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THE EFFECT OF SETUP OF THREE POINT LINKAGE ON ENERGETIC AND PERFORMANCE PARAMETERS OF TRACTOR AGGREGATE

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Abstract

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The object of this paper is to analyze the effect of setup of three point linkage on energetic and performance parameters of tractor aggregate. For this purpose were made two series of measurements. The first series was realized with the tractor NewHolland T7050 aggregate with 5-furrow reversible plough plough KUHN HUARD VM 150 5 NS. Data such as engine load, engine revolution, diesel fuel consumption, diesel fuel temperature, were got from CAN Bus network during the measurement. Then were measured following parameters total time of ploughing, dephth of ploughing, time of turning and swath of the tractor aggregate. The specific consumption of diesel fuel and the efficiency of the aggregate were calculated using the aforementioned parameters.The second series of measurements was realized with the tractor Zetor Proxima Plus 115 aggregate with four-furrow plough Kverneland 150 B. During the measurement the data such theoretical and actual speed of the tractor and force in the top link of three point hitch were recorded in the computer. Then were measured following parameters such as main time of ploughing, dephth of ploughing and swath of the tractor aggregate. By the first and second tractor aggregate were approved linear dependence of slip, performance and fuel consumption on the force in top link of three point linkage.

three point hitch, force in the top link, slip, specific performance, specific fuel consumption

Continuously growing prices of energy and low prices of the agricultural products pushes farmers to save producing costs of agricultural commodities. With this demand it is closely connected to improving the quality and productivity of the soil processing. The main factor witch influences soil processing is drawbar efficiency. The drawbar efficiency describes effectiveness of transformation engine power on backplate. These problems describe various authors (Abeels, 1976; Bloome, 1983; Burt, 1982; Zoz, 2002). On the basis of their work, it is clear that it is possible to influence the drawbar efficiency, for example by type of tyres, their dimension and inflation, but especially by the size of the load on the driving wheels of the tractor. The load on the driving wheels of the tractor aggregate with carrier implements is possible to influence significant by setup of three point hitch and by selecting correct type of three point hitch regulation. The company Lemken responded on this observation and in year 2005 introduced hybrid plow VariTansanit, which is equipped with a hydraulically adjustable top link. This fact allows regulated the transfer of plough weight on the driving wheels of the tractor. This system allowed to degrease slip of driving wheels and to improve the performance and economic parameters of the tractor aggregate. The object of the contribution is to analyze the effects of the length of the upper link, or forces in the upper link at the performance and energy parameters of two different tractor aggregate.

MATERIAL AND METHOD

For the first part of the field measurement was used tractor New Holland T7050, which was aggregated with the plough KUHN HUARD VM 150 5 NS, see fig. 1. The measurement was realized in the cadaster village Rakvice. Soil moisture contents was between 14–16 percent during the tests. The next series of measurements was realized with the tractor Zetor Proxima Plus 115, which was aggregated with the plough Kverneland 150 B, see fig. 2. The field tests were realized in the cadaster village Přísnotice. Soil moisture contents was between 10–13 percent during the tests. By both tractor were carried out measurements of the parameters of the engine across PTO from the field tests.

Technical parameters of the tractor New Holland T7050

Wheel tractor with all wheel drive, type NewHolland T7050. Motor: Six cylinders. Fuel injection system high pressure Common Rail. Turbocharged with intercooler. Capacity 6 728 cm^3. Rated power 145 kW, Rated power with power boost 172 kW. Rated engine speed 2200 rpm. Max. power 156 kW, Max. power with power boost 177 kW. Max. torque at 1 400 rpm – 860 Nm. Max. torque at 1 600 rpm with power boost 965 Nm. Torque rise standard 37 %, with power boost 30 %. Transmission: PowerShift and PowerShuttle, fully driven under loaded wet multi plate clutch. Number of speeds 19 forward and 6 back. Possibility of the automatic gear shifting with adjusting of the revolutions decrease. Tires: Front axle: Michelin Multibib 540/65 R 30, back axle: Michelin Multibib 550/65 R 42. Weight during tests 7560 kg, maximal.: 12 000 kg. The measuring was done in the laboratory of The Institute of the Engineering and Car Transportation of MUniversity in Brno, across PTO according OECD methodology.

Plough characteristic

The manufacturer: KUHN HUARD. Model: VM 150 5 NS. Type: Variomaster 150. It is five-furrow attached reversible plough with continuous adjustable width of a tread. The change of the tread is done through the tractor outside hydraulic loop. The tread of one ploughing unit is adjustable in the range 14’–20’. The end of the wing is equipped with adjustable spring. Ploughing units are secured with hydro pneumatic locks with adjustable power for trenching.

Technical parameters of the tractor Zetor Proxima Plus 115

Wheel tractor with all wheel drive, type Zetor Proxima Plus 115. Motor: Four cylinders. Mechanical fuel injection system with row injection pump and mechanical regulation. Turbocharged with intercooler. Capacity 4 157 cm^3. Rated power 58 kW. Rated engine speed 2 200 rpm. Max. power 68 kW. Max. torque at 1 500 rpm–442 Nm. Torque rise 40 %. Transmission: Mechanical synchronized four gear, with two gear powershift and mechanical reversation. Two gear group transmission. Number of speeds 16 forward and 16 back.

Tires: Front axle: Mitas Radialdrive 340/85 R24, back axle: Mitas Radialdrive 420/85 R34. Weight during tests 4 751 kg. The measuring was done in the laboratory of Development Institute of Tractors in Brno, across PTO according OECD methodology.

Plough characteristic

The manufacturer: KVERNELAND. Model: 150 B. Type: 150 B 100–130.

It is four-furrow attached reversible plough. It is equipped with two rows of ploughing units with chisel blade. Before the last ploughing unit is located disc coulter. Ploughing units are secured with shear screw. In the rear of the frame is equipped with carrier wheel with shock absorber.

Methodology of the field tests

During the field tests tractor NewHolland aggregate with plough Kuhn Huard Variomaster 150 it was realized total 7 measurements. The engine worked in normal mode without a power boost and

1: *The combination of the tractor NewHolland T7050 in aggregation with the plough Kuhn Huard Variomaster 150*

2: *The combination of the tractor Zetor Proxima Plus 115 in aggregation with the plough Kverneland 150 B*

worked in the speed range 1 700–2 000 rpm during the measurements. Each measurement consisted of four measurement journeys on the parcel with three turn on the headland. In the central part of the length of the journey was measuring section, where was measured plough baem and depth of ploughing. Each transit tractor aggregate was measured slip wheels front and rear axles, all the tests were carried out with locked diferential. Working plough beam was measured according ON 47 0166. There were 10 stakes evenly placed on the whole length of the parcel 10 m far from the furrow. After 4 runs the distance of the individual stakes were measured from the side of the last furrow. During ploughing was also measured the total time and time for turn on the headland. The computer for storing data was connected during the work at the fields to the CAN BUS network of the tractor. The data stored contains the actual load of the engine, diesel oil consumption, temperature of the oil and other engine parameters. Simultaneously other variables were stored from external sensors. The radar RDS TGSS was mounted to the tractor to get the real speed of the aggregate. The revolution sensor was mounted to the disk of the back tractor wheel to get theoretical speed. The measurement takes place with various length of top link of three point linkage, resulting in force in top link. The force in top link was measured with strain sensor HBM U2A with measure range up to 100 kN.

For the field tests tractor Zetor aggregate with plough Kverneland 150 B it was paved six 30 meters long measuring sections on the straight part of the land. Before and after each measuring section was sufficient distance for the stabilization of the aggregate parameters. The measurements are repeated in both directions, thus by ploughing to the left and to the right. On the measuring section was measured plough beam according ON 47 0166 methodology and working depth according ON 47 0169 methodology. During the field tests were recorded dates from external sensor to the computer with frequency 100 Hz. For the measurement of actual running speed of the aggregate was on the tractor mounted GPS receiver, which also served for the measurement of the length of each measuring sections. For the measurement of the theoretical speed of the aggregate was located speed sensor to the special frame on the rear wheel of the tractor. The theoretical and actual speed was used for the calculation of slip, under the relation (1). The measurement takes place at a various length of top link, resulting in force in top link. The force in top link was measured with strain sensor HBM U2A with measure range up to 100 kN.

$$\delta = \frac{v_t - v_s}{v_t} \times 100, \ [\%] \qquad (1)$$

where:
v_t.....theoretical speed [km.h^{-1}]
v_s.... actual speed [km.h^{-1}].

Average working baem of plough is calculated according equation:

$$B = \frac{\sum_{i=1}^{n} b_i}{n \times z}, \ [\text{m}] \qquad (2)$$

where:
n .... number of measurements [-]
b_i.... i – nth measurements of the machine beam [m]
z..... number of runs of the aggregate [-].

The measurement of the depth of ploughing was done according ON 47 0169 norm. At the same places where the furrow was measured was measured depth of ploughing as well. Ten measurements were done after each run. The working depth was measured by depth gauge as orthogonal distance of field surface plane and the bottom of the furrow.

Average depth of the ploughing could be counted as:

$$h = \frac{\sum_{i=1}^{n} h_i}{n}, \; [\mathrm{m}] \qquad (3)$$

where:
n .... number of maesurement [-]
h_i.... immediate depth of ploughing [m].

Fluctuations of the working stroke and the ploughing depth was evaluated with variation coefficient from:

$$V = \frac{s}{x_s} \times 100, \; [\%] \qquad (4)$$

where:
s..... mean-root-square error (stroke, ploughing depth) [m].

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_s)^2}{n-1}}, \; [\mathrm{m}] \qquad (5)$$

x_i.... i-th value (stroke, depth) [m]
x_s.....average value of the tracked factor [m].

For setting energetic and performance parameters of the first aggregate (NewHolland) the total time was counted, for parcel processing it was so-called operational time T_{02} and total time of revolutions at headland T_{21} (extraneous time). On the base of those values it was calculated the main time T_1, by which the length of ploughing is characterised. By the second aggregate (Zetor) was measured only main time T_1.

$$T_1 = T_{02} - T_{21}, \; [\mathrm{s}] \qquad (6)$$

where:
T_{02}.... operational time [s]
T_{21}.... extraneous time [s]
T_1..... main time for ploughing of the measured parcel [s].

From measured dates were calculated size of ploughing parcel and then was according (7) calculated effective performance.

$$W_1 = \frac{S}{T_1} \times 3600, \; [\mathrm{ha.h^{-1}}] \qquad (7)$$

where:
S......... ploughed surface [ha]
T_1....... main time for ploughing of the measured parcel [s]
W_1.... effective performance [ha.h^{-1}].

Diesel fuel consumption was measured only at tractor NewHolland T 7050. Actual consumption (in litres per hour) was scanned from the CAN network with frequency 20 Hz. The reached average effective hour consumption according equation (8). The measured value of diesel fuel consumption was corrected according the dates measured in laboratory of Mendel university in Brno.

$$Q_{h_1} = \frac{\sum q_i}{T_1 \times f}, \; [\mathrm{l.h^{-1}}] \qquad (8)$$

where:
q_i.... immediate consumption during ploughing [l.h^{-1}]
T_1.. main time for ploughing of the measured parcel [s]
f..... frequency of the consumption taken from the network [Hz].

Effective diesel consumption at the hectare ploughed land was calculated according equation (9).

$$Q_1 = \frac{Q_{h_1} \times T_1}{3{,}6 \times S}, \; [\mathrm{l.ha^{-1}}] \qquad (9)$$

where:
Q_{h1}. effective hour consumption [l.h^{-1}]
T_1.. main time for ploughing of the measured parcel [s]
S...... ploughed surface [ha].

For more objective comparison, with include of depth of ploughing, was calculated the specific effective consumption according to (10).

$$Q_{1m} = \frac{Q_1}{h} \times 10, \; [\mathrm{ml.m^{-3}}] \qquad (10)$$

where:
Q_1.. effective diesel consumption at the hectare ploughed land [l.ha^{-1}]
h .... depth of ploughing [m].

RESULTS AND DISCUSSION

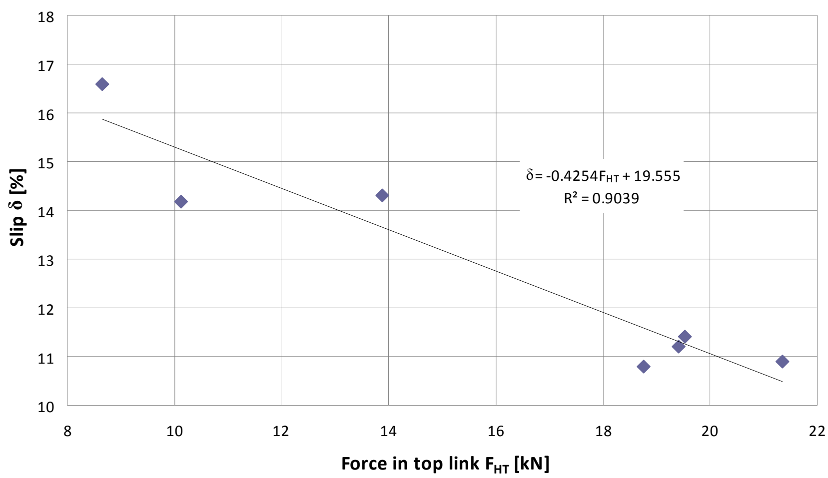
The measured and calculated values for the individual measurements are given in the following tables and graphs. The results of the measurement of the tractor NewHolland T7050 aggregated with plough Kuhn Huard are given in the first table. The measured values are plotted in a graph in figure 3 to 7. From the tables and charts, it is clear that the change of force in the top link of three point hitch affects the slip, the performance and fuel consumption of the tractor aggregate. The results of the measurements of the tractor Zetor Proxima Plus 115 with plough Kverneland 150 (B) are given in table II and are plotted in the graphs on the figure 8 and 9. From the tables and charts, it is clear that the change of force in the top link of three point hitch affects the slip, the performance and fuel consumption of the tractor aggregate.

The object of the measurements was to assess the influence of the length of the top link or force in the top link on the performance and energy parameters tractor aggregate. The first combination of a tractor NewHolland T7050 in aggregation with five-furrow plough Kuhn Huard Variomaster 150. For this tractor aggregate was calculated on the basis of the measured values, effective performance, effective fuel consumption. Then ware evaluated specific effective performance and specific effective fuel consumption. The second combination of the tractor Zetor Proxima Plus 115 in the aggregation with four-furrow plough Kverneland. For this tractor aggregate was evaluated only the slip and effective performance. The force in the top link influences the transfer of plough weight to the driving wheels of the tractor, and also the size of the slip of driving wheels.

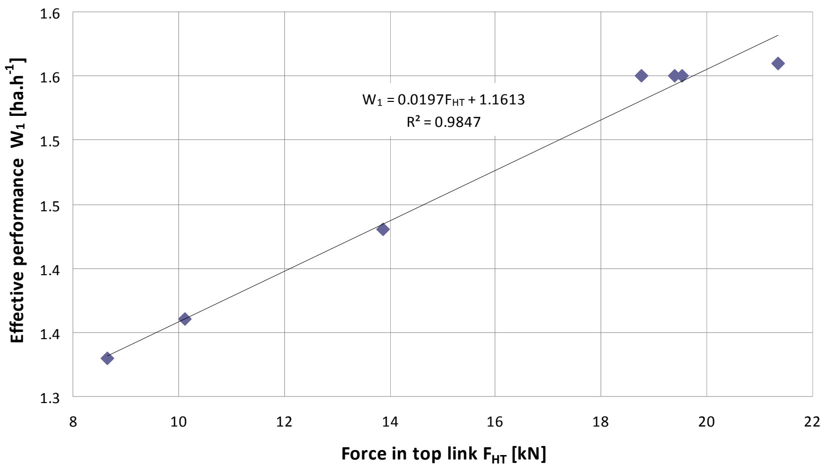
With the first tractor aggregate was made 7 measurements, while the length of top link was changed from 810 mm to 765 mm. Due shortening of the length of the top link from 810 mm to 765 mm increased the force in top link from 8.6 kN to 21.3 kN. Simultaneously slip of the drive wheel degreased from 16.6% to 10.9%. With the second tractor aggregate was made 16 measurements. The length of the top link was changed in the range from 660 mm up to 625 mm. In the measurement number 10 was length of the top link 660 mm and the force in top link of three point hitch was only 1.2 kN and slip of drive wheel 18.6%. By shortening the top link to 625 mm, to the force in the top link increased up to 20.5 kN, and the slip decreased to 11.6%. Similar results are achieved in FAL (Forschunganwalt für Landwirtschaft), where similar testing was carried out. When the force in top link of three point hitch increased, then the slip of the drive wheel decreased from 19% to 10%. The disadvantage of increasing

I: *Table of computed parameters from measured parameters of the tractor NewHolland T7050 aggregated with the plough Kuhn Guard Variomaster 150*

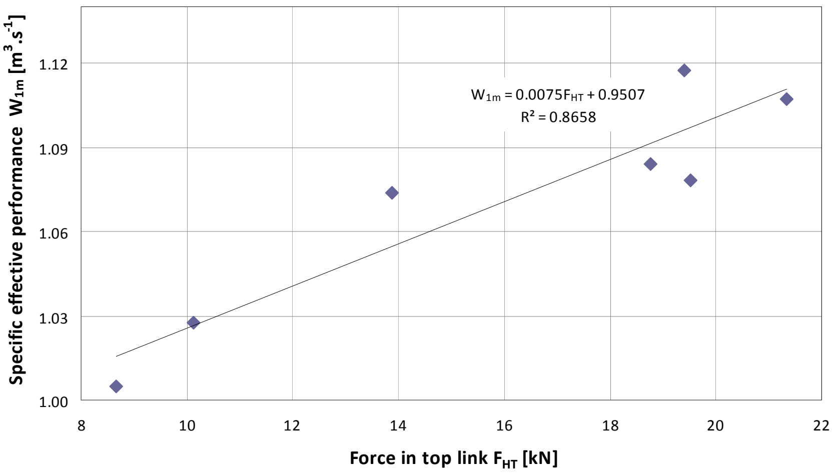
Tractor		**New Holland T7050**						
Measurements		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Hydraulic control		**position**	**position**	**position**	**position**	**position**	**position**	**position**
Lenght of top link	mm	810	790	770	765	765	765	765
Ø Force in top link F_{HT}	kN	8.66	10.12	13.88	19.40	18.76	19.53	21.34
Operational time T_{02}	s	811.00	793.00	805.00	755.00	741.00	775.00	742.00
Extraneous time T_{21}	s	106.70	110.59	120.50	97.71	112.51	110.05	104.38
Main time T_1	s	704.30	682.41	684.50	657.29	628.49	664.95	637.62
Ø Depth h	cm	27.20	27.20	27.00	25.90	25.20	25.10	25.60
Ø Stroke B	m	2.02	1.97	2.06	2.12	2.00	2.10	2.00
Variation coefficient – depth V_h	%	5.34	3.92	5.46	5.79	9.43	8.72	6.33
Variation coefficient – stroke V_B	%	1.38	0.91	0.99	1.25	1.23	0.45	1.53
Effective performance W_1	$ha.h^{-1}$	1.33	1.36	1.43	1.55	1.55	1.55	1.56
Specific effective performance W_{1m}	$m^3.s^{-1}$	1.00	1.03	1.07	1.12	1.08	1.08	1.11
Effective fuel consumption Q_1	$l.ha^{-1}$	27.00	25.60	24.00	22.10	21.30	20.50	20.80
Specific effective fuel consumption Q_{1m}	$ml.m^{-3}$	9.90	9.40	8.90	8.50	8.50	8.20	8.20
Ø Slip δ	%	16.59	14.17	14.31	11.21	10.79	11.40	10.90



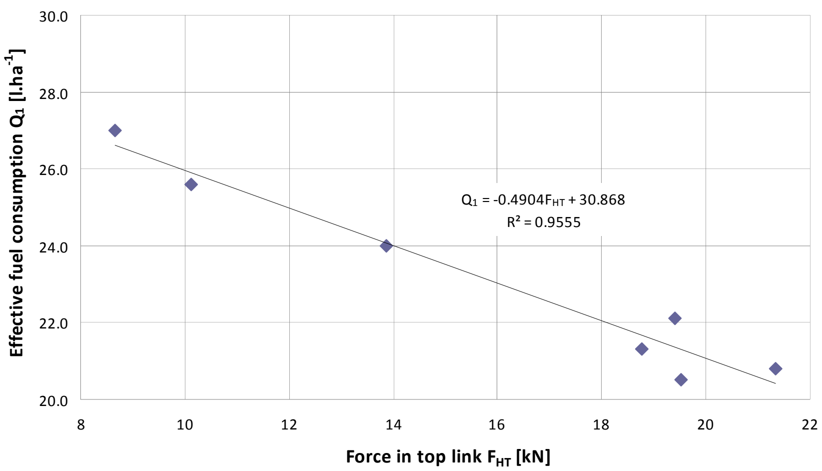
3: *The dependence of slip on the force in top link – the tractor NewHolland T7050 aggregated with the plough Kuhn Guard Variomaster 150*



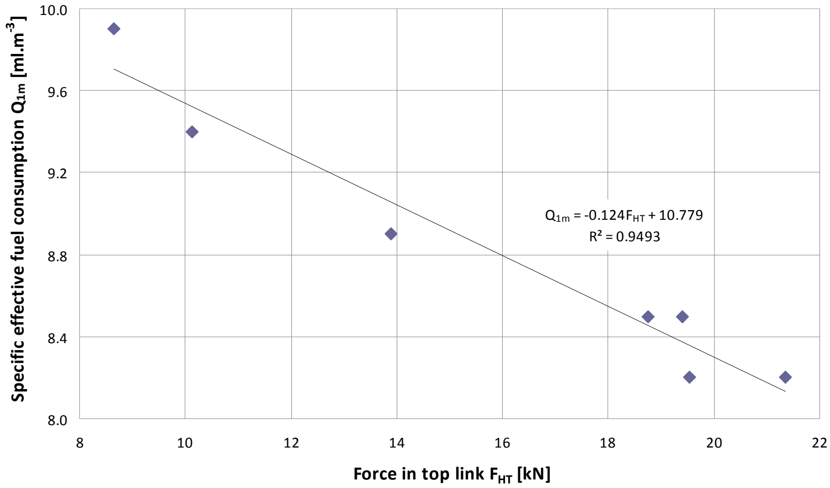
4: *The dependence of effective performance on the force in top link – the tractor NewHolland T7050 aggregated with the plough Kuhn Guard Variomaster 150*



5: *The dependence of specific effective performance on the force in top link – the tractor NewHolland T7050 aggregated with the plough Kuhn Guard Variomaster 150*



6: *The dependence of effective fuel consumption on the force in top link – the tractor NewHolland T7050 aggregated with the plough Kuhn Guard Variomaster 150*



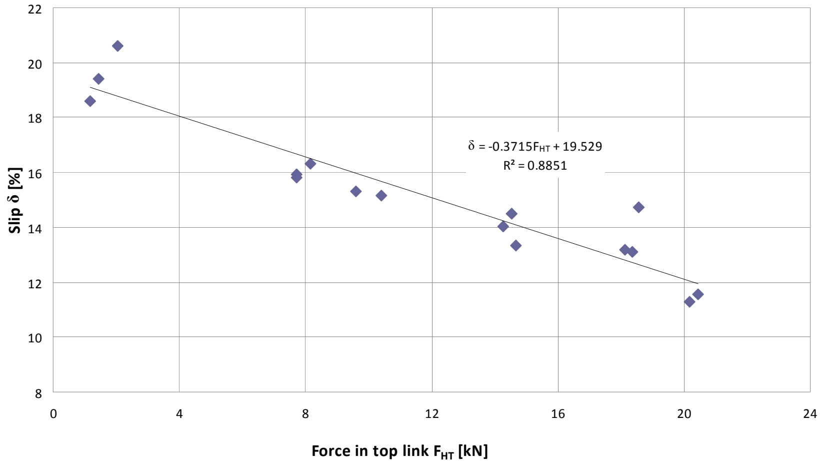
7: *The dependence of specific effective fuel consumption on the force in top link – the tractor NewHolland T7050 aggregated with the plough Kuhn Guard Variomaster 150*

II: *Table of computed parameters from measured parameters of the tractor Zetor Proxima Plus 115 aggregated with the plough Kverneland 150 B*

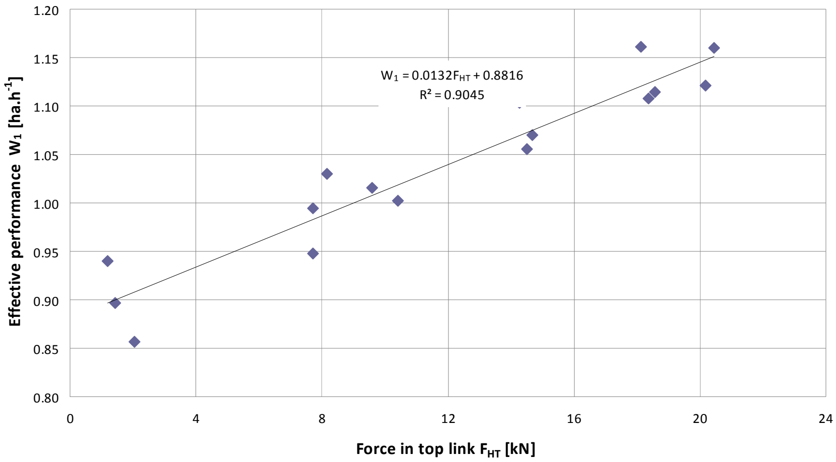
Tractor		**Zetor Proxima Plus 115**							
Maesurements		**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Hydraulic control		**force**	**force**	**force**	**force**	**force**	**force**	**force**	**force**
Lenght of top link	mm	660	660	660	639	639	639	639	639
Ø Force in top link F_{HT}	kN	2.06	1.45	1.19	7.71	7.73	9.59	8.17	10.40
Main time T_1	s	20.29	18.89	18.49	17.49	16.79	17.29	16.89	17.29
Ø Depth h	cm	21.00	21.40	19.20	23.40	22.40	18.80	20.00	21.40
Ø Stroke B	m	1.61	1.60	1.62	1.54	1.55	1.61	1.61	1.58
Variation coefficient – depth V_h	%	3.37	4.18	7.73	7.76	7.47	6.94	7.07	7.09
Variation coefficient – stroke V_B	%	1.21	1.05	0.87	0.96	0.98	1.16	0.52	0.35
Effective performance W_1	ha.h^{-1}	0.86	0.90	0.94	0.95	0.99	1.02	1.03	1.00
Ø Slip δ	%	20.60	19.40	18.61	15.92	15.82	15.30	16.33	15.17

II: *Continuation Tab. II: Table of computed parameters from measured parameters of the tractor Zetor Proxima Plus 115 aggregated with the plough Kverneland 150 B*

Tractor		**Zetor Proxima Plus 115**							
Maesurements		**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Hydraulic control		**force**	**force**	**force**	**force**	**force**	**force**	**force**	**force**
Lenght of top link	mm	625	625	625	625	625	625	625	625
Ø Force in top link F_{HT}	kN	14.52	14.28	14.68	18.13	18.37	18.56	20.45	20.19
Main time T_1	s	15.69	15.39	16.09	14.99	15.39	15.69	15.39	15.09
Ø Depth h	cm	22.20	23.40	22.80	19.40	18.50	18.00	18.00	19.00
Ø Stroke B	m	1.56	1.58	1.58	1.61	1.61	1.62	1.64	1.58
Variation coefficient – depth V_h	%	2.01	4.87	8.44	2.82	2.70	10.39	5.56	3.72
Variation coefficient – stroke V_B	%	0.70	0.72	0.53	0.71	0.52	0.83	0.43	0.83
Effective performance W_1	ha.h^{-1}	1.06	1.10	1.07	1.16	1.11	1.11	1.16	1.12
Ø Slip δ	%	14.48	14.03	13.32	13.20	13.11	14.72	11.55	11.27



8: *The dependence of slip on the force in top link – the tractor Zetor Proxima Plus 115 aggregated with the plough Kverneland 150 B*



9: *The dependence of effective performance on the force in top link – the tractor Zetor Proxima Plus 115 aggregated with the plough Kverneland 150 B*

the forces may be reducing the sensitivity of the control system of three point hitch, or too significant unloading of the front axle of the tractor. Whereas the slip is the largest loss component by tillage (Zoz, 1994) its reduction increase in running speed. This fact is also reflected in value of effective performance and in the efficient fuel consumption too. The first tractor aggregate had specific effective performance only 1 $m^3.s^{-1}$ in the first measurement and 1.11 $m^3.s^{-1}$ in the last measurement, which represents the relative increase of 11%. At the same time the specific effective fuel consumption decreased of 1.7 ml. m^{-3}, respectively relative decrease of 17%. Authors (Bauer, 2004; Duďák, 2002) reached the similar results.

For the second tractor aggregate were evaluated only the performance parameters. It was also shown to influence force in top link of three point hitch to the output parameters of the tractor aggregate. Specifically, by measurement 9, where the measured force in top link was only 1.45 kN, the tractor aggregate reached effective performance 0.9 $ha.h^{-1}$. In contrast, by measurement 22, was the force in top link 20.45 kN and the effective performance increased by 0.26 $ha.h^{-1}$, respectively relatively by 28.9%.

CONCLUSIONS

Based on the above graphic display is clear that the slip, effective performance, as well as effective fuel consumption show a linear dependence on the force in top link of three point linkage. At all linear interpolation was achieved the index of determination higher than 0.85, which shows a good correlation between the force in top link, slip and other output performance parameters of tractor aggregate. It is necessary to pay sufficient attention to set up three point hitch by tractor aggregate with carried implement. Because the setting of three point hitch have large influence on using potential tractor technique.

SUMMARY

The object of this paper is to analyze the effect of setup of three point linkage on energetic and performance parameters of tractor aggregate. For this purpose were made two series of measurements. The first series was realized with the tractor NewHolland T7050 aggregate with 5-furrow reversible plough plough KUHN HUARD VM 150 5 NS. Data such as engine load, engine revolution, diesel fuel consumption, diesel fuel temperature, were got from CAN Bus network during the measurement. Then were measured following parameters total time of ploughing, dephth of ploughing, time of turning and swath of the tractor aggregate. The specific consumption of diesel fuel and the efficiency of the aggregate were calculated using the aforementioned parameters. The second series of measurements was realized with the tractor Zetor Proxima Plus 115 aggregate with 4-furrow reversible plough Kverneland 150 B. During the measurement the data such theoretical and actual speed of the tractor and force in the top ling of the three point hitch were recorded in the computer. Then were measured following parameters such as main time of ploughing, dephth of ploughing and swath of the tractor aggregate. By the first and second tractor aggregate were approved linear dependence of slip, performance and fuel consumption on the force in top link of three point linkage. By the first tractor aggregate, was due to shortening of the top link to increase force from 8.6 kN to 21.3 kN. The slip of drive wheel decreased from 16.6 % to 10.9 %. The increase of force in top link was also reflected in relative increase by 11 % of specific effective performance and relative decrease by 17 % of specific effective fuel consumption. By the second tractor aggregate were achieved similar results. The increase of force in top link of three point hitch from 1.2 kN to 20.5 kN was reflected in decrease of slip from 18.6 % to 11.6 % and relative increase up to 28.9 % in the effective performance.

Acknowledgment

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