INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 4, Issue 4, 2013 pp.713-720
Journal homepage: www.IJEE.IEEFoundation.org

An experimental investigation of exhaust emission from agricultural tractors

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Abstract
Agricultural machinery is an important source of emission of air pollutant in rural locations. Emissions of a specific tractor engine mainly depend on engine speed. Various driving methods and use of implements with different work capacities can affect the engine load. This study deals with the effects of types of tractors and operation conditions on engine emission. In this study two types of agricultural tractors (MF285 and U650) and some tillage implements such as centrifugal type spreader, boom type sprayer and rotary tiller were employed. Some of the exhausted gases from both tractors in each condition were measured such as, hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2) and nitrogen oxide (NO). Engine oil temperature was measured at every step for both types of tractors. Difference between steady-state condition and operation conditions was evaluated. The results showed all exhaust gases that measured and engine oil temperature at every operation conditions are higher than steady-state condition. A general conclusion of the work was that, using various implements and employing different types of tractors effect on engine emissions. The results of variance analysis showed all exhausted gases had a significant relationship with types of implements used at 1%. Also, all exhausted gases except CO had a significant relationship with types of tractors. A further conclusion was that NO emission increased as engine oil temperature increased.
The final conclusion was about the difference between MF285 and U650; using U650 at operation conditions is better than MF285 in terms of pollution.

Keywords: Agricultural tractor; Air pollutant; Exhaust emission; Operation condition.

1. Introduction
Air pollution is a serious problem in all over the world. Diesel engines seem to have a large influence on air pollution because they are used for heavy-duty trucks and emit a higher level of pollutants than petrol engines, however diesel fuel has slightly higher energy content than petrol per unit volume. Off-road vehicles, trucks, buses and other types of heavy-duty vehicle are powered almost exclusively by diesel engines. Diesel engines make a significant contribution to air pollution [1]. An important proportion of the diesel engine emissions causing environmental problems are caused by work machinery such as agricultural tractors and forestry machines [2]. Exhaust emissions from agricultural tractors have a detrimental impact on human health and the environment. In order to reduce these emissions, standards have been introduced and are continuously being tightened [3]. The latest studies [4] have shown that emission values for agricultural tractor operations cannot be reasonably accurately calculated

from average emission factors without account being taken of the type of load on the engine in the operation performed.

Pollutants from diesel engines can be roughly divided into three elements [5]. The first one is NO_x. NO_x mainly consists of nitrogen oxide (NO) and nitrogen dioxide (NO_2). The concentration of NO in diesel exhaust is higher than that of NO_2, however NO_2 has much higher toxicity than NO. In addition to these two species, N_2O has been recently gathering attention because of its 200 times higher impact factor than carbon dioxide on global warming [6]. Although it can be said that NO, NO_2, and N_2O have different impacts on the environment. The most studies of diesel engine exhaust introduce them as the same species, which is named just NO_x.

The second element of diesel exhaust is hydrocarbons and CO. Hydrocarbons consist of thousands of species, such as alkanes, alkenes, and aromatic. Although their toxicity, carcinogenicity, and impact of oxidant formation vary from species to species, they are usually treated together as total hydrocarbons (THC) [7]. These uniform treatments of NO_x and THC have arisen for two reasons. The first one is that the exhaust gas of automobiles is regulated only by levels of NO_x and THC. Another one is the difficulty in measurement. Usually, an analysis of engine exhaust is performed by gas chromatography–mass spectrometry (GC–MS) [8]. However, achieving quantitative analysis takes a long time. Real time measurement is desirable for engine exhaust analysis because the exhaust gas composition changes in real time along with changes in the engine operating conditions. However, Performing GC-MS in real time is difficult. For these reasons, only a few studies were done about the details of exhaust gas compositions and the effects of engine operating conditions on the compositions [9, 10].

The last element of diesel exhaust is particulate matter (PM), which is important to diesel engine exhaust. PM is usually measured by weighing a filter which was exposed to exhaust gas and trapping PM. In a study is suggested that Nano-particles, generally having a diameter of less than 100 nm although there are different definitions, are more hazardous to human health than larger particles. The standard filter weighing method is regarded as less sensitive for such small particles. According to this reason, the European Commission decided to adopt a new PM measurement technique for automobiles. It is the number counting method, in which the numbers of particles from 23 nm to 2.5 µm are counted. This method has a higher sensitivity to small particles than the standard filter weighing method, because small particles and large particles are treated equivalently [11]. This discussion indicates that it is important to know the size distribution of particle emissions.

Recently, many researches are focused on exhaust gases of diesel and petrol engine, such as; A comparison between different methods of calculating average engine emissions for agricultural tractors evaluated by Hansson et al [2], Environmental impact of catalytic converters and particle filters for agricultural tractors determined by life cycle assessment investigated by Larsson and Hansson [3], Simulated farm fieldwork, energy consumption and related greenhouse gas emissions in Canada by Dyer and Desjardins [12] ,effects of vehicle type and fuel quality on real world toxic emissions from diesel vehicles by Nelson et al [13]. Emissions from heavy-duty vehicles under actual on-road driving conditions by Durbin et al [14], Detailed analysis of diesel vehicle exhaust emissions: nitrogen oxides, hydrocarbons and particulate size distributions by Yamada et al [15], Gaseous and particulate emissions from rural vehicles in China by Yao et al [16], and Shrivastava et al [17] investigated performance and exhaust emission of a diesel engine fuelled with Jatropha biodiesel and its blends, etc.

Therefore, the aim of this work was to measure average values of some exhaust gases such as hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2) and nitrogen oxide (NO) from different tractors in different operation conditions. Engine oil temperature was measured too.

2. Materials and methods

The aim of this study was to measure the correlation between some exhaust gases from two common and popular tractors in IRAN in different operation conditions. The tractors used were Messy Ferguson (MF285) and Romania (U650). The specifications of tractors are shown in Table 1. Data were recorded in the field with 6500 m^2 area and clay-loamy soil. The operations were done at autumn tillage. Both tractors were equipped with the same implements, worked at the same conditions and their exhaust gases were measured.

For this study, the following operations were considered to be most interesting:

1. Centrifugal type spreader with rotating disk spreader (Figure 1);
2. Rotary tiller with 1.2m wide and L forms share (Figure 1);
3. Boom type sprayer with 400L volume, 12 nozzles and gear pump (Figure 1);

The tractor speeds for spreader, rotary tiller and boom type sprayer were 8, 5 and 5 km.h^{-1} respectively, which were selected from standard method (ASAE D497.4 MAR99)[18]. The specifications of operation conditions are shown in Table 2.

Table 1. Specifications of the tractors

	Class	Model	Number of cylinders	Fuel type	Engine operating process	Engine power (kW)
Tractor 1	MF 285	1984	4	Diesel	4 - Storke	55.95
Tractor 2	U 650	1985	4	Diesel	4 - Storke	48.49

Figure 1. Details of specific device (1. Gas analyzer, 2. Gas inlet, 3. Oil temperature sensor)

Table 2. Specifications of operation conditions

Operation	Distance (m)	Time (min)	Tractor speed (km.h^{-1})	Power (kW)
Cen rifugal type spreader	1000	7.5	8	25
Boom type sprayer	800	9.6	5	29
Rotary tiller	1200	14.4	5	47

FGA-4100 automotive emission analyzer made in China was used for measurement of exhaust gases and engine oil temperature. The details of specific device are illustrated in Figure 1. As shown in Figure 1 exhaust gases entered five gas analyzers without dilution.

The flow ratio of the exhaust gases changed by changing the engine speed, and so the dilution ratio varied with changing engine speed. Patterns of driving could affect vehicle emissions significantly so they are very important in measuring vehicle emissions [19-21].Therefore, for solving this problem, engine speeds stabilized during operations with hand accelerator. Then engine speed stabilized at 2200 min^{-1}. Engine speed and loading torques are defined by the ECE R49 standard, so that 304 N.m torque with 2200 min^{-1} engine speed and 53 kW maximum powers are valid for both of tractors.

Fuel and lubricating oil were constant in both of tractors at every operation, because these parameters are effective on engine emission [22].

Finally, the recorded data were analyzed by using completely randomized designs (CRD).

3. Results and discussion

In this research we concentrated on details of exhaust gases from two common tractors that are used in IRAN at three operation conditions. All of the obtained emission results are presented in Tables 3 and 4. Difference between steady-state condition and operation conditions was evaluated. The results showed all exhaust gases that measured and engine oil temperature at every operation conditions are higher than steady-state condition

Table 3. Emission from MF285 in operation conditions

Operation	HC (ppm)	CO (%)	CO_2 (%)	O_2 (%)	NO (ppm)
Centrifugal type spreader	43.2	0.13	8.02	11.7	362.6
Rotary tiller	123.07	0.17	4.27	14.68	156.79
Boom type sprayer	94.10	0.14	3.15	16.25	66.5

Table 4. Emission from U650 in operation conditions

Operation	HC (ppm)	CO (%)	CO_2 (%)	O_2 (%)	NO (ppm)
Centrifugal type spreader	81.2	0.11	2.38	16.46	55.4
Rotary tiller	147.12	0.12	3.52	16.62	126.32
Boom type sprayer	61.5	0.11	2.63	15.35	113.63

3.1 HC emission

The measured HC values for both tractors in operation conditions are shown in Figure 2. Results showed when rotary tiller is used the value of HC emission goes higher than the other conditions. In addition, in all operation conditions except when we used boom type sprayer the amount of HC emissions from U650 are higher than MF285. Maximum HC was achieved for both tractors when rotary tiller was used. The results of variance analysis showed that amounts of exhaust HC have a significant relationship with types of tractors and implements at 1%.

3.2 CO emission

The amount of measured gases showed the value of exhaust CO in both tractors (Figure 3) as well as other diesel engines is very low in comparison with petrol engine [23]. Data recorded showed when we used rotary tiller CO emission, like HC emission, was higher than the other conditions. CO emitted from U650 was lower than MF285. The results of variance analysis showed that amounts of exhaust CO don't have a significant relationship with types of tractors, but have significant relationship with types of implement at1%. Therefore values of CO emission are independent from types of tractors.

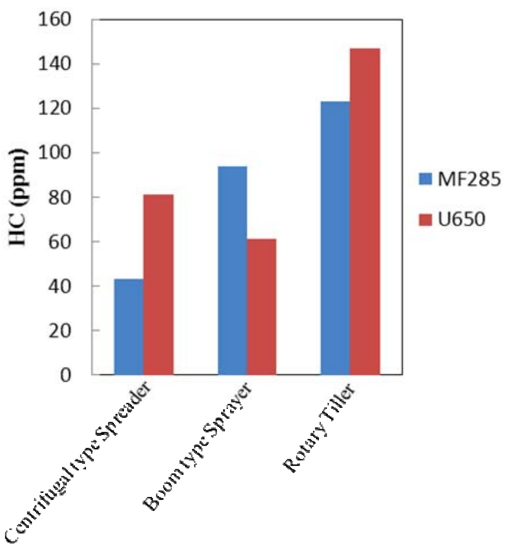

Figure 2. HC emission from tractors at operation conditions

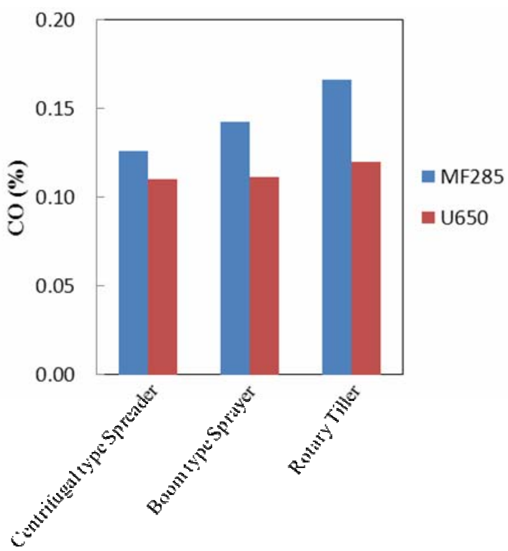

Figure 3. CO emission from tractors at operation conditions

3.3 CO_2 emission

The recorded data showed CO_2 values when we used centrifugal type spreader are higher than other operations (Figure 4). CO_2 emission from U650 was lower than MF285. The results of variance analysis showed that amounts of exhausted CO_2 have a significant relationship with types of tractors and implement at1%. Therefore values of CO_2 emission depend on types of tractors and implements used.

3.4 NO emission

The experimental data showed NO values at plowing operation are higher than other operations (Figure 5). The values of NO emission from U650 were lower than MF285 at all operations except when we used boom type sprayer.

As depicted in Figure 6, in each tractors NO emission increased as the engine oil temperature increased. Also, the mentioned result was reported for the relationship between NO emission and in-cylinder temperature by Yamada et al [15]. The results of variance analysis showed that amounts of exhausted NO have a significant relationship with types of tractors and implements at 1%. Therefore values of NO emission depend on types of tractors and instrument.

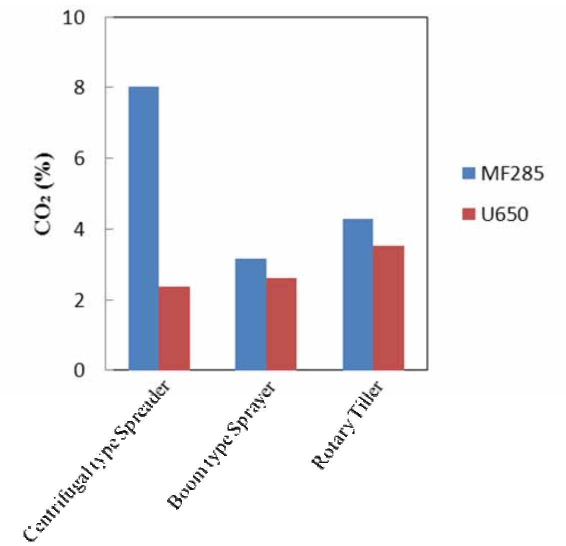

Figure 4. CO_2 emission from tractors at operation conditions

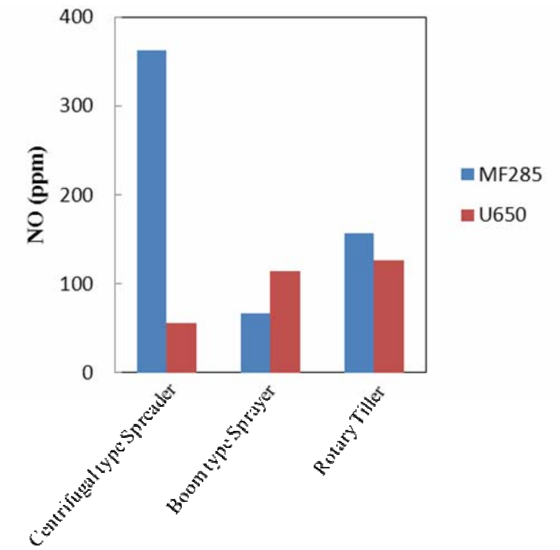

Figure 5. NO emission from tractors at operation conditions

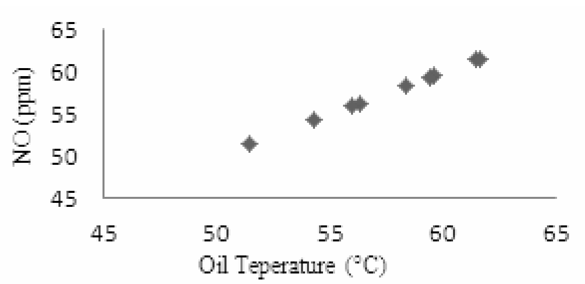

Figure 6. Relationship between NO emission and engine oil temperature

3.5 O_2 emission

The recorded values of O_2 showed the volume of this gas is higher in rotary tiller operation than other operations (Figure 7). The results of variance analysis showed that amounts of exhausted O_2 have a significant relationship with types of tractors and implements at1%. Therefore values of O_2 emission depend on types of tractors and instrument. The values of O_2 emission from U650 were higher than MF285 at all operations except when we used boom type sprayer.

3.6 Engine oil temperature
As shown in Figure 8, the recorded values of engine oil temperature showed this parameter in U650 is higher than MF285 at operations conditions except when we used boom type sprayer.

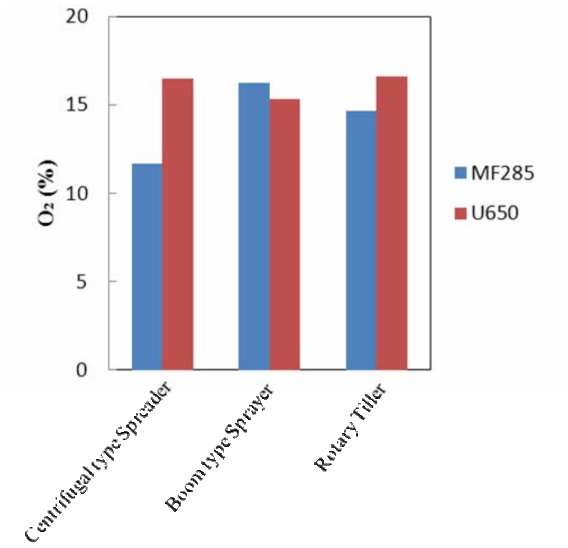

Figure 7. O_2 emission from tractors at operation conditions

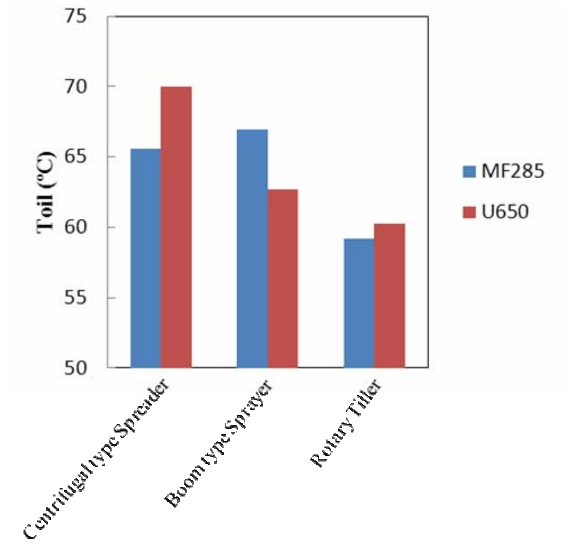

Figure 8. Engine oil temperature from tractors at operation conditions

4. Conclusion

Evaluation of exhaust gases from diesel engine is important. In this study emission from two current tractors in IRAN at three operation conditions was reported. Some exhaust gases (HC, CO, CO_2, O_2 and NO) and engine oil temperature were measured. HC and O_2 emission from MF285 were lower than U650 when we used centrifugal type spreader and rotary tiller, CO, CO_2 from MF285 were more than U650, and NO emission from MF285 were more than U650 when we used centrifugal type spreader and rotary tiller. NO emission increased as engine oil temperature increased. CO emission from tractors like other diesel engines is very low in comparison with petrol engines.
All of exhaust gases except CO have a significant relationship with types of tractors and implements at 1% as shown in Table 5. This subject was presented by Durbin et al [14], for NO emission from heavy-duty vehicles.
It can be clearly seen that amount of exhaust gases depends on amount of loading on tractor.

Table 5. Variance analysis

	Tractor			Implement		
	Mean Square	F	Significant Level	Mean Square	F	Significant Level
HC	1160.35	420.5	0.01>	8.15	0.015	0.01>
CO	0.12	27.86	0.01<	0.009	2.85	0.01>
CO_2	199.32	139.25	0.01>	2.99	0.144	0.01>
O_2	29.64	20.05	0.01>	2.06	0.25	0.01>
NO	141113	107.01	0.01>	2711	0.05	0.01>

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