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VERIFYING POWER CLAIMS OF HIGH-POWER AGRICULTURAL TRACTORS WITHOUT A PTO TO SELL IN NEBRASKA

M. F. Kocher, V. I. Adamchuk, J. A. Smith, R. M. Hoy

ABSTRACT. Nebraska law requires the Nebraska Tractor Test Board of Engineers to compare results of the tests of an agricultural tractor model with the manufacturer’s claims regarding power, fuel use, and other performance ratings in order to recommend a permit to sell that tractor model in the state. PTO tests are conducted to verify the manufacturer’s PTO power and fuel claims for tractor models. In recent years, several tractor manufacturers have been producing models of large tractors either without a PTO or with a PTO not capable of transmitting the full engine power and, therefore, have chosen to advertise engine power. The objective of this project was to determine a reasonable alternative to removing engines from these tractors for tests to determine whether these tractors met their power claims. Linear regression analyses of advertised engine power claims and OECD Code 2 drawbar power test results from 48 tracked (R² = 0.98) and 43 4WD tractors (R² = 0.99) were used to establish two linear relationships to verify the engine power claims for these tractors. These relationships provide a reasonable means of verifying engine power claims for large agricultural tractors without a PTO, or without a PTO capable of transmitting full engine power.

Keywords. Tractor, Power, Testing, Nebraska Tractor Test Lab, PTO power, Drawbar power, Nebraska Tractor Test Law.
met simultaneously at either the rated engine speed or the standard PTO speed (University of Nebraska Board of Tractor Test Engineers, 1998). The Board of Tractor Test Engineers also has provisions for manufacturers to meet drawbar power performance claims (University of Nebraska Board of Tractor Test Engineers, 1998).

To maintain competitive standing in the marketplace, manufacturers prefer to advertise the highest possible power level. However, to avoid the potentially severe consequences of not meeting their power claims, they must also advertise power levels their products can meet during testing.

In recent years, several tractor manufacturers have been producing multiple models of large tractors either without a PTO or with a PTO not capable of transmitting the full engine power. These manufacturers have elected to advertise engine power claims instead of drawbar power claims as, of the three possible outlets at which full power can be measured (engine, PTO or drawbar), drawbar power is typically the most variable, depending primarily on weather conditions and the tractor setup during testing. Thus it is logical for the manufacturers to prefer advertising engine power rather than drawbar power for these tractor models.

Nebraska law gives the Board of Tractor Test Engineers the authority to require that the engines from these tractors be tested. That seems to be a simple solution, but it has a couple of significant drawbacks. From the manufacturer’s viewpoint, it would add labor, time, and expense to the testing of these tractor models, as disassembly (and subsequent reassembly) of each tested tractor is required to prepare for an engine test. From the lab’s viewpoint, the additional time required to test these models would reduce the number of tractors that could be tested in the test season. This reduction in the rate at which tractors could be tested would negatively impact both the lab and the manufacturers.

The Board of Tractor Test Engineers and the manufacturers have struggled for several years to develop a reasonable alternative. The manufacturers suggested the Board of Tractor Test Engineers review past test data to determine if a criterion such as a minimum value for the ratio of drawbar power to advertised engine power could be used as an indirect method to verify engine power claims. This is similar to the approach used to relate drawbar power to PTO power, and PTO power to gross or net flywheel power in ASABE Standards EP496.3 and D497.5 (ASABE Standards, 2008a, 2008b).

The objective of this work was to develop a reasonable alternative to engine testing that could be used to determine whether these large tractors tested according to the OECD Code 2 test procedure meet their advertised engine power claims.

**PROCEDURE**

Tractor test data for large [advertised engine power greater than or equal to 175 kW (235 hp)] 4WD and rubber-tracked tractors tested in Nebraska between 1988 and 2006 were summarized for analyses. This resulted in a data set that included information from 48 tracked (rubber belt track) tractor models (including Case-IH, Challenger, and John Deere models) and 43 4WD tractor models (including AGCO, Case-IH, John Deere, and New Holland models). The relevant information items collected from the test data were: year the tractor was tested, advertised engine power, measured maximum drawbar power at rated engine speed, and chassis type (4WD or tracked). The advertised engine power ranged from 175 to 373 kW (235 to 500 hp) for the 4WD tractors, and from 175 to 425 kW (235 to 570 hp) for the tracked tractors. Maximum drawbar power at rated engine speed ranged from 131 to 313 kW (176 to 420 hp) for the 4WD tractors, and from 120 to 321 kW (160 to 431 hp) for the tracked tractors.

The ratio of maximum drawbar power at rated engine speed to advertised engine power (hereafter referred to as drawbar-engine power ratio) was calculated for each tractor. Separate analyses were conducted for the 4WD and the tracked tractors, as when the data were plotted, there appeared to be two closely related, but different groups. Graphs were prepared and linear regression analyses conducted to determine the strongest prediction equation for advertised engine power. The relationships investigated included: drawbar-engine power ratio as a function of maximum drawbar power at rated engine speed, drawbar-engine power ratio as a function of year the tractor was tested, and advertised engine power as a function of maximum drawbar power at rated engine speed.

A possible criterion for determining if engine power claims are met was obtained using the 99% upper confidence limits for the slope and intercept of the best prediction relationships.

**RESULTS AND DISCUSSION**

The drawbar-engine power ratio was calculated for each tractor and graphed as a function of maximum drawbar power at rated engine speed (fig. 1) and as a function of the year the tractor was tested (fig. 2). Separate regression results are shown for the 4WD and tracked tractors. Figure 1 illustrates a weak trend (small slope values) of increasing drawbar-engine power ratio with increasing drawbar power. Unfortunately, the regression equations were not excellent predictors for the drawbar-engine power ratio as the coefficients of determination (R^2 values) were less than 0.95. Figure 2 illustrates a weak trend of increasing drawbar-engine power ratio with increasing year of tractor test, and the regression equations in this figure are even poorer predictors of the drawbar-engine power ratio than the equations in figure 1.

Advertised engine power was graphed as a function of measured maximum drawbar power at rated engine speed for both the 4WD and tracked tractors (fig. 3). Regression results are shown in the figure for each data series. The relationships shown in this figure were much better predictors of advertised engine power, as the R^2 values were greater than 0.95 for both the 4WD and tracked tractors.

Figure 3 shows that for the 48 tracked tractors and 43 4WD tractors included in the dataset, a good prediction for advertised engine power could be obtained from measured maximum drawbar power at rated engine speed. The region below the lines represents a region of understated advertised engine power, or a region where engine power claims could definitely be considered as met. As an example, the point of 200-kW maximum drawbar power at rated engine speed and 200-kW advertised engine power is below the lines. Because of losses in the drive train and tractive efficiency, engine
power must be greater than drawbar power. Hence, a tractor that can deliver 200-kW drawbar power must have an engine capable of producing more than 200-kW engine power. The region above the lines represents a region where either advertised engine power is overstated or the tractor has driveline and/or tractive efficiencies that are lower than normal. The goal of these analyses was to establish limits (lines) dividing the regions where advertised engine power levels are considered to be met (acceptable levels of advertised engine power) from the regions where advertised engine power levels are not considered to be met. The Board of Tractor Test Engineers wanted to define these lines somewhere above the data points in this dataset to make some allowance for drive train efficiencies and/or tractive efficiencies slightly less than those achieved with the tractors in this dataset.

One approach to defining the limit for acceptable advertised engine power is to use a linear equation obtained with the upper 99% limit of the confidence intervals for the parameters (slope and intercept) of the regression line. This line is shown for the tracked tractors in figure 4. This approach allows for limited uncertainty in the future as the acceptance margin increases very gradually as maximum drawbar power at rated engine speed increases. A similar graph is shown for the 4WD tractors in figure 5. The Board of Tractor Test Engineers also noted that all tractors included in the dataset met these criteria for acceptable advertised engine power.

The Board of Tractor Test Engineers presented these data and analyses to the U.S. OECD Coordinating Committee (tractor manufacturers) for discussion. As no significant objections were presented by the manufacturers, the Board of
Figure 3. Relationships between advertised engine power and maximum drawbar power at rated engine speed for large tracked and 4WD agricultural tractors.

Figure 4. Upper limit of the 99% confidence interval of the parameters of the regression line for large tracked agricultural tractors.

Figure 5. Upper limit of the 99% confidence interval of the parameters of the regression line for large 4WD agricultural tractors.
Tractor Test Engineers voted unanimously in November of 2007 to adopt the following criteria for determining whether advertised engine power claims are met for large tractors without a PTO, or with a PTO not capable of transmitting full engine power (University of Nebraska Board of Tractor Test Engineers, 2007).

For tracked tractors, advertised engine power claims will be considered met when:

\[
AEP \leq 1.273 \times MDBP + 34.8 \text{kW} \quad (1)
\]

where

- \( AEP \) = advertised engine power, kW (hp)
- \( MDBP \) = maximum drawbar power at rated engine speed, kW (hp)

For 4WD tractors, advertised engine power claims will be considered met when:

\[
AEP \leq 1.150 \times MDBP + 32.4 \text{kW} \quad (2)
\]

where

- \( AEP \) = advertised engine power, kW (hp)
- \( MDBP \) = maximum drawbar power at rated engine speed, kW (hp)

Since the adoption of Board Action No. 31 in November of 2007, four tractors without a PTO have been tested. Two of these tractors were rubber-tracked tractors, and two were 4WD tractors. The advertised engine power for all four of these tractors [between 350 and 400 kW (470 and 535 hp)] met the criteria of equations 1 and 2.

There have been, and continue to be, different standards for determining engine power. SAE J1995 has been used to determine gross engine power. United Nations Economic Commission for Europe Regulation 120 (ECE R120) is also used to determine net engine power for a bare engine (no accessories). The ECE R24 regulation tests engine power available at the flywheel while the engine is powering normal engine auxiliaries such as the cooling fan and alternator, but without application-specific auxiliaries such as air conditioning compressors, and hydraulic pumps. Power may be reported as either rated net power at the rated engine speed or as maximum net power at the engine speed at which maximum power is obtained. Another standard used to determine engine power is ISO 14396. Differences in the accessories powered by the engine and engine operating conditions during the test can result in differences in the engine power ratings. As changes in standards and tractor power occur over time, the Nebraska Board of Tractor Test Engineers can work with tractor manufacturers to determine appropriate changes to the coefficients in equations 1 and 2.

**SUMMARY AND CONCLUSIONS**

The University of Nebraska Board of Tractor Test Engineers is required by Nebraska Law to verify tractor manufacturers’ power claims. The OECD Code 2 maximum PTO power test is the method normally used to verify power claims, but this cannot be applied to large tractors without a PTO or with a PTO that cannot transmit full engine power. The Board of Tractor Test Engineers and manufacturers desired a method that did not require removal of the engine from the tractor for testing, and still used OECD Code 2 performance data to verify manufacturers’ advertised engine power claims. Analyses of advertised engine power claims and OECD Code 2 test results for maximum drawbar power at rated engine speed from 48 tracked and 43 4WD tractors were used to establish two linear relationships to verify the engine power claims for these types of tractors.

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**REFERENCES**


