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Methane Number Improvement of Gas from LNG Regasification Unit

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Abstract. Methane Number (MN) is one of quality requirement of gas as fuel for gas engine, which indicates fuel capability to avoid knocking in the engine. Higher MN provides better quality of gas for gas engine. Natural gas with higher methane (CH_4) and fewer higher hydrocarbon, tends to have higher MN score. This study aims to obtain heating methods of LNG to produce vapor that has appropriate MN as a fuel gas supply to gas engine. The simulation for LNG regasification prepared is an approach to the design of the existing regasification facility of the power plant in Bali. The temperature ranges for LNG heating simulation were obtained based on saturated temperatures of LNG phase envelopes. In the simulation. to obtain a certain MN value can be conducted by adjusting the temperatures at two different values i.e. above -110 ℃ and below - 80 ℃. To produce LNG vapor that has MN of 80 either through higher temperature of heating (HT heating) or lower temperature of heating (LT heating) requires more energy than direct heating without MN improvement. Heat loading for LT heating is higher than HT heating due to more temperature defference between LT and heating fluid temperatures. The ability of engine to produce power decreased with decreasing fuel gas MN. The power increment increases for lower MN gas if MN improvement is conducted.

1 Introduction

Liquefied natural gas (LNG) is mainly used in power industry as a fuel gas for gas engine to produce electricity. Utilization of natural gas in the power industry requires quality standards in accordance with the design of the generating machine to produce maximum power. Fuel quality insufficiency refers to the need/design of the generating machine can cause derating, i.e. the decrease in power capable of generating machinery. In a closed combustion engine, a gas engine (reciprocating gas engine), one of the gas quality parameters used is methane number (MN). The MN is defined as the percentage of methane in a methane/hydrogen mixture which has the same knocking behavior as the gas mixture to be investigated under well-defined testing conditions [1-3]. Knocking in internal combustion engine results from the spontaneous ignition of a portion of the end gas mixture in the combustion chamber ahead of the propagating flame [4-5]. The range of the minimum MN required depend on the engine manufacturer. The higher the value of MN of the fuel gas, the better the gas to be used as fuel in order to avoid knocking (detonation) [6]. One of the effects of the knocking on the engine is the decline in generating power. Pure methane (CH_4) has a value of MN 100 which shows that as a fuel has the ability to avoid the occurrence of knocking, while Hydrogen (H_2) pure has a value of MN 0 (zero) which means it is very easy to cause knocking in the machine [7].

One of the gas generating machines used by a power plant in Indonesia requires an optimal MN of 80. Some brands of gas engines may require MN values less than 80. In order to obtain gas quality from LNG (liquefied natural gas) with better MN, it is necessary to increase the mole fraction of methane in the gas, which means that the mole fractions of the other components decrease. Increasing the mole fraction of CH_4 can be conducted by reducing the number of components other than CH_4 or converting other hydrocarbon components i.e. C2H6+ to CH_4. This study aims to obtain an alternative method of improving gas composition to attain an appropriate MN as a fuel gas supply to gas engine.

2 Methods

The LNG regasification gas quality data used in this study were taken from data owned by one of power plants which operate Power Plant Gas Diesel Engine (PLTDG) in Bali. The data used were the sampling of gas quality data from LNG regasification in the period of January to August 2017. Analyses of hydrocarbon components in LNG was based on the LNG main component i.e. CH_4, C2H6 (ethane) and C3H8 (propane) as the ratio of these components has an effect on MN value of the fuel gas. The simulation for LNG

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regasification prepared is an approach to the design of the regasification facility of the power plant in Bali. This approach was conducted due to the limited access to the design facility in relation to the facility design copyright. The main method of regasification used was heating using hot water/steam from a gas-fired boiler. The simulation referred to the gas composition to the plant with the lowest heating value ever used by the gas engine and the maximum quantity of gas output required by the engine.

3 Results and Discussion

This study used six data samples of natural gas composition having MN below 80. The natural gas data conditions, related to the composition and results of MN calculations are shown in Table 1. Based on the data on Table 1, there is a relationship between the value of the CH_4 composition to the MN values as shown in Fig. 1, where the higher the CH_4 mole fraction in a natural gas mixture the higher the value of the MN.
The LNG compositions for the simulation were calculated based on the natural gas and boil off gas (BOG) flowrates and compositions. The results were summarized in Table 2.

Table 1. Gas data conditions.

Compo-nent	Composition (mole fraction)					
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Methane	0.8742	0.8841	0.9087	0.9192	0.9317	0.9403
Ethane	0.0683	0.0631	0.0427	0.0377	0.0350	0.0325
Prophane	0.0403	0.0370	0.0334	0.0299	0.0223	0.0189
i-Butane	0.0082	0.0075	0.0066	0.0058	0.0050	0.0039
n-Butane	0.0088	0.0081	0.0082	0.0070	0.0058	0.0041
i-Pentane	0.0001	0.0001	0.0002	0.0002	0.0001	0.0001
n-Pentane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C6+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H/C Ratio	3.67	3.69	3.73	3.76	3.80	3.83
MN	66.64	68.25	71.55	73.82	77.20	79.90

The phase characteristics of LNG compositions are presented in Fig. 2., and Fig. 3., where under the same pressure conditions, the LNG with higher CH4 composition tend to have temperature range of two phases in the envelope more narrow than LNG with lower CH4 composition. These range of temperatures differences are very useful in controlling regasification temperature to remove CH4 from higher hydrocarbons in LNG regasification in order to increase the MN value. The LNG regasifications were simulated based on direct LNG regasification and LNG regasification for MN improvement. Direct LNG regasification is the process of regasification of LNG through one stage of heating to a required temperature and pressure of 25 □ and 8.5 bar, respectively, using heating steam at temperature and pressure of 180 □ and pressure 5 bar, respectively, as shown in Fig. 4. Meanwhile, the LNG regasification for MN improvement is conducted through two stages of heating as shown in Fig. 5.

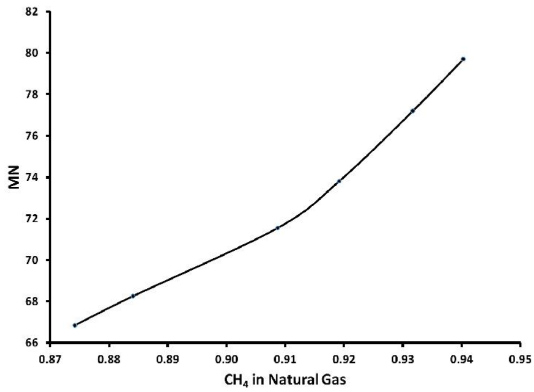

Fig. 1. The effect of CH_4 composition in natural gas on the value of MN.

Table 2. LNG compositions.

Component	Compositions (mole fraction)					
	LNG 1	LNG 2	LNG 3	LNG 4	LNG 5	LNG 6
Methane	0.8722	0.8822	0.9072	0.9179	0.9306	0.9394
Ethane	0.0694	0.0642	0.0434	0.0383	0.0356	0.0331
propane	0.0410	0.0377	0.0339	0.0304	0.0227	0.0192
i-Butane	0.0083	0.0076	0.0068	0.0059	0.0051	0.0039
n-Butane	0.0090	0.0082	0.0083	0.0072	0.0059	0.0042
i-Pentane	0.0001	0.0001	0.0002	0.0002	0.0001	0.0001
n-Pentane	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C6+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
H2O	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Fig. 6 shows the effect of CH_4 composition in LNG on the heat loading for heating of 50 MMSCFD LNG. The heat loading decreased with increasing the CH_4 composition in LNG due to the lower heat flow of LNG with higher CH_4 composition. To obtain a better MN value from LNG composition, CH_4 was separated from its mixture in LNG and then was used as the gas delivered to the primary use so that the gas content has more suitable CH_4 mole fraction. The separation process is conducted by gradually heating of LNG as shown in Fig. 5., where LNG is preheated in HX 1 Sp and HX 2 Sp heat exchanger at temperature causing 2 (two) phase conditions i.e. liquid and vapor. The liquid phase is

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dominated by C_2H_6 and heavier hydrocarbons. After this separation process. CH_4-rich gas can be prioritized for distribution to users/plants after mixed with BOG. Meanwhile. C_2H_6-rich and heavier hydrocarbons can be used as gases for heating/steam heat. If there is a lack of energy for the heater, the shortage can be taken from the gas supplied to the plant. However, if the use of Gas Heaters is not as large as the available amount, then the rest can be distributed to the plant and mixed with CH_4 and BOG rich gas.

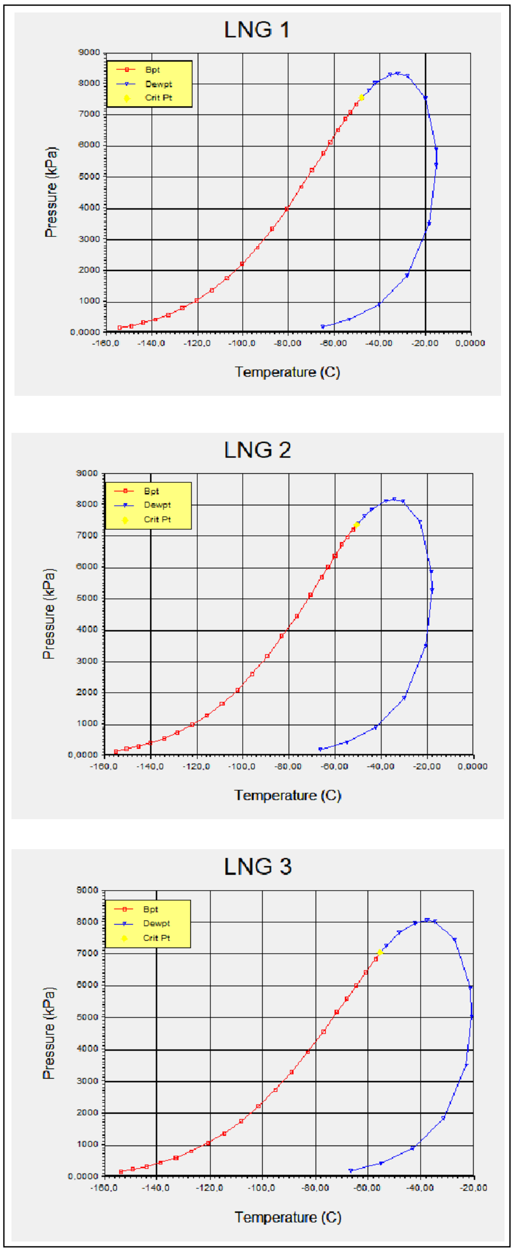

Fig. 2. The LNG phase envelope characteristics LNG 1 – 3.

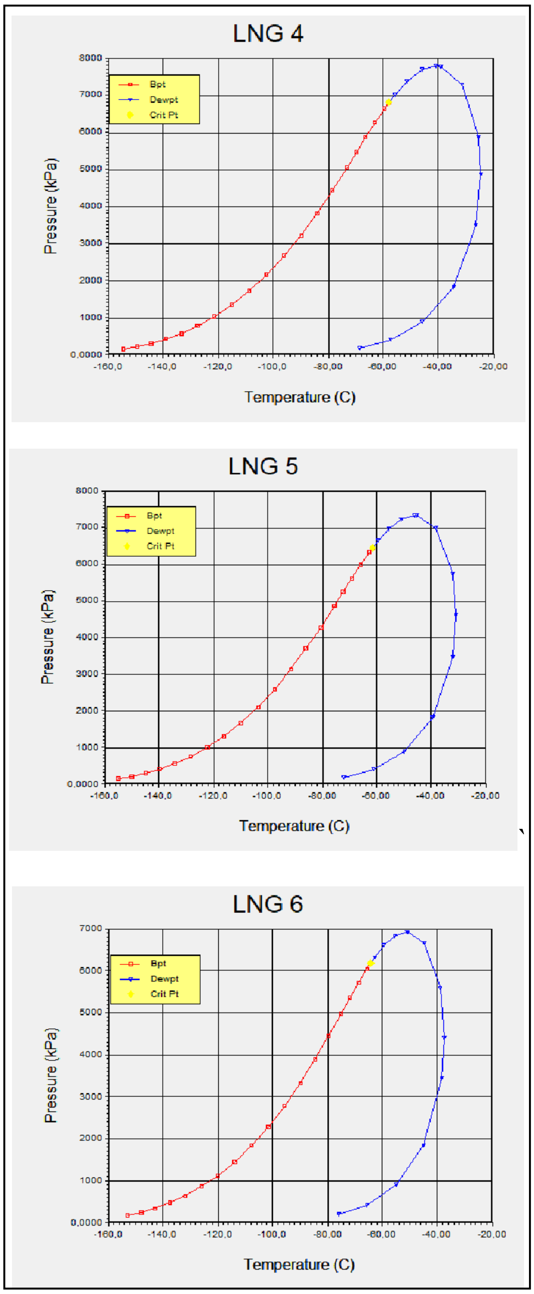

Fig. 3. The LNG phase envelope characteristics LNG 4-6.

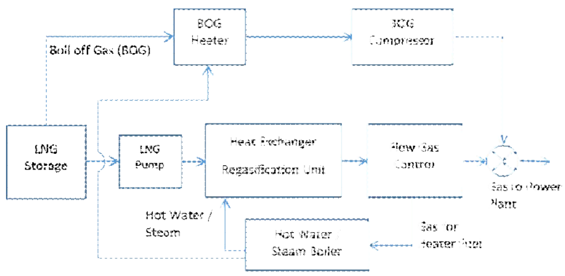

Fig. 4. Block diagram direct LNG regasification

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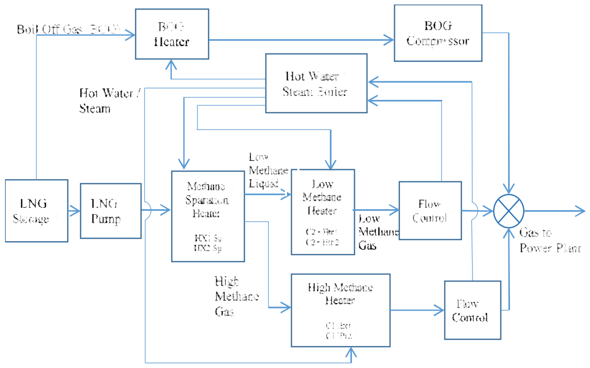

Fig. 5. Block diagram of LNG regasification for MN improvement.

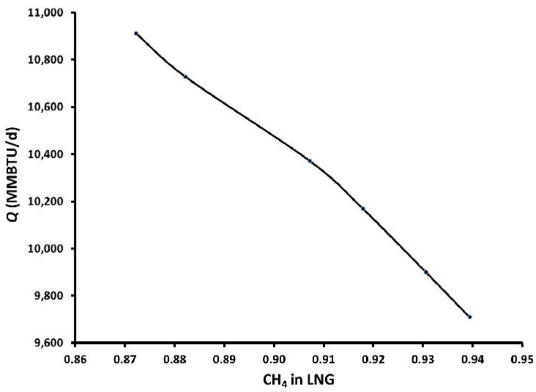

Fig. 6. The effect of CH_4 composition in LNG on the heat loding for heating. *Q*.

In the simulation, the target to be achieved is to find the composition and MN of the gas delivered to the plant according to the required temperature and pressure of 25 °C and 8.5 bar, respectively. Therefore, the working pressure on the heat exchanger and BOG is at 8.5 bar, and each LNG is processed as follows:

1. To adjust the output temperature of LNG in the HX_1 Sp and HX_2 Sp heat exchanger according to:
   a. Minimum Simulation is to set the output temperature at the value less/close to the condition of temperature cross on the heat exchanger C1 Htr_1 Sp and C1 Htr_2 Sp. Both heat exchangers serve to increase the temperature of the CH_4-rich gas in the HX_1 Sp and HX_2 Sp heat exchangers. Temperature Cross is a condition in which the heating fluid and the heated fluid are at the same temperature before the expected temperature of the fluid coming out of the heat exchanger is reached.
   b. Maximum Simulation is to set the temperature less/close to the condition of temperature cross on heat exchanger C2+ Htr1 Sp and C2+ Htr2 Sp. Both heat exchangers are the heater for the material stream dominated by C2H6 and heavier hydrocarbons produced from the previous process.
   c. Simulation MN 80 is a simulation with output temperature from HX1 Sp and HX2 Sp heat
2. To set the temperatures of gas out of High Methane Heater, so as the temperature of Gas to Power Plant is 25°C.

The simulation results of the steps were the temperature range for further simulation to find the MN of each samples as shown in Fig. 7. The different in temperature range of each samples also give different MN number, but have similar type of trend as demonstrated in Fig. 8. In the simulation, it was shown that to obtain a certain MN value can be conducted by adjusting the temperatures at two different values. With respect to each sample studied, there are two control temperatures can be applied to obtain MN of 80 i.e. above -110 °C and below - 80 °C as shown in Fig. 8 for LNG sample 1. However, the temperature range of heating cannot produce vapor which has MN of 100, even though the heating temperature was below the evaporation temperature of C_2H_6.

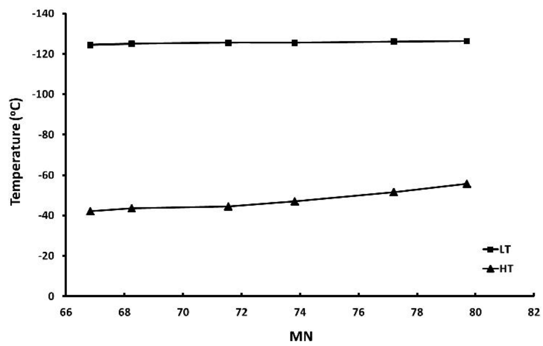

Fig. 7. The range of higher and lower temperatures for obtaining MN simulation.

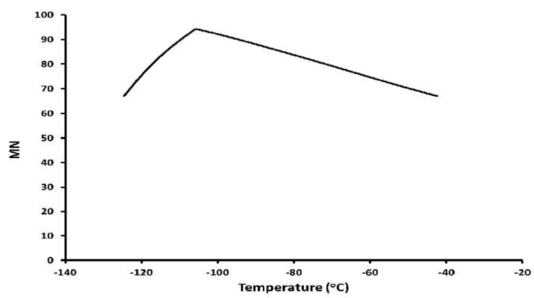

Fig. 8. The MN values as a function of heating temperatures for LNG sample 1.

The heat loading to produce LNG vapor that has MN of 80 in the heat exchangers for lower and higher temperatures of heating are demonstrated in Fig. 9. It is illustrated that to produce LNG vapor that has MN of 80 either through higher temperature of heating (HT heating) or lower temperature of heating (LT heating) requires more heating energy than direct heating without MN improvement. Heat loading for LT heating is higher than HT heating due to more temperature difference

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between LT and heating fluid temperatures as shown in Fig. 9.

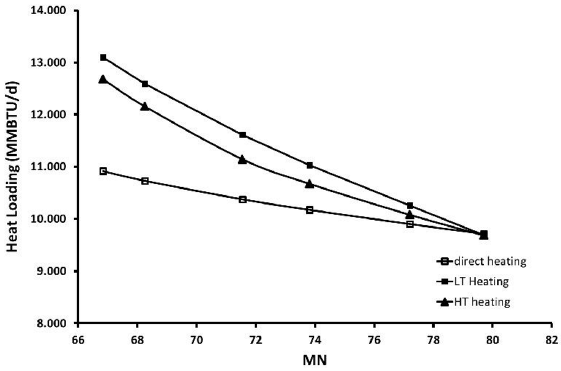

Fig. 9. The heat loading for direct, LT and HT heatings as a function of MN of LNG.

The influence of MN on engine capability was approached by assuming that the gas engine has a maximum capability when using fuel gas with minimum MN at 80. The power produced by the engine decreased with decreasing gas MN as shown in Fig. 10. On the other hand, if the MN improvement is conducted to the gas, the power increment increased with decreasing MN. Furthermore, the decrease in the power produced will increase the fuel gas consumption in the gas engine.

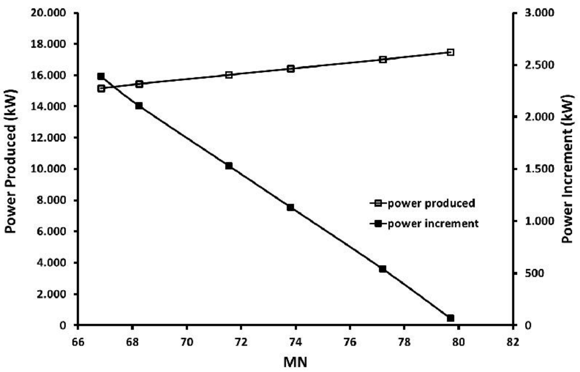

Fig. 10. The power produced by the gas engine and power increment as a function of MN of LNG.

4 Conclusions

The value of MN of fuel gas is very importance in producing power in gas engine. Generally, gas engine requires MN value of minimum 80 has to be fulfilled in MN quality to produce maximum power. Therefore, there is a need to improve MN from the fuel gas if its MN value is far from 80. In LNG regasification, the evaporation can be conducted at lower temperature or higher temperature to produce gas at MN of 80. To produce gas at MN of 80 from the LNG samples in this study can be conducted at the temperature above -110 □ or below -80 □. In the LNG regasification, the heat needed to produce MN vapor of 80 increased with decreasing MN of LNG. There was more heat required for lower temperature evaporation than higher temperature evaporation due the temperature different between heating temperature and heating fluid temperature. The ability of engine to produce power decreased with decreasing fuel gas MN. Therefore, the power increment increases for lower MN gas if MN improvement is conducted.

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References

1. B. Gieseking and A. S. Brown. Fuel. **185**. 932-940 (2016).
2. P. S. Roy, C. Ryu, and C. S. Park. Fuel. **224**. 121-127 (2018).
3. D. Puente, F. J. Gracia, and I. Ayerdi. Sens. and Act. B: Chem. **110**. 181-189 (2005).
4. S. Szwaja. K.R. Bhandary. J.D. Naber. J. Hy. En. **32**. 5076-5087 (2007).
5. M. Malenshek and D. B. Olsen. Fuel. **88**. 650-656 (2009).
6. K. Saikaly, O. Le Corre, C. Rahmouni, and L. Truffet. Fuel Proc. Tech. **91**, 641-652 (2010).
7. J. P. Gómez Montoya, A. A. Amell, and D. B. Olsen. Fuel. **186**. 168-175 (2016).

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