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# Replacement of Palm Methyl Ester to Rapeseed Methyl Ester for Tar Removal in the Nong Bua Dual Fluidized Bed Gasification Power Plant

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**Abstract.** The blockage problem of tar in a biomass power plant is a main problem and it must be removed. Rapeseed methyl ester (RME) was imported and used as scrubbing solvent to scrub tar at a 1 MW<sub>e</sub> Nong Bua prototype Dual Fluidised Bed (DFB) gasifier in Nong Bua district, Nakhonsawan province, Thailand. Using local oil in Thailand is an attractive choice from economic viewpoint. Previous lab test study on naphthalene solubility in different local oils in Thailand was investigated. Local palm methyl ester (PME) shows the competitive performance to the RME. In this research, PME was tested to scrub tar in an oil scrubber at the Nong Bua DFB gasifier plant. Gravimetric tar content after passed a PME scrubber was measured and compared to that from a RME oil scrubber. The results show that both solvents have similar tar removal performance due to their contents of ester, methanol, and glycerin are similar. In addition, viscosity of both solvents has no significant effect on tar removal. From the current research, therefore, PME has been used as solvent in an oil scrubber at 1 MW<sub>e</sub> Nong Bua prototype DFB gasifier with technical and economic reasons.

## 1. Introduction

Steam biomass gasification in a dual fluidized bed (DFB) gasifier is proven technology to transform biomass via thermo-chemical gasification reactions to produce usable product gas [1]. The product gas from the DFB gasifier is of high quality with high caloric value, high hydrogen content, and nitrogen free [2]. The product gas consists primarily of hydrogen, carbon monoxide, carbon dioxide, and methane. Other substances such as tars, sulfur compounds, and nitrogen compounds are also presented in small amount in the product gas [3, 4].

One of the substances that is the undesirable product of gasification process comprises a complex mixture of hydrocarbon, which is described in terms of "tar" [5]. Tar is divided into five classes based on the molecular weight of tar composition, which are (1) GC-undetectable, (2) heterocyclic aromatics, (3) light aromatic (1 ring), (4) light polycyclic aromatic hydrocarbon (PAH) compounds (2

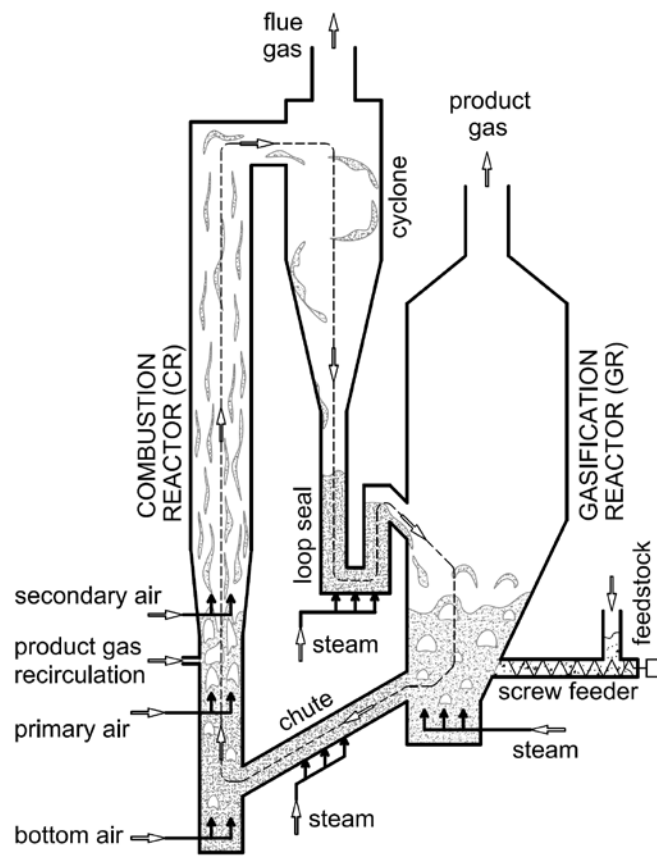


- 3 rings), and (5) heavy PAH compounds (4 - 7 rings) [5, 6]. Major tar components generally detected in the steam gasification product gas are class 4, 5 and 2, respectively. Class 4 tars are naphthalene, indene, biphenyl, acenaphthalene, fluorene, phenanthrene, and anthracene. Class 5 tars are fluoranthene, pyrene, chrysene, and perylene and class 2 tar is phenol [6]. Tar causes blockage and fouling problem by condensation and polymerization at low temperature in the downstream system [5, 6]. To avoid this blockage issue and lead to plant shutdown, tar must be completely removed from the product gas. Among tar removal technique, oil scrubber is wise technology due to its characteristic that can dissolve tar more than water according to “like dissolves like principle” [7, 8]. In the commercial DFB steam gasification process in Europe, rapeseed methyl ester (RME) has been used for tar removal in a packed column scrubber and the tar removal efficiency is higher than 99% [9]. Additionally, in the previous research on investigation of the naphthalene solubility in different local oils in Thailand in a laboratory [10], it was discovered that the local palm methyl ester (PME) showed the most satisfactory performance in the naphthalene solubility. The PME has given the comparable naphthalene solubility value to the RME [10]. RME had been used to scrub tar in an oil scrubber, during the initial stages of commissioning, in the 1 MW<sub>el</sub> Nong Bua prototype DFB gasifier which was engineered and developed by Gussing Renewable Energy (Thailand) company [11]. The product gas from wood gasification was satisfactorily removed from tar by RME [11]. However, the RME was imported from Germany, and it cannot be locally produced in Thailand. Therefore in this present research, the local PME was being tested at the Nong Bua DFB gasifier plant. The results of tar concentration outlet of the PME scrubber were measured and then compared with the results from the RME scrubber.

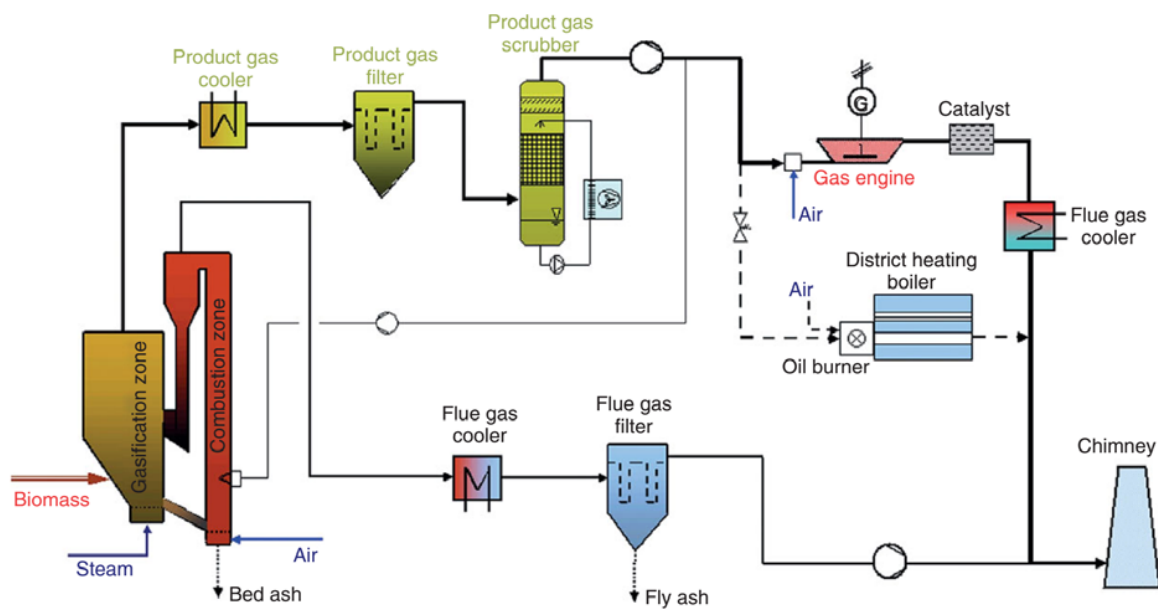
## 2. Experimental section

### 2.1 Nong Bua DFB gasification plant description

In the present study, wood chips are used as a supply fuel in the 1 MW<sub>el</sub> prototype DFB steam gasifier [12]. The concept of the DFB gasifier is to separate the combustion and gasification reactions into two zones, in order to obtain the nitrogen free in product gas. They are the bubbling fluidized bed (BFB) gasification and fast fluidized bed (FFB) combustion zones as presented in Figure 1. Biomass is fed into the BFB gasification reactor with steam as a gasifying agent. Heat is transferred from the combustion reactor via circulating bed material to the gasification reactor. Calcined olivine was chosen as a bed material due to its hardness and high catalytic activity in biomass stream gasification [2, 12, 13]. Residual biomass or char which was produced in the gasification reactor is transported into the combustion reactor via chute for additional heat supply to the gasifier system. A schematic diagram of the CHP-DFB biomass gasifier process in Nong Bua is shown in Figure 2 [11]. The product gas generated from the gasification reactor at above 800°C was cooled to 150-180°C in the cooling system. Then, the product gas was removed from particles such as char, ash, and fine bed material by the bag filter. A biodiesel scrubber was used to clean the product gas from all tars and small amount of particles. The temperature of the product gas was decreased to 40°C after the scrubber and then increased to 60-70°C after the blower. The clean product gas was ready to be used in the gas engine to produce electricity and heat.



**Figure 1.** The DFB stream gasifier [14].



**Figure 2.** Schematic diagram of the CHP-DFB biomass gasifier process in Nong Bua [11].

### 2.2 Scrubbing solvent

Two scrubbing solvents were used in tar removal scrubber. RME was imported from a company in Germany. PME was purchased from a local company in Thailand. Table 1 shows the density and viscosity of both oils. Density of oils was determined using Archimedes' principle. Viscosities of oils were measured by Brookfield DVIII Ultra Ads Viscometer. Ester groups were analyzed by Gas Chromatograph-Mass Spectrometer (GC-MS). In addition, methanol and glycerin were analyzed by a supplier follow standard EN 14110:2019 and EN 14105:2011, respectively. Chemical component of oils present in Table 2. In the GC-MS analysis, each oil was diluted with hexane to the ratio of 100 hexane: 1 oil. The total volume of 0.2  $\mu\text{L}$  of this sample was injected into HP-5 Column. Helium was used as a carrier gas at the flow rate of 0.9 ml/min. The oven temperature was started from 40°C until the temperature reached 250°C.

**Table 1.** Physical properties of both solvents at room temperature.

Solvent	Density ( $\text{g/cm}^3$ )	Viscosity (cP)
RME	0.8817	4.93
PME	0.8758	4.97

**Table 2.** Chemical components of both solvents.

Major component	RME (% wt)	PME (% wt)
<b>Ester<sup>a</sup></b>	<b>98.000</b>	<b>98.800</b>
- Palmitic acid <sup>b</sup>	4.312	44.359
- Oleic acid <sup>b</sup>	73.063	40.432
- Linoleic acid <sup>b</sup>	16.391	7.766
- Other <sup>b</sup>	4.234	6.243
<b>Alcohol<sup>a</sup></b>	<b>0.140</b>	<b>0.206</b>
- Methanol <sup>a</sup>	0.020	0.017
- Glycerin <sup>a</sup>	0.120	0.189
<b>Other<sup>a</sup></b>	<b>1.860</b>	<b>0.994</b>

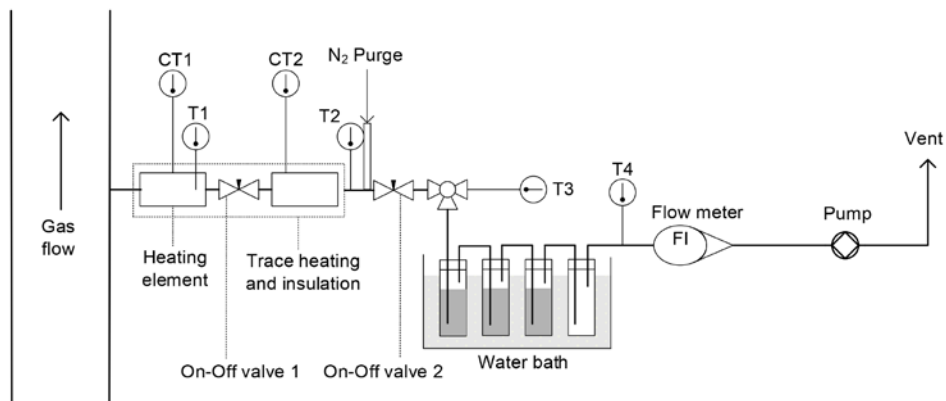
<sup>a</sup> data from supplier specification sheet

<sup>b</sup> data from sample analysis by KMITL lab

### 2.3 Tar sampling and analysis

Tar in the product gas after passing through the solvent scrubber was collected and analyzed to compare the outlet tar content when RME and PME were used as scrubbing solvent. Tar sampling and analysis in the product gas was performed based on European Standard CEN/TS 15439:2006 Biomass gasification – Tar and particles in product gases – Sampling and analysis. Figure 3 presents a schematic diagram of tar sampling port setup [11].

For tar sampling, the sampling line was heated above the tar dew point to prevent tar condensation and blockage in the sampling line. The product gas after the solvent scrubber was sucked by a vacuum pump and a gas flow rate was controlled by a flow meter (Figure 3). Tar was collected in Pyrex bottles which were filled with solvent grade of toluene. Ice bath acts as a cooling to reduce the gas temperature, and tar is condensed and trapped by cold toluene. For the tar analysis, tar was separated from toluene by rotary evaporator and oven at set conditions. The weight of tar after evaporation and dried or called the gravimetric tar was recorded in  $\text{g/Nm}^3$ .

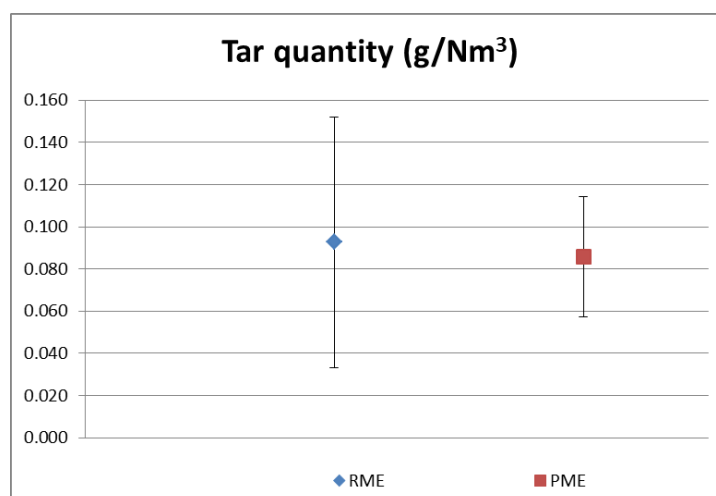


**Figure 3.** Schematic diagram of tar sampling port setup [11].

### 3. Results and discussion

In the previous research, naphthalene solubility was investigated in oils. RME shows slightly better naphthalene dissolving than PME. Nature of solute and solvent affect the solubility. Viscosity of solvent is related to diffusion coefficient, which low viscosity causes high diffusivity and dissolution rate [7, 15]. The fast dissolution rate often has high solubility. As shown in Table 1, RME shows the insignificantly lower viscosity than PME with 4.93 and 4.97 cP, respectively. In terms of chemical components, ester content and alcohol group of both oils are no differences as shown in Table 2. As shown in Table 2, main components of the ester group in both oils comprise palmitic acid, oleic acid, and linoleic acid. Palmitic and oleic acid are a non-polar substance while linoleic acid is a polar substance [16-18]. The amount of palmitic combined with oleic acid in PME is slightly higher than RME, which are 84.791% and 77.375%, respectively. Due to both oils have similar non-polar substances which can dissolve tar and they also show no difference in viscosity. Thus, gravimetric tar in a biomass power plant after passed both oils in the oil scrubber is similar as presented in Figure 4. Minimum gravimetric tar values in the producer gas from a RME scrubber and a PME scrubber are 0.031 and 0.030 g/Nm<sup>3</sup>, respectively while the maximum values from a RME scrubber and a PME scrubber are slightly different with 0.186 and 0.107 g/Nm<sup>3</sup>, respectively. Average gravimetric tars using RME and PME are 0.093 ± 0.059 and 0.086 ± 0.028 g/Nm<sup>3</sup>, respectively.

PME has shown a high tar removal performance as much as RME. Therefore, PME can be used as scrubbing solvent in the Nong Bua DFB gasifier plant instead of RME, based on the results of this current study.



**Figure 4.** Average gravimetric tars after passing a tar scrubber when using RME and PME as scrubbing solvent.

#### 4. Conclusion

Gravimetric tar from 1 MW<sub>el</sub> prototype dual fluidized bed (DFB) gasifier in Thailand was investigated when RME and PME was used as a scrubbing solvent. PME shows the satisfied results. Tar quantity after passed PME is not significantly different when compared to RME. Thus, PME will be used in the scrubber of the 1 MW<sub>el</sub> Nong Bua DFB gasifier plant, considering both technical and economic reasons.

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