ANALYSIS AND COMPARISON EXHAUST GAS EMISSIONS FROM AGRICULTURAL TRACTORS

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ABSTRACT: 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 were employed. Some of the exhausted gases from both tractors in each condition were measured such as, hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂) and nitrogen oxide (NO). Engine oil temperature was measured at every step for both types of tractors. A general conclusion of the work was that, using various implements and employing different types of tractors can affect some of 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. In addition, results showed that values of exhausted HC and O₂ in MF285 were lower than U650. While, the other exhausted gases (CO, CO₂, and NO) in MF285 were higher than U650. 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: Air Pollution; Agricultural Tractor; Exhaust Gases; Tillage

INTRODUCTION

An important proportion of the diesel engine emissions causing environmental problems are caused by work machinery such as agricultural tractors and forestry machines (Hansson et al., 2001). 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 (Larson and Hansson, 2011). These standards only concern existing vehicles. However, vehicles older than 10 years are responsible for 25-40% of all exhaust emissions from off-road machines (Lindgren, 2007). The latest studies (Hansson et al., 1999) 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. Large variations in emissions were found between different operations, even when the emissions were related to the mechanical energy output of the engine (emissions in g kWh⁻¹). Often the objective of the farmer, especially when performing heavy operations such as plowing or harrowing, is to obtain the maximum work-rate, not to minimize emissions. Amount of emissions that arise from a specific operation depend on engine load characteristics. The engine load can be influenced by alternative driving techniques, by the design of the drive train and by the use of implements with different work capacities (Danfors, 1988; Johansson et al., 1999). Pollutants from agricultural tractors engines like other diesel engines can be roughly divided into three elements (Heywood, 1998). The first one is NOₓ. NOₓ mainly consists of nitrogen oxide (NO) and nitrogen dioxide (NO₂). The concentration of NO in diesel exhaust is higher than that of NO₂; however NO₂ has much higher toxicity than NO. In
addition to these two species, N₂O has been recently gathering attention because of its 200 times higher impact factor than carbon dioxide on global warming (http://www.lpcg.nrcgc.ca/). Although it can be said that NO, NO₂, and N₂O have different impacts on the environment. The most studies of diesel engine exhaust introduce them as the same species, which is named just NOx.

The second 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 it 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 (Kittelston, 1998). This indicates that it is important to know the size distribution of particle emissions.

The last 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) (ACGIH Website). These uniform treatments of NOx and THC have arisen for two reasons. The first one is that the exhaust gas of automobiles is regulated only by levels of NOx and THC. Another one is the difficulty in measurement. Usually, an analysis of engine exhaust is performed by gas chromatography–mass spectrometry (GC–MS) (Borras et al., 2009). 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 (Schulz et al., 1999; Gullett et al., 2006).


Therefore, the aim of this work was to measure average values of some exhaust gases such as hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂) and nitrogen oxide (NO) from different tractors in different operation conditions. Engine oil temperature was measured, too.

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 m² 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.
2. Moldboard plows with four bottom 1.44 m wide and 0.18 m depth working.
3. Eight tines cultivator with 1.9 m wide.
4. Rotary tiller with 1.2 m wide and L forms share.
5. Boom type sprayer with 400L volume, 12 nozzles and gear pump.
6. Eight tine chisel plow with 0.1 m depth.

The tractor speeds for spreader, plow, cultivator, rotary tiller, boom type sprayer and chisel plow were 8, 6, 8, 5, 7 km.h⁻¹ respectively, which were selected from standard method (ASAE D497.4 MAR99). The specifications of operation conditions are shown in Table 2.

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 Fig 1. As shown in Fig 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 (Hansen et al., 1995; Kean et al., 2003; Yao et al 2007). 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 (HEI, 1995).

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

**RESULTS AND DISCUSSION**

In this research, we concentrated on details of exhaust gases from two common tractors that are used in IRAN in different operation conditions (that were introduced in previous section).

All the obtained emission results for all operation conditions and both tractors are presented in Fig 2, 3,4,5,6 and tables 3, 4.

![Figure 1. Details of specific device](image)

1. Gas analyzer
2. Gas inlet
3. Oil temperature sensor

<table>
<thead>
<tr>
<th>Class</th>
<th>Model</th>
<th>Number of cylinders</th>
<th>Fuel type</th>
<th>Engine operating process</th>
<th>Engine power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor 1</td>
<td>MF 285</td>
<td>1984</td>
<td>4</td>
<td>Diesel</td>
<td>55.95</td>
</tr>
<tr>
<td>Tractor 2</td>
<td>U 650</td>
<td>1985</td>
<td>4</td>
<td>Diesel</td>
<td>48.49</td>
</tr>
</tbody>
</table>
Table 2. Specifications of operation conditions

<table>
<thead>
<tr>
<th>Operation</th>
<th>Distance (m)</th>
<th>Time (min)</th>
<th>Tractor speed (km.h⁻¹)</th>
<th>Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrifugal type spreader</td>
<td>1000</td>
<td>7.5</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>Moldboard plows</td>
<td>800</td>
<td>8</td>
<td>6</td>
<td>45</td>
</tr>
<tr>
<td>Cultivator</td>
<td>1000</td>
<td>7.5</td>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>Rotary tiller</td>
<td>1200</td>
<td>14.4</td>
<td>5</td>
<td>47</td>
</tr>
<tr>
<td>Boom type sprayer</td>
<td>800</td>
<td>9.6</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>Chisel plow</td>
<td>900</td>
<td>7.7</td>
<td>7</td>
<td>36</td>
</tr>
</tbody>
</table>

Figure 2. HC emission from tractors at operation conditions

Figure 3. CO emission from tractors at operation conditions

Figure 4. CO₂ emission from tractors at operation conditions

Figure 5. NO emission from tractors at operation conditions

Figure 6. O₂ emission from tractors at operation conditions

Figure 7. Engine oil temperature from tractors at operation conditions
Figure 8. Relationship between NO emission and engine oil temperature

Table 3. Emission from MF285 in operation conditions

<table>
<thead>
<tr>
<th>Operation</th>
<th>HC (ppm)</th>
<th>CO (%)</th>
<th>CO₂ (%)</th>
<th>O₂ (%)</th>
<th>NO (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrifugal type spreader</td>
<td>43.2</td>
<td>0.13</td>
<td>8.02</td>
<td>11.7</td>
<td>362.6</td>
</tr>
<tr>
<td>Moldboard plows</td>
<td>47.75</td>
<td>0.16</td>
<td>8.92</td>
<td>10.7</td>
<td>431</td>
</tr>
<tr>
<td>Cultivator</td>
<td>45.1</td>
<td>0.13</td>
<td>8.34</td>
<td>11.40</td>
<td>365.8</td>
</tr>
<tr>
<td>Rotary tiller</td>
<td>123.07</td>
<td>0.17</td>
<td>4.27</td>
<td>14.68</td>
<td>156.79</td>
</tr>
<tr>
<td>Boom type sprayer</td>
<td>94.10</td>
<td>0.14</td>
<td>3.15</td>
<td>16.25</td>
<td>66.5</td>
</tr>
<tr>
<td>Chisel plow</td>
<td>53</td>
<td>0.12</td>
<td>3.1</td>
<td>15.1</td>
<td>74</td>
</tr>
</tbody>
</table>

Table 4. Emission from U650 in operation conditions

<table>
<thead>
<tr>
<th>Operation</th>
<th>HC (ppm)</th>
<th>CO (%)</th>
<th>CO₂ (%)</th>
<th>O₂ (%)</th>
<th>NO (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrifugal type spreader</td>
<td>81.2</td>
<td>0.11</td>
<td>2.38</td>
<td>16.46</td>
<td>55.4</td>
</tr>
<tr>
<td>Moldboard plows</td>
<td>82</td>
<td>0.15</td>
<td>5.15</td>
<td>13.88</td>
<td>119.5</td>
</tr>
<tr>
<td>Cultivator</td>
<td>66.75</td>
<td>0.08</td>
<td>2.2</td>
<td>16.58</td>
<td>68.25</td>
</tr>
<tr>
<td>Rotary tiller</td>
<td>147.12</td>
<td>0.12</td>
<td>3.52</td>
<td>16.62</td>
<td>126.32</td>
</tr>
<tr>
<td>Boom type sprayer</td>
<td>61.5</td>
<td>0.11</td>
<td>2.63</td>
<td>15.35</td>
<td>113.63</td>
</tr>
<tr>
<td>Chisel plow</td>
<td>64</td>
<td>0.09</td>
<td>2.7</td>
<td>16.67</td>
<td>65</td>
</tr>
</tbody>
</table>

**HC emission**

The measured HC values for both tractors in operation conditions are shown in Fig 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 sprayerthe 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%.

**CO emission**

The amount of measured gases showed the value of exhaust CO in both tractors (Fig 3) as well as other diesel engines is very low in comparison with petrol engine (DEFRA, ACE Information Programme, Air pollution and Rain Fact sheets Series: KS4 and A). 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.

**CO₂ emission**

The recorded data showed CO₂ values at plowing operation are higher than other operations (Fig 4). CO₂ emission from U650 was lower than MF285. The results of variance analysis showed that amounts of exhausted CO₂ have a significant relationship with types of tractors and implement at1%. Therefore values of CO₂ emission depend on types of tractors and implements used.

**NO emission**

The experimental data showed NO values at plowing operation are higher than other operations (Fig 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 Fig 8, 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.,(2011). 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.

\[ O_2 \] emission

The recorded values of \[ O_2 \] showed the volume of this gas is higher in chisel plow operation than other operations (Fig 6). The results of variance analysis showed that amounts of exhausted \[ O_2 \] have a significant relationship with types of tractors and implements at 1%. 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.

\[ O_2 \] emission

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CONCLUSION

Evaluation of exhaust gases from diesel engine is important. In this study emission from two current tractors in IRAN at 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, while other emission (CO, CO\(_2\), NO) from MF285 were more than U650. Therefore use of U650 suggested for agricultural operations, because it emitted lower pollution in comparison with MF285. CO emission from tractors like other diesel engines is very low in comparison with petrol engines. NO emission increased as engine oil temperature increased. All of exhaust gases except CO have a significant relationship with types of tractors and implements at 1%. This subject was presented by Durbin et al., 2008, for NO emission from heavy-duty vehicles. It can be clearly seen that amount of exhaust gases depends on amount of loading on tractor.

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