Energy Efficiency Classification of Agricultural Tractors in Korea

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Abstract

Purpose: This study was conducted to classify the energy efficiency of 131 tractor models tested during from 2006 to 2010 in Korea. Methods: Four sub-indexes were developed using the fuel consumptions at 60% and 90% of rated speed with partial loads and at pull speeds of 3.0 km/h and 7.5 km/h with maximum drawbar pull. Weighting factors of the sub-indexes were also considered to reflect the characteristics of tractor’s actual working hours in Korea. Four sub-indexes were integrated into a classification index. Using the developed classification index, a five-classification system was made on the basis of normal distribution of tractors over the classification range. Percentage of 1st grade interval was expected to be close to 15%, 2nd grade 20%, 3rd grade 30%, 4th grade 20%, 5th grade 15%. Results: Number of 1st grade was 21, 2nd grade 23, 3rd grade 39, 4th grade 33, 5th grade 15 among 131 models. Conclusions: Classification index was developed by integrating four sub-indexes. By the classification method using developed index, distribution of classified tractors was acceptable for practical application.

Keywords: Agricultural tractor, Classification Index, Energy efficiency

Introduction

The number of agricultural tractors sold in Korea has been increasing during the period from 2005 to 2010 (e.g. 10,121 units in 2005 and 13,891 units in 2010). The total number of agricultural tractors used in Korea was 267,871 in 2011 (MIFAFF, 2011). Fossil fuel consumed by agricultural tractors in Korea is increasing as the increase of tractors.

Saving energy has become a big issue throughout the world. Many countries have legislated effective energy saving. Classification of energy efficiency is an indirect way to reduce fuel consumption. Grading energy efficiency of products can provide customers with the information on decision-making. To implement energy efficiency classification to agricultural tractors is very important from the energy saving perspectives. The classification of agricultural tractors by energy efficiency has been introduced in foreign countries. In Spain, based on OECD 1 and 2, classification index was developed using fuel consumption and power data, and 214 tractor models were classified by those indexes (Gil-Sierra et al, 2007). In France, classification of agricultural tractors by energy efficiency was carried out by joint scientific work of Spain and France(OECD, 2009). In Turkey, 55 tractor models were classified by seven-classification system.(OECD, 2012).

In Korea, research for the classification of agricultural tractors by energy efficiency has begun recently. Equation to predict fuel consumption for partial loads at non-rated speeds was developed and five-classification method using a certain index was suggested (Kim et al., 2010).

To implement energy efficiency classification, a classification index should be developed based on the fuel consumption data. The test report on OECD tractor can

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provide reasonable data for Korean tractors. However, since Korean test procedure is not the same as OECD one, we need to develop new one for Korean tractors.

This paper presents an index development procedure based on Korean agricultural tractors test reports and a five-classification method was developed for energy efficiency classification procedure.

### Materials and Methods

#### Available data

There are different methods between OECD and Korean ones. Unlike the OECD test, Korean test method follows Korean version. Among the test procedure the available codes were selected. Table 1 compare the OECD test method and Korean one to develop classification index.

#### Index zones

Four zones in OECD tractor test report were chosen to develop a classification index (Table 2).

#### Sub-index $C_{rate}$

Five operational points in the rated speed zone were chosen from the torque curve (Figure 1), and the sub-index $C_{rate}$ was defined as the average value of specific volumetric fuel consumption (SVFC) over all points.

\[
C_{rate} = \frac{1}{5} \left( SVFC_1 + SVFC_2 + SVFC_3 + SVFC_4 + SVFC_5 \right) = \frac{1}{5} \sum_{i=1}^{5} \frac{Q_i}{P_i}
\]

where, \( P_i \) = power at point i, \( i = 1, 2, 3, 4, 5 \) (kW)
\( Q_i \) = fuel consumption at point i (L/h)

### Table 1. OECD test vs. Korean test

<table>
<thead>
<tr>
<th>Test</th>
<th>OECD CODE 2</th>
<th>Domestic</th>
<th>Available data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main power take-off</td>
<td>Maximum power test</td>
<td>included</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Test at full load and varying speed at rated engine speed</td>
<td>included</td>
<td></td>
</tr>
<tr>
<td>Fuel consumption tests</td>
<td>Tests at varying load at standard power take-off speed [540 or 1000 min(^{-1}) (rev/min)]</td>
<td>not included</td>
<td>engine speed(min(^{-1})), power(kW), fuel consumption(L/h)</td>
</tr>
<tr>
<td>Drawbar power and fuel consumption test, unballasted tractor</td>
<td>Tests at varying load at five extra points for calculating fuel consumption characteristics</td>
<td>not included</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The power available at the drawbar of the unballasted tractor over a range of different gears/speed settings</td>
<td>included</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. Four Zones for developing classification index

<table>
<thead>
<tr>
<th>Name of Zone</th>
<th>Meaning of Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated speed</td>
<td>Varying load at rated engine speed with full throttle</td>
</tr>
<tr>
<td>Standard PTO speed</td>
<td>Varying load at standard PTO speed with full throttle</td>
</tr>
<tr>
<td>Non-rated speed</td>
<td>Partial load at reduced speeds with reduced throttle</td>
</tr>
<tr>
<td>Drawbar</td>
<td>Drawbar performance at pull speeds of 3.0 km/h and 7.5 km/h</td>
</tr>
</tbody>
</table>