Mühendislikte Yakıtlar, Yangın ve Yanma Dergisi, Vol(No): 10(1), 2022

MÜHENDİSLİKTE YAKITLAR, YANGIN VE YANMA DERGİSİ
FUELS, FIRE AND COMBUSTION IN ENGINEERING JOURNAL

eISSN: 2564-6435
Dergi sayfası: http://dergipark.gov.tr/fce

Geliş/Received
18.05.2022
Kabul/Accepted
05.09.2022

Doi

DİZEL MOTORLARDA DİMETİL ETER KULLANIMININ MOTOR PERFORMANSINA ETKİLERİ ÜZERİNE BİR DERLEME ÇALIŞMASI

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ÖZ

Bu çalışma, dizel motorlarda dimetil eter (DME)'in saf veya yakıt katkısı olarak kullanımı üzerine yapılmış çeşitli çalışmaların sonuçlarından yararlanılarak derlenmiştir. Dizel motorlarda zararlı egzoz emisyonlarını azaltmanın birkaç yöntemi vardır. Bunlardan ilki motor tasarımında ve yakıt enjeksiyon sisteminde modifikasyonlar yaparak yanmanın iyileştirilmesidir, ancak bu pahalı ve zaman alıcı bir yöntemdir. İkinci yöntem ise katalitik konvektör ve partikül fitresi gibi donanımlar kullanmaktır, ancak bu donanımlar motor performansını olumsuz yönde etkiler. Hem egzoz emisyonlarını azaltmak hem de motor performansını artırmak için uygulanan son yöntem çeşitli alternatif yakıtların veya yakıt katkılarının kullanılmasıdır. Dizel motorlardaki en önemli emisyonlar azot oksitler (NOx) ve partikül maddelerdir (PM). Çoğu araştırmacı emisyonları azaltmanın en iyi yolunun doğalgaz, biyogaz, biyodizel gibi alternatif yakıtların veya konvansiyonel veya alternatif yakıtlarla birlikte çeşitli yakıt katkılarının kullanılması olduğunu bildirmektedir. Bu nedenle, alternatif yakıtlar ve yakıt katkıları üzerine yapılan çalışmaların sonuçlarının birlikte değerlendirilmesi pratik uygulamalar için oldukça önemlidir. Bu çalışma, DME'in dizel motorlarda yakıt veya yakıt katkısı olarak kullanılmasının motor performansı üzerindeki etkilerinin incelenmesine odaklanmıştır. Yapılan çalışmada performans parametreleriyle ilgili bazı sayısal değerler şöyledir. Egzoz gazı sıcaklığı dizel yakıtıyla kıyaslandığında saf DME için %13.6-18.6, LPG+DME karışımı için %12-17.8 azalmıştır. Egzoz gazı sıcaklığı saf DME ile kıyaslandığında DME+NH3 karışımı için %65.6-74.2 azalmıştır. Ancak, saf biyodizel ile kıyaslandığında egzoz gazı sıcaklığı biyodizel-DME (DME15) karışımı için %9-59 artmıştır. Aynı miktarda enerji girişi olduğunda dizel yakıtıyla kıyaslandığında DME için motor torku %29.1-32.8 oranında artmıştır. Ancak, aynı miktarda yakıt girişi olduğunda dizel yakıtıyla kıyaslandığında DME için motor torku %16.7-37.9 azalmıştır. Motor gücü ise dizel yakıtı ile kıyaslandığında dizel-DME (DME30) karışımı için %9.1-41.2 azalmıştır. Özgül yakıt tüketimi dizel yakıtı ile kıyaslandığında saf DME için düşük motor devirlerinde %3.1-4.6 azalırken yüksek motor devirlerinde ise %2.9-5.9 artmıştır. Özgül yakıt tüketimi dizel yakıtı ile kıyaslandığında dizel-DME (DME10) karışımı için düşük motor yükünde %15.7 artarken yüksek motor yükünde ise %4.4 azalmıştır. Dizel- DME (DME20) karışımı dizel yakıtı ile kıyaslandığında özgül yakıt tüketiminde %11.6 azalma sağlamıştır. Saf DME biyodizel yakıtı ile kıyaslandığında özgül yakıt tüketiminde %6.5-11.6 azalma sağlamıştır. Farklı oranlarda biyodizel-DME karışımları (DME5, DME10 ve DME15) biyodizel yakıtı ile kıyaslandığında özgül yakıt tüketiminde sırasıyla %19, %21.2 ve %25 artışa neden olmuştur. Saf DME dizel yakıtıyla kıyaslandığında efektif verimde %0.4-16.2 artış sağlamıştır. Dizel-DME (DME20) karışımı dizel yakıtıyla kıyaslandığında efektif verimde %8.9-17.6 artış sağlamıştır. LPG+DME karışımı dizel yakıtıyla kıyaslandığında efektif verimde %36.7-68.1% düşüşe neden olmuştur. Farklı oranlarda biyodizel-DME (DME5, DME10 ve DME15) karışımları biyodizel yakıtıyla kıyaslandığında efektif verimde sırasıyla %6, %10 ve %3 artış sağlamıştır.

Anahtar Kelimeler: Dizel motor performansı, Dimetil eter, Yakıt katkıları

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A Review Study on the Effects of Dimethyl Ether on Engine Performance in Diesel Engines

ABSTRACT

This review was compiled from the results of various studies which were performed on using dimethyl ether as a fuel or fuel additive in diesel engines. There are different methods for the reduction of the hazardous emissions of diesel engines. The first method for the reduction of harmful emissions is improved the combustion by modification of engine design and fuel injection system, but this process is expensive and time consuming. The second method is the using various exhaust gas devices like catalytic converter and diesel particulate filter. However, the use of such devices affects negatively diesel engine performance. The last method to reduce emissions and also improve diesel engine performance is the use of various alternative fuels or fuel additives. The major pollutants of diesel engines are oxides of nitrogen (NOx) and particulate matter (PM). It is very difficult to reduce NOx and PM simultaneously in practice. The most researches declare that the best way to reduce these emissions is the use of various alternative fuels i.e. natural gas, biogas, biodiesel or using some additives with the alternative fuels or conventional diesel fuel. Therefore, it is very important that the results of various studies on alternative fuels or fuel additives are evaluated together to practice applications. Especially, this study focuses on the usage of dimethyl ether in diesel engines as fuel or fuel additive. This review study investigates the effects of using dimethyl ether on the engine performance characteristics. The numerical values about the study on the performance parameters are as follows. The exhaust gas temperature was reduced about 13.6-18.6% by pure DME and was reduced about 12-17.8% by LPG+DME blend as compared to diesel fuel. The exhaust gas temperature was reduced about 65.6-74.2% for DME+NH3 blend as compared to pure DME. However, exhaust gas temperature was increased about 9-59% for the DME15 blend as compared to biodiesel fuel. The engine torque for the equivalent fuel energy input was increased about 29.1-32.8% when using the pure DME as compared to diesel fuel. However, the engine torque for the same amount of fuel input was decreased about 16.7-37.9% when using pure DME as compared to diesel fuel. The engine power was reduced about 9.1-41.2% for the DME30 blend as compared to diesel fuel. The brake specific fuel consumption was decreased about 3.1-4.6% at low engine speeds and was increased about 2.9-5.9% at high engine speeds by pure DME as compared with diesel fuel. The brake specific fuel consumption was increased about 15.7% at low engine load and was decreased about 4.4% at high engine load for DME10 blend as compared to diesel fuel. The brake specific fuel consumption was improved with DME20 blend approximately 11.6% in comparison with diesel fuel. The brake specific fuel consumption was reduced about 6.5-11.6% with pure DME as compared by biodiesel fuel. The brake specific fuel consumption for DME5, DME10 and DME15 were higher 19%, 21.2% and 25% than that of biodiesel fuel. The brake thermal efficiency values obtained with pure DME were higher than those of diesel fuel about 0.4-16.2%. The brake thermal efficiency values for DME20 blend were higher about 8.9-17.6 than those of diesel fuel. The brake thermal efficiency values were lower about 36.7-68.1% for LPG+DME blend as compared to diesel fuel. The brake thermal efficiency values of DME5, DME10 and DME15 were higher about 6%, 10%, and 3% respectively than that of neat biodiesel.

Keywords: Diesel engine performance, Dimethyl ether, Fuel additives

1. INTRODUCTION

Diesel engines are prime power sources among the automobile engines because of their better performance, higher fuel economy and lower exhaust emissions of hydrocarbons (HCs), carbon monoxide (CO) and carbon dioxide (CO_2) than gasoline engines [1]. However, current diesel engines emit higher levels of particulate matter (PM) and nitrogen oxides (NOx) than those of gasoline engines. Therefore, many researchers have researched to develop low-pollution diesel engines and progressive studies have been conducted on alternative fuels which may produce clean diesel engine emissions [2]. Among the various alternatives, DME is the most promising alternative for automotive fuel from the standpoint of energy security, because it can be industrially produced from coal, natural gas and many kinds of biomass fuels [3]. However, physical properties of DME such as lower viscosity, lubricity, combustion enthalpy and boiling point need the modifications to diesel engine internal structures and components. The technology with pure DME as an alternative fuel for CI engine and vehicle is still under development stage. However, DME can be used as an additive fuel with diesel and other alternative fuel [4]. It is very important that the results of various studies on dimethyl ether are evaluated together to practice applications. This review study investigates the effects of using dimethyl ether on the engine performance characteristics such as engine torque and power, brake specific fuel consumption and brake thermal efficiency.

2. CHARACTERISTICS OF DIMETHYL ETHER

DME is the simple ether with the chemical formula of CH3–O–CH3 as seen in Fig. 1. In general, the physical properties of DME are similar to those of LPG. Therefore, the storage, fuel handling, and transportation requirements for DME are similar to those for LPG [3]. DME can be produced using indirect or direct synthetic methods as seen in Fig. 2. Indirect synthetic methods generate DME through a dehydration reaction after synthetic reaction of methanol, while direct synthetic methods make DME directly from natural gas [5]. DME production costs less than diesel fuel or gasoline on an energy equivalent basis. DME economics are similar to CNG or LNG, when large scale plants are considered [6]. DME is gaseous and almost non-toxic at atmospheric pressure and room temperature. Therefore, DME needs to be pressurized to over 0.5 MPa to keep it in a liquid state under ambient temperature and pressure conditions. The fuel delivery pressure should be increased to 1.7-2.0 MPa under engine operating conditions to prevent vapor lock in the fuel injection system [7, 8].

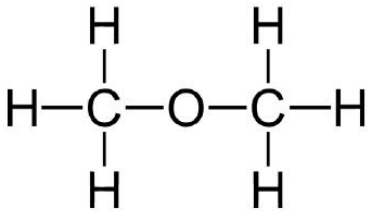


Fig. 1. Chemical structure of DME [5]

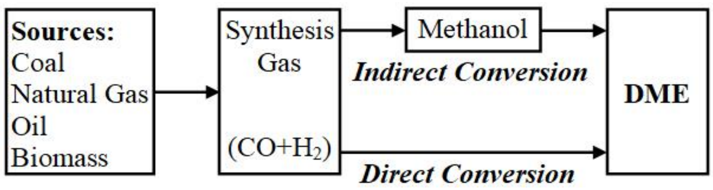


Fig. 2. Production methods of DME [9]

The properties of DME and diesel fuel are shown in Table 1. It can be seen that the properties of DME are quite different from those of diesel fuel. DME has high vapor pressure and low boiling temperature, which is a gas fuel at room temperature and atmospheric pressure. The heating value of DME is significantly lower than conventional diesel fuel. Therefore, the fuel supply and injection system, and the combustion system of the engine should be redesigned or modified [10]. The cetane number of DME is higher than that of diesel fuel, which demonstrates good ignition capability. The latent heat of evaporation of DME is much higher than that of diesel fuel, which is beneficial for reducing the mixture temperature. DME has only C–H and C–O bonds, without C–C bonds, and contains about 34.8% oxygen. Because of these properties, DME combustion produces almost zero PM emissions, low noise level and can tolerate a higher EGR rate to reduce NOx emissions to a greater extent than with conventional diesel fuel [6]. The low viscosity of DME causes leakage in the fuel supply system, which relies on small clearances for sealing. Its lower lubricity characteristics result in intensified surface wear on the moving parts within the fuel injection system. Therefore, addition of proper additives to prevent leakage and surface wear is essential for DME. The compressibility of DME is generally higher than that of diesel, so DME also requires more compression pump work compared to the diesel. In general, DME deteriorates the rubber seals, mainly due to its corrosive nature. For that reason, all existing rubber seals in injection systems should be replaced with non-corrosive materials [1]. Another advantage of DME is that it is non-corrosive to the fuel system structure and metal surfaces [5].

Table 1. The properties of DME and diesel fuel

Property	Diesel	DME
Chemical formula	C_xH_y	CH_3-O-CH_3
Molecular weight, g	170	46.07
Boiling point, °C	180-360	-24.9
Liquid density, kg/lt	840	668
Liquid viscosity, cP	4.4-5.4	0.15
Lower heating value, kJ/kg	42500	28430
Ignition temperature, °C	250	235
Cetane number	40-55	55-60
Stoichiometric air/fuel ratio	14.6	9
Modulus of elasticity, N/m^2	1.486x10^9	6.37x10^8
Mass fraction of carbon	86	52.2
Mass fraction of hydrogen	14	13
Mass fraction of oxygen	0	34.8

3. STUDIES ON DIMETHYL ETHER

In the literature, there are many studies on the production technologies, fuel properties, combustion characteristics, engine performance and exhaust emissions of DME. In studies on production technologies, different production techniques have been examined and evaluated in terms of cost [9, 11, 12]. In the studies on the fuel characteristics, the properties of DME especially different from diesel fuel such as the presence of oxygen in its content, lower density, lower viscosity, lower heating value and insufficient lubricity were investigated [5, 13-15]. In studies on injection characteristics, studies have been made on how DME improves spray and injection characteristics thanks to low density and low viscosity [16-23]. In studies on combustion characteristics, the effects of DME on parameters such as ignition delay time, combustion duration, mass fraction burnt, cylinder pressure and combustion temperatures were investigated [13, 24-36]. In studies on engine performance characteristics, the effects of DME on engine performance parameters such as engine torque and power, specific or total fuel consumption and brake thermal efficiency have been investigated [37-58]. In studies on exhaust emission characteristics, the effects of DME on the emissions such as carbon monoxide (CO), hydrocarbon (HC), particulate matter (PM) or soot, nitrogen oxides (NOx) and carbon dioxide (CO_2) have been investigated [59-78]. In the present study, only the effects of DME on engine performance are investigated.

4. EFFECTS OF DIMETHYL ETHER ON ENGINE PERFORMANCE

4.1. Air-Fuel Ratio

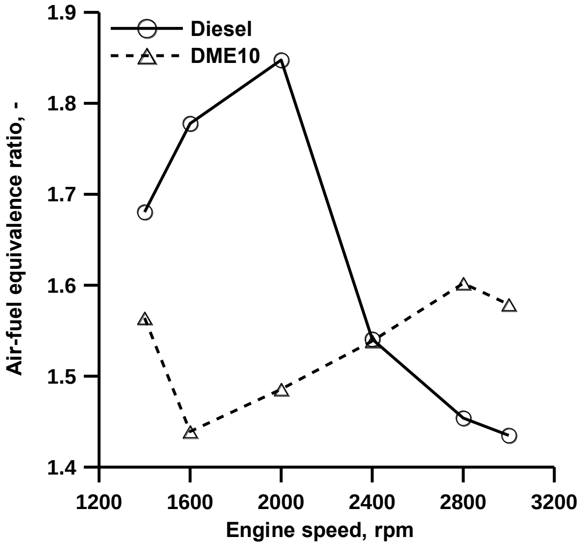
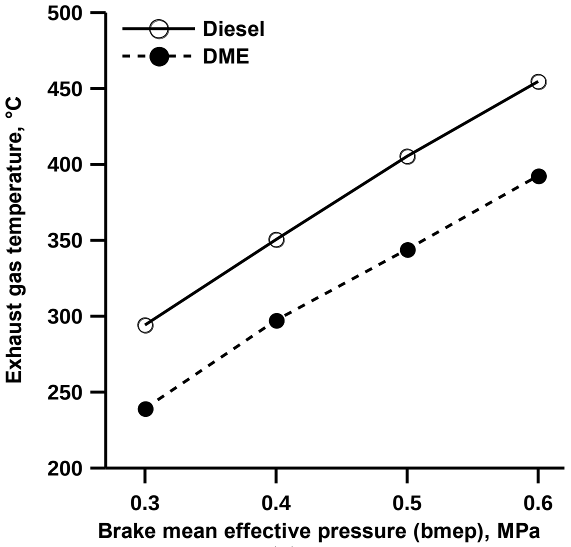


Fig. 3. Effects of DME additive on air-fuel equivalence ratio [55]

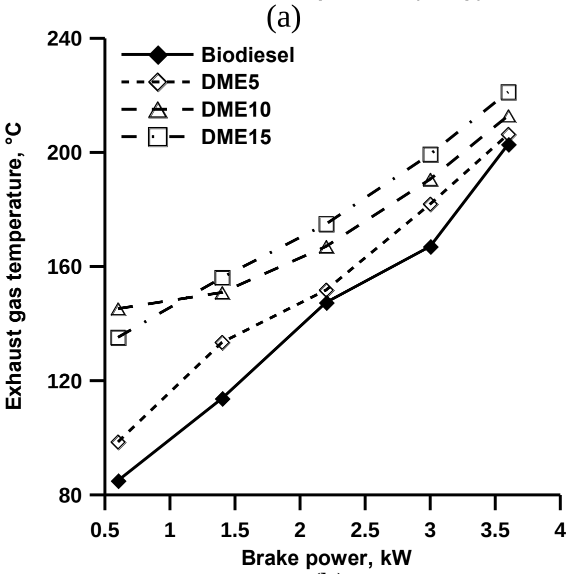
Fig. 3 compares the air-fuel equivalence ratio of DME10 blend with that of neat diesel operation. It can be seen that the air-fuel ratio of DME10 blend is lower at low engine speed and higher at high engine speed than in the case of neat diesel operation. This is due to the higher amount of fuel delivery at low engine speed and the lower amount at high engine speed. The lower air-fuel ratio will result in a higher output torque at low engine speed [55].

4.2. Exhaust Gas Temperature

Fig. 4(a) shows a comparison of the exhaust gas temperatures between DME and diesel fuel. The exhaust gas temperature is plotted against brake mean effective pressure with the injection timing as a parameter. It should be noted that the exhaust gas temperature is lower for DME by around 50 °C. The reason of this is the lower energy content of DME. The exhaust gas temperature is lower about 13.6-18.6% for pure DME in compared to diesel fuel [54]. In Fig. 4(b), the exhaust gas temperatures were increased for all the fuels with the increase of applied load. It is seen that the exhaust temperature of DME with biodiesel is increased because of enhanced combustion, compare to biodiesel fuel. DME15 shows higher temperature distribution at each load test on the engine than the other fuels namely DME5 and DME10. The main reason for large difference between DME15 and biodiesel, may be the improved combustion of DME15, due addition of dimethyl ether with biodiesel. Another reason may be the shortened combustion period of DME15 with increased flame velocity. Exhaust gas temperature was higher about 9-59% for the DME15 blend in compared to biodiesel [63].



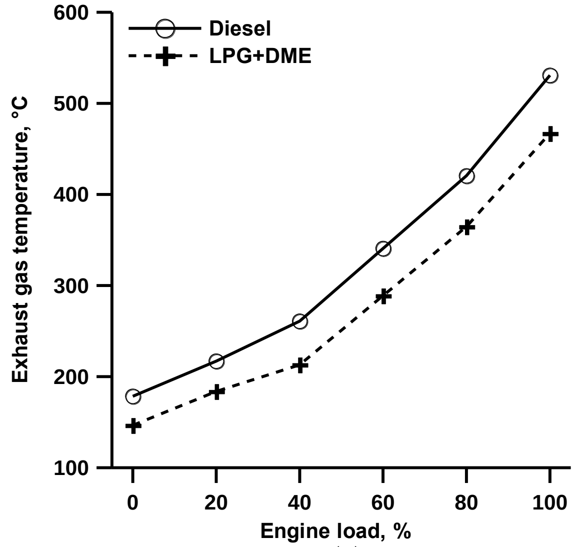
(a)



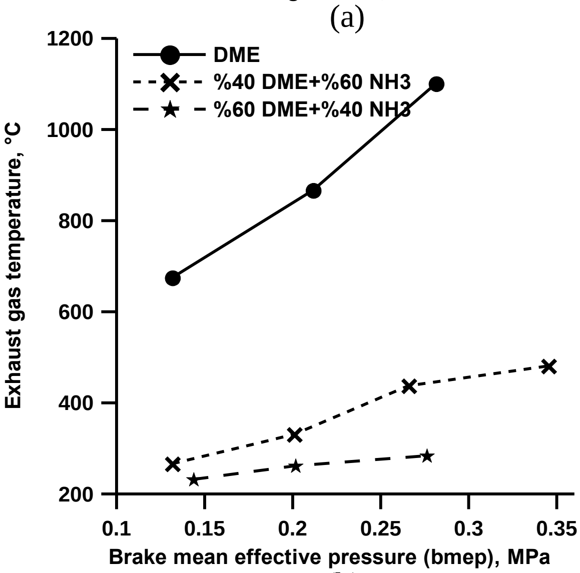
(b)

Fig. 4. Effects of a) DME [54] and b) DME with biodiesel [63] on exhaust gas temperature

Fig. 5(a) depicts the variation of exhaust gas temperature under different engine load conditions. It can be seen that in the case of LPG+DME operation, the exhaust gas temperature is found to be lower by about 40-50 °C throughout the load spectrum as compared to diesel operation due to the higher latent heat of vaporization of DME that cools the intake charge which in turn reduces the peak temperature of the combustion in the engine cylinder. The exhaust gas temperature for the LPG+DME blend was lower about 12-17.8% as compared to diesel fuel [24]. Fig. 5(b) shows the comparison of exhaust temperature versus bmep. The exhaust temperatures for 100% DME are higher than those for both 60%DME+40%NH3 and 40%DME+60%NH3. It should also be noted that as the ammonia concentration in the fuel is increased, the exhaust temperature decreases. The exhaust temperatures is lower about 65.6-74.2% for 60%DME+40%NH3 in comparison with pure DME. The reduction in exhaust temperature is due to the loss in energy of the combustion process caused by the high latent heat of ammonia. This is especially evident in the case of 40%DME+60%NH3 where the fuel charge has had sufficient time to fully evaporate, drawing the latent heat energy out of the in-cylinder air [41].



(a)

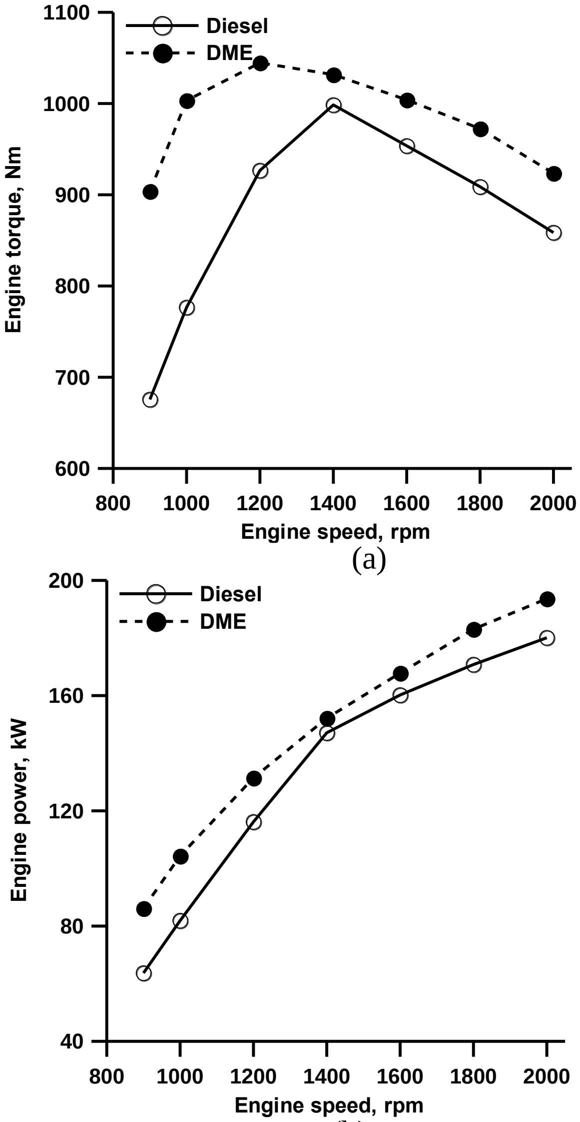


(b)

Fig. 5. Effects of a) DME+LPG [24] and b) DME +NH3 [41] on exhaust gas temperature

4.3. Engine Torque and Power

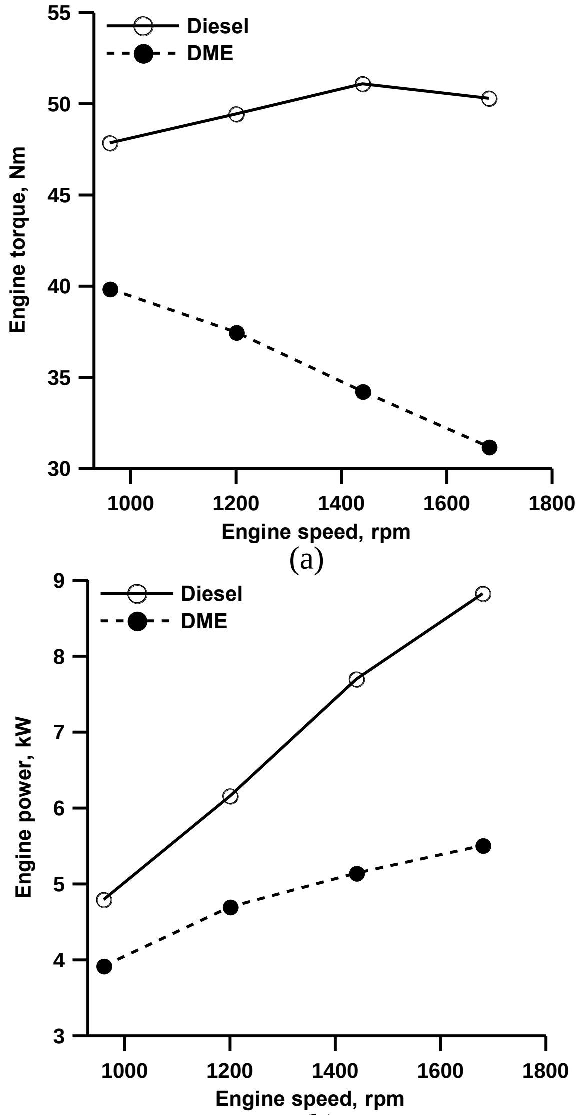
Fig. 6 (a) and (b) show the comparison of engine torque and power between DME and diesel fuel engine. It is seen that both torque and power of DME are greater than those of diesel at all engine speeds, especially at lower engine speed. The torque of the DME engine was increased by 29.1% and 32.8% at the speed of 1000 rpm and 900 rpm, respectively, in comparison with the diesel engine. Maximum output is usually determined by smoke limitation in diesel engines. However, there is no smoke limitation in DME engine due to its smoke-free combustion [10].



(b)

Fig. 6. Effects of pure DME on a) engine torque and b) engine power [10]

As seen in Fig. 7 (a) and (b), the torque and power are lower with DME than diesel fuel. The differences in engine torque and power are more obvious as the engine speed increases. The decreases in torque and power are sourced from the differences in fuel properties such as the vapor pressure, elastic modulus, density and energy content. Main reasons for the torque and power decrease are that lower energy content and higher vapor pressure of DME. The engine torque was decreased about 16.7-37.9% when using the pure DME fuel as compared by diesel fuel [47].



(b)

Fig. 7. Effects of DME on a) engine torque and b) engine power [47]

Fig. 8 (a) compares the power output of engines fuelled with the two kinds of fuel at the speed characteristic of full load. It can be seen from the figure that the power output of the engine fuelled with the blend is higher than that of the engine fuelled with neat diesel at low speed (at 2000 rpm and below), regardless of the heating value of the blend being lower than that of neat diesel fuel. However, the power for blend fuel operation is lower at high speed (2200 rpm and above) than that for neat diesel fuel operation. The larger delivery energy of the blend at low engine speed and the higher thermal efficiency achieve a higher power output at low engine speed for blend operation. The lower power output at high speed is due to the smaller delivery energy for the blend compared with neat diesel [54].

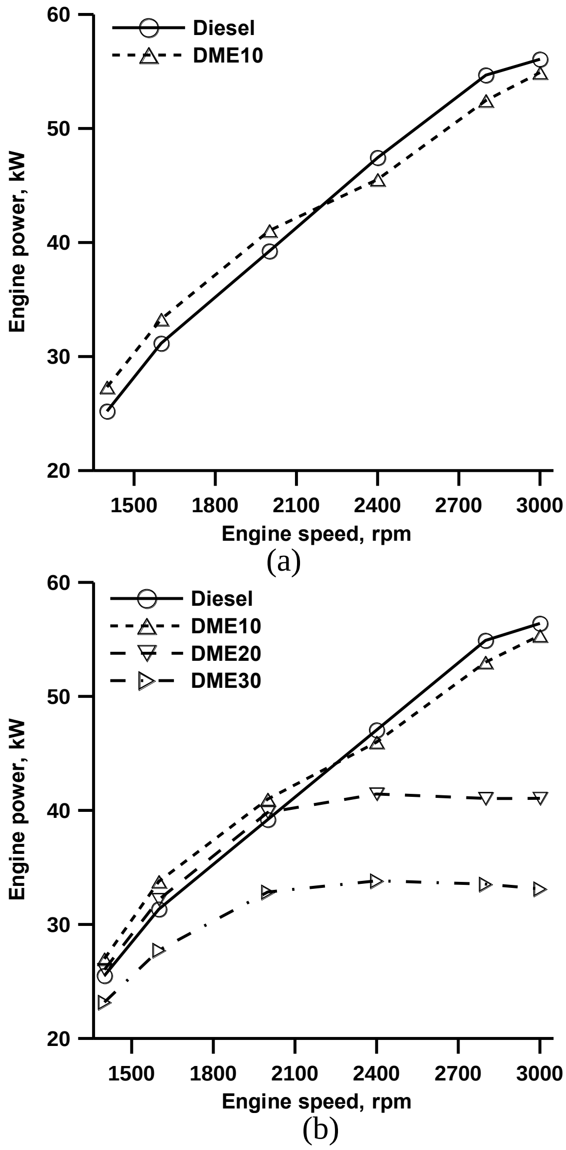


Fig. 8. Effects of the diesel-DME blends on engine power a) [54] and b) [66]

Fig. 8 (b) shows the comparison of power output of the engine fuelled with four kinds of fuels at speed characteristic of full load. It can be seen from the figure that the power output of engine fuelled with DME10 and DME20 are higher than those of neat diesel at low speed (at 2000 rpm and below), regardless of that the low calorific value of blend is lower than that of neat diesel fuel. (The low calorific value of DME10 is 96.7% of that of diesel and the low calorific value of DME20 is 93.4% of that of diesel.) It is possible that the larger fuel delivery energy for DME10 and DME20 operation achieve a higher power for blend operation at low engine speeds. But the power for blend fuel operation is lower at high speeds (2200 rpm and above) than that of neat diesel fuel operation due to the lower calorific value and smaller fuel delivery energy for blend comparison with neat diesel. Power output of DME30 is much lower than those of diesel operation due to its lower calorific value, which is only 90.1% of that of diesel. Low power output of diesel-DME blend fuelled engine can be improved by enlarging fuel supply amount of pump per cycle. It is also obvious that power output of engine decrease with the increase in DME content at full load. The engine power was lower about 9.1-41.2% for the DME30 blend as compared to diesel fuel [66].

4.4. Brake Specific Fuel Consumption

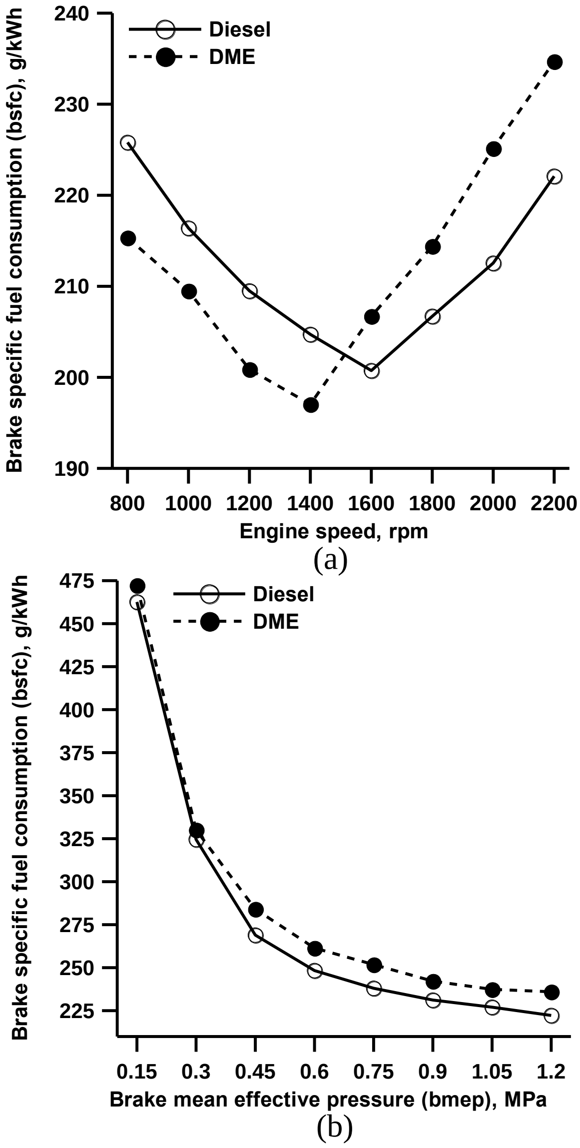


Fig. 9. Effects of pure DME on bsfc [10]

Figure 9 (a) and (b) shows the variations of bsfc with engine speed and load. It can be seen that for both fuels, the lowest bsfc is obtained in the range of speed where the maximum torque is achieved. It is found that in the case of full load, when engine speed is less than 1500 rpm, the equivalent bsfc of DME is better than that of diesel fuel. When engine speed is larger than 1500 rpm, the equivalent bsfc of DME is poorer than that of diesel fuel, which indicates that at high engine speed, the fuel consumption will deteriorate due to the lower heating value of DME. The bsfc was decreases about 3.1-4.6% at low engine speeds and was increases about 2.9-5.9% at high engine speeds for pure DME as compared with diesel fuel. With an increase in engine load, both bsfc of DME and diesel fuel are decreased. At the speed of 1400 rpm, the equivalent bsfc of DME engine is lower than that of the diesel engine at all test loads, especially at low load. At the speed of 2200 rpm, the equivalent bsfc of the DME engine is almost the same as that of the diesel engine at low load. With the increase of engine load, the equivalent bsfc of the DME engine tends to be higher than that of the diesel engine, especially at medium and high engine load. Due to the lower heating value of DME, to keep the engine output the same as that of the diesel engine, about 1.9 times as much as the diesel fuel volume should be injected into the combustion chamber per cycle, which leads to prolonged injection duration and combustion duration at high engine speed, and results in the deterioration of fuel consumption of DME [10].

Fig. 10 (a) depicts the effect of engine load on bsfc. The experimental showed the presence of DME can substantially reduce the bsfc compared to diesel fuel with higher engine load. The bsfc increases about 15.7% at low engine load and decreases about 4.4% at high engine load for diesel-DME blend as compared to diesel fuel. In order to the higher oxygen content of DME contributes to improved fuel oxidation even in locally rich fuel combustion zone [32]. Fig. 10 (b) shows the bsfc load characteristics at engine speed of 1800 rpm (maximum torque output speed). It can be seen that the bsfc was improved with the DME20 blend approximately 11.6% (28 g/kWh) at speed of 1800 rpm. The explanation for this is that since DME contains about 34.8% oxygen and has a faster evaporation speed and higher cetane number than diesel, the mixed DME in diesel enhances the combustion efficiency blended fuels, thus reducing fuel consumption [43].

Fig. 11 (a) and (b) compare the bsfc characteristics of the diesel fuel and DME10 blend at the different operating conditions. Under full-load speed characteristics and load characteristics, the bsfc of the DME10 blend was lower about 20 g/kWh (about 8%) on average compared with diesel. The reasons for the improvement in fuel economy are: 1) The ignition delay of DME is shorter than that of diesel owing to its higher cetane number which will result in a shorter ignition delay of the blend fuel, a smaller amount of premixed combustion, a lower maximum peak pressure and a lower rate of pressure rise in the cylinder, thus improving the thermal efficiency. 2) The boiling point of DME is very low (-24.9 °C), and it readily vaporizes and mixes with air in the cylinder, resulting in fast diffusion mixing and diffusion combustion velocity and a shorter combustion duration. According to the authors' test results, the total combustion of DME is 38° crank angle (CA) which is shorter than that of diesel operation (45° CA) resulting in a higher constant-volume degree of combustion. The blend fuel and its combustion have the same characteristics as neat DME [55].

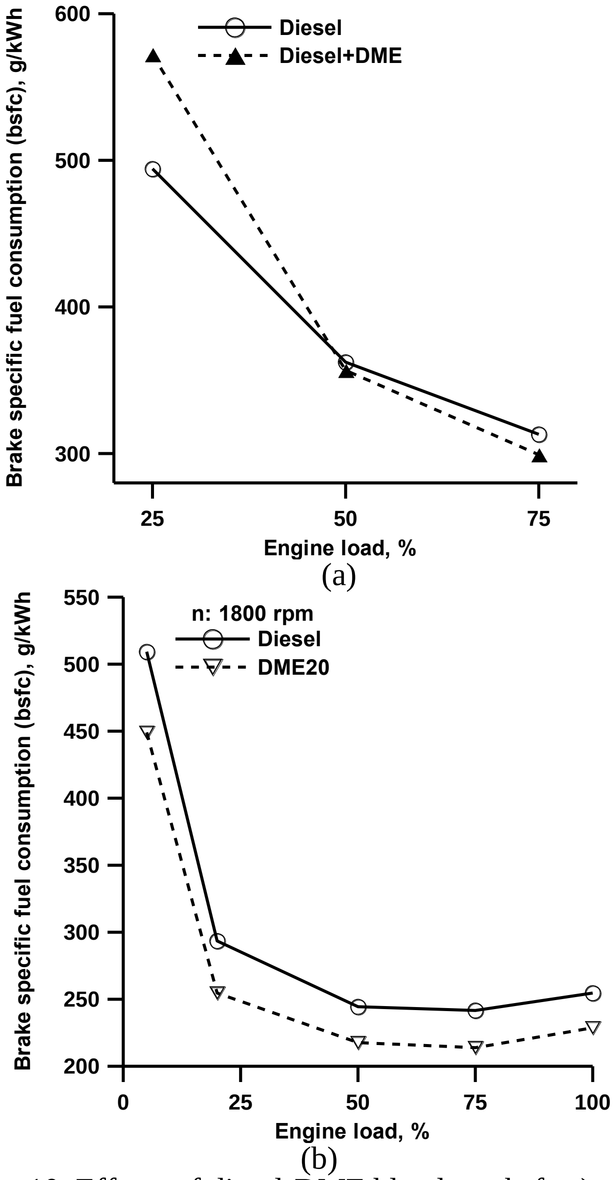


Fig. 10. Effects of diesel-DME blends on bsfc a) [32] and b) [43]

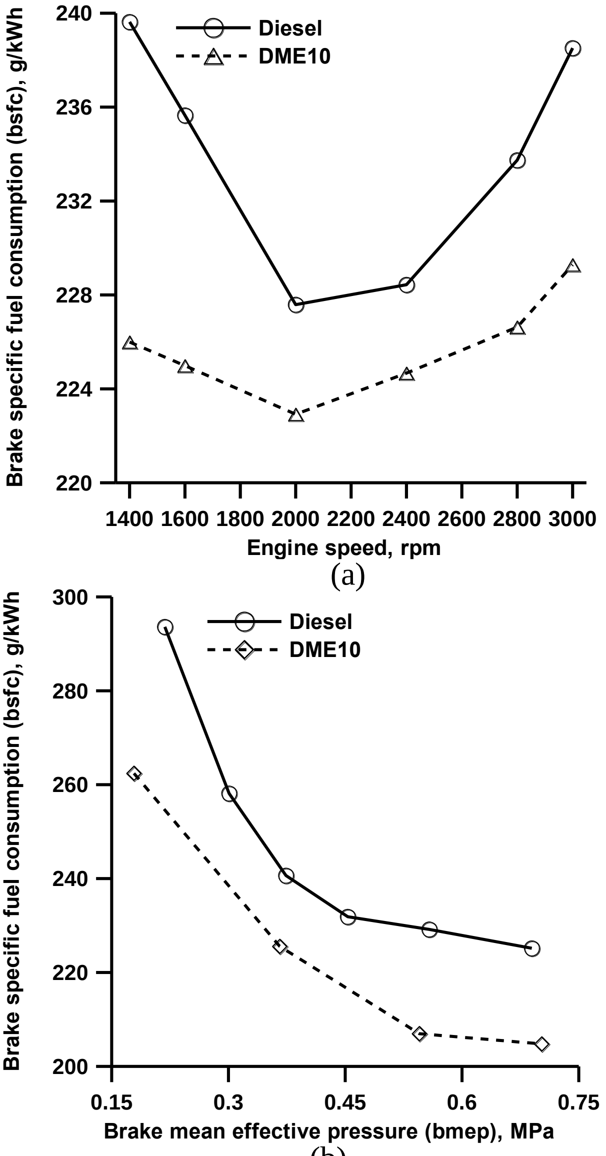


Fig. 11. Effects of diesel-DME blends on bsfc at the different operating conditions [55]

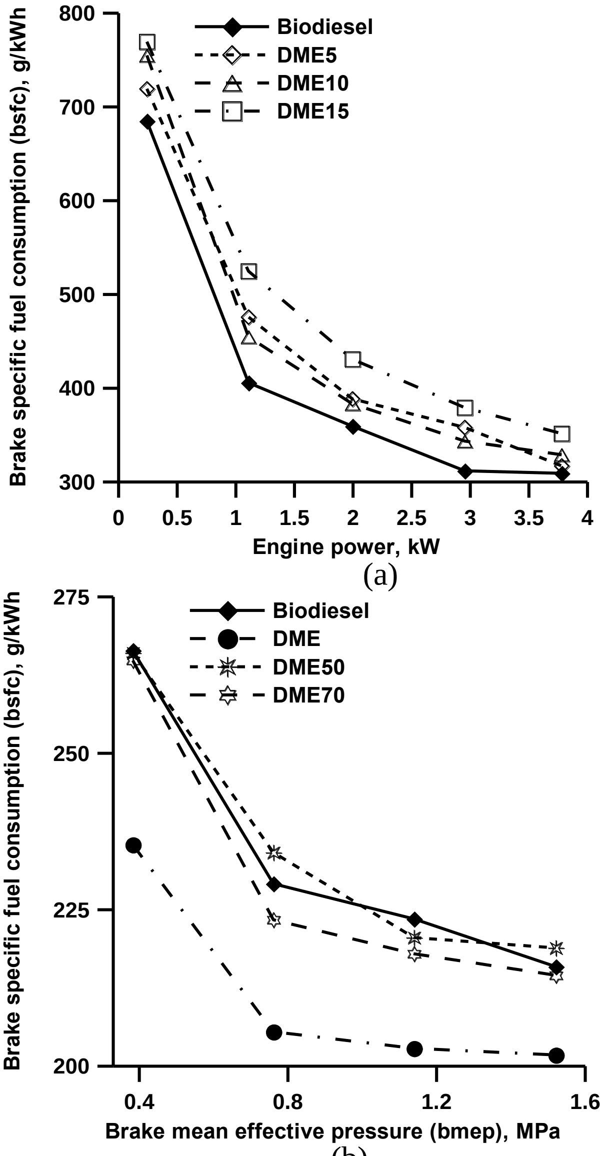


Fig. 12. Effects of biodiesel-DME blends on bsfc a) [59] and b) [65]

The bsfc variations by engine load for different fuels is presented in Fig. 12 (a). For all fuels, bsfc is found to decrease by increases in the load. Increased bsfc is found with all DME blends are due to the faster burning rates and more heat release rate. The bsfc of DME blends are higher than that of neat biodiesel for all loads. The bsfc for DME5, DME10 and DME15 are 19%, 21.2% and 25% higher than that of neat biodiesel. The increase of bsfc is mainly due to the lower calorific value of dimethyl ether compared with that of neat biodiesel [59]. The bsfc of biodiesel-DME blends is shown in Fig. 12 (b). With increase of bmep, the consumptions decrease. Compared to biodiesel, DME has good atomization performance; it mixed with air rapidly. The bsfc is reduced about 6.5-11.6% with pure DME in compared with pure biodiesel fuel. With the increase of DME proportion, the bsfc decreases [65].

4.5. Brake Thermal Efficiency

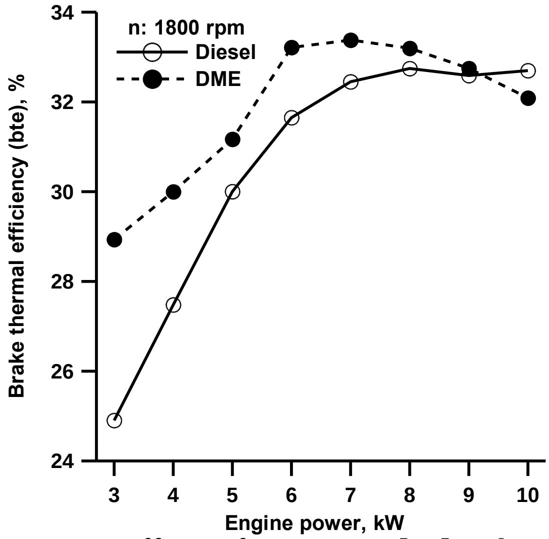
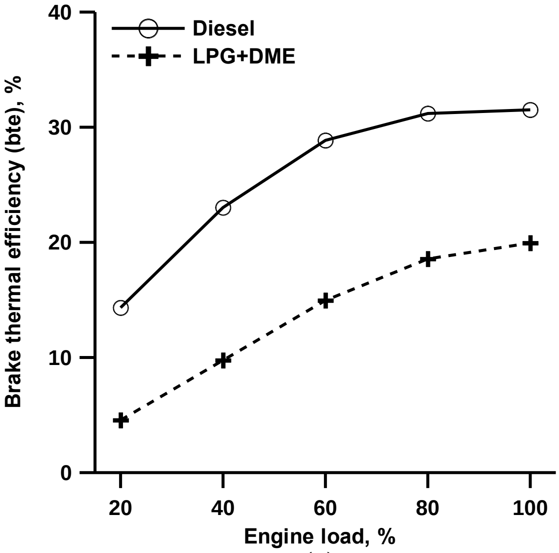
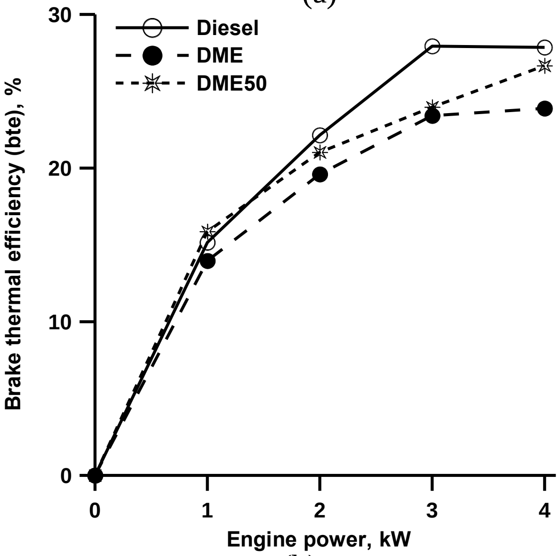


Fig. 13. Effects of pure DME [78] on bte

Fig. 13 shows the bte characteristics of the DME and diesel engine. It can be seen that the DME engine has a higher bte than diesel engine in the range of low and medium engine loads, but slightly lower efficiency at high load owing to its longer injection and combustion duration. However, it can be improved by adopting a much larger plunger diameter. The bte values of pure DME is higher than those of diesel fuel about 0.4-16.2% [78].



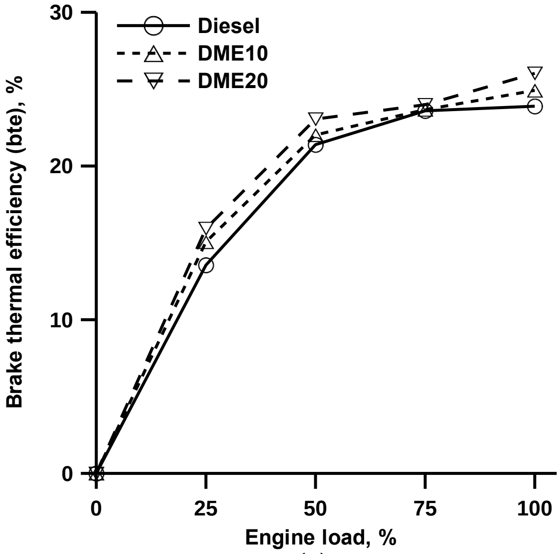
(a)



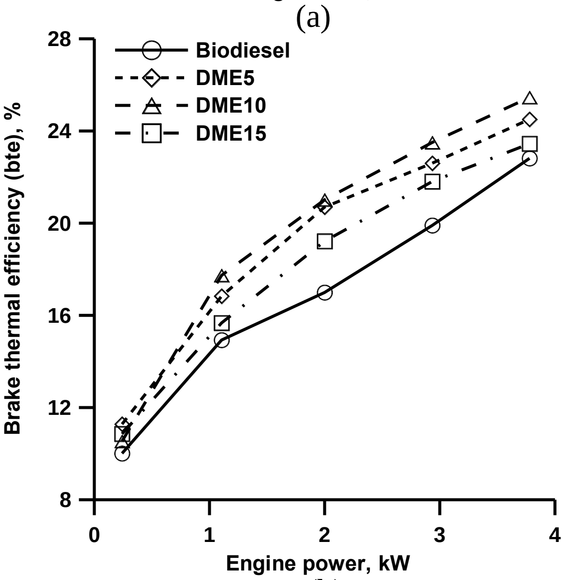
(b)

Fig. 14. Effects of a) LPG+DME blends [24] and b) the diesel-DME blends [53] on bte

Fig. 14 (a) shows the variation of bte against engine load for LPG+DME and diesel operation. It can be seen that the bte in LPG+DME mode is lower throughout the load spectrum than the diesel operation. The values of bte LPG+DME operation, it ranges from 5.1% to 20% whereas in the case of diesel operation it varies from 14.5% to 31.4%. The bte values are lower about 36.7-68.1% for LPG+DME blend compared to diesel fuel. The reason for the drop in bte is due to the higher latent heat of vaporization of DME that cools the intake charge, thereby reducing the temperature to about 19-20 °C, which in turn reduces the bte throughout the load spectrum compared to that of diesel operation [24]. Fig. 14 (b) depicts the bte of the compression ignition engine running with diesel, DME and diesel-DME blends. It can be observed that adding DME into the diesel fuel gives out almost the same performance as running with pure diesel fuel. Hence, DME serves as a suitable alternate fuel to replace a significant amount of the conventional diesel fuel [53].



(a)



(b)

Fig. 15. Effects of a) DME-diesel [56] and b) DME-biodiesel [63] on bte

Fig. 15 (a) shows the variation of bte with engine load. The bte is increased by using DME. As percentage of DME increases the bte also increases. This is due to low calorific value of diesel-DME blends. If the calorific value decreases the bte values increase. The bte values for DME20 blend are higher about 8.9-17.6 than those of diesel fuel [56]. The variation of bte with respect to load for different additive proportions of DME into biodiesel were considered for the present analysis and presented in Fig. 15 (b). In all cases, bte has the tendency to increase with increase in applied load. This is due to the reduction in heat loss and increase in power developed with increase in load. The bte of all blends of biodiesel-DME is higher than that of neat biodiesel. This is due to better mixture formation as a result of high volatility, lower viscosity and lower density of the blended fuels. The bte of DME5, DME10 and DME15 blends gives the higher efficiency compared to neat biodiesel. This is because of addition of more additives of DME decrease the viscosity of mixture and improves the atomization and hence better combustion takes place. It is observed from the figure that bte of DME5, DME10 and DME15 is 6%, 10%, and 3% higher than that of neat biodiesel at full load [63].

5. CONCLUSIONS

The effects of using the dimethyl ether in diesel engines are investigated on the engine performance characteristics in this review study. The following conclusions can be summarized as results of the study.

- Exhaust gas temperature generally decreases when using the dimethyl ether or dimethyl ether blends with diesel fuel due to its lower heating value, while dimethyl ether and its blends with biodiesel gives the higher exhaust gas temperature due to enhanced combustion.
- Dimethyl ether can provide the increments in engine torque and power especially at low load conditions, but the engine cannot produce the required torque and power with dimethyl ether or its blends when the engine is operating at high load conditions.
- Dimetyl ether gives the lower or closer brake specific fuel consumption values to diesel or biodiesel fuel at low blending ratios up to %15. However, brake specific fuel consumption can increase at high blending ratios or when using dimethyl ether as pure especially at high load conditions.
- Dimetyl ether and its blends with diesel or biodiesel give the better brake thermal efficiency by improving the combustion because of the desired fuel characteristics and oxygen content of dimethyl ether.

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