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Evaluation Heavy Duty Tractor Performance Using CAN/Bus Technology

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ABSTRACT: Tractors in Italy are still primarily utilized for tillage operations, which represents one of the most important factors in the budget of arable farms. In this study CAN/Bus interface was used for measuring and recording tractor fuel consumption of 220 HP heavy duty tractor. Tests were carried out during ripper plow operations, investigating the effect of plow depth on tractor fuel consumption. Results showed that the tractor with heavy ripper plow attached and operating at depths of 70, 150, 200, 300, 400 mm consumes respectively 15.040, 18.420, 26.550, 30.600, 30.800 L/h. Increasing the plow depth from 70 to 400 mm lead to fuel consumption increasing by 50%.The average fuel consumption is 30 L/h in the common plows depth of 300 and 400 mm which is close to results reported from other authors in previous investigations. Instantaneous fuel consumption during operation of ripper plow at five depths shows increase of instantaneous fuel consumption when working depth increases. During the field tests variations in time-consumption diagram was observed, because of other factors, such as draft force variations and slippage, affecting fuel consumption during operations.

Keywords: fuel consumption, heavy duty tractors, CAN/Bus

INTRODUCTION

Increasing demands on the operational performance of vehicle engines lead to a massive implementation of electronic systems for their regulation and control. Increasing requirements of emission reduction, including performance and fuel savings need precise monitoring, which is provided only with the support of electronics. This trend can be seen also in agricultural machines and tractors in particular. Besides the engine, also other functional units such as transmission, hydraulic system and others are equipped with Electronic Control Units (ECU). In order to effectively control the various systems, it is necessary to ensure communication between the control units. ECU receives the information necessary for effective management from the internal sensors, in which the engine, gearbox and other parts of the vehicle are equipped. Data from the sensors are processed by the appropriate control unit and can be transmitted via the internal digital network CAN-Bus (Controller Area Network) of the vehicle so that optimum control can be achieved. CAN-Bus is currently the most widely used bus for internal communication network of sensors and control units of vehicles.

In using and choosing of tractors and other agricultural field machinery, fuel cost is an essential component of the overall cost of operation. Agricultural tractors are one of the most important machines in agriculture. In order to increase efficiency of agricultural products it is needed to increase the machine working efficiency. Taylor (1980) estimated that in the US for each 1% improvement in traction efficiency, 75-80 million gallons (284-303 million of liter) of fuel can be saved annually. In order to save non-renewable fossil energy sources it is essential to optimize fuel consumption.

Many parameters affect fuel consumption in tillage operation, such as the climate, the soil structure and humidity, tractor type (two or four wheel drive), tractor size, and the tractor-implement relationship. Tractor fuel consumption measurement methods are in Nielsen and. Sorensen (1993). Fuel consumption can be measured in directly variously. One method is to measure the fuel in tank before and after the operation. This solution produces many errors in this measurement, especially when tests are short in time. Nevertheless this method is still in use. (Nati *et al*, 2010) Use of flow meter sensors with high accuracy and precision on the tractor give better results (Facello *et al*, 2013).

The measurement system should be connected in a way that no problem occurs in fuel entering the system and measurement accuracy does not decrease (Nielsen, 1987). In new high technology tractor, fitted with CAN/Bus, it is possible to get directly from the tractor's ECU data, such as fuel consumption, draft force, wheel slip, and speed of tractor.

Research has been conducted to assess fuel consumption of tractor using flow meter sensors in tillage operations. Alimardani (1987) designed a system for measuring and recording of tractors tractive efficiency factors. In this system fuel consumption of tractor was measured by two flow meter sensors (model LS-4150) with appropriate measuring range between 2-40 liters per hour and working accuracy of 1%. For measuring engine fuel consumption, one sensor was placed between fuel filter and injector pump and another sensor was located in passage of returning fuel from injectors to tank. By measuring the amount of fuel passing through each sensor, fuel consumption of tractor's engine was determined.

Al-Suhaibani and Ghaly (2006) defines tillage as the process of creating a desirable soil condition for seed germination and growth. Tillage provides good weed control with low herbicide cost, allowing controlling diseases and insects by destroying them through burying of crop residues. Three aspects are involved in soil tillage: the power source, the soil, and the implement (Olatunji, 2007). McLaughlin *et al.* (1993) developed a research tractor to be used in regular field work as a general purpose research tool, in which a series of sensors and an on-board data logger were fitted for measuring and recording tractor operational parameters such as engine speed, drawbar load and fuel consumption. In their research the fuel consumption data were mapped and showed distinct patterns of varying fuel consumption, and engine power, which were due to field topography, and variability in soil conditions.

Yule *et al.* (1999) developed a data acquisition system to monitor in-field performance of an agricultural tractor. In their research fuel consumption was measured using a MS™ Mk4 fuel flow meter. In this way the fuel measuring system does not influence the tractor's standard fuelling arrangements in any way. Natsis *et al.* (1999) considered the influence of soil type, soil water and share sharpness of a moldboard plow on energy consumption, rate of work and tillage quality. They used a small cylindrical fuel container branched to the main fuel line, equipped with a transparent fuel level indicator in order to measure the fuel consumption. A study by Hansson *et al*, (2003) a methodology for measuring the effects of transient loads on fuel efficiency of agricultural tractors was considered. They developed a system for measurement of fuel consumption which used a flow sensor consisting of four radial pistons linked to a crankshaft with an incremental pulse encoder. The transducer gave 250 pulses/mL with an accuracy of 0.5% and the measurement range was from 0 to 40 L/hr. Possibility of fuel savings and reduction of CO_2 emissions in soil tillage in Croatia was studied.

The CAN Bus provides the central communication link on, virtually, every modern agricultural machine. Tractors, combines, and other powered vehicles use CAN Bus technology to connect multiple individual ECU and exchange sensor and control data. It is based on the ISO 11783 Standard for electronics communications protocol for agricultural and forestry equipment (Cox, 2002). The advent of CAN technology has improved vehicle diagnostics, simplified electronic control design, and enabled advanced implement management through standards such as ISOBUS. (Darr *et al.,* 2012). It is one of the major innovative technologies introduced in the agricultural system in latest time (Cavallo *et al.*, 2014).

This paper reports results on the investigation carried out on tractor fuel consumption variation measured for different working depths and different speed of tractor during ripper plow operations using CAN/Bus data. The aim of the measurements was to verify the possibility of using the data collected from the CAN-Bus of a tractor to measure the instantaneous fuel consumption of a tractor engine during field operations.

MATERIAL AND METHOD

The CAN/Bus data recording system was fitted on 220 HP 4WD standard tractor Fig. 1. The total mass of the tractor was 8780 kg and it was equipped with a 2 steps Continuous Variable Transmission (CVT). A two row ripper with roller with a working width of 4 meter was used for the field tests, test were performed at 6 and 9 km/h. The tests were conducted at five tillage depth of 70, 150, 200, 300 and 400 mm.

Fig. 1. Tractor and ripper were used in tests.

Experiments were conducted in the IMAMOTER experimental farm located at 12 km south west of the Turin (NW Italy). The tests were carried out in March 2015. Corn was grown on the testing field in the year 2014. Fig. (2). Show the place of testing.

Fig. 2. Study area in Torino, Italy.

Soil bulk density measurement. Before carrying of the tests 4 samples of soil were collected to determine the bulk density. Samples were collected using cylindrical core samplers. Bulk density and moisture content of samples were determined following the Dehroyeh's method (2005). Equations (1) and (2) show calculations to determine bulk density and soil moisture content, respectively.

$$B_d = \frac{m_s}{V_c} \qquad \ldots(1)$$

Where:
B_d = bulk density [kg/m^3]
m_s = soil mass in the cylinder [kg]
V_c = the cylinder volume [m^3]

$$MC_{db} = \frac{W_b - W_a}{W_b} \qquad \ldots(2)$$

Where:
MC_{db} = the moisture content based on dry base
W_b = sample mass before drying
W_a = sample mass after drying

The field trials were conducted under real conditions of agricultural production and using regular equipment currently adopted in the area. The testing area was performed on field approximately 350 m long and 150 m wide. Three replications were considered for any combination of conditions of depth and speed. CAN/Bus data were converted MATLAB (version 2013) format for data analysis.
Duncan's Multiple Range test at 5% probability was performed to compare the means of different treatments using SPSS 16.0 (Version, 2014) software.

RESULTS AND DISCUSSIONS

The average bulk density of the soil have been performed was 1471 kg /m^3, while the average soil moisture content was 17.26%. In table (1) the mean fuel consumption at different depths are summarized. Results of Duncan Multiple Range test indicates significant differences between fuel consumption values at the five depths.

Table 1: Fuel Consumption at different plowing Depths for speed of 6km/h. [L/h].

Depth [mm]	Repetition			Average	Standard Deviation
	1	2	3		
70	12.19	11.9	12.4	12.1	±0.83
150	13.39	13.51	13.14	13.3	±0.75
200	18.43	17.98	18.24	18.2	±1.13
300	25.20	25.44	25.04	25.2	±1.02
400	26.76	25.67	26.55	26.3	±1.21

According to the data collected, and as shown in Fig. 3, the fuel consumption increases with depth of work.
Fuel consumption of farm tractor for plowing operations in tractor speed of 6 km/h was statistically significant with increase in plowing depth ($p \leq 0.05$). The linear relationship between tractor fuel consumption and plowing depth is represented as Equation .2 and is shown in Fig. 3.

$F = 0.489D + 8.1028$ …(3)
$R^2 = 0.9261$
Where:
F = fuel consumption [L/h]
D = plowing depth [mm]

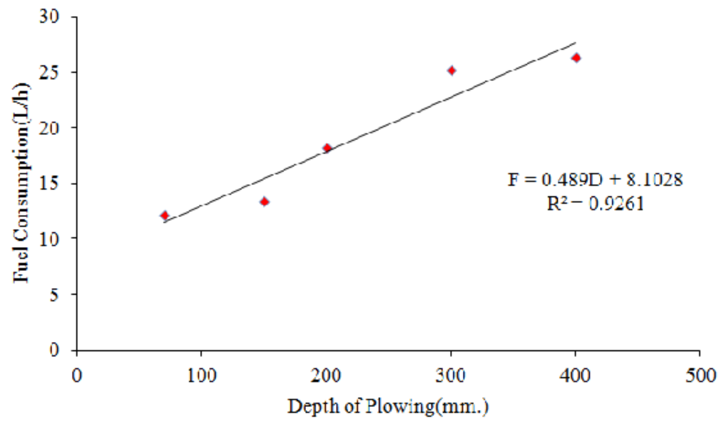

Fig. 3. Tractor fuel consumption and different plowing depth with speed of 6 km/h.

Figure 4 includes the information about the increasing of fuel consumption with the increase of the plowing depth at 9 [km/h] speed of tractor. In table (2) the mean fuel consumption at different depths are summarized. Results of Duncan Multiple Range test indicates significant differences between fuel consumption values at the five depths. The linear relationship between tractor fuel consumption and plowing depth at this speed is represented as Equation [4].

Table 2: Fuel Consumption at different plowing Depths for speed of 9km/h. [L/h].

Depth(cm)	Repetition			Average	Standard Deviation
	1	2	3		
7	15	15.32	14.8	15.04	±0.743
15	18.49	18.2	18.56	18.42	±0.81
20	26.67	26.1	26.87	26.55	±1.21
30	30.32	31.02	30.46	30.6	±1.20
40	30.37	31.11	30.93	30.8	±1.11

$F = 0.5158D + 12.728$ …(4)

$R^2 = 0.8532$

Where:

F = fuel consumption [L/h]

D = plowing depth [mm]

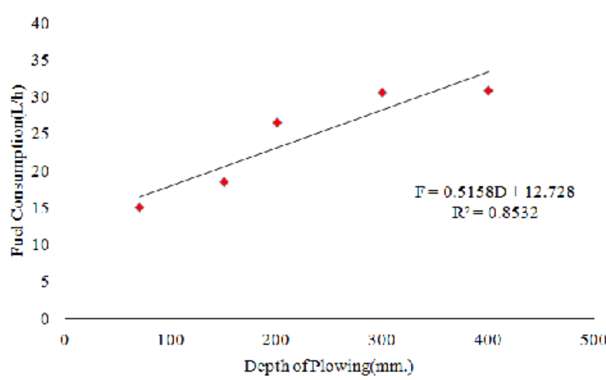

Fig. 4. Tractor fuel consumption on different plowing depth with speed of 9 [km/h].

Results of the experimental activity showed that increasing depth from 70 to 200 mm (130 mm increase) fuel consumption increased by 50.4%. If depth increased from 200mm to 400 mm (200 mm increase) fuel consumption would increase by 44.5%.

Other parameters such as draft force, acceleration of cabin and rear drive axle, increased with increasing the depth of plow and speed of tractor. In some case was observed that draft force decrease to negative, because with using the electromagnetic draft sensor, all force in all direction measured and in low speed and low depth in, some test, we record negative draft force.

CONCLUSION

CAN/Bus technology is a useful way to control the tractor performance. In this study the variation of fuel consumption at different depths of ripper operations at two speeds of tractor was carried out.

The results of the investigations showed that the fuel consumption increased with increasing the plowing depths. The plowing speed was studied and results of the study indicated that the fuel consumption increases with increasing the speed.

However, plowing depth, according to the study, results to be the most impactful factor in the determination of tractor fuel consumption during ripper plowing operations. The depths of plowing operation should be determined based on the root type, length and size of crop to be grown, while the availability of time, soil texture and implement width will determine the speed required to carry out the operation.

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