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FULL LENGTH ARTICLE

Performance of tractor and tillage implements in clay soil

Saeed Ranjbarian [a], Mohammad Askari [b,*], Javad Jannatkhah [b]

[a] *Department of Mechanical Engineering of Agricultural Machinery, Faculty of Agriculture, Urmia University, Urmia, Iran*
[b] *Department of Mechanical Engineering of Agricultural Machinery, Faculty of Agricultural Technology and Natural Resources, University of Mohaghegh Ardabili, P.O. Box 165, Ardabil, Iran*

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Abstract A mobile instrumentation system was developed and mounted on an MF 285 tractor to measure the performance parameters of the tractor and attached implements. The system measures implement draft, fuel consumption, real forward velocity, tillage depth and engine speed. Other parameters such as wheel slippage, drawbar power and traction efficiency would be calculated by ASABE standard. Overall energy efficiency for the tractor-implement system was calculated, too. Three implements included of moldboard plow, disk plow and chisel plow at four forward velocities (1.5, 2.3, 3 and 4 km/h) in 23 cm depth and 1500 rpm engine speed was examined. Analysis of variance (ANOVA) of resulted data revealed that increase of forward velocity results in increase of implement draft, wheel slippage, drawbar power and overall energy efficiency but results in decrease of traction efficiency. Furthermore, fuel consumption decreased by increase of velocity from 1.5 km/h to 3 km/h but increased by increase of velocity from 3 km/h to 4 km/h. Moreover, it was observed that draft requirement for implements in tests ranged from 8.2 kN for the disk plow to 13 kN for the chisel plow and fuel consumption ranged from 10.72 L/ha for the chisel plow to 26.5 L/ha for the moldboard plow. The ranges in mentioned parameters indicate that energy saving can be readily done by selecting energy-efficient implements and by proper matching of the tractor size and operating parameters to the implements.

1. Introduction

Performance data from various tractors and implements are essential for farm machinery management and manufacturers alike. Proper selection of tractors and implements for a particular farm situation to minimize energy inputs for crop production can be determined from these performance parameters (Al-suhaibani, 1992). It becomes more critical as energy costs escalate because the field machines contribute a major portion of the total cost of crop production systems. Since the advent

* Corresponding author. Tel.: +98 935 991 5284; fax: +98 451 277 9558.
E-mail address: mohammadaskari@uma.ac.ir (M. Askari).
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of the farm tractor, researchers have been developing equipment to measure tractor performance. A number of instrumentation systems based on data logger and computers have been developed to measure the performance of tractors and implements. These systems vary in complexity and sophistication from measuring one or two parameters and recording display readings by hand (Williford, 1981) to on-board microcomputer-based monitoring of several operating parameters (Wolf et al., 1980; Adsit and Clark, 1981; Wendte and Rozeboom, 1981; Tompkins and Wilhelm, 1982; Grevis-James et al., 1983; Clark and Adsit, 1985; Thomson and Shinners, 1989; McLaughlin et al., 1993; Al-Janobi et al., 1998; Sahu and raheman, 2008; Al-Hamed et al., 2010; Al-Suhaibani et al., 2010; Younis et al., 2010). A review on different instrumentation systems shows that the majority of these systems were designed for an exclusive tractor and not easily adoptable to others, they are not portable.

Measurement of implement draft and developing draft prediction equations has received most of the attention in tractor instrumentation systems (Zoerb et al., 1983; Musunda and Bigsby, 1985; Harrigan and Rotz, 1995; Grisso et al., 1996; Al-Suhaibani and Al-janobi, 1997 and Kheiralla et al., 2004). Many of the results of these researches have been summarized in ASABE Standard D497.6 (ASABE Standards, 2009). This standard uses a simplified draft prediction equation proposed by Harrigan and Rotz (1995):

$$D = \mathrm{Fi}[A + B \times S + C \times S^2]WT \quad (1)$$

where D is the implement draft; Fi is a dimensionless soil texture adjustment parameter with different values for fine, medium, and coarse textured soils; A, B, and C are machine-specific parameters; S is field velocity; W is implement width; and T is tillage depth. The quadratic coefficient for velocity, C, is zero for all tillage tools except subsoilers, manure injectors, and moldboard plows (ASABE Standards, 2009). The objective of the standard is to provide a draft prediction equation that is applicable to a wide range of soil conditions. The standard provides a good estimate of tillage implement draft but indicates that a range in draft of up to $\pm 50\%$ can be expected within the same broad textural soil class (Mclaughlin et al., 2008). There are many types of tillage systems such as different combinations of plows as primary and harrows as secondary implements. Draft and energy data for many of these implements are sparse or non-existent. Energy input data for a range of conventional primary tillage implements under local conditions are essential for selecting the most energy-efficient systems. On the other hand, past global researches indicated that the draft requirement of chisel plow was about half of the draft requirement of the moldboard plow in equal width and depth operation (Kepner et al., 1978). Recently, extensive activities for replacing moldboard plow by chisel plow in dry farming have been done in all over the world (Shafei, 1995).

One of the main indexes of energy consumption in tillage operation is overall energy efficiency of tractor. The overall energy efficiency transferred energy from tractor (for implement launch) per energy equivalent of fuel consumption in different operations (Serrano Joao et al., 2005). The overall energy efficiency indicated the general condition of tractor performance. This index is more important comparing draft efficiency and specific fuel consumption in survey of tractor performance (Crowell and Bowers, 1985). Crowell and Bowers (1985) reported that the normal range for overall energy efficiency (OEE) is 10–20%. A tractor-implement combination having an overall energy efficiency below 10% indicates poor load matching or/and low tractive efficiency, while a value above 20% indicates a good load match or/and high tractive efficiency. Many researchers believed the increasing of overall energy efficiency for tractor and implements and correct matching of tractor and agricultural machinery can be effective in decreasing fuel consumption (Samiei Far et al., 2015). With regard to the mentioned issues, the following objectives were considered for the present study:

(1) Development of a portable instrumentation system for tractors up to 90 kW (120 hp) covering the range of the common agricultural tractors in use in the Middle East.
(2) Measurement and record the performance of Massey Ferguson (MF285) tractor that is the most common tractor in Iran and other district countries.
(3) Determination of the draft requirements of primary tillage implements applied to a clay soil.
(4) Verifying the applicability of the ASABE standard equation for predicting the draft requirements of tillage implements in west Azerbaijan province, northwest of Iran.

2. Material and methods

2.1. General setup of the instrumentation system

The instrumentation system includes of a three point hitch dynamometer, a fuel meter, a fifth wheel, a depth meter, an engine rpm meter and a data acquisition system. The three-point hitch dynamometer was used to measure draft requirements of mounted implements of categories II and III. It consisted of two frames, on both frames the three-point linkages were installed so that the dynamometer could be placed between the tractor and the implement. Maximum draft force that was measured by this dynamometer was 3000 kg (30 kN). The details concerning the design and other aspects of the facility can be found in Askari et al. (2011).

Fuel consumption was measured by using a secondary tank of 8 l capacity with a level marked tube and bulb with volume 138.6 cm^3. The tank was installed and connected to the tractor fuel Tank through hoses and two valves. The tank was first filled with fuel during the actual run. The tractor was first let go on its fuel from the main tank. To measure the fuel consumption during a specific field operation, the secondary tank was utilized through the valves to fill the bulb. Then, turn the valves off and used stop watch when the fuel arrived to the first mark of the bulb. After the fuel arrived to the second mark, turn off the stop watch at the same time. The bulb had constant volume, so it is easy to calculate the fuel consumption. Fig. 1 shows the secondary tank and connecting hoses.

The real forward velocity was measured using a fifth wheel attached to a suitable position underneath the tractor as shown in Fig. 2. A magnetic pick-up mounted to the fifth wheel sensed the rotation of a toothed gear with 12-tooth (12 pulses/revolution) that was attached to the fifth wheel. The