

Performance, Emission and Pump Wear Analysis of JP-8 Fuel for Military Use on a 558 kW, CIDI Diesel Engine

2010-01-1518

Published
05/05/2010Anand Kumar Pandey and MR Nandgaonkar
College of Engineering

Copyright © 2010 SAE International

ABSTRACT

Investigating the impact of JP-8 fuel on diesel engine performance and emission is very important for military combat vehicles, due to its great potential as alternative fuel under single fuel strategy program for military operation. There is a known torque, horsepower and fuel economy penalty associated with the operation of a diesel engine with JP-8 fuel. On the other hand, a few experimental studies have suggested that JP-8 fuels have the potential for lowering exhaust emissions, especially NO_x, CO, HC and smoke opacity compared to diesel fuel. This research evaluates the effect of using JP-8 fuel in a heavy duty diesel engine on performance, emission, and pump wear, and subsequently proposes change to the fuel injection pump calibration to match the designed required operational engine performance with diesel fuel. Experiments were carried out on a 558 kW, B-46-6, supercharged, 12-cylinders, CIDI engine with a hydraulic dynamometer. The results indicate that torque and horsepower of diesel fuel can be matched with fuel economy penalty lower than 4.5%, by increasing the volumetric fuel quantity to compensate the lower density of JP-8 fuel. The lower cetane number of JP-8 fuel caused a slight increase in ignition delay but improved the combustion at load condition, thus lowering the combustion noise. Emissions such as CO, HC, NO_x, and smoke opacity were measured on engine maximum operating speed of 2000 rpm at 100% load condition, whereas volumetric fuel consumption was measured between 1200-2000 engine rpm under load conditions. The fuel pump wear was tested after 100 hours run.

INTRODUCTION

Military tactical and combat vehicles are mostly powered by diesel engine. Supercharged diesel engines offer high power

and favorable reliability. Use of JP-8 fuel (Jet propellant 8, kerosene based) in combat vehicles under single fuel concept (1), for both helicopters and ground combat vehicles, offers a chance for logistical streamlining. As approximately 65 percent military supply is bulk diesel fuel, standardization of single fuel reduces costs and optimizes logistics. The properties of JP-8 fuel are similar to diesel fuel (Table 1).

Diesel engines are designed for both military and commercial use, but their base calibrations are based on the use of diesel engine. The fuel injection pump required necessary calibrations by increasing the volume of JP-8 fuel to match the mass of fuel per stroke for dual use (diesel/JP-8) with optimal performance (12).

The objective of this research is to investigate the effect of using JP-8 fuel in military combat diesel engine on combustion, performance, emissions, and pump wear. In addition, propose calibrations, i.e. modification of fuel injection pump that could be required to compensate for possible performance losses associated with use of JP-8 fuel.

Table 1. Properties of fuels selected for engine experiments

Fuel Properties	Diesel	JP-8	Test Method
Relative Density@15°C	840	805	ASTM D-4052
Distillation, °C 10%Rec.Temp 50%Rec.Temp 90%Rec.Temp	218 283 348	151 200 238	ASTM D-86
Sulphur Content, %wt	0.033	0.253	ASTM D-4294
Flash Point (° C)	65.0	44.5	ASTM D-93
Viscosity @ 40°C (cSt)	2.6	1.4	ASTM D-445
Cetane No	51	46	ASTM D-613
Boiling point Range (° C)	173 -335	169 -283	ASTM D-86
LHV MJ/kg	42.9	43.4	ASTM D-240
Aromatic Content, % (Vol)	28.4	13.6	ASTM D-1319

Table 2. Engine specifications

Make	B-46-6
Rated Brake Power (kW) at 2000 rpm	585
Rated Torque (N-m) at 1400 rpm	3188
Number of cylinder	12
Bore x Stroke (mm)	150 x 180
Displacement volume (cc)	38886
Compression ratio	14:1
Lubrication System	Forced Feed
Cooling System	Water cooled
Breathing	Super charged

EXPERIMENTAL SET-UP

A supercharged B-46-6, 12-cylinder, four stroke, variable speed, compression ignition direct injection (CIDI) diesel engine was tested for this research (Figure 1). The basic specifications of the engine are given in Table 2. An SAJ electronic fuel meter was used to measure the fuel flow rate. Gas analyzer (CO, HC, NO_x; Indus Automotive Exhaust Monitor, Model PEA 205 (Table 3) using electrochemical sensors) was used to measure engine exhaust emission along with digital sound level meter, AGRONIC (model 8928, range 40-130 db, resolution 0.1 db) and AVL smoke meter (model 437, range opacity 0-100% HSU, resolution opacity

0.1% HSU) were used to measure emissions on a dry basis, and the results were subsequently converted to a wet basis.

Cylinder pressure has been measured using a piezo-electric pressure transducer and charge amplifier. Experiments were performed with JP-8 fuel at 100% load conditions. The Performance were studied and compared with diesel baseline fuel. All measurements were performed using the original engine settings.

Table 3. Exhaust Emission Analyzer Specification

Emission	NO _x (ppm)	HC (ppm)	CO (vol)
Operating Range	0-5000	0-10000	0-20
Accuracy	0.050	2	0.02
Repeatability	±1%	±20ppm	±0.1%

(See Figure 1 after last section of paper.)

METHODOLOGY

Engine speed was increased to 1000 rpm, and then increased to 2000 rpm with increment of 100 rpm, after completion of a warm-up procedure. At each stage, the engine was stabilized for 10 minutes, to obtain steady-state condition. After the engine was warmed, the first test was taken with diesel fuel then it was switched over to JP-8 fuel; and general experimental procedure was carried out. A fuel switching arrangement was provided to change over from one fuel to another, while the engine was running. At the end of JP-8 fuel experiment, the JP-8 fuel valve was closed and the diesel fuel valve opened. The engine was kept running for 15-20 minute before shut down to flush out the remaining balance of JP-8 fuel from the fuel lines, injection pump, and injectors so that it would be useful for the next set of experiment.

RESULT OF WORK AND DISCUSSION

The engine performance and emission characteristics of diesel and JP-8 fuels are compared at maximum operating speed and 100% load.

RATE OF HEAT RELEASE

The heat release rate based on the recorded cylinder pressure data was analyzed. The heat release rate at selected operating

points of diesel vs. JP-8 fuel is shown in Figure 2a. Ignition delay with JP-8 is higher than that of the diesel fuelled engine. A number of fuel properties can have an impact on ignition delay, but the primary effect is likely from the lower cetane number of JP-8 than diesel fuel.

PERFORMANCE CHARACTERISTICS

JP-8 fuel has a cetane rating significantly lower than the tested diesel fuel, slightly higher heating value, lower viscosity, and density. The lower density will cause an insignificant loss in power; Power decrease with JP-8 fuel seems significant with respect to diesel fuel (Figure 2b, 2c).

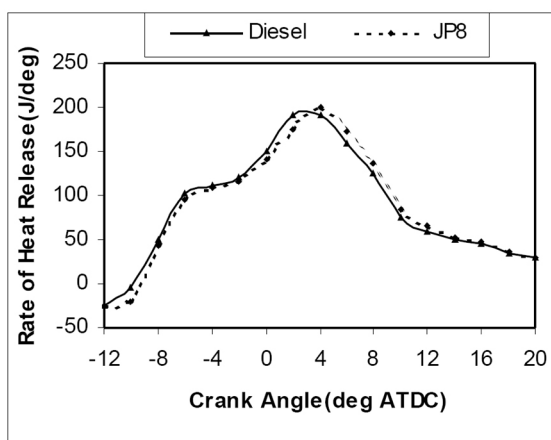


Figure 2a. Heat release rate of diesel vs. JP-8 fuels at full load condition

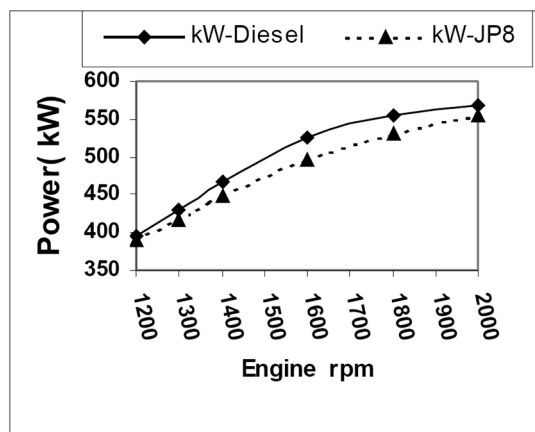


Figure 2b. Power output for diesel vs. JP-8 fuels.

lower density of JP-8 fuel leads to a lower LHV on a volume basis. Other researchers, on smaller engines, also found increase in BSFC when diesel engine was tested with JP-8 fuel (2,4).

A comparison of the net heat of combustion values of fuels tested shows that JP-8 fuel has 2% higher heat of combustion value. This implies that BSFC of the engine operating on JP-8 fuel should be 2% less than that of the engine operating on diesel fuel. Whereas other researchers (12) have measured BSFC values for JP-8 fuel on turbocharged engine about 2-4% greater than that for diesel fuel, significantly higher than predicted, whereas on military supercharged engine, BSFC has measured 4.5% higher than diesel fuel. Although JP-8 fuel has higher LHV than diesel fuel on a mass basis, its lower density leads to lower LHV on a volume basis. Lower viscosity will also result in increased losses from the pumping element leakage. Statistical analysis shows that there is no significant difference in leakage loss between the two fuels.

Thus it is possible to match the performance of the engine with diesel fuel by increasing the volume of JP-8 fuel to match the mass of fuel per stroke.

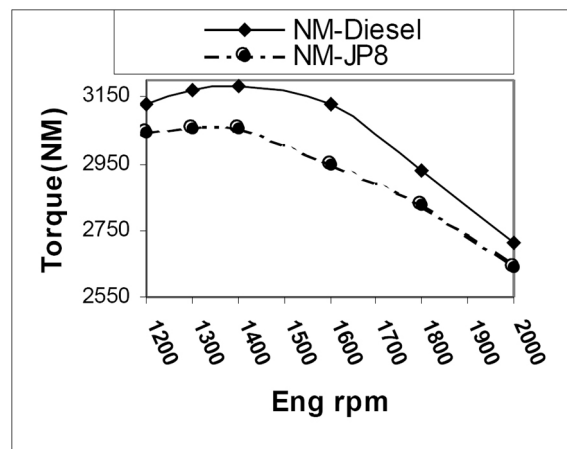


Figure 2c. Brake torque for diesel vs. JP-8 fuels.

BSFC

The brake specific fuel consumption (BSFC) from baseline diesel fuel is shown in Fig 3. As seen in the Fig 3, the JP-8 has higher BSFC than diesel fuel. Although JP-8 fuel has a higher LHV than diesel fuel on a mass basis (Figure 2a),