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THE EFFECT OF EHR SYSTEM SETTING ON FUEL CONSUMPTION AND TRACTOR ENGINE SPEED VARIATION

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Abstract

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The work is aimed on possibilities of fuel consumption reduction via EHR system setting with the influence on tractor engine speed variation. During tractor utilization in agricultural applications fuel consumption is measured and evaluated. The main objective of this text is fuel consumption reduction verification. Firstly, article describes tractor engine parameters acquirement. Complete engine characteristic is obtained from laboratory experiments. This was essential step for lowest fuel consumption area detecting. Next, the principle of EHR system function is clarified. Then connection between complete engine characteristic and EHR system setting interaction is mentioned and the aim of field measurement is set. Another part is devoted to field measurement conditions and EHR system setting. This part is essential for the possibility of field measurement re-examination. Deep plowing with John Deere 6920S and Lemken Vari Diamant 10 was realized. The EHR various settings were examined and their effect on tractor engine speed variation was observed.
The results show possibility of fuel consumption reduction. The properly chosen aggregation of tractor power and plough type with correct electro-hydraulic system setting brings fuel consumption reduction. This conclusion may be used for fuel savings in global scale for better economic utilization of tractor.

Keywords: EHR system, fuel consumption, three-point hitch, draft control, position control, engine speed variation

INTRODUCTION

Since 19th century combustion engine is used as tractor drive unit (Grecenko, 1963). Nowadays engines went through lots of evolutionary changes and improvements. Modern tractor engine conception uses fuel injection with high pressure also variable geometry turbocharger for high pressure intake is used. Air-to-air intercooler is used for compressed air temperature lowering. For achieving strict EURO norms catalytic reduction technology or exhaust gas recirculation is utilized. These technologies are among the many which makes from tractor engine highly sophisticated device (Bauer, 2013).

High technical level of tractor engine allows it to operate in optimal working conditions and also full potential of the engine can be used. This brings benefits in the form of low specific fuel consumption, high efficiency and high performance with high value of torque, all with fulfilling strict emission limits (Semetko, 1985).

Tractors are universal working machines due to their three point hitch. First so called draft-control system was invented by Harry Ferguson in 1925. The principle of his idea is still used (Ferguson H. G., 1925). Nowadays three point hitch is equipped by electronic-hydraulic hitch control. This system is used in many agronomical operations and its purpose is to obtain and assume specific conditions reliant on EHR system settings. Good example is usage of this system in deep plowing. In this operation, as more variable conditions of soil are, that more attention should be paid to EHR system setting.

From an economic perspective, constant engine speed in the optimal fuel consumption range should be maintained for achievement lowest running cost. This phenomenon is closely related with engine speed variation and draft force which is generated from the plowing operations (Bauer, 2013). Also draft force fluctuation is closely connected to EHR system settings (S. M. Md. Ismail, 1981). This brings the main point of the research idea which is hidden between EHR system function and tractor engine interaction.

MATERIAL AND METHODS

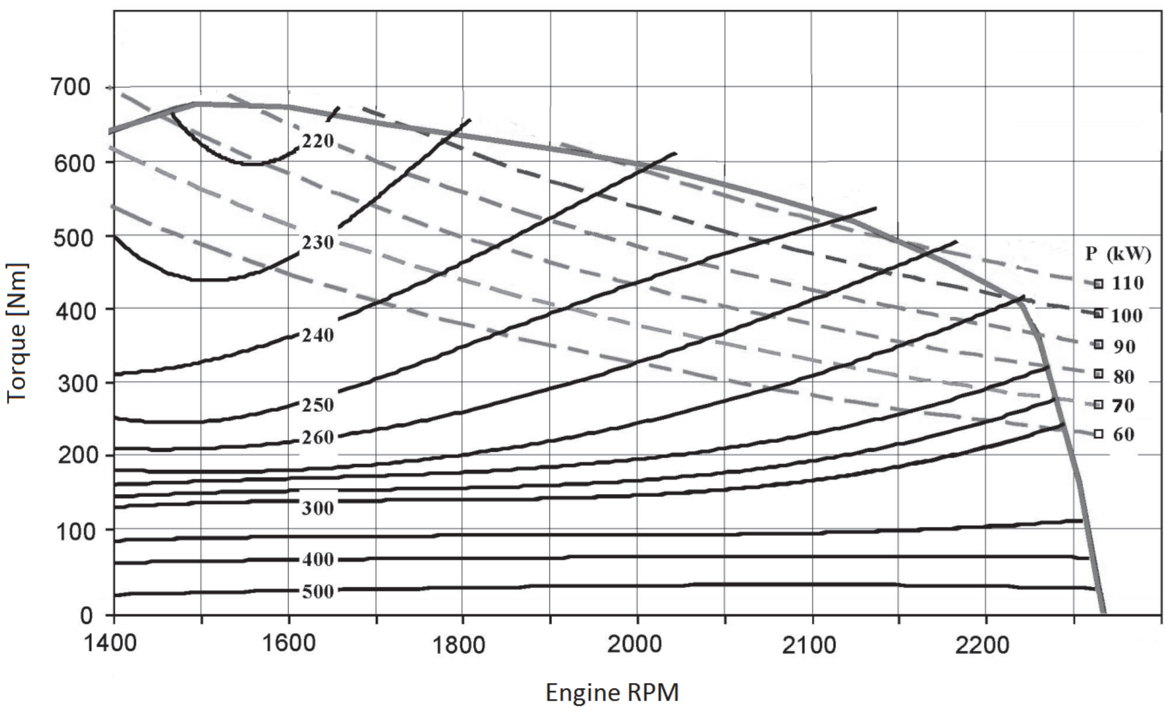
Tractor Engine Parameters

The measurement was realized with John Deere 6920 tractor. This engine use high pressure Common Rail technology and turbocharging. For compressed air cooling, air-to-air intercooler is used. John Deere 6920 has got in-line 6 cylinder engine with 4 valves per cylinder. Capacity is 6790 cm^3 with 106.5 mm bore and 127 mm stroke. Engine is water cooled and it's used viscous fan. Important parameter of tractor engine is complete characteristic. This diagram shows set of curves representing dependence of monitored variables on two basic values. In point of view of lowest running cost is preferred to keep an engine in area of lowest fuel consumption. For lowest fuel consumption area determining is essential to run the measurement of above-mentioned characteristic. Eddy current dynamometer was used for measuring complete engine characteristic via tractor PTO. Measured parameters are shown in Tab. I. Eddy current dynamometer is plotted in Fig. 2

Complete engine characteristic was obtained from laboratory measurement. It is shown in Fig. 1. This diagram describes dependence of engine RPM on torque, performance and specific fuel consumption. It was necessary to obtain this characteristic of tested tractor engine for mapping of lowest fuel consumption area. As can be seen from Fig. 1, this area is located approximately from 1450 to 1650 engine RPM with fully loaded engine and its specific fuel consumption reaches value of 220 $g.kWh^{-1}$. Exact value with lowest specific fuel consumption is printed in Tab. I.

I: *John Deere 6920S measured parameters*

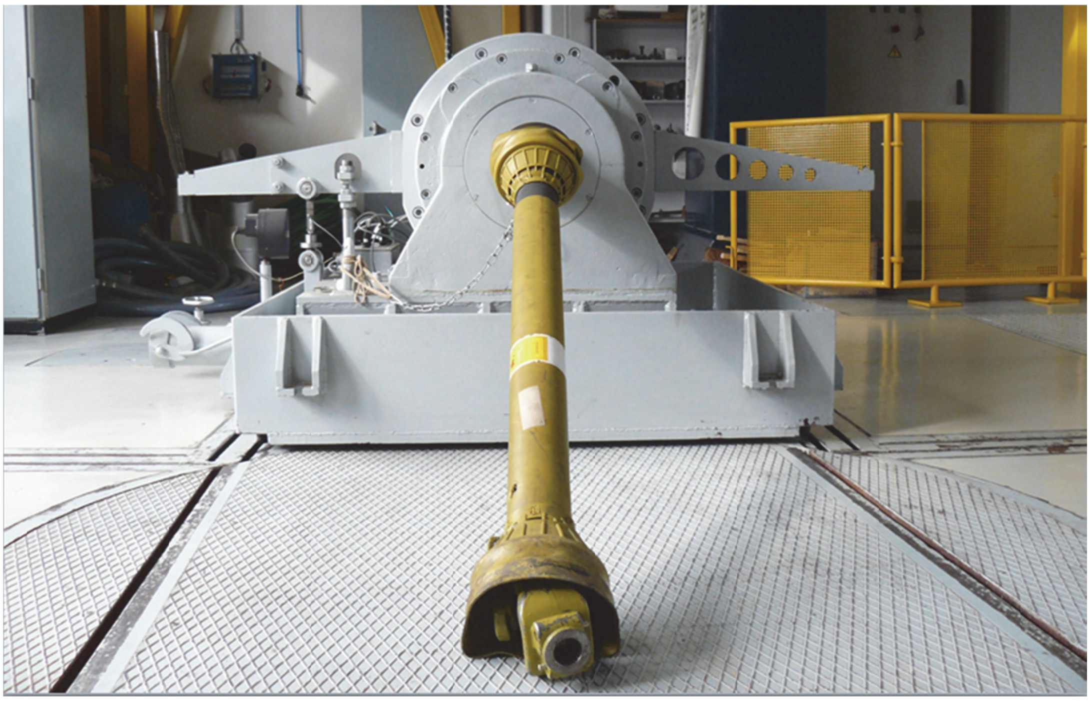
Max power	114.63 kW at 1811 RPM	**Bore/Stroke**	106.5/127 mm
Max torque	653.62 Nm at 1577.1 RPM	**Cylinder numb.**	6
Lowest specific consumption	218.39 $g.kWh^{-1}$ at 1654.9 RPM	**Capacity**	6877 cm^3
Nominal engine output	104.32 kW at 2106 RPM	**Valves per cylinder**	4
Torque rise	38.12%	**Serial number**	CD 6068H897748
Constant power scale	1650–2050 RPM	**Fuel capacity**	250 l



1: *John Deere 6920S engine complete characteristic*

II: *Lemken Vari Diamant 10 parameters*

Vari Diamant 10			
(Box section frame 160 × 160 × 10 mm)			
Number of furrows	6 + 1	**Year**	2004
Working width (cm)	180–385	**Type**	semi-mounted
Total weight (kg)	5000		reversible
From kW/HP	110/150		six-furrow



2: *Eddy current dynamometer*

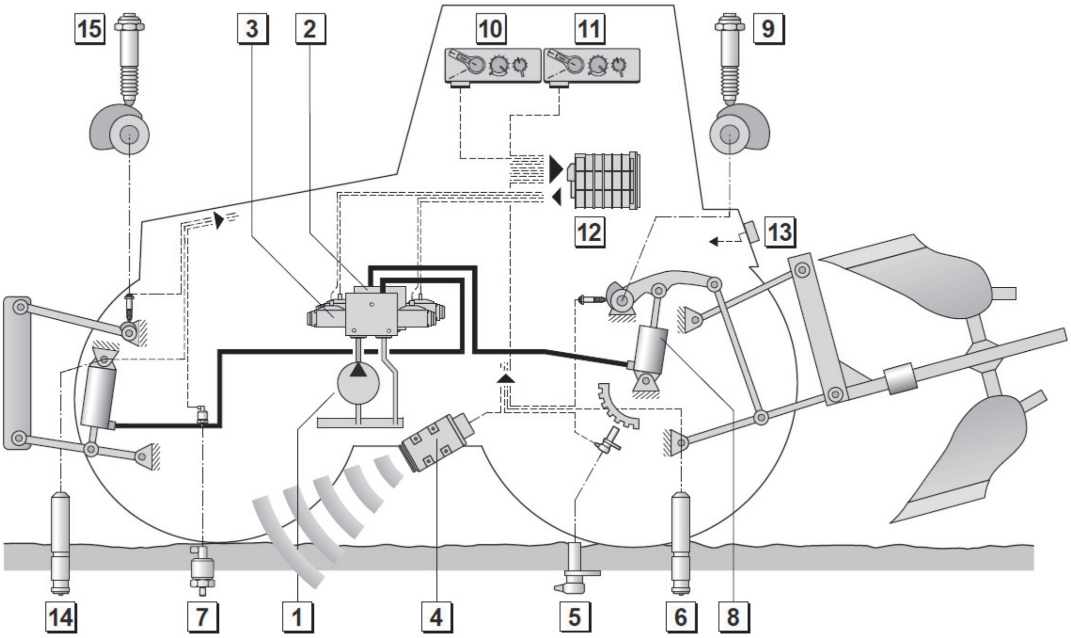
Lemken Vari Diamant 10 Parameters

Semi-mounted plough with six furrows was used for deep plowing. Specification of this plough is shown in Tab. II. Box section frame with working width of 385 cm and total weight of 5 000 kg was used in its construction.

Principle of BOSCH Electrohydraulic System

Nowadays tractors using BOSCH electro-hydraulic hitch control. This system replaced hydro-mechanical hitch control which was invented by Harry Ferguson in 1925. Individual elements, essential for EHR system, generating input signals for EHR control unit are shown in Fig. 3. Description is mentioned below the figure. From scheme can be seen placement of each sensor which is essential for EHR system function. Draft sensor located in lower arms pins measures draught force generated by used implement. Position sensor located near to lift arms pins measures position of lift arms through cam fixed on lift arms shaft. Other important sensors are speed sensor and radar velocity sensor. These two take care about actual tractor speed and rear wheels speed. From these outputs wheel slip is calculated in EHR control unit. Output signals from above mentioned sensors are scanned during tractor utilization on field operations. Also there are input parameters set by tractor operator via control panel. Based on all these parameters EHR system is possible to control weight-transfer from the pulled implement to the tractor rear axis without interference of agricultural technical requirements (RE 95170/01.12).

There is a possibility to set this system into a several modes. First one is position control. In this case the controlled variable is the position of the hitch. Position sensor is operated by a cam on the hitch, supplies the feedback signal. Next is draft control. Control variable in draft control mode is the force at the trailing linkage. If the tractor power is being used optimally, for example when ploughing undulating land and inhomogeneous soil, constant draught force is kept. The feedback signal is supplied by the draft sensors. Another option is mixed control. In this case, the actual values of position and draft are mixed in an adjustable ratio at the control panel from 100% of position control and 0% of draft control to 0% of position control and 100% of draft control. Mixed control allows the variations in working depth due to fluctuations



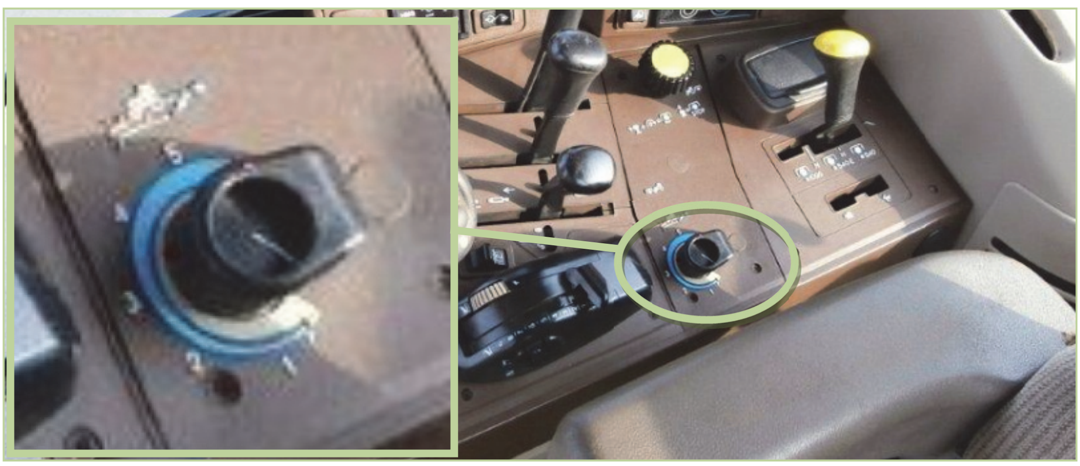
1 – hydraulic pump	5 – speed sensor	9 – position sensor	13 –rear-end actuation
2 – Hitch control valve, rear	6 – draft sensor	10 – control panel, rear	14 – draft sensor
3 – Hitch control valve, front,	7 – pressure sensor	11 – control panel, front	15 –induc. pos .sensor
4 – Radar velocity sensor	8 – lift cylinder	12 – ECU	

3: *EHR system components*

in soli resistance, which occur with pure draft control, to be reduced. Another option is slip control. This function is carried out by the radar and speed sensor. Goal of this setting is to achieve lower tire wear, soil treating with greater care, less strain to tractor operator and last but not least vehicle doesn't get stuck in difficult weather conditions. These are basic settings used in draft operations. There are another options primarily used in transport or mounted implements applications like vibration damping or pressure control. For example pressure control keeps pressure in hydraulic rods of lift arms in constant value. As a result, aggregated tools carried in hitch are lightened by constant power. This could be used in mowing operations.

Theoretical Part of Experiment

Phenomenon of EHR setting on engine speed variation during ploughing was observed. Weight-transfer between tractor and plough is affected by mixed control percentage adjustment. According on this force, tractor engine is loaded. This effect can be utilized for operating of tractor engine in optimal power. This state is economically advantageous because lowest fuel consumption is achieved. Via potentiometers, mixed control is adjusted to pre-defined positions. Setting panel of John Deere 6920S is plotted in Fig. 4. In this case number 5 represents full position control. If potentiometer is moved to position number 1, full draft control is



4: *EHR control panel – draft, position or mixed control settings* selected. Between these two positions mixed control is situated.

Inhomogeneity of soil caused oscillation of plough draft force. Using the draft, position or mixed EHR system control plough draft force transferring from plough to tractor three point hitch can be affected. Engine RPM fluctuation is one of the most important watched parameters for economical aspect. This fluctuation is caused by above-mentioned phenomenon. Variability of engine RPM is statistically evaluated and it is characterized by mean, maximum and minimum value, standard deviation and by coefficient of variation. After detailed examination of complete engine characteristic plotted in Fig. 1, can be concluded that the optimal engine workload is achieved at 1600 RPM. At this value, lowest fuel consumption is reached. RPM fluctuation leads to engine operation at non-economic zone. When tractor is used for ploughing its engine can be operated at economic zone only with correctly adjusted electro-hydraulic system. This leads to low values of fuel consumption. Another advantage of EHR system usage is lowering of tractor driving wheels slip resulting at higher tillage efficiency.

Experiment Conditions

Field measurement was realized at light sandy loam soil with ambient air temperature of 28 °C. Samples of soil were taken before measurement for soil humidity analysis. After drying of samples, humidity was determined. Its value was 21.4 °. John Deere 6920S with Lemken Vari Diamant 10, trailed six mouldboard revolving plough reached weight of 10 980 kg. Electro-hydraulic control system was adjusted on two basic settings. First of them – 20% draft control with 80% position control and last 80% draft control with 20% position control. These two settings were measured in several field tests. Tractor was equipped with set of measuring sensors. Output signals were evaluated by Spider 8 control kit. Internal variables as engine RPM and actual fuel consumption were read out from CAN-Bus. Unique software in LabVIEW 8 was created. This was used for data recording. Actual speed was measured by RDS TGSS radar with 24.125 GHz frequency with 0.5 W radiated power. Angular inclination from horizontal axis was set on 37 °. Pulsar output relative to 1 m distance was 128.52 pulse. Accuracy of used device was in range between 1–4% according on speed travel. Plow shot and ploughing depth were adjusted on measurement beginning and during the tests were unchanged. Full fuel delivery was set by hand accelerator. On test field 30 m long sections were defined. Another 40 m long section was admeasured for setting values and data stabilization. Each of EHR control setting was triple measured. For wheel slip measuring, wheel track of rear axis was measured after 5 wheel rotations. On each 2 meters of travelled distance ploughing depth and range were measured out. All of data was recorded with 20 Hz frequency.

Measured and Computed Values

Actual fuel consumption was provided by CAN-Bus. By using the equation number 1 calculation of hour consumption, which is based on immediate fuel consumption Q_{hi} and number of measurements n, was determined. Out of hourly fuel consumption specific fuel consumption by using equation 2 was counted. For determination of effective performance of the set equation 3 was used, which deals with size of plowed area S and time T_1 at which was the area plowed. Finally from this parameter efficiency was counted.

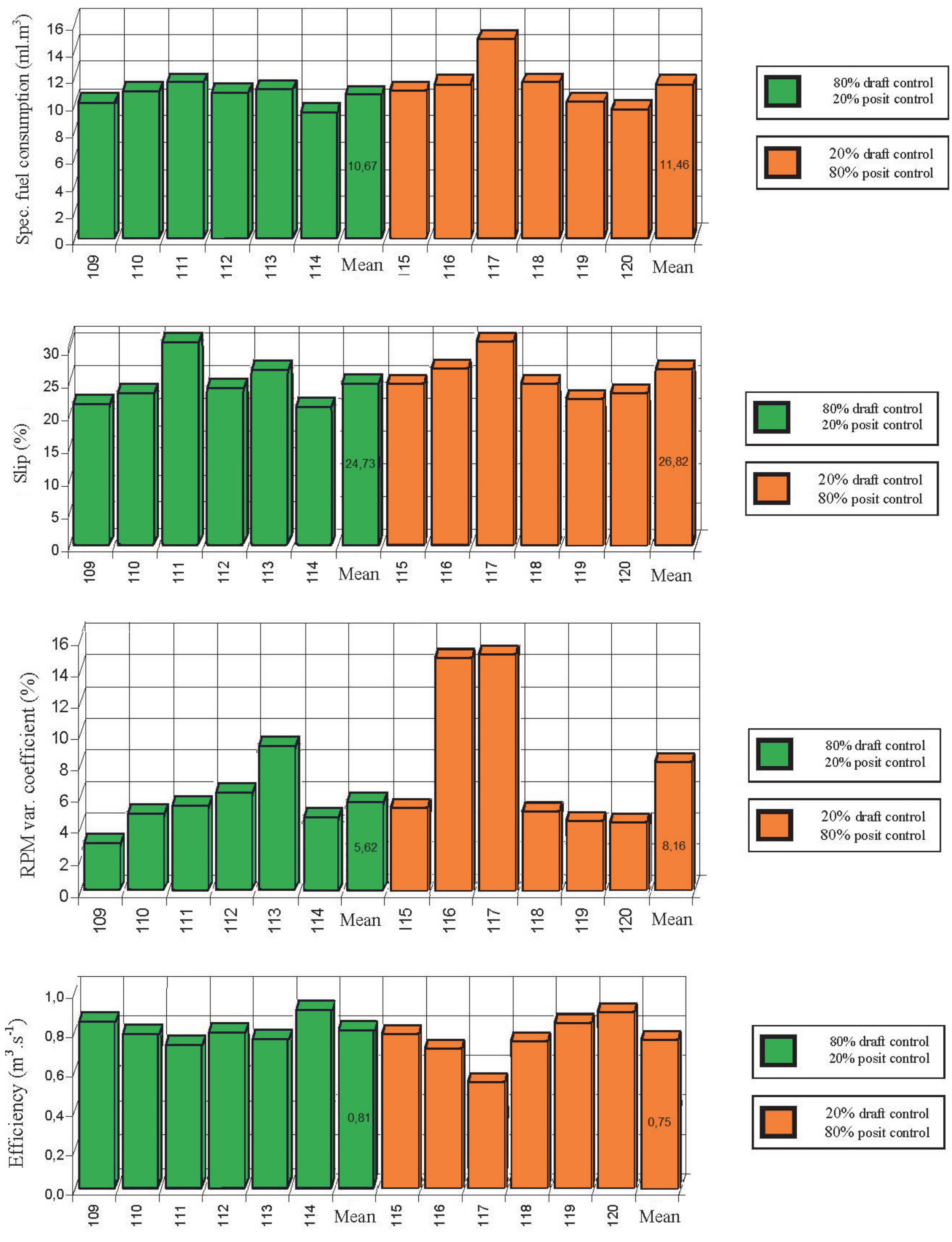
$$Q_h = \frac{\sum_{i=1}^{n} Q_{hi}}{n}, \text{ [l.h}^{-1}\text{]} \quad (1)$$

$$Q_m = \frac{0.1 \times Q_h \times T_1}{S \times h}, \text{ [ml.m}^{-3}\text{]} \quad (2)$$

$$W_1 = \frac{S}{T_1}. \text{ [ha.h}^{-1}\text{]} \quad (3)$$

RESULTS

Because of wide range of obtained values, tables with measured and calculated values are not included at this text. For visibility important values are shown in graphs in Fig. 5. At these graphs changes of individual parameters are plotted in dependence on settings of EHR regulation system. At bar charts individual measurements are shown, also their average values are assigned for objective assessment. There is an evidence in comparing of specific fuel consumption between applied regulations that when bigger portion of draft control is set, amount of fuel can be saved. The phenomenon of engine RPM fluctuation with EHR system interaction is already mentioned. This helps to keep engine in economical range of RPM. Similar trend is also seen in measured slip of the drive wheels shown in Fig. 5. There is small peak loads in three point hitch arms due to acting of EHR draft regulation. Peak loads would have led to additional forces which negatively affects rear axis wheel slip. Variation coefficient of engine RPM is one of the most important parameters. There is also can be seen decreasing trend in favor of the draft regulation. At this time low RPM fluctuation is measured. Result of this phenomenon is lower intensity on shifting gears which brings wear reduce and also lower demands for tractor operator. Last but not least tillage efficiency shows excellent responses. Draft control setting positively affects tillage efficiency. This represents last graph in Fig. 5. Tillage efficiency is close connected to rear axis slip. Logically, when rear axis slip decrease, there is increase in tillage efficiency.



5: *Diagrams of spec. fuel consumption, slip, RPM var. coefficient and efficiency*

CONCLUSION

The paper deals with electro-hydraulic system setting with tractor engine speed variation interaction. This work is focused on options in fuel consumption lowering. For maximum operating efficiency, a tractor engine should be operated near its rated capacity (Grisso, R., 2009). With mixed control interaction constant draught force can be achieved. This force subsequently acts via tractor hitch on traction wheels. The wheel slip is a critical parameter for fuel consumption and field performance (Moitzi, G., 2013). As can be seen from realized field measurement, usage of mixed control brings field performance increase due to rear wheels slip decrease. This conclusion supports the theory of fuel consumption savings with maximum usage of engine performance which is achieved in specific field of engine speed range. Also essential is to keep the engine's speed in that specific field with lowest fuel consumption. Electro-hydraulic system with mixed control settings take care about this goal. Elimination of engine speed variation is obtained due to constant draught force maintained by this system. This phenomenon is supported by theory. From measured and calculated values is evident, that the plowing with draft control causes saving of fuel in all cases. In comparison with position control – results shown in Fig. 5, fuel consumption is reduced with efficiency increase. Another positive impact of draft control system setting is that the procentic value of coefficient of variation, which expresses fluctuation of engine RPM, reaches lower values compared to position control. Conclusion from text mentioned above is fact that draft control is able to keep engine in low range of engine RPM fluctuation even when composition of soil is changed unlike the position control. If the tractor operator loads engine to such an extent, that it works with low specific fuel consumption and if they will plow with draft control, than operator doesn't have to keep economic mode of engine by shifting of gears. These are essentials conclusions achieved by correct EHR system settings.

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REFERENCES

BAUER, F. 2013. *Traktory a jejich využití.* 2nd Edition. Brno: Bauer František.

BOSCH REXROTH. RE 95170/01.12. © 2012. *Product mobile hydraulics.* [online]. Avalible at: http://www.airlinehyd.com. [Accessed: 2014, January 10].

FERGUSON, H. G. 1925. *Apparatus for coupling agricultural implements to tractors and automatically regulating the depth of work.* Patent GB No. 253566.

GREČENKO, A. 1963. *Kolové a pásové traktory.* SZN Praha.

GRISSO, R. D., PITMAN, R. M. 2001. Gear up and throttle down – saving fuel. *Virginia Cooperative Extension paper.* Publication 442–450.

ISMAIL, S. M. Md. 1981. A preliminary investigation of a combined slip and draught control for tractors. *Journal of Agricultural Engineering Research*, 26: 293–306.

MOITZI G. 2013. Energy consumption in cultivating and ploughing with traction improvement system and consideration of the rear furrow wheel-load in ploughing. *Soil a Tillage Research*, 134: 56–60.

SEMETKO, J. a kol. 1985. *Mobilní energetické prostředky 2.* Bratislava: Vydavatelství Příroda.

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