Exhaust Emissions and Performance of Diesel Engine Fueled with Biomass-based Oil Blends

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Abstract
The purpose of this study was to compare methyl ester from soybean oil, waste soybean oil/diesel fuel blend (Blend 50) and waste soybean oil/polystyrene pyrolysis oil blend (Blend PS) with conventional diesel fuel when fueling a diesel engine. Blends of 50% by volume were investigated. The experimental test engines were Mitsubishi D-800 diesel for performance and emissions, and Yanmar YDG250A diesel engine for biomass-based generator. Their exhaust emissions, performance data were collected for steady state operation at all load conditions.
Experimental results show that NOx emissions for Blend PS increase to 20%. HC, HCHO and CO emission levels are higher for Blend PS at lower load conditions. All of the biomass-based fuels (Blend 50, Methyl ester and Blend PS) reduce smoke pollution degree compared to the baseline diesel fuel. The largest reductions in smoke degree are observed with Methyl ester, which yielded 40% reduction compared to the diesel fuel. Fuel consumption is lower for diesel oil due to its higher calorific value. From indicator diagram in cylinder, ignition delay of Blend PS is large at lower load conditions. Carbon deposits on cylinder head are observed after 400 hours operating on Blend 50 and diesel oil. Based upon evaluation of engine performance and emissions, biomass blends appear to be renewable, ecologically acceptable fuels of diesel engine. Diesel engine/Generator can be operated on biomass fuels to produce electric power as the distributed power system.. Also discussed are the usability of biomass-based fuels as alternative fuel, as well as availability for treatment processes of the waste plant oil and waste plastics.

Equipment and procedure
Test engine specifications are shown in Table 1. Fig. 1 shows the overall engine test set-up. Blend 50 (diesel fuel containing 50% volume waste soybean oil), methyl ester from waste soybean oil, Blend PS (pyrolysis oil from polystyrene containing 50% volume waste soybean oil) and JIS #2 diesel fuel were used for this investigation. The physical properties of test fuels are shown in Table 2.

Experimental results
The NOx and CO emissions are similar for Blend 50, methyl ester and diesel fuel, though the NOx and CO with Blend PS is higher compared to these oils as shown in Fig.2. Fig.3 shows that the HC and HCHO emissions are higher for Blend PS at lower load conditions. Specific fuel consumptions for all the soybean blends are somewhat higher in inverse proportion to calorific value of fuel. The smoke pollution degree is measured by using Bosch smoke meter. Fig.4 show the variations of smoke intensity with engine load for blend oils and diesel fuel. The smoke emission is the highest for the diesel fuel and is somewhat lower for all soybean blends. Fig.5 shows the combustion chamber pressure records at 28% load. Blend PS had a much longer ignition delay than other oils and this contributed to the higher CO, HC and HCHO. The ignition delay period is similar for all fuels at higher load. The photo shows the carbon deposits on cylinder head after 400 hours operating with Blend 50 and diesel fuel, while the engine running has been smooth throughout. Yanmar diesel engine/generator YDG250A can operate on Blend PS and produce electric power of 2kW.

Table 1 Test engine specifications

Model	MITSUBISHI D-800	Power output	5.1kW at 2400rpm
Cylinders	1	Chamber type	DI
Displacement	411cc	Injection timing	19 deg. BTDC
Compression ratio	18:1		

Table 2 Physical properties of test fuels

Properties	Diesel Fuel	Blend 50	Methyl ester	Blend PS
Density(30.C) kg/.	836	883	885	912
Viscosity(35.C)./s	3.25	11.49	4.59	6.76
Lower calorific value MJ/kg	43.5	39.8	37.2	40.4
Cetane index	54.6	48.0	53.7	-
Carbon residue wt%	0.01	0.19	0.08	0.31
C:H:O wt%	86:14:0.1	81:13:6	76:12:12	84:10:6
Sulfur wt%	0.02	0.01	0.01	0.01
Nitrogen wt%	0.1	0.1	0.1	0.3
Ash wt%	0.01	0.01	0.03	0.01

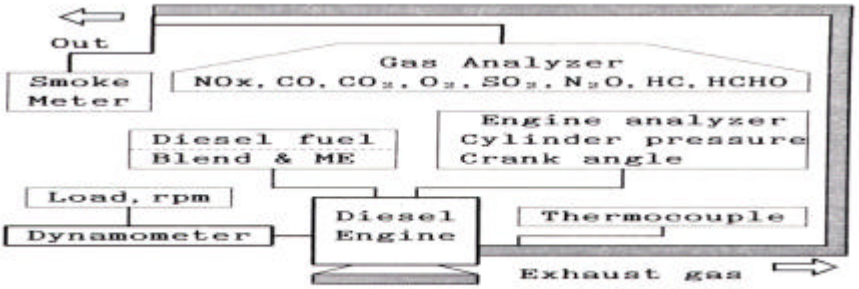

Fig. 1 Diesel engine test set-up operated on diesel fuel, blend fuels and methyl ester (ME)

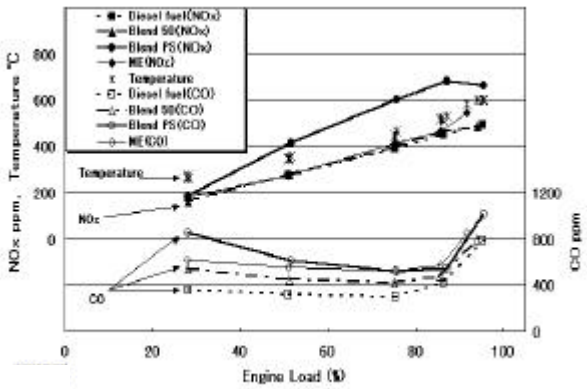

Fig.2 NOx, CO concentrations and exhaust gas temperature

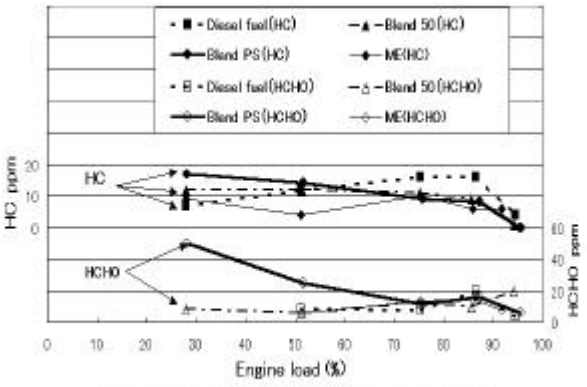

Fig. 3 HC and HCHO concentrations in exhaust gas

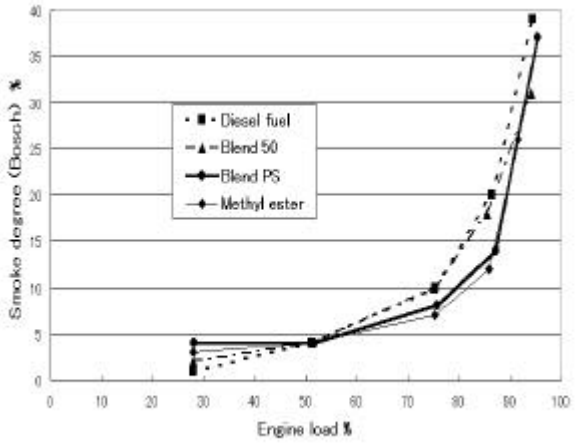

Fig.4 Smoke pollution degree of diesel exhaust

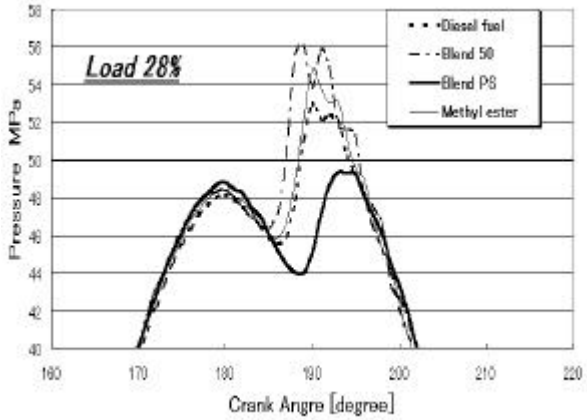

Fig.5 Cylinder pressure records