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AVERAGE AND INSTANTANEOUS FUEL CONSUMPTION OF IRANIAN CONVENTIONAL TRACTOR WITH MOLDBOARD PLOW IN TILLAGE

H. Fathollahzadeh[1], H. Mobli[2], A. Rajabipour[2], S. Minaee[3], A. Jafari[2] and S.M.H. Tabatabaie[2]
[1]Department of Agricultural Machinery, Islamic Azad University, Shahre-Rey Branch, Iran
[2]Department of Agricultural Machinery, Faculty of Biosystems Engineering, University of Tehran, Karaj, Iran
[3]Department of Agricultural Machinery, Faculty of Agriculture, University of Tarbiat Modarres, Tehran, Iran
E-Mail: fatolazade@ut.ac.ir

ABSTRACT

John Deere 3140 tractors work powerful and useful in Iran farmlands. In this study two fuel flow meter sensors were used for measuring tractor fuel consumption and the measurement system was installed on diesel engine of a 72.3kW John Deer 3140 tractor. A three-share moldboard plow was used for studying the effect of plow depth variations on tractor fuel consumption. Results showed that the tractor with the moldboard plow attached and operating at depths of 0.15, 0.25 and 0.35 m consumes 27.446, 30.096 and 34.06 liters of fuel per hectare, respectively. Increasing plow depth from 0.15 to 0.25 and 0.15 to 0.35 m increases fuel consumption by 9.66 and 24.1%, respectively. The average fuel consumption is 30 L/ha in the common plow depth of 0.2 to 0.25 m which is close to results reported from other parts of the world. Instantaneous fuel consumption during operation of moldboard plow at three depths shows increase of instantaneous fuel consumption when working depth increases. In the farm experiments, only working depth of plow was changed but variations in time-consumption diagram showed that there were other factors affecting draft and thereby fuel consumption during operation.

Keywords: tractor, tillage, fuel consumption, flow meter, moldboard plow, depth.

INTRODUCTION

Agricultural tractors are one of the machines in agricultural productions which have great importance. It is obvious in order to increase efficiency of agricultural products; it is needed to increase the machine working efficiency. For example Taylor [19] estimated that in the US for each 1% improvement in traction efficiency, 75-80 million gallons of fuel could be saved annually. Duo to the limitation of nonrenewable fossil energy sources it is essential to optimize fuel consumption.

John Deere 3140 tractor is one of useful tractor with high economic life and high efficiency in Iran. Ashtiani [4] studied about economic life of some kind of tractors and reported that John Deere 3140 has fairly high economic life. Ajabshirchi [2] reported that with determining mathematical model of maintenance cost for tractors, John Deere 3140 has fairly low maintenance cost. Another advantage of John Deere 3140 is high traction efficiency that Shaker [17] has reported. Maleki [12] studied about determining of maximum authorized time for driving a tractor and specified that maximum authorized time for driving is for John Deere 3140. Many number of John Deere 3140 tractors were entered in Iran from 1983 to 1991 but due to the high economic life, low maintenance cost, high traction efficiency, maximum authorized time for deriving and etc, John Deere 3140 is used much in Iran's farmlands and Iranian farmers use this tractors as a powerful and useful tractor. In Iran the economic life of tractors was determined 13 years however John Deere 3140 tractors work powerful and useful in Iran farmlands now [1].

There are many parameters in a tillage operation that can affect fuel consumption of a tractor, such as type and structure of soil, climate, relative humidity, tractor type (two or four wheel drive), tractor size, and the tractor implement relationship. So, tractor fuel consumption in different methods is not constant and varies from one to another [15]. Measuring consumed fuel of engine in direct method can be done variously. One method is: measuring the fuel in tank before and after the test operation. But, there are many errors in this measurement, especially when total fuel consumption in a short test is low. Another method is: using flow meter sensors with high accuracy and precision on the tractor. The measurement system should be connected in a way that no problem occurs in fuel entering the system and measurement accuracy does not decrease [16].

Research has been conducted for measuring fuel consumption of tractor using flow meter sensors in tillage operations. Alimardani [3] designed a system for measuring and recording of tractors effective 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. McLaughlin [13] developed a research tractor 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 as the tractor is doing normal field work. In their research the fuel consumption data were mapped. The map showed distinct patterns of varying fuel consumption, and engine power, which were due to field topography, and variability in soil conditions. Yule [21] 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 manufactured by JPS Engineering, Birmingham, England. Flow meter consisting of a full flow filter, a 'demand only' fuel pump, a positive displacement flow sensor and a heavily finned fuel return tank. The energy to drive the flow sensor was provided by a slave electrical fuel pump. In this way the fuel measuring system does not influence the tractor's standard fuelling arrangements in any way. Natsis [14] considered the influence of soil type, soil water and share sharpness of a mould board 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 to measure the fuel consumption. In a study by Hansson [9] 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 (VAF Instruments B.V., Dordrecht, the Netherlands) M31C 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 by [7]. In this research, fuel consumption was measured by applying a volumetric system. Bedri [5] developed an instrumentation package for monitoring tractor performance. The package included a data acquisition system and transducers for monitoring forward speed, rear wheel speed, fuel consumption and drawbar pull. The developed instrumentation package was mounted on a Fiat DT980 tractor. They used an RS 256-225 turbine flow transducer having a range of 3-90 L/hr to measure fuel flow rate. The transducer was connected between the main fuel tank and the injector pump for measuring the fuel flowing from the tank. The return fuel from the injector 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 down stream from the fuel transducer. Kheiralla [10] measured tractor fuel consumption at various depths and speeds by using oval flow meter sensor. The mentioned flow meter was located between injector pump and fuel filter and experiment data was saved on an extra memory and was analyzed by transferring them to a computer. Yet, there are no researches about instantaneous consumption of fuel in tillage operation. In addition, there are no detailed studies in Iran related to consideration of tractor fuel consumption in tillage operations which use moldboard plow and no research has been conducted using flow meter sensors.

In this research, tractor fuel consumption variation was measured at different working depths of moldboard plow using a special system designed for measuring tractor fuel consumption. Diagram of flow-time fuel consumption was displayed when moldboard plow attached to tractor, because application of instantaneous consumption diagram can be useful and effective in determination of transient loads on engine and instantaneous variation of fuel consumption.

MATERIALS AND METHODS

Fuel measuring system

In fuel measuring system, an electronic board is used to receive and save digital pulses sent by the flow meter sensors. In this system, a battery (as power supply), a monitoring unit, a keyboard (for controlling the operation of system), a memory (for recording data in fields where sampling and transferring data directly to computer is not possible), a connector for serial port (for adapting voltage level of micro controller to computer) and the main controller which was an AVR Atmega16.

Flow meter sensors

The flow meter used for measuring input fuel value to injector pump was turbine type (VISION2000) and 6900 pulses were sent for passing one liter of the fuel. Some specifications of this sensor were: appropriate working range: 0.1-3 liter per minute, length: 55 mm, weight: 15 g and accuracy: $\pm 0.8\%$ [8]. A sensor of turbine type model (RS256-225) was used to measure returning fuel from injectors and injector pump to the tank [5].

Tractor and moldboard plow used in research

The measurement system was installed on diesel engine of a 72.3kW John Deer 3140 (3998 kg). A three-share moldboard plow with a working width 1.4 meter operating at 3 km per hour speed was used for studying the effect of plow depth variations on tractor fuel consumption. The reason for using these tractor and moldboard plow was popularity of them in Iran. The experiment was conducted at three tillage depth of 0.15, 0.25 and 0.35 m.

Research location and soil

Experiments were conducted in the experimental farm of agriculture faculty of Tehran University located in 3 km south west of the Karaj city with 300 mm average rainfall during October 2008. The soil at the experimental site was loamy texture (31.94% sand, 74.76% silt, and 24.27% clay) where corn was grown during 2007. Air temperature measured 16-18 ˚C during the test.

System installation

In addition to the sensor installed where fuel enters the injector pump, another flow meter was located in fuel returning pipe to the tank [3]. Total engine fuel consumption in a given distance of operation was calculated by subtracting the reading from the two sensors and the result was saved in memory. Also, consumption amount per second was measured by the measurement system to consider instantaneous consumption. The related data was displayed by monitoring unit and saved.

Soil bulk density measurement

For measuring bulk density, three soil samples from different parts of the land were collected using a cylindrical core sampler. Collected samples were immediately put in plastic bags to conserve moisture during transferring to the laboratory. Bulk density of soil was calculated by eqn. (1) [6].

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

Where

B_d = bulk density (kg/m^3)

Ms = soil weight in the cylinder (*kg*)

V_c = the cylinder volume (m^3)

Measurement of soil moisture

Samples were taken to measure soil moisture in the surface layer, 0.1 to 0.15 m and 0.2 to 0.25 m. Samples were weighted before and after 105˚C. Moisture content of soil samples by was calculated using eqn.(2) [6].

$$MC_{db} = \frac{W_b - W_a}{W_b} \times 100 \quad (2)$$

Where

MC_{db} = moisture content based on dry weight

W_b = sample weight before drying

W_a = sample weight after drying

Experimental procedure

The field trials were conducted under real work conditions of agricultural production and used farmers' equipment. A part of land with length of 50 m was chosen for the test. Moldboard plow with a given working width was used for tillage. Depth and acquiring tractor rpm were adjusted uniformly and stabilized in an area with length of 10 meters before the mentioned land. Start button was pressed when tractor entered to the land and stop button was pressed when plow received into final point. Three replications were considered for every test depth for measuring the effect of tillage depth on tractor fuel consumption. Duncan's Multiple Range test at 5% probability was performed to compare the means of different treatments by using the computer software SPSS 12.0 (Version, 2003).

RESULTS AND DISCUSSIONS

Table-1 shows tractor fuel consumption during plowing 0.15, 0.25 and 0.35 m depths with 18.35% soil moisture and 1106 kg/m^3 bulk density. As shown in this Table, operating the moldboard plow required 27.446, 30.096 and 34.06 liters of fuel per hectare in depths of 0.15, 0.25 and 0.35 m, respectively. Results of Duncan Multiple Range test indicates significant differences between fuel consumption values at the three depths (Table-1), the fuel consumption increasing with depth of work, as expected.

Table-1. Fuel consumption data for various plowing depths (l/ha).

	Replication				
Depth (m)	**1**	**2**	**3**	**Average***	**Standard deviation**
0.15	27.363	27.432	27.545	27.446[a]	± 0.091
0.25	31.661	29.782	28.845	30.096[b]	± 1.433
0.35	33.079	35.727	33.373	34.060[c]	± 1.451

* Fuel consumption for operating a 1.4 m wide moldboard plow.

Table-1 and Figure-2 show that a 66% increase in cutting area of soil layer by plow increases fuel consumption by 9.65%, whereas, a 40% increase in cutting area with depth increasing from 0.25 to 0.35 m, increases fuel consumption by 13.17%. Maybe a reason for more increase of fuel consumption for increasing 40% than 66% cutting area when depth changes from 0.15 to 0.25 m because of (due to results of most researches) specific draft reduces up to a specific depth, but after that increases. Also, reports show that the least specific draw for some of the 36cm shares has been at depth 0.13 to 0.18 m [18].

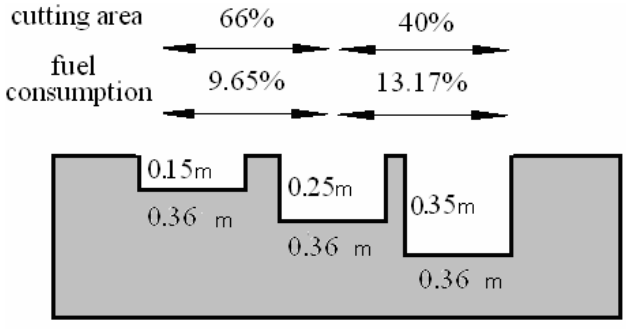

Figure-1. Variations of cutting area and fuel consumption during depth change.

Results showed that with increasing depth from 0.15 to 0.25m (0.1 m increase) fuel consumption increased by 9.66%. If depth increased from 0.15 m to 0.35 m (0.2cm increase) fuel consumption would increase by 24.1%.

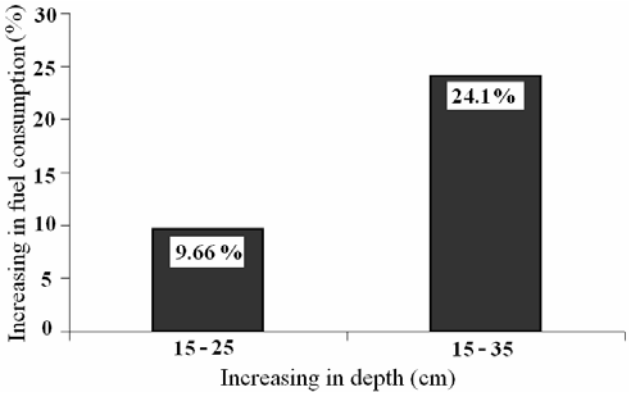

Figure-2. Effect of depth increase on fuel consumption.

Figure-3 shows a linear relationship between fuel consumption and working depth of moldboard plow represented by eqn. (3).

$$Fc_m = 0.33h + 22.26 \quad (R^2 = 0.987) \qquad (3)$$

Where

Fc_m = fuel consumption (L/ h)

h = working depth (cm)

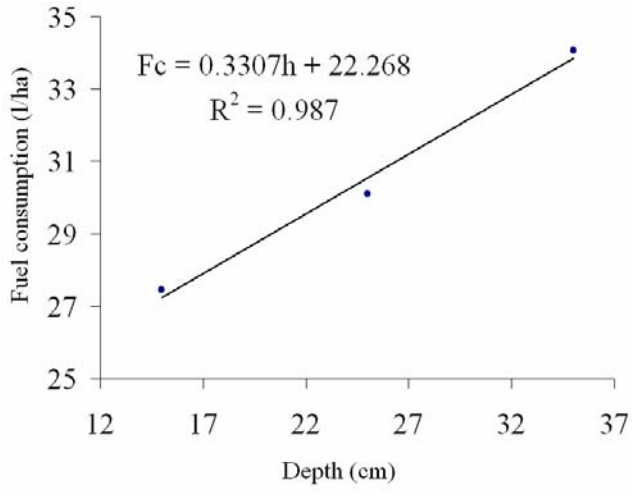

Figure-3. Tractor fuel consumption as a function of working depth of moldboard plow.

Instantaneous fuel consumption during operation of moldboard plow at three depths of 0.15, 0.25 and 0.35 m is shown in Figure-4. The diagram shows increase of instantaneous fuel consumption when working depth increases. In the farm experiments, only working depth of plow was changed as one of the effective factors in fuel consumption rate, but variations in time-consumption diagram of moldboard plow with approximate speed 3 km/hr show that there are other factors affecting draft and thereby fuel consumption during operation such as soil texture, moisture content, soil compression ratio, plant residue and bulk density [18]. Fuel consumption maps can be developed using this technique indicating. Indicating spatial variations resulting from topography and soil conditions [13].

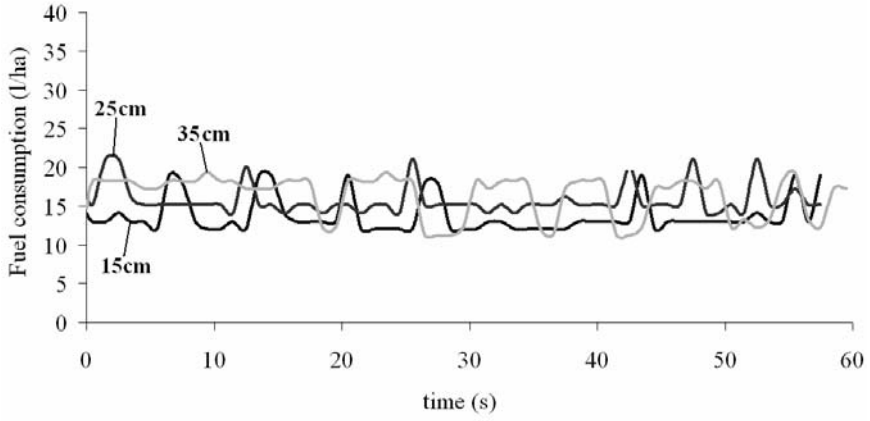

Figure-4. Instantaneous fuel consumption by tractor engine.

There are some related studies that show important factors affecting fuel consumption for tillage operations with moldboard plow.

Kheiralla [10] measured fuel consumption for a moldboard plow with three shares attached to a 64kw MF3060 tractor in various conditions. They reported fuel consumption values of 21.2 and 24.6 for 0.18 and 0.235 m depths, respectively.

Although there are different conditions, average fuel consumption value obtained in this study, are close to those reports by [10].

Filipovic [7] in Croatia did a research on fuel consumption value for each applied implement in various

tillage systems. They used a moldboard plow for common tillage system attached to a 92 kW four wheel drive tractor. Results showed that moldboard plow in tillage operation (for planting wheat and soybean) consume 28.16 and 34.45 liters of diesel fuel per hectare. Filipovic [7] did not measure tillage depth and fuel consumption value and they only studied common tillage operation. Fuel consumption value in this study measured 27.44 to 34.06 (L/ha) which is in conformity with Filipovic results. Yalcin [22] studied fuel consumption during usage of moldboard plow (common tillage system) in dry and wet soils. Tractor used in their experiments was a 40kW FIAT 54C. They reported 30 and 23 L/ha of fuel consumptions for wet and dry soils, respectively. These results show that the range of fuel consumption is close to that found in the present studies. Weidema [20] showed some of their results about fuel consumption of various implements in their research. They considered a moldboard plow with three shares attached to a 60kW tractor when slip and working rate were 13.2% and 0.564 hectare per hour, respectively. Fuel consumption was reported 32 liter per hectare. They operated common regional tillage and their results are the same in comparison with current fuel consumption results for maximum depth. Koga [11] in their report mentioned that a 59kW tractor operating a moldboard plow consumed 29.8 liters of fuel per hectare. Their operating system was common tillage system.

CONCLUSIONS

The tractor with the moldboard plow attached and operating at depths of 15, 25 and 35cm consumes 27.446, 30.096 and 34.06 liters of fuel per hectare, respectively. Increasing plow depth from 0.15 to 0.25 m and 0.15 to 0.35 m increases fuel consumption by 9.66 and 24.1%, respectively. The average fuel consumption is 30 l/h in the common plow depth of 0.2 to 0.25 m which is close to results reported from other parts of the world.

Flow-time diagram showed that some of important and effective factors of instantaneous fuel consumption during tillage operations vary continuously in farm. Some of these factors that can be mentioned are soil texture, moisture content, soil compression ratio, plant residue and bulk density. Fuel consumption map could be developed using instantaneous fuel consumption data and a positioning system.

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