INVESTIGATION OF INTERACTION BETWEEN TRACTOR LOAD AND DATA COLLECTED IN THEIR MODULES

Antanas Juostas, Algirdas Janulevičius
Lithuanian University of Agriculture
antanas.juostas@kesko.lt, algirdas.janulevicius@lzuu.lt

Abstract. The paper presents tractor working conditions during their working life by using the data collected in their electronic controllers. Load profiles of „Massey Ferguson" tractors, where the working hours, during the working period, summarized under engine speed and cyclical fuel injection methodology are introduced. The investigation results show how many hours the investigated tractors are working at a low (up to 30 % of maximum torque (M_{max})) at a medium (30-50 % M_{max}) and high (>50 % M_{max}) engine load. The result shows what part of time at different engine load tractors worked at low (up to 1100 rpm), at medium (1100-2100 rpm) and high (more than 2100 rpm) engine speed. The paper presents medium distribution of tractor working hours at different engine load conditions. The investigation shows the possibilities for improving tractor handling technologies by using a wider range of engine power and by decreasing fuel consumption.

Keywords: tractor, histogram, torque, engine speed, working hours, load, load profiles, power.

Introduction

Trade technology of agricultural products requires more powerful and universal tractors. During constructing the tractor aggregates attention has to be paid to the tractor optimal working load conditions. Tractors work efficiently if their engines are well loaded and work at economical speed conditions. It means, when tractor engine power is used at more than 80 % and at possibly low engine speed. At a higher transmission gear and at lower engine speed the tractor generates the same level of power. However, a tractor operated in a higher gear and at lower engine speed can achieve the same working speed and up to 4-6 % of reduction in fuel consumption [1-5].

The investigation shows that many tractors and their equipment on the farms are drawn without any reasonable methodology and taking into account the optimal engine operating conditions. Mostly tractors worked only partly loaded, i.e., utilized only a part of tractor power and traction force [6-10]. Tractors and their engines during working life worked for quite a few hours at idle speed [8-10]. A few data about how reasonable and efficient tractors worked during working life are presented.

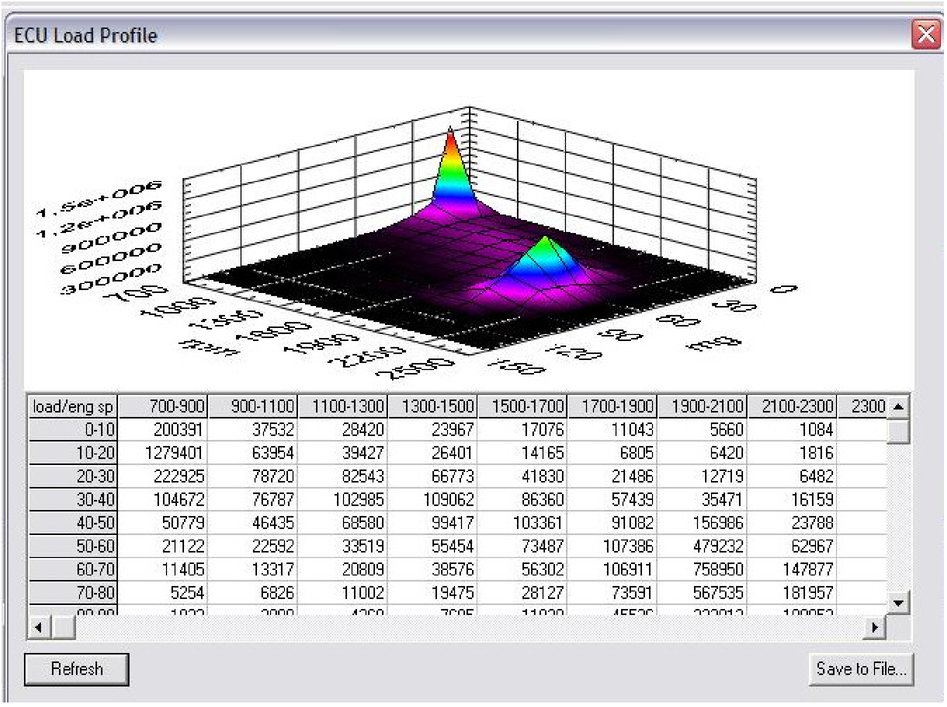
More tractors and equipment are equipped with electronics. Different mechatronic systems operate the working processes and collect information. Microprocessors in Massey Ferguson tractors collect fundamental information such like: worked hours under certain engine speed and cyclic fuel injection. The main working factors of Deutz Fahr Agrotron, Claas Atles and other tractors (working hours at different engine speed and torque) are permanently recorded and stored in the microprocessors. This information can be read and printed by help of a special testing program. Such database allows to analyze the tractor working conditions [11-13]. The analysis of tractor engine load conditions, during its working life, would let us evaluate reasonability of the tractors use. The analysis would show a direction for improvement of the tractor use, fuel consumption and harmful impact to environment.

The task of the work is to investigate the tractor working quality evaluation possibilities according to the information collected in their microprocessors (working hours under certain engine speed and cyclic fuel injection) and investigate the tractor medium–power performance quality by the load factors (engine speed and torque aspects) during its working life.

Materials and methods

For investigation of the working quality during the working period Massey Ferguson MF 6499 tractors were chosen. These tractors are equipped with the EEM-3 „Electronic Engine Management 3„ system. The EEM 3 system is designed for diesel engines. The basic function of the EEM-3 engine control system is continuous adjustment and measuring of the load, quantity of fuel and rotating speed [11-13].

For investigation of the tractor engine working quality, during its work life, load profiles were taken from the engine control units [13]. The load profiles are written with help of laptop and an adapter to the vehicle connector and an extension cable. Figure 1 shows an engine load profile. The engine load profile is divided in groups, such like engine speed (n) and cyclic fuel injection quantity (b_c). The load profile shows how long the tractor worked under cyclic fuel injection of 0-10, 10-20, 20-30... and 190-200 mg. In the load profile and its table it can be seen how long the tractor engine worked under engine speed of 700-900, 900-1100, 1100-1300, 1300-1500, 1500-1700, 1700-1900, 1900-2100, and 2100-2300 rpm.



load/eng sp	700-900	900-1100	1100-1300	1300-1500	1500-1700	1700-1900	1900-2100	2100-2300	2300
0-10	200391	37532	28420	23967	17076	11043	5660	1084	
10-20	1279401	63954	39427	26401	14165	6805	6420	1816	
20-30	222925	78720	82543	66773	41830	21486	12719	6482	
30-40	104672	76787	102985	109062	86360	57439	35471	16159	
40-50	50779	46435	68580	99417	103361	91082	156986	23788	
50-60	21122	22592	33519	55454	73487	107386	479232	62967	
60-70	11405	13317	20809	38576	56302	106911	758950	147877	
70-80	5254	6826	11002	19475	28127	73591	567535	181957	

Fig. 1. **Load profile of Massey Ferguson tractor MF6499**

Engine speed, during its work, is set by an accelerator pedal (lever), which gives a rate control to the governor. The governor according to the engine load (torque) regulates the fuel injection quantity. During the engine test hourly fuel consumption B_d was determined, for example, kg per hour [7]. The fuel consumption depends on the developed engine power. Specific fuel consumption b_e shows, how much fuel is used for effective engine work unit:

$$b_e = \frac{9554\ B_d}{M_e\ n} = \frac{1000\ B_d}{P_e} \quad (\text{g kWh}^{-1}) \tag{1}$$

According to the known cyclic fuel injection quantity b_c (mg) hourly fuel consumption B_d (kg) could be counted:

$$B_d = b_c \frac{m_c}{n_\tau} \frac{n}{60} \frac{3.6}{1000} \quad (\text{kg}) \tag{2}$$

where m_c – number of cylinders;
n_τ – revolutions of the crankshaft during one cycle of cylinder work;
n – engine speed.

From equation 1 and 2 equation dependence on torque and fuel consumptions can be obtained:

$$M_e = \frac{9554\ B_d}{b_e\ n} = 0.57 \frac{m_c}{n_\tau} \frac{b_c}{b_e} \quad (\text{Nm}) \tag{3}$$

The obtained equation shows, that engine torque can be calculated when cyclic fuel injection quantity and specific fuel consumption are known. The specific fuel consumption depends on engine speed and its load. The engine characteristics of MF 6499 series tractor, done according to the testing results of „Cemagref“ company [14], are shown in Fig. 2.

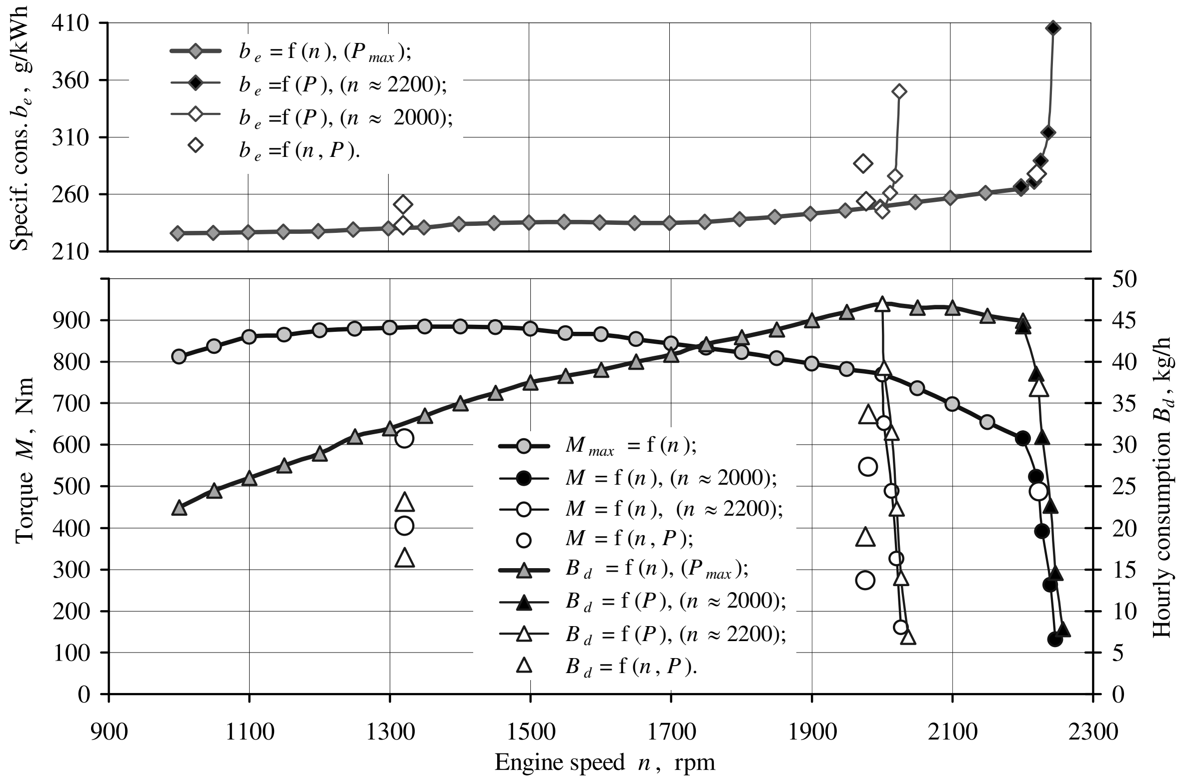


Fig. 2. **Characteristic curves sheet of Massey Ferguson tractor MF6499 series [14]**

From the specific fuel consumption given in Fig. 1, hourly fuel consumption and engine speed characteristics composed specific fuel consumption dependence on hourly fuel consumption at various engine rate conditions (Fig. 3).

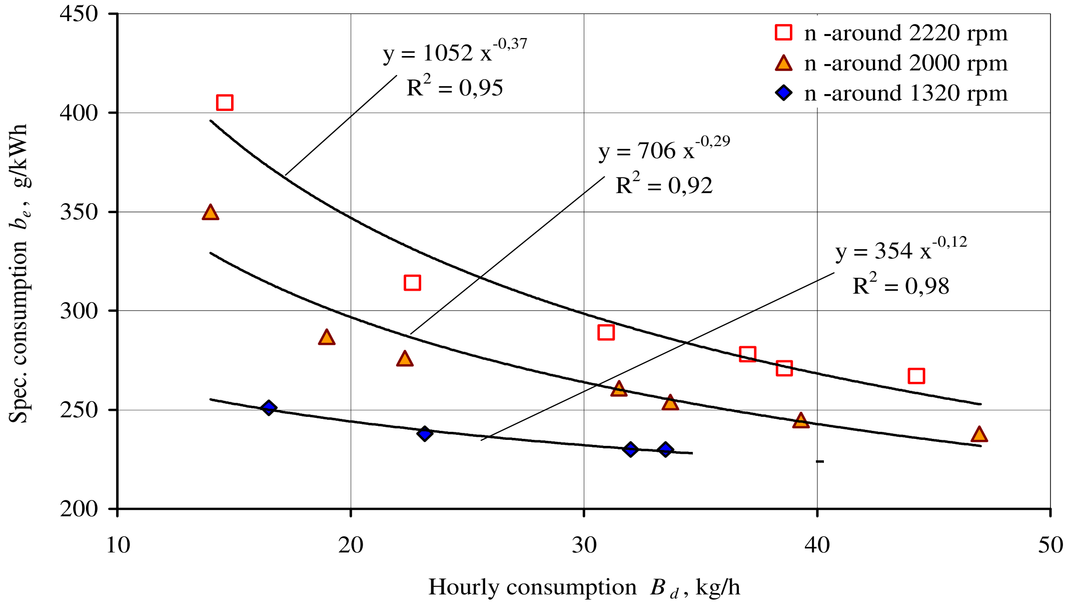


Fig. 3. **Specific fuel consumption dependence on hourly fuel consumption at various engine rate conditions**

From Fig. 3 it can be seen, that the specific fuel consumption variation under considerate engine rate conditions runs according to the dependence:

$$b_e = k_1 \left(B_d\right)^{-k_2} \tag{4}$$

where k_1 and k_2 – coefficients depending on engine load and revolutions.

After inserting mathematical expressions b_e and B_d into equation 3 we obtain an equation dependence on engine torque, revolutions and cyclic fuel injection:

$$M_e = \frac{0.57\, b_c}{k_1 \left(\frac{0.06\, n\, b_c}{1000} \; \frac{m_c}{n_\tau} \right)^{-k_2}} \; \frac{m_c}{n_\tau} \quad \text{(kW)} \tag{5}$$

The obtained equation shows that engine torque can be calculated when cyclic fuel injection of a respective work condition and relation coefficients k_1 and k_2 are known. Investigation of tractor work quality (engine speed and engine load conditions), during its working period, will be done on the basis of dependence equation (5) from work load profile (engine work time at engine speed and cyclic fuel injection) and engine characteristics.

To investigate the tractor work quality MF6499 tractors with different engine working hours on it were chosen (Table 1). For investigation of the working quality, during working period, Massey Ferguson MF 6499 tractors from different kinds of farms were taken. The tractors performed ploughing, soil tillage, seeding, transport and other jobs.

Table 1

Data of the investigated tractors

Tractor model	Nominal power kW / speed, rpm	Number of tractors	Engine hours
Massey Ferguson MF 6499	158 / 2200	1	2075
		2	1374
		3	3048
		4	1521
		5	769
		6	466

Results and discussion

The investigation results of 6 Massey Ferguson MF 6499 tractors are presented in Fig. 4. The investigation results show how many hours the investigated tractors were working at low (up to 30 % of maximum torque (M_{max})) at medium (30-50 % M_{max}) and high (>50 % M_{max}) engine load. The results show what part of time at different engine load the tractors worked at low (up to 1100 rpm), at medium (1100-2100 rpm) and high (more than 2100 rpm) engine speed.

As we can see from Fig. 4 all the investigated tractors during their working life worked the most part of working hours (about to 30-40 %) at high torque (>50 % M_{max}) and medium engine speed (1100-2100 rpm). The next biggest part of working hours (about to 20-30 %) worked at a very low engine speed and very low torque. A little part of hours the tractors worked at high torque (>50 % M_{max}) and nominal engine speed. Under economical conditions at high (>50 % M_{max}) engine load and medium (1100-2100 rpm) engine speed a tractor worked 30-40 % of the total working hours.

It will be observed that a pretty part of hours the tractors worked at small torque (30-50 % M_{max}) and medium (1100-2100 rpm) engine speed.

As we can see from Fig. 4 from all investigated Massey Ferguson MF 6499 tractors the best working load had the tractor No. 2. The tractor at low (up to 30 % of the maximum torque (M_{max}) working load and at low (<1100 rpm) engine speed worked for the shortest period of time, 20 % of the total working hours. The biggest period of time (near to 30 %) the tractor worked at high (>50 % M_{max}) working load and medium (1100-2100 rpm) engine speed. At high engine load (M >50 % M_{max} and at nominal engine speed (>2100 rpm) the tractor worked 18 % of the total working life. We can see that the tractor No. 2 has the best (economical) engine load of all investigated tractors.

The medium working life distribution during their working life of investigated Massey Ferguson MF 6499 tractors is shown in Fig. 5. The investigated Massey Ferguson MF 6499 tractors worked (less than 40 % of the total working hours) at high (>50 % M_{max}) working load and at medium (1100-2100 rpm) and high (>2100 rpm) engine speed. A large part of time (>35 %) the tractor worked at low engine load. At low (0-30 % M_{max}) engine load and at low (<1100 rpm) engine speed the tractor worked up to 25 % of the total working hours. With low (0-30 % M_{max}) engine load and medium

(1100-2100 rpm) engine speed the tractor worked 10 % of the total working hours. The last working condition is unavoidable because of travelling from and to the field.

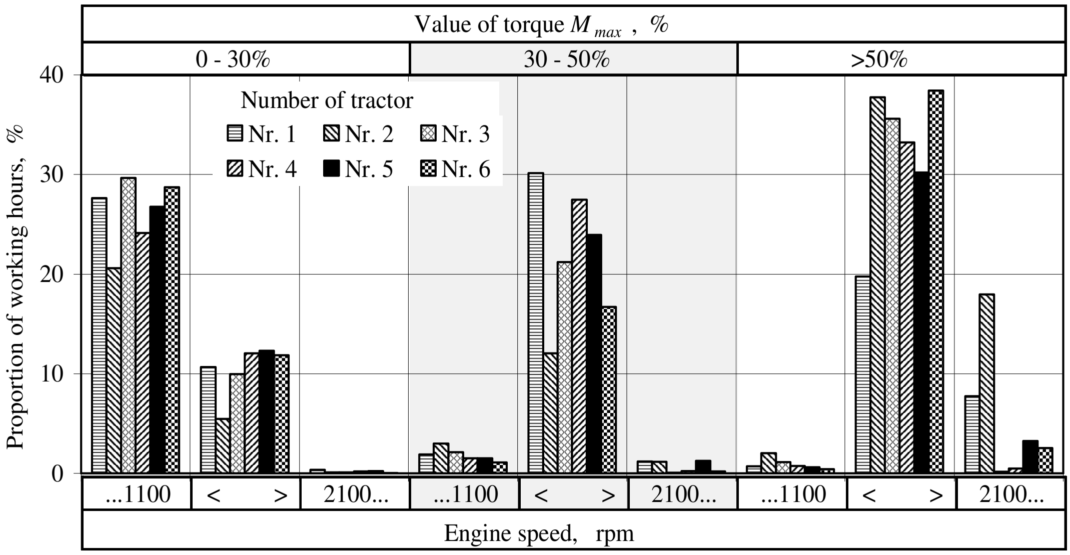


Fig. 4. **Distribution of working hours of Massey Ferguson MF 6499 tractors in different engine load conditions**

It can be observed that a pretty part (up to 20 %) of hours the tractors worked at small torque (30-50 % M_{max}) and medium (1100-2100 rpm) engine speed. This result of investigations showed big possibilities for improving the tractor handling technologies, by using a wider range of engine power and by decreasing fuel consumption.

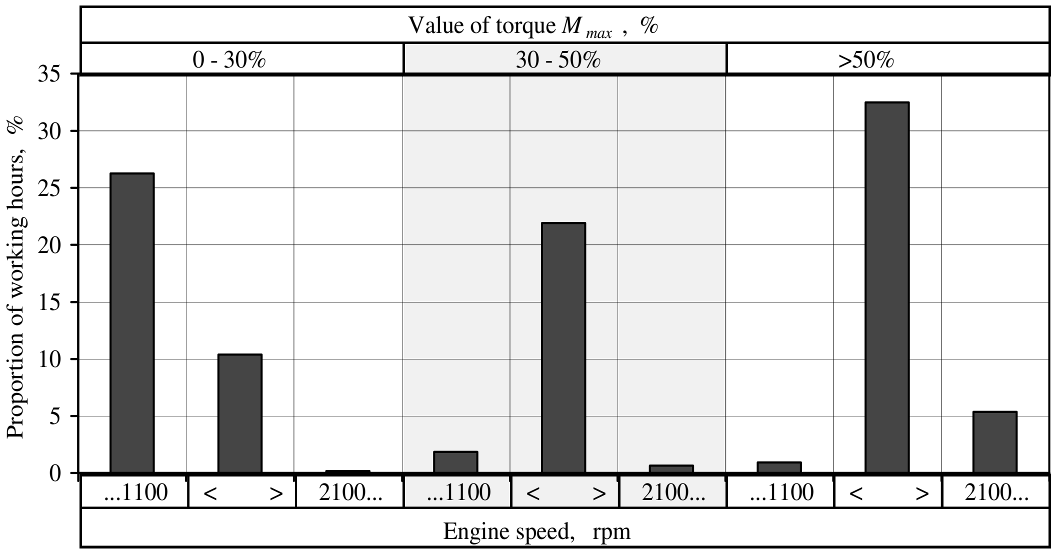


Fig. 5. **Medium distribution of working hours of Massey Ferguson MF 6499 tractors in different engine load conditions**

The investigation results show that tractors on a farm are operating differently from the engine load and speed point of view. The biggest dispersion of tractor working time is at high (>50 % M_{max}) engine load conditions when the engine is working at medium (1100-2100 rpm) and higher than 2100 rpm engine speed (Fig. 4). Big dispersion of working hours is at low engine load and idle speed conditions. Quite a big dispersion of working hours shows that the tractors were operated in non optimal conditions. The accomplished investigations showed big possibilities for improving the tractor handling technologies, by using a wider range of engine power, by decreasing fuel consumption. The improvement possibility is proven by better Massey Ferguson MF 6499 tractor (No. 2) load factors (engine speed and torque aspects) during its working life.

Conclusions

1. The tractors operation quality can be evaluated by using the engine work time data collected in their electronic processors and recorded as a histogram of load profile (under engine speed and cyclic fuel injection). The developed tractor engine torque can be calculated from the known engine speed at respective work conditions, cyclic fuel injection and relation coefficients k_1 and k_2.
2. A large part of working hours (up to 35 %) all investigated Massey Ferguson MF 6499 tractors worked at very low torque (0-30 % M_{max}). Up to 25 % of working hours the tractors worked at very low torque (0-30 % M_{max}) and very low engine speed (>1100 rpm). These tractor engine working conditions are not good from both economical and technical point of view.
   At high torque (>50 % M_{max}) and medium (1100-2100 rpm) and high (>2100 rpm) engine speed, the tractors on the average worked up to 40 % of the total working hours.
   A big part (up to 20 %) of hours the tractors worked at small torque (30-50 % M_{max}) and medium (1100-2100 rpm) engine speed.
3. The accomplished investigations showed big possibilities for improving the tractor handling technologies, by using wider range of engine power, by decreasing fuel consumption.

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