The effect of the operational characteristics of the tractor composite electronic measurement system by the standards of emotion on the performance of chisel plows in a clay loam soil

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Abstract:A microcontroller based instrumentation package was designed, developed and mounted on an 81 kW Massey Ferguson 399 (MF-399) tractor. This package continuously measures and monitors various performance parameters of the tractor and implement. These parameters were: actual and theoretical forward speed, slip, fuel consumption and draft force. The package comprised of four components: power supply, transducers, data acquisition, and display unit. Power was taken from the tractor battery. The minimum resolution of the rear wheel and fifth wheel are 0.010213 and 0.002199 m per pulse respectively. The average calibration constant for fuel consumption was 0.00004545 liter per pulse. The data acquisition system was capable of scanning the data at 0.1 s intervals. The system performed well during the field operations and the results obtained showed that the accuracies of the transducers were acceptable.

Keywords:data acquisition ,draft, fuel consumption, MF-399 tractor, microcontroller

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1 Introduction

Instrumentation systems to measure and monitor tractor performance have been developed by machinery manufacturers and universities. Tractor data acquisition systems are generally complicated and expensive.Many of them are assigned to one tractor and not easily adaptable to other tractors or machines.Many researchers (Alimardaniet al., 1987; Reed and Turner, 1993; Raheman and Jha, 2007; Pranav et al., 2010; Al-Suhaibaniet al., 2010; Singh and Singh, 2011) designed systems for measuring various performance parameters of tractor and implement. These parameters includeactual forward speed, theoretical forward speed, fuel consumption, and drawbar pull. From these measurements, drawbar power, slip, tractive efficiency and specific fuel consumption could be calculated.Actual forward speed has been measured from rotational velocity of non-powered wheel (Raheman and Jha, 2007; Pranav et al., 2010), additional or fifth wheel device (Al-Suhaibaniet al., 2010), Doppler Effect device or microwave radar (Reed and Turner, 1993). Each of these three methods has benefits and drawbacks. Non-powered wheel method is quite simple and easy to adopt, but the actual forward speed depends on soil conditions and weight transfer. By using fifth wheel method, the actual forward speed is independent ofsoil condition and weight transfer. Doppler Effect or microwave method provides an accurate actual forward speed but the device is very expensive and cannot be used when speed is less than 0.5 km/h(Pranav et al., 2010).Also the performances of these sensors are affected by the surface conditions (Khalilianet

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al.,1989). Theoretical forward speed has been calculated by measuring the rotational velocity of rear wheels using rotary encoders, proximity and magnetic sensors (Raheman and Jha, 2007; Pranav et al., 2010; Al-Suhaibaniet al., 2010; Singh and Singh, 2011).Researches have been conducted for measuring fuel consumption of a tractor using flow meter sensors.Alimardaniet al. (1987) designed a system for measuring fuel consumption of a tractor. They used two LS-4150 flow meter sensors in the system. For measuring engine fuel consumption, one sensor was placed between the fuel filter and the injection pump and another sensor was located in the line returning fuel from the injectors to the tank. By measuring the amount of fuel passing through each sensor, fuel consumption of the tractor engine was determined. Singh and Singh (2011) used a turbine flow transducer (RS 256-255) for measuring fuel consumption of a 50 kW tractor.The transducer was connected between the main fuel tank and the injection pump for measuring the fuel flowing from the tank. The return fuel from the injection pump and the injectors was cooled via a heat exchanger placed in front of the tractor radiator and then returned to an intermediate vented fuel tank downstream from the fuel transducer.The drawbar pull has been measured from strain gaged three-point links and three-point hitch dynamometer (Al-Suhaibaniet al., 2010).

So far, there are no detailed studies related to measuring tractor performance parametersby transducers in field operations in Iran.There are about 1470 tractor units Massey Ferguson 399 (81 kW) in Fars state, Iran (Raoufatet al., 2011).Considering extensive agricultural activities in Fars state, south of Iran and large number of farm tractors, this research was devoted to developing and installing an instrumentation package capable of measuring, recording and monitoring some MF-399 tractor performance parameters. These parameters were theactual and theoreticalforward speed, slip, draft force and fuel consumption.

2 Materials and methods

An instrumentation package was developed and installed on a MF-399 tractor. Basically, it comprised of four components: power supply, transducers, data acquisition, and display unit. The system had in-built power supply, capable of being operated by 12 V DC. An inverter was used to convert 12 V DC from tractor battery to 230 V AC. This 230 V AC was then stepped down to 12 V DC using a transformer.

The general arrangement of the data acquisition system, transducers and tractor are shown in Figure1.

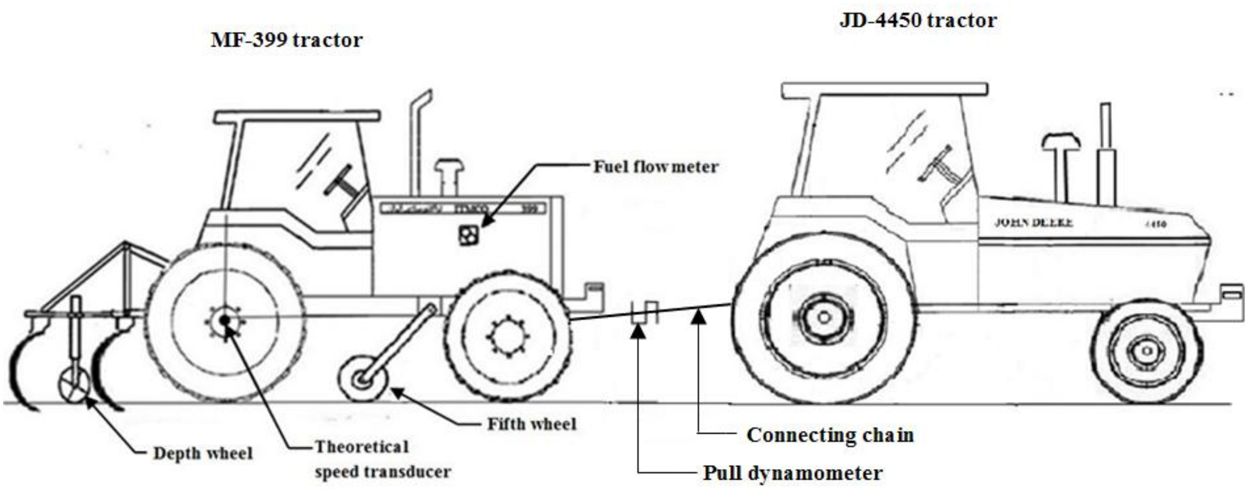

Figure 1Location of the transducers on the instrumented tractor.

2.1 Transducers

Fuel consumption was measured with two turbine flow transducers (VISION-1000, Switzerland) of a range of 0.1-2.5 L/min. One transducer was connected between the fuel filter and the injector pump of tractor; another transducer was used to measure the fuel returning from the injectors and the injector pump to the tank. The actual speed was measured using a fifth wheel attached to a suitable position underneath the tractor, while the theoretical speed came from the right rear wheel. Two shaft encoders (Autonics, South Korea) with 500 pulse/ revolution were used in this study. One shaft encoder was mounted on the fifth wheel and used to measure actual speed. Another shaft encoder was mounted on the right rear wheel for measuring theoretical speed.The speed data were input to microcontroller to calculate the wheel slip and generate a digital display of the same. The following Equation 1 was used to calculate the slip% from the above speeds (Pranav et al., 2010).

$$S = 1 - \frac{V_a}{V_t} \times 100 \qquad (1)$$

Where S is slip, V_a is actual forward speed and V_t is theoretical forward speed.

A load cell (Keli, China) was used to measure the draft force according to RNAM[2]method. The implement was mounted on the MF-399 tractor which was used to support it but did not provide power. This was drawn by another tractor (John Deere 4450)through the load cell mounted on the tractor hitch. Hence, the draft force was measured once the rolling resistance of the MF-399 tractor was subtracted.

2.2 Data acquisition system

The data acquisition system consisted of an electronic circuit and a portable computer linked together via a USB port (Figure 2).

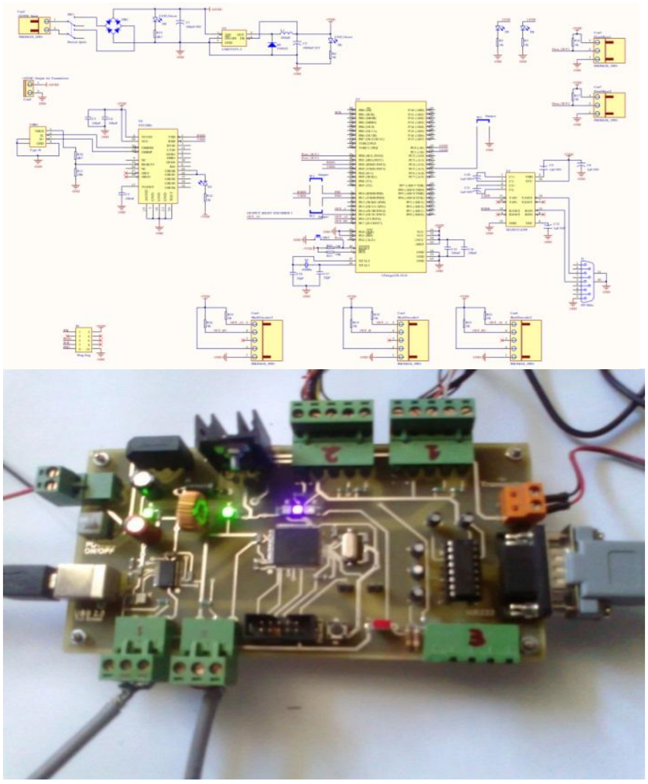

Figure 2 Data acquisition system and electronic circuit

This circuit received the output signals of transducers and sends them to the port of Atmega128 AVR microcontroller. The microcontroller calculated slip, fuel consumption, theoretical forward speed and actual forward speed and at the same time these results were displayed on portable computer screen. Finally these results were stored in excel type files. The data were scanned and sampled at 0.1 s intervals.The detailed electronic circuit diagram for measuring performance parameters and displaying them on the portable computer screen is given in Figure 3.

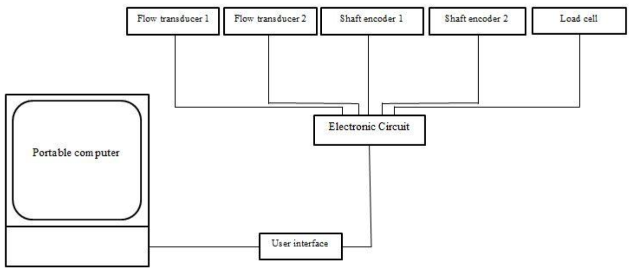

Figure 3 Block diagram of data acquisition system

2.3 Generalized software

There is a need to input some parameters to measure and monitor tractor performance.These parameters

[2]-Regional Network for Agricultural Machinery

include driver wheel diameter, driven wheel diameter, actual forward speed and COM port number. While the actual forward speed from the fifth wheel isn't equal with input actual speed to the software, the microcontroller doesn't store any data.A window based graphical user interface is provided to input theses required parameters.The interface was written in C^{++}.The main window of the programis shown in Figure 4.This window shows performance parameters of the tractor and implement.

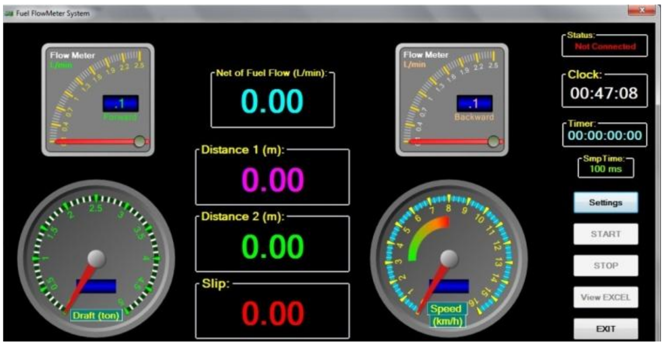

Figure 4Main window of the software.

2.4 Calibration and testing the instrumentation package

All the transducers used in the package were calibrated. The fuel transducers were calibrated by collecting the output pulses for a known volume (200 ml) of diesel fuel. They gave 22000 pulses per liter which counts to a calibration constant of 0.00004545 liter per pulse. For calibration of the two shaft encoders used on the wheels; the number of pulses per revolution for each of them was checked. The circumferences of the rear wheel of the tractor (18.4/15-34) were measured under recommended inflation pressure (136kPa) on a straight tarmacadam course with no load at a speed of 0.5 km/h to assure the absence of slip. The rear wheel circumference measured an average of 5.10697 m and the minimum resolution of the rear wheel shaft encoder was 0.010213 m per pulse. The fifth wheel circumference measured an average of 1.09955 m and the minimum resolution of the fifth wheel shaft encoder was 0.002199 m per pulse.Since the load cell output was in voltage, load cell calibration was needed. For this purpose, TM-1020 load cell transmitter was used (TIKA Engineering™, Iran).The transmitter had two calibration modes: LD- Mode and Full scale Mode.LD- Mode calibration was performed using two reference weights. One of these weights was 20% of load cell capacity and theother weight was zero. Full scale Mode calibration was performed using load cell parameters. In this mode the sensitivity of the load cell and full scale output of the load cell are needed.In this research the second mode was used. In this mode the sensitivity of the load cell (2.0001 mv/v) and full scale output of the load cell (50kN) were the inputs of TM-setting window of the transmitter software.

2.5 System performance

To evaluate the data-acquisition system's capability to monitor the performance of the tractor, field tests were conducted. Prior to the field tests, initial checkout and testing of the data acquisition system were performed at the base station.

2.6 Field tests

The field tests were conducted in Badjgah Research Station, Shiraz University located in NW Shiraz, Iran. The soil texture at the experimental site wasclay loam consisting of 35% sand, 30% silt and 35% clay. The average cone index and moisture content, dry basis (d.b.) of the soil for a range of depths between 0 and 20 cm were 2840 kPa and 8.4% respectively. Cone index values were obtained by taking penetrometer readings at 5 cm increments to depths of 20 cm at several locations of the plots using a cone penetrometer according to ASABE Standards S313.2 with a cone base area of 130 mm^2(ASABE Standards, 2009).A 225 cm mounted-type chisel plow (Rau, Germany) with nine spring curved shanks in two rows and two gauge wheels was used for the field tests.A tractor speed of 3 km/h and implement depths of 10, 15 and 20 cm were selected for field tests. During the field tests, the tractor was operated in a suitable gear to attain the target speed. In order to obtain the implement depths during field operation, corresponding depths were preset in the base station.

After conducting the field test for the first implement depth, the tractor was taken back to the base station for presetting the next implement depth. Wooden blocks of heights 10, 15 and 20 cm were used to preset the implement depths. For the first depth setting, the chisel plow was mounted on thetractor and then the three point hitch height lever in the tractor cab was operated to keep the chisel plow resting on the floor.The tractor, together with the implement, was pivoted such that the four wheels of the tractor were exactly on the top center of four wooden blocks of same height (10 cm). The three point hitch height lever was operated to lower the implement to touch soil surface. The chisel plow was leveled by adjusting the top link and lift link together. Then a chalk marking was provided against the present position of the three point hitch height lever to indicate the first depth. For the other each depth, prior to the field test, the same procedure was repeated and corresponding markings were provided against the three point hitch height lever to indicate the depths. Here we have adopted the same methodology adopted by other researchers.The plot area was 10 m wide and 50 m long (500 m^2).To begin the field tests, the three point hitch height lever was operated to lower the implement corresponding to the first implement depth (10 cm).Then the tractor was accelerated to the required operating speed with a known gear before entering the first test area. The data acquisition system was activated by entering the diameter of rear wheel and diameter of fifth wheel and thenthe start button has been pushed.Data acquisition continued until the end of the test area and it was stopped by pressing the push button switch again as the tractor passed the flag showing the end of the test area. After finishing the field test for the first implement depth, the tractor was taken back to the base station for the next depth setting. Depth setting was made as described above and the tractor was again driven straight towards the second test area. While the tractor approaching the test area, the implement was lowered corresponding to the implement depth, 15 cm before entering the test area. For the data acquisition, the same procedure was repeated as in the first test area. After setting the implement depth at the base station, data acquisition was also performed in the third test area with the implement depth, 20 cm and the same operating speed.

3 Results and discussion

All the sampled data from the runs (three replicates) wereanalyzed to obtain a statistical description for the parameters: tractor speed anddraft force(Table 1).Table 1shows that the values of the coefficient of variation for all the parameters were within the normal range of 10% about the mean (ASABE, 2009). These variations could be expected under field conditions.The data acquisition system had no significant effect on transducer signals.The mean tractor speeds in all the three test areas were almost very close to each other.

Table 1 Statistical description of measured and calculated parameters of 9 shanks mounted-type chisel plow

Description	Speed, km/h	Draft force, kN
Preset implement depth, 10 cm		
Mean	2.45	2.30
Min	2.26	2.17
Max	2.66	2.40
Standard deviation	0.20	0.11
CV[a] (%)	8.16	5.13
CNU[b] (%)	16	10.18
Preset implement depth, 15 cm		
Mean	2.70	5.58
Min	2.61	4.89
Max	2.74	6
Standard deviation	0.07	0.60
CV[a] (%)	2.60	10
CNU[b] (%)	4.82	19.90
Preset implement depth, 20 cm		
Mean	2.76	12.85
Min	2.62	12.40
Max	2.79	13.08
Standard deviation	0.02	0.38
CV[a] (%)	0.7	3.01
CNU[b] (%)	6.15	5.28

Note: [a] Coefficient of variation

[b] Coefficient of non-uniformity of readings, $\frac{\max - \min}{\text{mean}} \times 100$

4 Conclusions

A precision instrumentation package was developed and installed on a Massey Ferguson (MF) 399 tractor to measure and record tractor and implement performance parameters such as actual forward speed, slip, fuel consumption and draft force in field operations. The average resolutions for fuel consumption, rear wheel speed and fifth wheel speed transducers were 0.00004545 L per pulse, 0.010213 m per pulse and 0.002199 m per pulse respectively. The TM-1020 load cell transmitter was used for load cell calibration. The instrumentation package was tested in the field and its performance was found to be good. This package was found to be accurate and reliable in sampling, storing and processing the data collected from the various transducers during the field operation.

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