Fueling 5.9L and 7.3L Navistar Engines with Biodiesel-20

Leon G. Schumacher Steven C. Borgelt Mark D. Russell William G. Hires1 The authors are Leon G. Schumacher, Associate Professor, Steven C. Borgelt, Assistant Professor, Mark D. Russell, Research Specialist, and William G. Hires, Associate Professor, Agricultural Engineering Department, University of Missouri, Columbia, MO 65211.

ABSTRACT

Fueling diesel engines with a blend of biodiesel and petroleum diesel may result in both an improvement in engine exhaust emissions and a renewable source of fuel for these engines. Investigations of the impact of fueling diesel engines with a blend of biodiesel and petroleum diesel have been ongoing at the University of Missouri-Columbia as well as at other locations. The impact upon emissions and real-world performance of diesel engines has been the focus of our work. The research evaluated the utilization of a 20%/80% biodiesel/petroleum diesel blend, (BD20). Regulated engine exhaust emissions, power, and fuel consumption results are shown. An analysis of the findings suggests that overall emissions may be reduced while maintaining both acceptable power and fuel consumptions.

KEYWORDS: Biodiesel, Emissions, Engine Tests, Engine Emissions

INTRODUCTION

Recent research indicates that a twenty percent (20%) blend of Biodiesel with diesel fuel (BD20) provides the optimum improvement in exhaust emissions from diesel engines. This project evaluated two City of Columbia Public Works vehicles fueled by this optimum blend. The vehicles were operated under normal operating conditions. The operating characteristics and exhaust emissions for these vehicles were monitored and compared to a control group of vehicles fueled with No. 2 low sulfur diesel(LSD).

PURPOSE AND OBJECTIVES

The purpose of this investigation was to investigate the effects of fueling diesel engines with BD20. A variety of biologically derived oils (rapeseed, sunflower, lard, and others) may be used to produce biodiesel. The biodiesel used in this project was derived from soybeans. Two Public Works vehicles, a city bus and a refuse truck, were fueled with BD20. Specific objectives of this investigation were to:

1. To evaluate the general operating characteristics of a working vehicle fueled with BD20.

2. To determine the exhaust emissions of vehicles fueled with BD20.

METHODOLOGY

Test Equipment

A Celesco Model 200 opacity meter was used to determine engine exhaust opacity. This opacity meter meets or exceeds ISO 3178 and SAE J1243A requirements.

Power measurements were made using a Superflow 601 Chassis Dynamometer. The accuracy of this dynamometer is within one percent of the measured value.

A NOVA 7550P5B portable engine exhaust emissions analyzer was used to quantify the engine exhaust emissions. This analyzer meets BAR 84 requirements.

Vehicles.

Two Ford F350 vehicles with Navistar 7.3L engines and two Navistar 4700 LP vehicles with 5.9L Navistar engines were used in this project. Each vehicle was pretested, operated in a normal manner for six months and then post-tested for power and exhaust emissions during the project. The vehicles were closely matched vehicles in normal operation at the City of Columbia. The 7.3L engine is indirect injected and naturally aspirated with a rated power of 126.8 kW. The 5.9L engine is direct injected and turbocharged with a rated power of 141.7 KW.

Fuel.

The biodiesel was analyzed by Cleveland Technical Center, North Kansas City, Missouri. The density of the biodiesel was 0.865 g/ml at 21oC (70oF). The diesel fuel used was reference diesel No. 2 diesel fuel, density = 0.832 g/ml at 21oC (70oF). The density of the fuel was utilized to mix the blends on a mass basis to produce the desired volume ratio. An analysis of the fuels used to prepare the BD20 blend can be found in Table 8.

Testing Procedures

The engines were tested at recommended operating engine coolant temperatures. The manufacturer's rated torque and RPM operating range were used to determine the number of test lugs while testing the engine at Fabick Power Systems. Power, HC, NOx, CO, and engine exhaust opacity were measured six times for the 7.3L engine and seven times for the 5.9L engine. The data were recorded at 30 second intervals during the last two minutes of each test lug (Note the explanation that follows)

Table 1. Test Engine Speeds used to evaluate power, fuel consumption and exhaust emissions.

Engine RPM Test Lug 7.3L 5.9L		
1	1600	1700

2	1950	1900
3	2300	2100
4	2650	2300
5	3000	2500
6	3350	2700
7	N/A	2900

RESULTS

Power.

Small differences in the power were noted for the BD20 engines when compared to the diesel fueled control engines. Changes in power ranged from an increase of 13% to a reduction of 3%.

Table 2. Power(kW) averaged over all test lugs for 5.9L & 7.3L Navistar Engines fueled with BD20.

	Engine	Vehicle	Diesel	BD20	%Change
Pretest Posttest	5.9L 5.9L	1433 1433	77.09 64.92	86.93 92.57	12.8 9.0
Pretest Posttest	7.3L 7.3L	311 311	63.38 56.78	62.64 55.08	-1.2 -3.0

Opacity.

Schumacher et al. (1992), (1993) and Feldman et al. (1992) observed smoke reductions when fueling with a soybean derived biodiesel and rapeseed derived biodiesel. Smoke emissions were lower during the posttest. Changes ranged from a 31% increase to a 44%reduction in engine exhaust smoke. The high opacity readings on the 7.3L pretest were due to the test conditions.

Table 3. Opacity(%) for 5.9L & 7.3L Navistar Engines

fueled with BD20.

	Engine	Vehicle	Diesel	BD20	%Change
Pretest Posttest	5.9L 5.9L	1433 1433	2.55 1.51	2.57 1.98	0.8 31.1
Pretest Posttest	7.3L 7.3L	311 311	8.72 1.24	7.32 0.70	-16.1 -43.5

Carbon Monoxide Emissions.

Carbon monoxide emissions for the test vehicles were mixed. The test engines produced fewer CO emissions during the pretest while fueled with BD20 (as compared to fueling with No. 2 LSD). The test engines unexpectedly produced higher CO emissions during the posttest when fueled with BD20 (as compared to fueling with No. 2 LSD).

Table 4. Carbon Monoxide Emissions(%) for 5.9L & 7.3L

Navistar Engines fueled with BD20.

	Engine	Vehicle	Diesel	BD20	%Change
Pretest Posttest	5.9L 5.9L	1433 1433	0.03 0.03	0.02 0.03	-33.3 0.0
Pretest Posttest	7.3L 7.3L	311 311	0.29 0.06	0.23 0.08	-20.7 -33.3

Oxides of Nitrogen Emissions.

A direct relationship existed between the concentration of Biodiesel in the fuel and the amount of oxides of nitrogen exhaust emissions. Both engines produced lower levels of NOx during the posttest as compared to the pretest when fueled with a 20:80 blend.

Table 5. Oxides of Nitrogen(ppm) for 5.9L & 7.3L Navistar

Engines fueled with BD20.

	Engine	Vehicle	Diesel	BD20	%Change
Pretest Posttest	5.9L 5.9L	1433 1433	564.5 421.8	597.8 500.3	5.9 18.6
Pretest Posttest	7.3L 7.3L	311 311	519.0 428.7	506.3 421.3	-2.4 -1.7

Hydrocarbon Emissions.

An inverse relationship existed between the concentration of biodiesel in the fuel and the amount of hydrocarbon exhaust emissions. Hydrocarbon emissions were reduced each time the engine was tested when compared to tests conducted while fueled with reference diesel fuel.

Table 6. Hydrocarbon(ppm) for 5.9L & 7.3L Navistar Engines

fueled with BD20.

	Engine	Vehicle	Diesel	BD20	%Change
Pretest Posttest	5.9L 5.9L	1433 1433	5.25 12.75	3.75 8.75	-28.6 -31.4
Pretest Posttest	7.3L 7.3L	311 311	10.33 13.33	9.67 3.33	-6.4 -75.0

Fuel Consumption During Engine Power Testing.

BD20 fueling produced mixed results in terms of fuel consumption. In general, small reductions in fuel consumption were noted.

Table 7. Fuel Consumption During Engine Power Testing (Lph) for

5.9L & 7.3L Navistar Engines fueled with BD20.

	Engine	Vehicle	Diesel	BD20	%Change

Pretest Posttest	5.9L 5.9L	1433 1433	33.6 34.1	33.2 33.3	-1.2 -2.4
Pretest Posttest	7.3L 7.3L	311 311	32.9 30.9	31.5 31.3	-4.3 1.5

Table 8. Fuel properties of Biodiesel and Reference Diesel fuel

Fuel Property	Fuel ASTM Biodiesel Low Sulfur Test Reference Procedure Diesel		
Density g/L Gross Heat Value MJ/Kg Cloud Point 0C Pour Point 0C Flash Point 0C Viscosity @ 0C Sulfur Carbon Residue Cetane Number Ash Free Glycerine Total Glycerine % Ester	D1298 D2382 D2500 D97 D92 D445 D129 D524 D613 D482 G.C. G.C. G.C.	0.86-0.90 37.2 3.3c (38 0F) Max -2.2C (28 0F) Max 149C (300 F) Min 4.00-5.50Cst 0.02% Max 0.1% Max 48 Min 0.02% Max 0.03% Max 0.2% Max 97.5% Min	0.8466 42.4 -14C (6 0F) -23C (-10 0F) 67C (152 0F) 2.7Cst 0.033% 86.8% 46.7 N/T N/Ap. N/Ap. N/Ap.

Distillation in 0C		264 (508 0F)	187 (369 0F)
IBP		327 (622 0F)	213 (416 0F)
5		331 (628 0F)	222 (431 0F)
10		N/T	233 (451 0F)
20		335 (636 0F)	244 (471 0F)
30		337 (638 0F)	264 (507 0F)
50		340 (644 0F)	285 (545 0F)
70		N/T	298 (568 0F)
80		343 (650 0F)	314 (597 0F)
90		350 (662 0F)	328 (622 0F)
95		351 (664 0F)	338 (640 0F)
End			

N/T = Not tested

N/Ap = Not applicable

G.C. = Gas Chromatograph

CONCLUSIONS

The tests conducted indicate that an unaltered diesel engine can be fueled with predictable results. Specific conclusions and trends noted were based on the results of this investigation.

1. Smoke density (opacity) decreased with BD20 fueling. The BD20 blend also showed decreased, when comparing the pretest and post-test. However, the tests showed wide variations in the data.

2. Carbon monoxide (CO) exhaust emissions increased from the pretest to the post-test. This may show that CO exhaust emissions may increase over time with BD20 fueling.

3. Hydrocarbon (HC) exhaust emissions decreased with BD20 fueling when compared to diesel fueling. The BD20 fueled engines emitted less HC during the post-test than during the pretest.

4. Oxides of Nitrogen (NOx) increased with BD20 fueling.

5. The effects on engine power are engine specific. The 7.3L engine power increased while the 5.9L engine power decreased when fueled with BD20.

6. Fueling duration may also impact engine power. The 5.9L engine produced more power during the posttest.

RECOMMENDATIONS

The Environmental Protection agency has mandated that the level of oxides of nitrogen emissions be equal or less than the emissions produced by the engine if fueled on reference diesel fuel. The findings of this investigation suggest that extended fueling with a 20:80 blend, rather than a screening test such as that conducted by Fosseen and Goetz, (1993), could serve to reduce the oxides of nitrogen emissions without reducing power or increasing fuel consumption. Based on these observations, the following recommendations are made:

1. Engine optimization strategies should be developed that fully take advantage of the physical and chemical makeup of biodiesel.

2. Additional controlled biodiesel blend fueling projects should be initiated that assess the engine exhaust emissions prior to and after extended periods of fueling with biodiesel blends. These efforts are needed to fully characterize the engine exhaust emission trends that can be expected when fueling with biodiesel/petroleum diesel blends.

3. Additional controlled biodiesel blend fueling projects are needed to fully access engine life when fueling with biodiesel blends.

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