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CHARACTERISTICS OF PADDY OPERATIONS WITH BIODIESEL FUELLED TRACTOR

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ABSTRACT 20% biodiesel (BD20) and 100% biodiesel (BD100), alternative fuels for tractors, were tested for its power and competitiveness in the various paddy operations including plowing and rotary tilling in the paddy fields. Troubles such as no ignition or abrupt stopping were not monitored during operations of plowing, rotary tilling and travelling on the road. According to the tractor PTO test in accordance with OECD tractor PTO test codes, no significant PTO power difference was found between the three fuels. However, fuel consumption rates were quite different between the biodiesels and diesel fuel in the paddy works, when biodiesel content went up; fuel consumption rate went up too. About 35~40% more fuel was needed for rotary tilling operation than plowing operation. Within the operations, maximum difference occurred at rotary tilling of wet paddy and this difference was as high as 20%, between BD100 and diesel fuel, 5.45 versus 6.53 l/hr. Regarding exhaust gases, more CO_2 was discharged from diesel fuel than biodiesels, but more NO_x was discharged with biodiesels. It was difficult to differentiate CO quantities between the three different fuels.

Keywords : Biodiesel, Tractor, Plowing, Rotary tilling, Fuel consumption, Exhaust gas, PTO output, Engine RPM

INTRODUCTION Biodiesel is widely used in northern European countries and north America for heating fuel of buildings and facilities and transportation fuel for bus and big truck. It reported that 100% BD is using for metro bus fuel and construction machinery fuel in the developed countries. Biodiesel is first introduced for diesel engine in Germany, of which soybean oil was the source of biodiesel, but cheaper fuel, diesel fuel originated from fossil oil, replaced the diesel fuel. For a long time, diesel fuel has been regarded as fuel for diesel engine. However, recently fossil fuel price goes up and up and alternative fuels such as biodiesel or bioethanol seem very promising alternatives. Biodiesel is known for providing better combustible condition in diesel engine since it has two more oxygen molecular than diesel fuel, contributing 11% more oxygen amount than diesel fuel when it is combusting in the engine chamber. Biodiesel combustion discharges less toxic exhaust gases than diesel fuel. According to the study conducted by Lee(2004), 20% biodiesel combusting internal diesel engines discharge polluted matters 20% less, carbon monoxide 12% less, fine dust 12% less, NO_X 2% more, SO_X 20% less, aromatic chemicals 13% less than those of diesel fuel. The reason for NO_X incremental is that cetane number of biodiesel is higher than diesel fuel, in general higher cetane number fuels are highly volatile, a highly favourable combustion condition for a large amount of NO_X production. According to the study conducted by Kim et al (2008), biodiesel replacing diesel fuel in the hot air heater for greenhouse heating encountered no barriers in terms of combustion performance and toxic emission gases. Waste oil based biodiesel showed the same patterns as those of soybean based biodiesel in hot air heater combustion. Several investigations on biodiesel fuel application on engine were conducted in international and domestic, where Prankl et al (2006) tested various biodiesels in single cylinder engines and reported that no difference in degree of engine worn-out, quality of exhaust gases and changes of engine oil viscosity but some inferiorities related to engine performance and carbon accumulation was found between biodiesel and diesel fuel fuelled engine. Diesel engine of agricultural tractor for biodiesel fuel, 5% BD, was tested and its feasibility was approved (Ministry of agriculture and Forestry, 2003). However, no investigation was carried out for field feasibility of biodiesel fuelled agricultural tractor. The objective of this study is to evaluate field performance of biodiesel fuelled tractor with comparing diesel fuel tractor.

MATERIALS AND METHODS

Fuel Preparation Three different fuels, BD20, BD100, diesel fuel, were prepared for this study. BD was purchased from a domestic biodiesel processing factory where soybean oil is the primary resource for biodiesel processing. Quality of 100% BD was approved by Korean Petroleum Quality Inspection Agency that satisfied all aspects of biodiesel fuel should have. BD20 was processed by mixing diesel fuel 80% and biodiesel 80% in volume base.

Equipments Two operations, plowing and rotary tilling, were incorporated in this study, for which we have operated a tractor, Daedong LX 470 (Daedong Inc., Korea), rated power of 37.3 kW at rated engine speed of 2,600rpm and nominal PTO output of 29.4 kW, a plow of 1.6m in width and five rows and a rotavator of 1.7m in width.

Measurements Travelling speed of tractor, exhaust gas components, engine speed, fuel consumption rate and PTO torque were measured and recorded by using several instruments in order to define characters of biodiesel fuelled tractor. For the measurement of fuel consumption rate, we installed a pulse type flow meter (MO5, Macnaught, Australia) between the fuel tank and the fuel pump. Engine speed of the tractor was measured by a tachometer installed in the tractor which was operated by the pickup sensor in the tractor gearbox. The signal was converted to 0 to 12 volts and signal boundary level was 3.5~6.8 volts, and it showed 567Hz at engine speed of 2,000rpm. All the data were transmitted by a telemetry system and recorded in a notebook for later usages.

PTO power measurements PTO power measurement was conducted at full load test, part load test and part load test at various engine speeds. Of the full load and part load test the engine speed was fixed at 2,600rpm, rated speed, on the other hand part load test at different engine speed was simulated to the actual field operation of tractor. Thus, we varied the engine speed and measured PTOs. PTO power test was performed by PTO performance tester (Ag400, Froude, United Kingdom) at the engine performance test laboratory, Department of Agricultural Engineering, National Institute of Agricultural Science (NIAS), Suwon, Korea. PTO test of full load started at the rated speed, 2,600rpm, and gradually reduced the engine speed by 100rpm and measured PTOs. PTO test of part load was carried out in the engine speed range of 2,600~1,400rpm lowering PTO torque 85%, 75%, 50% , 25% and no torque condition. PTO test of part load at different engine speed was performed at 90% and 60% of the rated speed and measured PTO power and fuel consumption rate.

Figure 1. PTO performance test.

RESULTS AND DISCUSSIONS

PTO Power PTO power tested was performed at the engine performance test laboratory located in NIAS. Figure 2 shows the curve of PTO power, right Y axis, and fuel consumption rate, left Y axis, depending on the various engine speeds, X axis. At full load condition, PTO power of diesel fuel engine was varied from 9.6 kW to 28.1 kW, and it indicated 10.9, 16.45, 10.8, 21.7, 21.5, 27.1 kW at the different engine speed and load combination. As shown in Figure 2, we noticed that no significant differences in PTO power were found between diesel fuel and BD used in this experiment. However, there was some differences of fuel consumption rate among the fuels; 3.8~11.2 l/hr for BD100 and 3.5~11.2 ℓ/hr for diesel fuel.

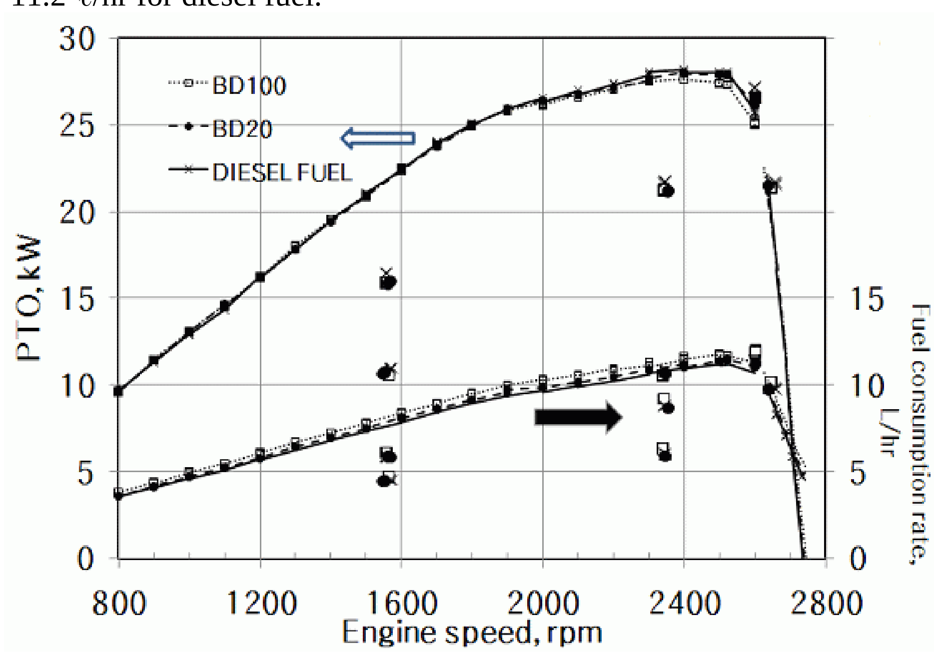

Figure 2. Engine speed, fuel consumption rate and PTO output.

Engine speed and fuel consumption rate Figure 3 shows a relationship between engine rpm and fuel consumption by the different fuel in the field operation of the tractor.

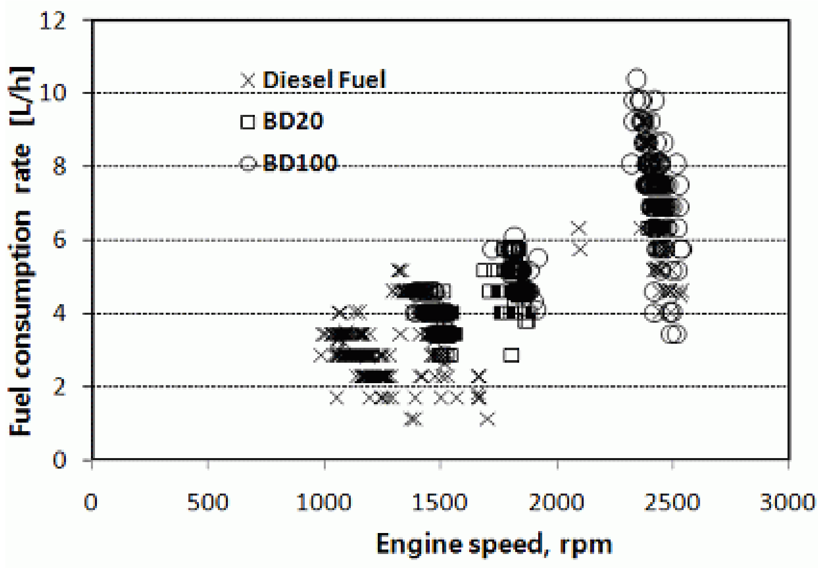

Figure 3. Engine RPM and fuel consumption rates by the different fuels.

The data shows that as engine speed increases fuel consumption rate increases for all three different fuels. However, there are wide variations in fuel consumption rate at about 2,600rpm, rated engine speed.

Fuel consumption rate by different operations Figure 4 shows fuel consumption rates at the different farm operations; plowing, rotary tilling in dry paddy and rotary tilling in wet paddy.

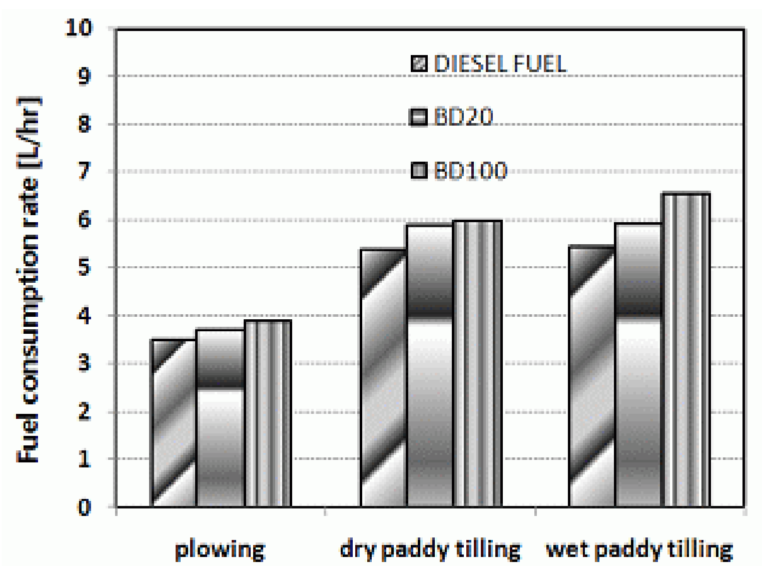

Figure 4. Fuel consumption rate by the different paddy operations.

In plowing operation, fuel consumption rate of diesel fuel, BD20 and BD100 were 3.51, 3.67 and 3.8ℓ/hr, respectively. In rotary tilling operation of dry paddy, they were 5.37, 5.85, 5.96 ℓ/hr, and rotary tilling of wet paddy they were 5.45, 5.88 and 6.53 ℓ/hr. Obviously, rotary tilling operation regardless of paddy condition consumed more fuel than plowing operation as shown in Figure 4. About 35~40% more fuel were needed for rotary tilling operation than plowing operation. However, within operations it is hard to determine difference of fuel consumption rate, thus we employed SAS program in order to figure out the fuel type difference to the fuel consumption rates. Duncan’s Multiple Range test with SAS GLM procedure was run to find the effect of fuel type to fuel consumption rate.

Table 1 Comparison of means of fuel consumption rate in the different fuel for plowing by Duncan's multiple range test in the (α=0.05, MSE= 0.098).

Duncan Grouping※	Mean of fuel consump. rate	Number of observation	Fuel type
A	3.88	100	BD100
B	3.66	105	BD20
C	3.51	113	diesel fuel

※Means with the same letter are not significantly different

Table 1 tabulated the output of Duncan’s multiple range test for the difference of fuel type to fuel consumption rates of plowing. As we have anticipated, some differences existed among fuel type on fuel consumption rate. Difference of fuel type was true for the fuel consumption rate of two rotary tillings, too. Within the operations, maximum difference occurred at rotary tilling of wet paddy as of 20%, between BD100 and diesel fuel, 5.45 and 6.53 ℓ/hr.

Exhaust gas components Figure 5 shows exhaust gas components of diesel fuel, BD20 and BD100 combustion in the engine. Diesel fuel combustion discharged the greatest amount of CO_2, 8.7%, next was BD20 of 8%, and BD100 produced 7.8%, the smallest. The discrepancies in CO_2 amount among the three fuels was carbon amount difference among the three fuels. Since 100% BD contains more oxygen molecular by 11% than diesel fuel so it helps to produce more NOX than diesel fuel. NO_X concentration of BD100 was 815.1ppm, but 775.8ppm for diesel fuel, thus 5% more NO_X produced from BD100. NO_X amount is still controversial in the biodiesel related research community. Some claims NO_X is increasing in the vehicles’ biodiesel combustion including big trucks but some reported it is decreasing in the experiment of house heating with biodiesel combustion (Environmental Building news, 2003). Discharged CO amounts were 26~28ppm in the three different fuels. According to the literature (Environmental Building News. 2003), CO amount was decreasing as BD was increasing, but in this experiment it was hard to find the trend because of rough precision of the apparatus we have used. In theory, because of 11% more oxygen molecular, CO amount should gone down as biodiesel content goes up.

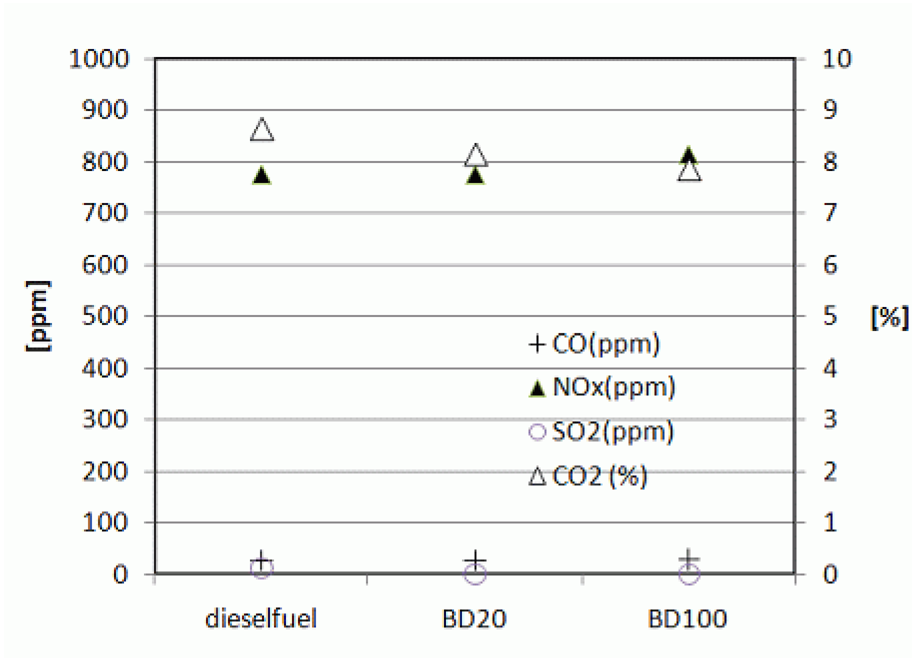

Figure 5. Major exhaust gases by the fuel kinds.

Adoptability of biodiesel in tractor Biodiesel is widely used in the transportation vehicles and construction equipments in the European countries. Through this experiment, we found no problems encountered when we used BD20 and BD100 as fuel for tractor and no power shortages occurred when the tractor was working in the paddy. Actually we worried that we could meet some troubles such as ignition, abrupt engine stop due to flogging in fuel filter or something else. Fortunately, during the paddy operations we did not get into any troubles. Tractor driver commented that no distinct differences existed between the fuels when he was operating the tractor working paddy works. However, except cold season biodiesel could be a good alternative for diesel fuel as long as economic justification is guaranteed.

Figure 6. Views of plowing and rotary tilling operation by biodiesel tractor.

Conclusions 20% biodiesel(BD20) and 100% biodiesel(BD100), alternative fuels for tractor, were tested for its power and competitiveness in the various paddy operations including plowing and rotary tilling in the paddy fields. Troubles such as no ignition or abrupt stopping were not monitored during the works of plowing, rotary tilling and travelling on the road. According to the tractor PTO test in accordance with OECD tractor PTO test codes, no significant PTO power difference was found between the three fuels. However, fuel consumption rates were quite different between the biodiesels and diesel fuel in the paddy works that biodiesel content went up fuel consumption rate went up too. About 35~40% more fuel were needed for rotary tilling operation than plowing operation. Within the operations, maximum difference occurred at rotary tilling of wet paddy as of 20%, between BD100 and diesel fuel, 5.45 and 6.53 ℓ/hr. Of the exhaust gases, more CO_2 amount was discharged from diesel fuel than biodiesels, but more NO_x amount from biodiesels. It was difficult to differentiate the CO quantities between the three different fuels.

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