1. Introduction

To date, extensive biofuels utilization is still recognized as a way to reduce dependence on crude oil and as a source of renewable energy [1]. Although the use of ethanol as a fuel has only two-thirds of the energy content of gasoline, ethanol has the required positive character on IC engine burning. The positive characters are laminar flame propagation speed and higher octane rate compared to gasoline [2]. Another positive behavior of ethanol as a fuel is the ownership of the hydroxyl group of molecules ethanol so it is an oxygenate fuel and it’s a polar substance. The chemical formula for alcohol is $C_n H_{2n+1} OH$. The addition of alcohol to gasoline allows perfect combustion, better combustion efficiency and friendlier emissions [3].

The disadvantage of using alcohol as a fuel, especially those with short carbon chains, is the low energy content that has an impact on increasing fuel consumption [4]. The increase in alcohol fraction in gasoline also affects the problem of mixture separation, metal corrosion and changes in fuel vapor pressure [5]. However, the use of alcohol as fuel is the most logical solution to overcome the crisis of fossil fuels without making any changes to the existing engine construction [6].

Methanol is a biodegradable fuel. The use of methanol has been suggested as fuel as a means of extending the supply of liquid fossil fuel consumption [7]. Most methanol is derived from natural gas, coal and some are obtained through biomass synthesis. Methanol has long been used as a fuel, both as a mixture of gasoline and as a dedicated fuel. Methanol shows a good market signal for it's easy to obtain, has a low price [8], easy to store, and distributed broadly [9]. Methanol also has a high-octane number allowing engine design to have a high compression ratio to improve thermal efficiency. Another advantage of methanol is a high evaporation enthalpy so that it positively impacts its volumetric
efficiency [8]. The energy content of methanol is less than gasoline so that the higher fuel consumption would be theoretically predicted for methanol and gasoline blends than for regular gasoline. Lately, many researchers in the field of alternative fuels for automotive, are interested in studying methanol as a mixture of fuels both gasoline and diesel [10], so that methanol has the potential to become a favorite alternative fuel candidate in the future.

One recent study by the authors is that polar ethanol is capable of inducing non-polar hydrocarbons ethanol and forming molecular clusters to change the evaporating character and other properties of fuel blends [6]. From the previous findings and the potential for ethanol as a cosolvent will provide a better mixing role between methanol polar and non-polar gasoline. Ethanol molecule as a cosolvent concept was presented in Figure 1.

![Figure 1. Ethanol molecule as a surfactant concept](image1)

The hydroxyl groups (head) in the ethanol molecule are polar and have the potential to form hydrogen bonds with other molecules that contain nitrogen, oxygen and flour elements. The concept of ethanol role as cosolvent on the separated gasoline methanol blend offered is presented in Figure 2.

![Figure 2. The role of ethanol addition on the separated methanol gasoline blend concept](image2)

Until now the implementation of methanol as a fuel blend is still limited to a light mixture of around 4-5% v / v, by using cosolvent to maintain the stability of the fuel blend [11]. Methanol has a high limit to mix blend with gasoline, so the mixture separation is easy [12]. Previous research also stated that an increase in the methanol fraction in gasoline would cause the problem of separating the fuel mixture [5]. This study presents essential findings from the addition of ethanol to the gasoline-methanol blends in several conditions of the fuel blend storage temperature. This article aims to reveal the role of ethanol as a cosolvent in maintaining the stability of a gasoline methanol blend.

2. Experiments

2.1. Fuel blends preparation
This study used commercial gasoline supplied by PT. Pertamina. Methanol and ethanol analytical reagent grade with a molar weight (MW) of 20.1 and 46.07-gram mole\(^{-1}\) and purity 99.5% and 99.7%
respectively. Smart-Lab, Indonesia supplied methanol and ethanol. The detailed properties of fuel which is used in this study were presented in Table 1.

| Properties                      | Gasoline | Ethanol | Methanol |
|---------------------------------|----------|---------|----------|
| Purity (%)                      | n/a      | 99.7    | 99.8     |
| Chemical formula                | C₅₋₁₀H₁₂₋₂₂ | C₂H₅OH | CH₃OH    |
| Boiling Temperature (°C)        | 27–225   | 78.2    | 65.2     |
| Hydrogen (% mass)               | 12.5     | 34.7    | 12.57    |
| Carbon (% mass)                 | 87.5     | 52.2    | 37.5     |
| Oxygen (% mass)                 | 0        | 34.7    | 49.93    |
| Low heating value (MJ kg⁻¹)     | 44.0     | 26.9    | 20.1     |
| Molecular Weight (gram mole⁻¹)  | 106.22   | 46.07   | 32.04    |
| Density @ 20 °C (kg L⁻¹)        | 0.737    | 0.785   | 0.792    |
| Reid vapor pressure             | 53–60    | 17      | 32.4     |

2.2. Experimental apparatus
This research was carried out by mixing polar methanol and non-polar gasoline in a test tube as shown in Figure 3.

The methanol fraction used in this study was 30, 50 and 70% v/v. Mixing methanol gasoline is done manually using a stirring spoon, then the fuel blend was allowed to stand for a while until the methanol-gasoline mixture was shown as shown Figure 4.
A 5 ml pipette with the accuracy of 0.5 ml reading is used to drip ethanol into the fuel mixture until the separation mixture was removed. A 50 fps DSLR camera was used to take pictures of each mixture and treatment conditions. A rear light was used to sharpen the image from the camera.

3. Result and Discussion

3.1. Separated gasoline methanol blend

The first gasoline methanol blend in the reaction glass was set to 4 ml. After stirring, the gasoline methanol mixture was waited for up to 100 minutes, and images are taken using a Camera. Visualization of mixing methanol gasoline with various of fractions blend is presented in Figure 5 below,

Figure 5. Separated gasoline methanol blends

Figure 5 shows that mixing the methanol-gasoline fraction 10, 15, 30, 50, and 70% v/v is separated. This phenomenon is easy to understand because methanol is a polar liquid while gasoline is a non-polar liquid. The results of this study are in line with the results of Bromberg & Cheng’s study, 2010, which states that the use of gasoline methanol mixture is limited to 4-5% v/v methanol fraction [11]. Figure 5 also shows that mixing methanol gasoline separately after mixing the blend (energizing) is stopped. This phenomenon was also revealed by Awad et al., 2018 that mixing gasoline methanol would cause separating the fuel mixture problem [12].

3.2. Homogeneous gasoline methanol ethanol blend

The results of mixing various fractions of methanol gasoline blend with the addition of ethanol are presented in Figure 6.

Figure 6. Homogeneous gasoline methanol blends
Figure 6 clearly shows that the addition of ethanol to the gasoline methanol blend produces a homogeneous fuel mixture. The minimum ethanol requirement to produce a homogeneous fuel blend is presented in Table 2.

| No | The volume of fuel blend (4 ml) | Methanol fraction v/v (ml) | Methanol fraction v/v (%) | Ethanol Min (ml) | Ethanol Min (%) |
|----|---------------------------------|---------------------------|---------------------------|------------------|-----------------|
| 1  | 3.6                             | 90                        | 0.4                       | 10               | 0.425           | 11.0           |
| 2  | 3.4                             | 85                        | 0.6                       | 15               | 0.308           | 8.0            |
| 3  | 2.8                             | 70                        | 1.2                       | 30               | 0.300           | 7.5            |
| 4  | 2.0                             | 50                        | 2.0                       | 50               | 0.208           | 5.0            |
| 5  | 1.2                             | 30                        | 2.8                       | 70               | 0.100           | 2.5            |

Table 2 shows the minimum ethanol requirements to form a homogeneous mixture on various gasoline methanol fractions. The tendency of ethanol needs as a cosolvent in the gasoline methanol blend is presented in Figure 7.

**Figure 7.** The tendency of ethanol needs as a cosolvent in gasoline methanol blend

Figure 7 shows that the increasing methanol fraction in gasoline the fewer ethanol needs as a cosolvent. The need for ethanol as a cosolvent of the methanol-gasoline mixture up to 12% v/v, is inversely proportional to the increase in the methanol fraction. This interesting phenomenon is caused by ethanol and methanol, each of which has a hydroxyl group so that both have the potential as cosolvent.

3.3. The role of ethanol as a cosolvent in maintaining the stability of a gasoline methanol blend

The process of mixing a fluid with another is a physical process. Molecular interactions between molecular substances that mix is physical activities that can explain a homogeneous and separate blend. Gasoline (C_{5-10} H_{12-22}) is a non-polar hydrocarbon, while methanol (CH_3 OH) and ethanol (C_2H_5 OH) are short-group hydrocarbon chains that have hydroxyl groups at one end. However, ethanol has a hydrocarbon chain that is longer than methanol, so it has the potential to interact with gasoline hydrocarbons. This molecular interaction occurs between C_2H_5 as a tail (Figure 1) and the gasoline molecule. While the polar hydroxyl group at the end of ethanol becomes the head that interacts with the polar methanol molecule. The molecular interaction model between gasoline methanol and ethanol Figure 8.
Figure 8 shows that element H on the hydroxyl group of methanol has a negative partial charge interacting with element O on the hydroxyl group of ethanol which has a positive partial charge. This interaction is the strongest intermolecular interaction (hydrogen bond), while the interaction of non-polar groups of ethanol hydrocarbons with non-polar gasoline is a weak molecular surface force. In this molecular interaction housing, ethanol functions as cosolvent because, polar (hydroxyl) heads interact with polar methanol, while the non-polar tail side interacts with non-polar gasoline molecules (Figure 1). Figure 7 also gives an empirical explanation that using a high fraction methanol mixture is more beneficial because it only requires a small fraction of ethanol as a cosolvent. However, a good and satisfying scientific explanation needs to be carried out further study.

![Molecular Interaction Model](image)

**Figure 8.** Molecular interaction model between gasoline methanol and ethanol

4. Conclusion
A series of simple experiments have been carried out to prove the hypothesis that ethanol can function as a cosolvent of the gasoline methanol blend to mix homogeneously. Ethanol functions as a cosolvent of methanol for perfectly blending with non-polar gasoline because it has a longer chain hydrocarbon. The role of ethanol as a cosolvent caused by the OH (hydroxyl) as the head (polar) is attached to the polar methanol molecule while the CH (hydrocarbon) group as the tail (non-polar) interacts with the non-polar gasoline molecule.

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