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Biodiesel as an Additive for Diesohol

Kraipat Cheenkachorn[1,*], Monpilai H. Narasingha[2] and Juthawan Pupakornnopparut[1]

[1]Thermal Process Engineering Research Group, Department of Chemical Engineering, King Mongkut's Institute of Technology North Bangkok, Bangkok, Thailand

[2]Mechanical Process Engineering Research Group, Department of Chemical Engineering, King Mongkut's Institute of Technology North Bangkok, Bangkok, Thailand

*Author to whom correspondence should be addressed, email: kpc@kmitnb.ac.th

Abstract: A number of studies currently focus on the alternative fuels to reduce the reliance on petroleum fuels. Biodiesel and ethanol are among candidates which are studied and tested in many countries including Thailand. Blending ethanol with regular diesel to form diesohol has been known as one of the strategies to reduce the use of regular diesel. However, an emulsifier is needed to homogenize the blend. In this research, biodiesel offers an alternative application as an emulsifier and wear additive for diesohol. The emulsification tests were conducted to select the proper blends. A three-phase diagram was constructed to verify an appropriate composition of the emulsion. Physical and chemical properties of the selected blends were examined to meet the requirement of a conventional diesel. The results from the experiments are promising except the flash point. The on-going study shows that the diesohol homogenized by biodiesel can be a good candidate for diesel engine.

Keywords: Biodiesel, Diesohol, Emulsifier, Wear Additive, Alternative Fuel.

Introduction

Over the past decades, there has been an increase in effort to reduce the reliance on petroleum fuels for energy generation and transportation in Thailand and throughout the world. Among the proposed alternative fuels, biodiesel and diesohol have received much attention in recent years for diesel engines due to their advantages as the renewable and domestically produced energy resources. Moreover, the studies have shown that they are environmentally friendly because there is substantial reduction of unburned hydrocarbons, CO and particulate matter emission when it is used in conventional diesel engine [1]. Biodiesel can be produced from vegetable oils via transesterification process. Nevertheless, biodiesel has been employed not only as an alternative to the fossil derived fuels, but also as an additive for diesohol -- a blending of ethanol with regular diesel. Diesohol has been known as one of the preferences for Thailand to decrease the use of regular diesel fuel, since ethanol has been included in the national strategic plans and policies for energy [2, 3]. It is estimated that the use of ethanol can decrease the amount of petroleum-fuel imports up to 10-15%. There are two major types of ethanol; synthesis ethanol and bio-ethanol. More recently, the center of attention has shifted to the production and use of bio-ethanol for the energy resource in Thailand. This is due to the fact that it can be produced domestically, resulting in a growth in domestic economics. Nevertheless, it is found that ethanol has lower heating value than the regular diesel and the use of pure ethanol as an alternative can cause drawbacks to the effectiveness of engines. One of potential approaches to avoid such problem is to blend the ethanol with regular diesel fuel and use the blend, known as diesohol, as the power source for diesel engines.

However, ethanol and diesel fuel are inherently immiscible because of their difference in chemical structures and characteristics, and therefore need an effective emulsification technique for being an emulsion. These two liquid fuels can be efficiently emulsified into a heterogeneous mixture of one micro-particle liquid phase dispersed into another liquid phase by mechanical blending in cooperation with suitable emulsifiers. The emulsifier would reduce the interfacial tension force and increase the affinity between the two liquid phases, leading to emulsion stability [4]. A suitable emulsifier for ethanol and diesel fuel is suggested to contain both lipophilic part and hydrophilic part, in order to obtain an emulsion of diesohol. Such chemical structures can be found in biodiesel, as shown in Fig. 1. It is also reported that the presence of biodiesel or vegetable oil can improve the lubricating properties of diesel fuel [5, 6].

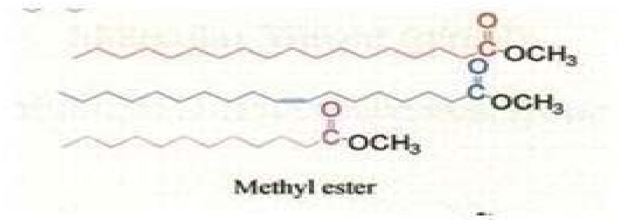

Fig. 1 Biodiesel chemical structure.

There are several studies concerning diesohol productions and utilization. Australia's Apace Research Ltd. [7, 8] has announced a success in the development of an emulsification technique using its innovative emulsifier. The diesohol emulsion for this study contained the regular diesel fuel at 4.5% vol, hydrated ethanol (5% water) at 15% vol, and emulsifier at 0.5% vol. The engine tests for the diesohol were onducted by using truck and bus, in comparison with the regular diesel fuel. The results obtained from the diesohol utilization showed the reductions of CO and CO_2 emissions and particulate matter (PM10) when compared to the low-sulfur diesel fuel.

However, the reduction of hydrocarbon (HC) distribution was not observed and there were some problems occurring during the use. In Thailand, there was a cooperative project between the Petroleum Authority of Thailand (PTT) Public Co. Ltd., Ford Motor Company, and National Metal and Materials Technology Center (MTEC) for the potential of using diesohol as an lternative to the regular diesel fuel [9]. The ethanol at 10% vol, regular diesel fuel at 89% vol, and imported emulsifier at 1% vol were used for the diesohol preparation. The vehicle testing was done by using a minibus. It is observed that the fuel properties of diesohol were found to be in consistent with the regular diesel, except that the flash point of diesohol was found to be lower. By following the European Testing Protocols, the diesohol showed the higher in the distribution of CO, CO_2, HC, NO_X, and PM10. It is obvious that a further study is needed in both diesohol production and utilization, especially in the area of domestic emulsifier. This leads to the objectives of this paper.

In this paper, the emulsification tests were conducted to select the proper blends among ethanol, diesel fuel and biodiesel. A three-phase diagram was also constructed in an attempt to verify an appropriate composition of the blend. Physical and chemical properties of the selected blends were examined to meet the requirement of a conventional diesel fuel. The results are expected to be beneficial for the future study of diesohol production and utilization.

Experimental Details

The primary purpose of this experimental study was to determine an appropriate composition of the diesohol emulsion, including emulsification characteristics and fuel properties of the emulsions at different blending compositions for the possibility of using those emulsions as alternative fuels for diesel engines. The experimental Procedures included preparation of the emulsions, homogeneity and emulsification stability test, and tests for fuel properties. A three-phase diagram was performed in order to verify the homogeneity of the mixture.

Table 1 Fuel properties of diesohol at 95% by vol diesel fuel and 5% by vol ethanol at different % biodiesel addition

Properties	Diesel	Palm-oil Biodiesel	Ethanol (Purity 99.5%)	Diesel : Ethanol 95 : 5 %volume				Testing Method
				Biodiesel 5% volume of mixture	Biodiesel 10% volume of mixture	Biodiesel 15% volume of mixture	Biodiesel 20% volume of mixture	
API @ 60 F	40.22	32.27	44.50	39.61	39.01	38.66	38.16	ASTM D 1298
Density (g/cm³)	0.823	0.864	0.794	0.82340	0.82596	0.82809	0.83001	ASTM D 1298
Initial boiling point (°C)	160	220	-	78	78	78	78	ASTM D 86
10%Distillation (°C)	225	315	-	197	199	198	198	ASTM D 86
50%Distillation (°C)	279	323	-	282	282	283	283	ASTM D 86
90%Distillation (°C)	345	331	-	340	340	338	337	ASTM D 86
Viscosity @ 40 °C (cst)	3.19	5.321	1.19	2.906	2.915	2.982	3.047	ASTM D 445
Pour point (°C)	6	6	-	-1	-1	-1	-1	ASTM D 97
Heating value (MJ/kg)	45.560	38.6	26.7	45.1980	44.4860	44.4306	44.2998	ASTM D 240
Cetane index	58.6813	50.7549	-	57.9384	57.0479	56.4084	55.7250	ASTM D 976
Carbon residue (%by wt.)	-	-	-	0.026	0.062	0.077	0.096	ASTM D 189

Table 2 Fuel properties of diesohol at 85% by vol diesel fuel and 15% by vol ethanol at different % biodiesel addition

Properties	Diesel	Palm-oil Biodiesel	Ethanol (Purity 99.5%)	Diesel : Ethanol 85 : 15 %volume				Testing Method
				Biodiesel 10% volume of mixture	Biodiesel 15% volume of mixture	Biodiesel 20% volume of mixture	Biodiesel 25% volume of mixture	
API @ 60 F	40.22	32.27	44.50	38.95	38.52	38.08	37.76	ASTM D 1298
Density (g/cm³)	0.823	0.864	0.794	0.82616	0.82824	0.83043	0.83201	ASTM D 1298
Initial boiling point (°C)	160	220	-	78	78	78	78	ASTM D 86
10%Distillation (°C)	225	315	-	79	79	79	79	ASTM D 86
50%Distillation (°C)	279	323	-	275	274	275	275	ASTM D 86
90%Distillation (°C)	345	331	-	339	338	337	337	ASTM D 86
Viscosity @ 40°C (cst)	3.19	5.321	1.19	2.460	2.514	2.583	2.635	ASTM D 445
Pour point (°C)	6	5	-	-5	-5	-5	-5	ASTM D 97
Heating value (MJ/kg)	45.560	38.6	26.7	41.9743	41.8875	41.7401	41.6929	ASTM D 240
Cetane index	58.6813	50.7549	-	55.6578	54.7060	54.1308	53.5737	ASTM D 976
Carbon residue (%by wt.)	-	-	-	0.118	0.160	0.166	0.216	ASTM D 189

To prepare the diesohol emulsions, the bio-ethanol with purity 99.5% and regular diesel fuel were obtained from PTT Public Co. Ltd. (Bangkok, Thailand) while the biodiesel, produced from palm oil, was acquired from Department of Chemical Engineering, Faculty of Engineering, Prince Songklanakarin University (PSU, Songkla, Thailand). Their fuel properties are presented in Table 1.

The regular diesel fuel and bio-ethanol were primarily mixed in a 200 ml flask with a magnetic stirrer to obtain the diesohol blend. The diesel fuel to bio-ethanol ratio (D:E) were varied at 95:5, 90:10, and 85:15% vol. The biodiesel used as an emulsifier for this study was then added into the mixture at the following concentrations; i) 5, 10, 15, and 20% vol of the mixture for D:E at 95:5% vol, and ii) 10, 15, 20, and 25% vol of the mixture for D:E at 90:10 and 85:15 % vol. After that, the diesohol emulsions were brought to the homogeneity and emulsification stability test, in which the emulsions were put in storage for 6 months. The fuel properties were conducted using reference methods published by American Society for Testing Materials (ASTM), as shown in all tables of result.

Table 3 Fuel properties of diesohol at 90% by vol diesel fuel and 10% by vol ethanol at different % biodiesel addition

Properties	Diesel	Palm oil Biodiesel	Ethanol (Purity 99.6%)	Diesel : Ethanol 90 : 10 volume				Testing Method
				Biodiesel 10% volume of mixture	Biodiesel 15% volume of mixture	Biodiesel 20% volume of mixture	Biodiesel 25% volume of mixture	
API @ 60 F	40.22	32.27	44.50	38.56	38.14	37.74	37.39	ASTM D 1298
Density(g/cm^3)	0.823	0.884	0.794	0.82803	0.83010	0.83209	0.83381	ASTM D 1298
Initial boiling point (°C)	180	220	–	78	78	78	78	ASTM D 86
10%Distillation (°C)	226	316	–	79	79	79	79	ASTM D 86
50%Distillation (°C)	279	323	–	277	276	275	275	ASTM D 86
90%Distillation (°C)	345	331	–	340	338	338	337	ASTM D 86
Viscosity @40 °C (cst)	3.19	5.321	1.19	2.706	2.718	2.768	2.777	ASTM D 445
Pour point (°C)	6	5	–	-2	-2	-2	-2	ASTM D 97
Heating value (MJ/kg)	45.560	38.6	26.7	43.1471	42.7656	42.7489	42.4263	ASTM D 240
Cetane index	58.6813	50.7549	–	55.3503	54.4266	53.5407	52.9371	ASTM D 976
Carbon residue (%by wt)	–	–	–	0.081	0.132	0.174	0.206	ASTM D 189

Results and Discussions

Homogeneity and emulsification characteristics

All diesohol emulsions prepared for this study were put in storage for 6 months at room temperature. The results show that all diesohol emulsions exhibit their good emulsion stabilities. No agglomeration of liquid droplets and sediment layer occurs physically in all diesohol emulsions. This is verified by a three-phase diagram as shown in Fig. 2. From the results, it is suggested that biodiesel is a suitable emulsifier for diesohol.

Fuel properties of diesohol emulsions

Table 1-3 show the fuel properties of all samples including the testing methods. The influence of palm-oil biodiesel addition on some selected fuel properties are illustrated in Fig. 3-12. For all diesohol emulsions, the results shown in Fig. 3 exhibit an increase in the percentage by weight of carbon residue with an increase in the amount of biodiesel added.

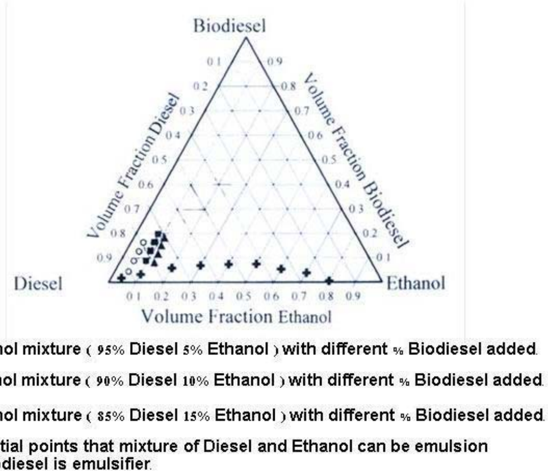

Fig. 2 The three-phase diagram.

However, it should be noted that the percentage by weight of carbon residue for nearly all diesohol emulsions are over the standard value of 0.050 for No. 2 diesel fuel, according to ASTM. The only emulsion that shows the acceptable percentage of carbon residue is the one with biodiesel addition at 5% vol mixture of diesel fuel at 95% vol and ethanol at 5% vol. This is due to the fact that the palm-oil biodiesel contains more carbon ratio than diesel fuel. As a result of that, more oxygen consumption is expected for a complete combustion when the biodiesel is added to the diesohol. The carbon residue normally affects the diesel engine. This problem can be reduced by using a turbocharger or increasing the temperature of the mixture of gas and air which enters a motor engine through the inlet. This would increase the oxygen intensity for combustion.

Fig. 4 and 5 present the results of viscosity and density tests, respectively. It is evident that both density and viscosity at 40 ^{o}C of diesohol emulsions increase with increasing the amount of biodiesel added at all ratios of diesel fuel to ethanol. This is attributed to the fact that the palm-oil biodiesel has higher density than the other two components. It is well recognized that the higher density leads to the higher flow resistance of fuel oil, resulting in higher viscosity. In addition, it isobserved that the viscosities at 40 ^{o}C of all diesohol emulsions are higher than the viscosity of the regular diesel fuel at the same temperature. This finding suggests that the higher viscosity can bring to the inferior fuel injection. However, the viscosities of all diesohol emulsions in this study are still under a standard limit value for diesel fuel.

Higher heating value (HHV) is one of the most important fuel properties. The results shown in Fig. 6 indicate that the HHV of diesohol decreases when more amount of biodiesel is added. The same trend is also observed when the amount of ethanol increases, comparing at the same amount of biodiesel added. This is owing to the lesser in the HHV of palm-oil biodiesel and ethanol.

Fig. 7 shows the results from the tests for initial boiling point. For all samples, it can be seen that the initial boiling point is identical at 78 ^{O}C and under the acceptable limit for diesel fuel. The initial boiling point of fuel reveals how unproblematic the engine startup is

To obtain crucial information for diesohol utilization, the temperatures at 10%, 50%, and 90% distillation were respectively monitored for all diesohol emulsions. If the temperature at 10% distillation is too low, "vapor lock" situation would occur and cause a serious problem to the engine. As seen in Fig. 8, the temperature at 10% distillation of diesohol emulsion at D:E 95:5 %vol is observed as in the range of 197-199 ^{O}C, which is higher than those of diesohol emulsions at the other two ratios and lower than that of diesel fuel. It is likely that the amount of biodiesel does not play role to the change in temperature at 10% distillation.

Comparing the temperature at 50% and 90% distillation of all diesohol emulsions with those of the regular diesel fuel, the data obtained from the tests show their quite closed values of temperature, as seen in Fig. 9 and 10. This means that these properties of diesohol emulsions are not in much difference from that of diesel fuel and still under the standard limit. Generally the temperature of fuel at 50% and 90% distillation have an effect on the performance and power of diesel engine. At 50% distillation temperature, the fuel is uniformly distributed and well mixed with air before being subjected to generate power for the engine.

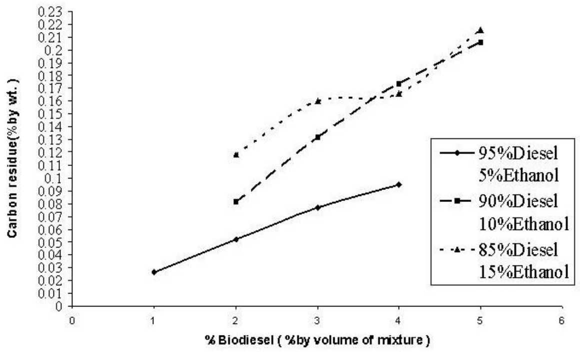

Fig. 3 Percentage of carbon residue of diesohol emulsions with different % biodiesel added.

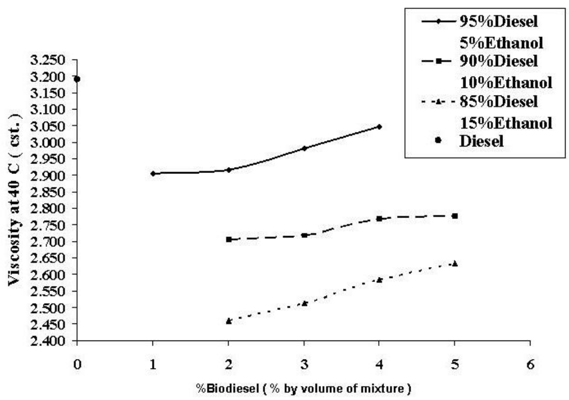

Fig. 4 Viscosity at 40 ^{O}C of diesohol emulsions with different % biodiesel added.

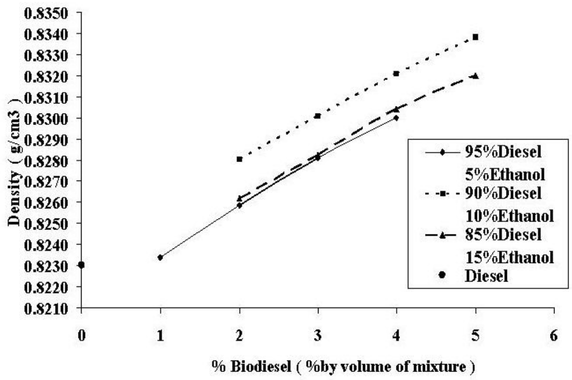

Fig. 5 Density of diesohol emulsions with different % biodiesel added.

Looking at cetane index which is also in proportional relation with API value, all diesohol emulsions were found to have lower values of cetane index than diesel fuel. It is observed that the cetane indices of diesohol emulsions decrease when increasing the amount of biodiesel added, as shown in Fig. 11. The lower the cetane index is, the poorer the ignition property will be. Cetane index also has effects on the engine startup, combustion control, and engine performance.

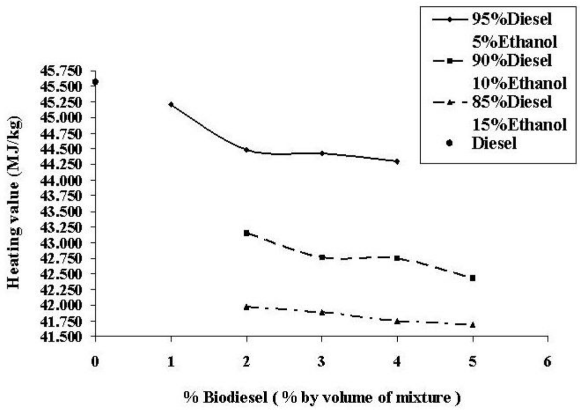

Fig. 6 Higher Heating Value (HHV) of diesohol emulsions with different % biodiesel added.

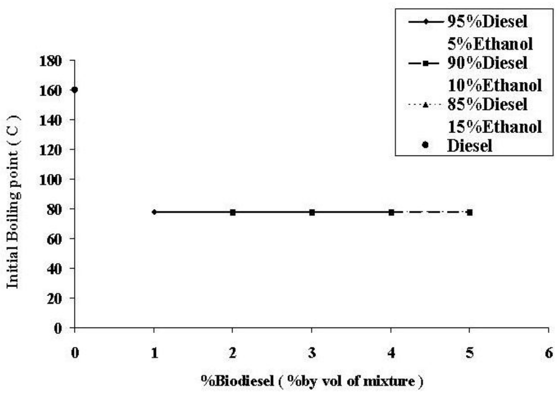

Fig. 7 Temperature at initial boiling point of diesohol emulsions with different % biodiesel added.

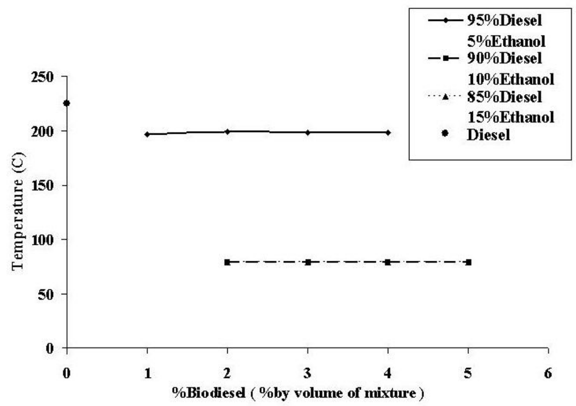

Fig. 8 Temperature at 10% distillation of diesohol emulsions with different % biodiesel added.

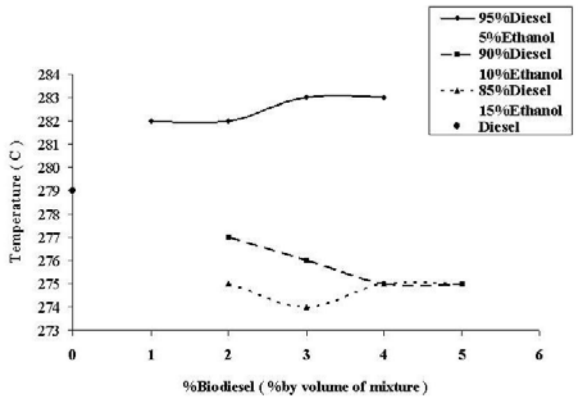

Fig. 9 Temperature at 50% distillation of diesohol emulsions with different % biodiesel added.

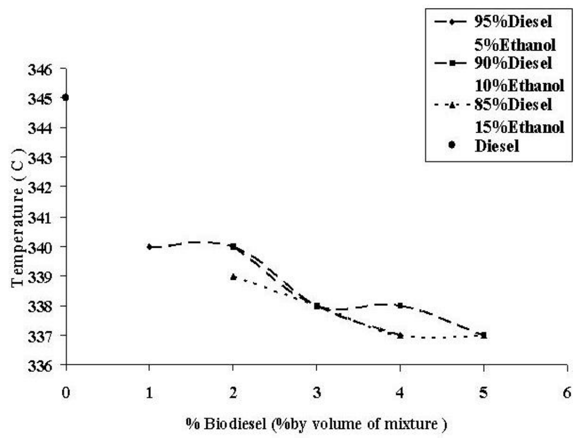

Fig. 10 Temperature at 90% distillation of diesohol emulsions with different % biodiesel added.

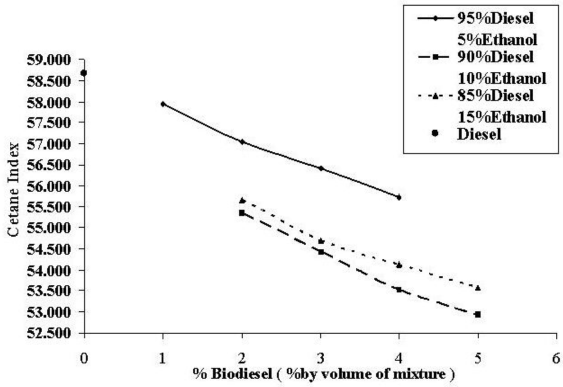

Fig. 11 Cetane index of diesohol emulsions with different % biodiesel added.

The flash point properties for all diesohol emulsions were also investigated and found to be extremely low in the range of 11 - 17 ^{O}C. As a result, the storage and transportation of diesohol must be taken care of in a special and proper way, in order to avoid an explosion.

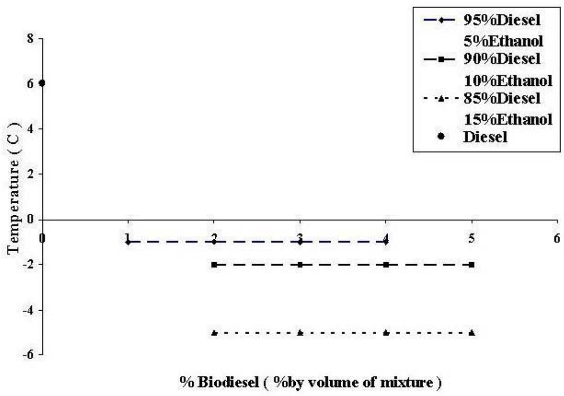

Fig. 12 Pour point of diesohol emulsions with different % biodiesel added.

Conclusions

The emulsification stability and fuel properties of diesohol emulsions were investigated in order to evaluate the potential of using biodiesel as an effective emulsifier for diesohol and making use of diesohol as an alternative fuel for diesel engine. The results of this study could be concluded as follows:

1. Palm-oil derived biodiesel can be used as an effective emulsifier for diesohol emulsions.
2. Nearly all fuel properties of diesohol emulsions are under standard limit for high speed diesel, except 10% distillation and flash point properties. These properties othe emulsions were, however, found to be poorer than that of the regular diesel fuel when the ratios or quantities of ethanol and biodiesel were increased.
3. An increase in the ratios of ethanol and biodiesel lead to an increase in the percentage by weight of carbon residue. Only the diesohol emulsion at D:E 95:5 % by vol with biodiesel addition at 5 % by vol of the mixture shows the value that under the standard

limit for the high speed diesel fuel. However, the others may be used as an alternative to the low speed diesel fuel.

4. In this study, a proper diesohol emulsion for diesel engine should be the one at D:E 95:5 % vol with biodiesel addition at 5% vol of mixture.

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