2009 LPG demand for the domestic sector was estimated to reach 3.67 million tons where 2 million tons of these are LPG for conversion programs (Director General of Oil and Gas, 2009). On the other hand, the supply of LPG in the country remains stuck on the value of around 1.8 million tons per year to the next few years. This situation clearly requires Indonesia to cover the shortage of LPG supply by importing large quantities. In order to overcome this situation, the use of alternative energy sources becomes very attractive solution. Dimethylether (DME) is an alternative energy source with an expectation to overcome LPG shortage because it has similar characteristics with LPG. DME can be produced from various raw materials, such as natural gas, coal, heavy oil, and biomass. It has simple chemical structure (CH3 - O - CH3). At the ambient temperature DME is a gas, non-toxic, and environmentally friendly. Because of its similarity, the infrastructure for LPG can also be used for DME (Semelsberger, *et al,* 2006). A new fuel such as DME is prospectively producible at lower cost than LPG provides the basis for one promising approach for generating revenues to subsidize the provision of clean fuels for the poorest households -- taking advantage of the fact that, although LPG often is not affordable by the poorest household, it is still affordable by more affluent households. When such new fuels are first introduced, they will tend to be supply limited, and their prices would tend to rise to the level of the marginal cost of the primary alternative, which in many parts of world will be the price of imported LPG (Goldemberg, *et al.* 2004).

In general, DME has competitive advantages, it can be used as a fuel for motor vehicles, power plants and for domestic purposes. In terms of its use as fuel, DME calorific value per mass (Kcal/Kg) is lower than propane and butane but higher than methanol, whereas based on the gas volume, calorific value of DME is higher than methane. In the event of a leak, DME is relatively safer than propane because it has smaller explosive limit (Priyanto, 2011).

As a cooking fuel, the properties of DME are very similar to LPG. DME is a gas that can easily be liquefied at low pressures and hence can be stored and carried onboard as a liquid. DME is easy to handle as it is nontoxic, noncarcinogenic, biodegradable, and harmless to the atmosphere. DME has similar physical properties as LPG and all the safety issues related to LPG apply to DME also. However, while carrying onboard as liquid DME is likely to have greater explosion hazard if it is spilled due to the wide detonability limits and also due to its low vapor density as the dispersion of DME is faster than gasoline (Himabindu and Ravikrishna, 2010).

Some countries in Asia such as Japan, China and Korea have applied DME as fuels in various sectors. In Korea, DME has been used as a fuel for power generation, transportation, household and industrial fuel (Gye Gyu Lim 2008). In Japan, DME has been applied as a fuel for industry and transportation sector (Ogawa, et al, 2003). In China, the government has pursued a number of national energy policies as integral components of its 5-year development plans including the unprecedented dissemination of several generations of fuel saving stoves in the majority of its rural populations (Edwards, *et al*, 2004). Currently, DME is widely available more than LPG because it can be manufactured from coal that is abundant in this country (Larson, 2004). The Chinese experienced the use of DME as LPG substitution at DME concentration more than 20% (Marchionna, 2008). The comparison of composition and combustion characteristics as well as chemical and physical properties of gaseous fuel for cooking is shown in Table 1.

The similarity characteristic of DME with LPG is a great opportunity to use both fuels in the form of a mixture. The composition of the mixture will determine the physical and chemical properties, the combustion performance, as well as the fuel economic point of view. The objective of this study is to determine the physical and chemical characteristics of DME compared to LPG. The goal is to obtain data on the chemical and physical characteristic of DME,

Table 1
Typical composition and combustion characteristics of gaseous fuels for cooking

Typical composition (% volume)	LPG	DME	Natural gas	Biogas	Biosyngas	Producer gas
H_2					51.8	14.7
CO					45.1	16.6
CO_2			0.1	45	2.7	18.4
N_2			1.4			50.6
CH_4 (methane)			91.8	55	0.4	0.3
C_2H_6 (ethane)	0.5		5.6			
C_3H_8 (propane)	34.3		0.9			
C_3H_6 (propylene)	24.4					
C_4H_{10} (butane)	28.2		0.1			
C_4H_8 (butene)	12.6					
C_2H_6O (dimethyl ether)		99.5				
Wobbe index (kJ/m^3)	69560	46198	48530	21960	17477	4990
Low calorific value (kJ/m^3)	87990	58437	37590	21850	12603	5160
Specific gravity to air	1.6	1.6	0.6	0.99	0.52	1.07

Sources: inflammability data from [Lewis and von Elbe, 1961] and physical properties from [Perry and Chilton, 1973].

stability and homogeneity of LPG-DME mixture (20% DME and 50% DME) for determination of the optimum blend of DME in LPG for commercial usage.

II. MATERIALS AND METHOD

This study was conducted in Combustion Laboratory of Lemigas. Preparation of DME and LPG samples were obtained from 50 kg commercial gases respectively, followed by testing of physical and chemical properties for these two samples. The characteristics tested include specific gravity, vapor pressure, volatility (weathering test), copper corrosion, total sulfur, composition, and water content. Characteristics of chemical and physical properties of DME and LPG were carried out based on ASTM (American Society for Testing and Materials). Blending was conducted by mixing 20% and 50% DME with LPG; each of samples was observed for 10 weeks. This 10 weeks value was set based on determination of normal commercial storage period. Every week, samples were taken from upper, middle and bottom parts (Figure 1). Samples

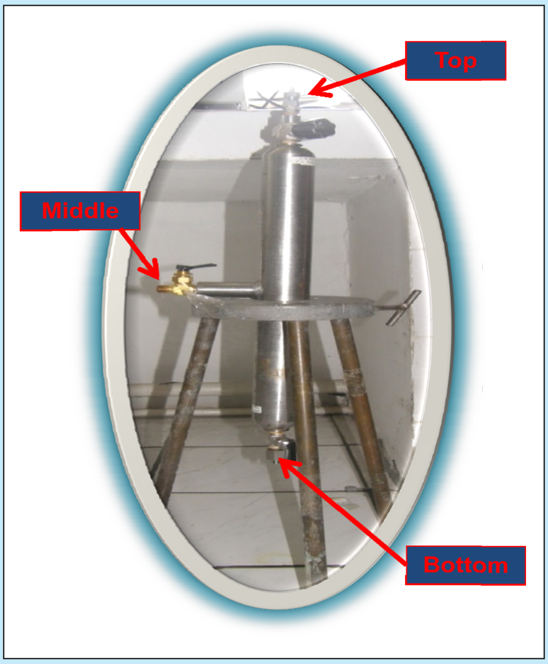

Figure 1
Position of sampling gas

were collected and analyzed for their stability, homogeneity and composition by GC method (ASTM 2011). In addition, visual observation on separation of gas properties was carried out via a glass chamber (Figure 2).

III. RESULTS AND DISCUSSION

A. Physical and Chemical Characteristics of LPG

Determination of physical and chemical characteristics of LPG includes seven parameters such as specific gravity, vapor pressure, weathering test, copper corrosion, total sulfur, water content, and chemical composition. Based on the test results shown in Table 2, all parameters have met specifications issued by the government.

B. Physical and Chemical Characteristics of DME

Test of physical and chemical characteristics of DME was carried out in accordance with the method used in LPG specifications released by the government. For the chemical composition test, only the purity of DME was measured because there are some differences in the compounds of LPG and DME. The results of analysis of DME characteristics are presented in Table 3. Based on the analysis results, six parameters have met LPG specifications issued by the government. It showed that DME used in this

Figure 2
Visual observation of homogeneity of DME-LPG Mixture

Table 2
Physical and Chemical Characteristics of LPG

No.	Characteristic	Unit	Sample	Limit		Methods	
			LPG	Min.	Max.	ASTM	Other
1	Specific Gravity 60/60°F	-	0.56	To be reported		D-1657	-
2	Vapour Pressure @100°F	Psig	112	-	145	D-1267	-
3	Weathering Test @36°F	% vol.	97,5	95	-	D-1837	-
4	Copper Corrosion 1 hour		1a	ASTM No.1		D-1838	-
5	Total Sulphur	grain/ 100 cuft	2.21	-	15	D-2784	-
6	Water Content		No free water	No free water		-	Visual
7	Composition :					D-2163	-
	C_2	% vol	0.38		0.8		
	C_3 and C_4	% vol	99.19	97.0	-		
	C_{5+} (C_5 and heavier)	% vol	0.45		2.0		

Table 3
Physical and Chemical Characteristics of DME

No.	Characteristic	Unit	Sample	Limit		Methods	
			DME	Min.	Max.	ASTM	Other
1	Specific Gravity 60/60°F	-	0.74	To be reported		D-1657	
2	Vapour Pressure @100°F	Psig	110	-	145	D-1267	
3	Weathering Test @36°F	% vol.	99.95	95	-	D-1837	
4	Copper Corrosion 1 hour		1a	ASTM No.1		D-1838	
5	Total Sulphur	grain/ 100cuft	1.13	-	15	D-2784	
6	Water Content		No free water	No free water		-	Visual
7	Composition : DME	% vol	99.96	-	-	D-2163	

Table 4
Physical and Chemical Characteristics of LPG Mix DME 20%

No.	Characteristic	Unit	Sample		Limit		Methods	
			Day 0	After 10 weeks	Min.	Max.	ASTM	Other
1	Specific Gravity 60/60°F	-	0.57	0.57	To be reported		D-1657	-
2	Vapour Pressure @100°F	Psig	100	100	-	145	D-1267	-
3	Weathering Test @36°F	% vol.	98	98.5	95	-	D-1837	-
4	Copper Corrosion 1 hour		1A	1A	ASTM No.1		D-1838	-
5	Total Sulphur	grain/ 100cuft	1.61	1.56	-	15	D-2784	-
6	Water Content		No free water	No free water	No free water		-	Visual

study could be mixed with the LPG. In addition, the chemical composition of 99.96% DME shows this DME has very high purity.

C. Analysis of LPG Mix DME 20%

Similar to the test of physical and chemical characteristics of DME, the test of LPG mix DME 20% was carried out in accordance with the method used in LPG specifications issued by the government as well. It only included six parameters consist of specific gravity, vapour pressure, weathering test, copper corrosion, total sulphur, and water content. Composition test was conducted separately to observed LPG mix DME homogeneity and stability.

In this study, physical and chemical characteristic of LPG mix DME 20% was carried out twice, i.e. in the beginning (Day 0) and at the end of the stability test (after 10 weeks) as shown in Table 4. Based on the test results, there are no significant changes in both conditions especially for specific gravity, vapour pressure, copper strip corrosion and water content. However, there are slightly changes for weathering test (from 98% to 98.5%) and total sulphur (from 1.61 to 1.56) after 10 weeks. It could be occurred because of equipment repeatability factor and measurement uncertainty. Nevertheless, these differences have no significant effect because they are still in the range of specification limit. In general, physical and chemical properties of LPG mix DME 20% are stable after being stored for several weeks.

This stability could also be seen from the homogeneity and stability test results as presented in Figure 3. Samples for this analysis were taken from top, middle and bottom part of the glass chamber. Five different tests were carried out within 10 weeks for each part of samples. Figure 3 shows

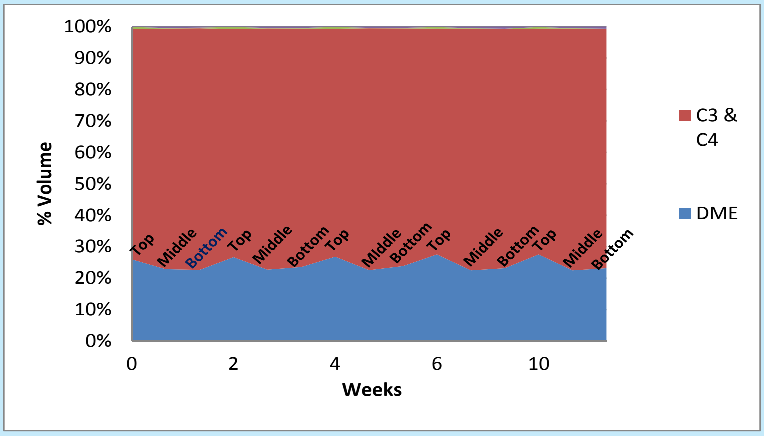

Figure 3
Homogeneity and Stability Test of LPG-DME Mixture (20% DME - 80% LPG)

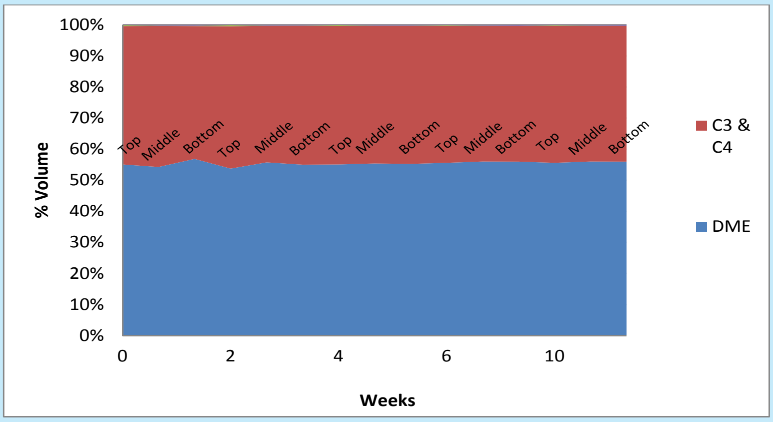

Figure 4
Homogeneity and Stability Test of LPG-DME Mixture (50% DME - 50%LPG)

Table 5
Physical and Chemical Characteristics of LPG Mix DME 50%

No.	Characteristic	Unit	Sample		Limit		Methods	
			Day 0	After 10 Weeks	Min.	Max.	ASTM	Other
1	Specific Gravity 60/60°F	-	0.59	0.59	To be reported		D-1657	-
2	Vapour Pressure @100°F	Psig	110	110	-	145	D-1267	-
3	Weathering Test @36°F	% vol.	99	99	95	-	D-1837	-
4	Copper Corrosion 1 hour		1A	1A	ASTM No.1		D-1838	-
5	Total Sulphur	grain/100 cuft	0.81	0.78	-	15	D-2784	-
6	Water Content		No free water	No free water	No free water		-	Visual

C3 and C4 (major chemical composition of LPG) as one part while the other part is composition of DME. Based on the test results, both LPG and DME composition have not been changed and relatively stable during 10 weeks period of storage. Yet, there is slightly disparity for the top part of sampling point. It could be happened because the top sampling point was in gas phase while the middle and bottom sampling points were in liquid phases.

D. Analysis of LPG Mix DME 50%

Similar to the test of physical and chemical characteristics of LPG mix DME 20%, the test of LPG mix DME 50% was carried out in accordance with the method used in LPG specifications issued by the government as well. It only included six parameters consist of specific gravity, vapour pressure, weathering test, copper corrosion, total sulphur, and water content. Composition test was conducted separately to observed LPG mix DME homogeneity and stability.

In this study, physical and chemical characteristic of LPG mix DME 50% was carried out twice, i.e. in the beginning (Day 0) and at the end of the stability test (after 10 weeks) as shown in Table 4. Based on the test results, there are no significant changes in both conditions especially for specific gravity, vapour pressure, weathering test, copper strip corrosion and water content. However, there is slightly a change for total sulphur (from 0.81 to 0.78) after 10 weeks. Yet, there is no significant effect because it is still in the range of specification limit. In general, physical and chemical properties of LPG mix DME 50% are stable after several weeks of storage.

This stability could also be seen from the homogeneity and stability test results as presented in Figure 4. Samples for this analysis were taken from top, middle and bottom part of the glass chamber. Five different tests were carried out within 10 weeks for each part of samples. Based on the test results, both LPG and DME composition have not been changed and relatively stable during 10 weeks period of storage.

IV. CONCLUSIONS

Based on the results of analysis, this study demonstrates that physical and chemical characteristics of DME still meet the specifications for LPG mixture released by the Government. However, the chemical composition cannot be evaluated with the specification of LPG mixture because of differences in the compounds of the fuels. The test results of stability and homogeneity for LPG with 20% and 50% DME in the mixture are relatively homogeneous and stable during 10 weeks test period. The author suggests that a standard specification for DME should be issued as soon as possible as an alternative fuel for LPG substitution.

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