UDC 631

ISSN 1333 - 2651

UNIVERSITY OF ZAGREB FACULTY OF AGRICULTURE
AGRICULTURAL ENGINEERING DEPARTMENT
FACULTY OF AGRICULTURE UNIVERSITY OF OSIJEK
FACULTY OF AGRICULTURE AND LIFE SCIENCES UNIVERSITY OF MARIBOR
AGRICULTURAL INSTITUTE OF SLOVENIA
HUNGARIAN INSTITUTE OF AGRICULTURAL ENGINEERING
CROATIAN AGRICULTURAL ENGINEERING SOCIETY

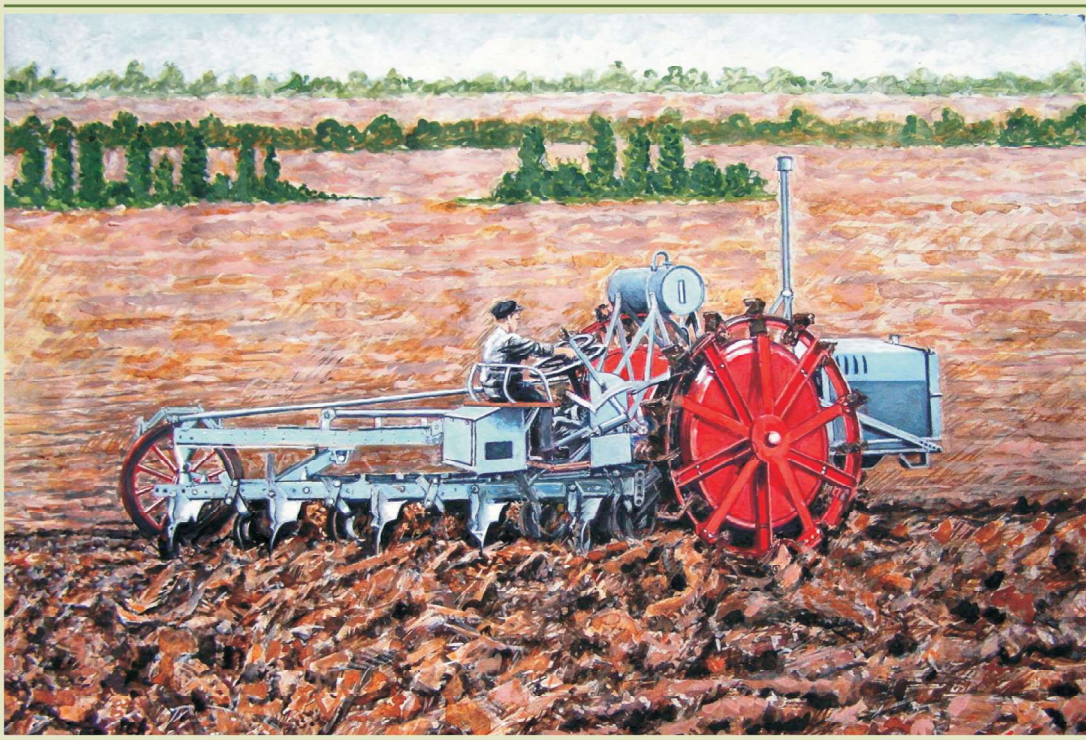
AAESEE

EurAgEng

PROCEEDINGS OF THE
38. INTERNATIONAL SYMPOSIUM ON
AGRICULTURAL ENGINEERING

Actual Tasks on Agricultural Engineering

OPATIJA, CROATIA, 22. - 26. FEBRUARY 2010



SVEUČILIŠTE U ZAGREBU AGRONOMSKI FAKULTET
ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
POLJOPRIVREDNI FAKULTET SVEUČILIŠTA U OSIJEKU
UNIVERZA V MARIBORU FAKULTETA ZA KMETIJSTVO IN BIOSISTEMSKE VEDE
KMETIJSKI INŠTITUT SLOVENIJE
MAĐARSKI INSTITUT ZA POLJOPRIVREDNU TEHNIKU
HRVATSKA UDRUGA ZA POLJOPRIVREDNU TEHNIKU
AAESEE

AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

ZBORNIK RADOVA

38. MEĐUNARODNOG SIMPOZIJA IZ PODRUČJA MEHANIZACIJE POLJOPRIVREDE

OPATIJA, 22. - 26. veljače 2010.

Izdavači *Published by*	Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, Svetošimunska 25, 10000 Zagreb HINUS, Miramarska 13 b, Zagreb
Glavni i odgovorni urednik *Chief editor*	Silvio Košutić e-mail: skosutic@agr.hr
Tehnički urednik *Technical editor*	Hrvoje Zrnčić
Organizacijski odbor *Organising committee*	Krešimir Čopec, Vinko Duvnjak, Goran Fabijanić, Dubravko Filipović, Zlatko Gospodarić, Igor Kovačev, Đuro Banaj, Robert Zimmer, Rajko Bernik, Viktor Jejčić, Miran Lakota, Tomaž Poje
Znanstveni odbor *Scientific committee*	Nikolay Mihailov (Bulgaria), Silvio Košutić, Robert Zimmer, (Croatia), Peter Schulze-Lammers, Joachim Müller (Germany), Daniele De Wrachien, Ettore Gasparetto (Italy), Maohua Wang (P. R. China), Victor Ros (Romania), Milan Martinov (Serbia), Jaime Ortiz-Canavate (Spain), Vilas M. Salokhe (Thailand), Rameshwar Kanwar (USA), Bill A. Stout (USA)
Naklada *Number of copies*	200

ISSN 1333-2651

http://atae.agr.hr

Slika s naslovnice korištena je dobrotom autora gospodina Dušana Jejčiča
Cover painting is printed by courtesy of author Mr Dušan Jejčič
Oblikovanje naslovnice / Cover design: Marko Košutić

Svi radovi u Zborniku su recenzirani.
All papers in Proceedings are peer reviewed.

Radovi u Zborniku su indeksirani u bazama podataka od 1997.:
Papers from the proceedings have been indexed since 1997 into databases:

Current Contents Proceedings, ISI - Index to Scientific & Technical Proceedings, CAB International - Agricultural Engineering Abstracts, Cambridge Scientific Abstracts - Conference Papers Index, InterDok.

38. SIMPOZIJ
AKTUALNI
ZADACI
MEHANIZACIJE
POLJOPRIVREDE

UDC
631.
Pre rad
Re paper

THE INFLUENCE OF DIFFERENT TRACTION SYSTEMS ON TRACTORS PERFORMANCE IN SOIL TILLAGE

ZORAN MILEUSNIC, MILAN DJEVIC, RAJKO MIODRAGOVIC, MARIJA BOZIC

Faculty of Agriculture, Belgrade

ABSTRACT

This paper presents results of testing two different traction systems and analysis of their influence on tractor's efficiency in soil tillage. Results of the field testing concerning energy requirements and technical-economical characteristics in two different tillage systems it can be concluded that tractor with rubber belts was significantly efficient in comparison to tractor with dual tires. The tractor with rubber belts achieved 27.05 % higher rate of work and 11.67% higher energy efficiency. The fuel consumption of the tractor with the rubber belts traction system was 15.17% lower compared to the tractor with tractor with dual tires.

***Key words**: tractor traction system, tillage, energy efficiency.*

INTRODUCTION

It is very well known that the selection of tractor traction system is very significantly related with the production conditions and agro-technical requirements. The common production practice of achieving "maximum yields", besides all of various factors, imposes very intensive soil exploitation, proper tillage system applied and the maximal energy efficiency.

In this paper testing results of the tractors with two traction systems in tillage are presented. In order to provide maximum yields an up-to-date technology level is required, so, according to Hillel, D. (1982), Koolen, A.J., Kuipers, H. (1983), and Ronai, Đ. (1986):

- primary tillage by plough should be done to minimize compaction by either "plough pan" or tractor wheels,
- secondary tillage could be done with the various implements,

- final soil compaction is unavoidable as a consequence of plough pan as well as "wheel pan".

The choice of tractor type and its category depends on agro-technical requirements, possible combination with various implements, scope and deadline of tillage operations and particular soil conditions Mileusnić, Z. *et. al*., (2009), Obradović, D. (1990). To provide proper tillage quality, various operations demand adequate velocity. There is difference between motion velocity in the working regime of η_t and technology velocity equal to optimum work quality. The technology velocity should run within the exploitation range of velocity at $\eta_{t\ max}$. In the opposite case the tractor is inadequate and must be replaced. Deviation from this rule is acceptable in case of relatively small working scope when it is more rational to use the existing tractor with lower η_t and lower rate of work than to buy a new one Chancellor, W., Zhang, N. (1989), Nikolić R *et. al* (2007), Novaković, D. (1992) and (1993), and [10].

The aim of this paper is to compare different traction systems and define its influence on tractors performance in soil tillage.

MATERIAL AND METHOD

Testing material were two tractors with different traction system, used in tillage as follows :

- two types of traction systems (Tab. 1)
- two types of surfaces with the applied tillage model (Tab. 2): stubble and ploughed.

Table 1 Technical characteristics of the tested tractors

Technical characteristics	C	T
1. Tractor concept	Track laying	Articulated wheel
2. Engine power (kW)	201	198
3. Specific engine fuel consumption (g/kWh)	261	228
4. Gear No.	10+2	16+2
- min/max (km/h)	4.2/29.3	2.6/32.2
5. Drive	Rubber belts	Dual pneumatics
- front	-	18.4/15-38
- rear	-	18.4/15-38
- width/length (mm)	622/2718	-
6. Mass (kg)	15500	11700
7. Energy supply (kW/t)	12.97	16.92

Table 2 Tillage operations, implements, working velocity and specific soil resistance

Operation	Implement	Velocity (km/h)	Specific resistance
1. Stubble shallow ploughing - 12 cm	Plough	10	10 (N/cm^2)
2. Ploughing – 40 cm	Plough	5	10 (N/cm^2)
3. Tillage with disc harrow	Disc harrow ϕ 810 mm	9	11 (kN/m)
4. Disc harrowing	Disc harrow ϕ 610 mm	9	5 (kN/m)
5. Seed-bed preparation	seed-bed cultivator	10	4.5 (kN/m)

Comparison of traction systems according to fuel and energy consumption was based on the parameters calculated with equation 1 to 7 as follows:

a) Working width of the implements:

- ploughs:

$$b = \frac{F_v}{k_{or} \cdot a} \tag{1}$$

- disc harrows and seed-bed cultivators:

$$b = \frac{F_v}{k_s} \tag{2}$$

b) Rate of work:

$$W = 0.1 \cdot b \cdot v \tag{3}$$

c) Working hours per hectare:

$$1/W \tag{4}$$

d) Fuel consumption per hectare:

$$Q_{ha} = \frac{Q}{W} \tag{5}$$

e) Technological energy consumption:

$$E_{ha} = \frac{F_v \cdot v}{W} \tag{6}$$

f) Energy generated from one liter of tractor fuel consumed:

$$Eq = \frac{Pv}{Q} \tag{7}$$

List of symbols

T - four wheel tractor

C - tractor with rubber belts

ηt - tractor efficiency coefficient

b (cm) - plough working width

a (cm) - plough working depth

F_V (N) - drawbar force

W (ha/h) - Rate of work

P_V (W) - drawbar power)

v (km/h) - velocity

Q_{ha} (1/ha) - fuel consumption per hectare

Q_h (1/h) - fuel consumption per hour

E_{ha} (kWh/ha) - technological energy consumption

E_Q (kWh/l) - energy generated from 1 l of fuel

δ (%) - slip

q (g/kWh) - specific tractor fuel consumption

φ (-) - adhesion coefficient

k (N/cm^2) - specific ploughing resistance

l/W (h/ha) - working hours per hectare

RESULTS AND DISCUSION

Characteristics of the rubber belts in stubble are shown in Table 3. and in plough-field in Table 4.

Table 3 Performance of tractor with rubber belts at stubble ploughing

Parameters at P_{vmax}							
P_V (kW)	F_V (kN)	v (km/h)	δ (%)	Q_h (l/h)	q (g/kWh)	φ (-)	η_t (-)
133.32	129.72	3.70	12.51	63.36	394	0.812	0.663
152.42	96.06	5.71	5.03	63.25	344	0.631	0.758
155.43	83.64	6.69	3.75	63.37	338	0.550	0.773
153.20	70.26	7.85	2.91	63.38	342	0.462	0.762
150.89	61.36	8.85	2.50	63.34	348	0.404	0.751
147.45	51.44	10.32	2.01	63.31	356	0.338	0.733
142.49	42.43	12.09	1.50	63.25	368	0.279	0.709

Tractor with rubber belts in stubble provided maximum tractor efficiency coefficient of 0.773 at: Pv=155.43 kW, Fv=83.64 kN, v=6.69 km/h, δ=3.75%, Q=63.37 l/h, q=338 g/kWh and φ=0.550

Table 4 Performance of tractor with rubber belts at harrowing ploughed soil

Parameters at P_{vmax}							
P_V (kW)	F_V (kN)	v (km/h)	δ (%)	Q (l/h)	q (g/kWh)	φ (-)	η_t (-)
82.81	87.68	3.40	18.84	63.23	633	0.590	0.412
104.22	69.77	5.37	8.78	63.23	503	0.459	0.518
108.54	60.80	6.43	6.00	63.24	483	0.400	0.540
106.93	51.07	7.54	4.52	63.20	490	0.336	0.532
105.52	44.69	8.50	3.08	63.26	497	0.294	0.525
102.91	37.39	9.91	2.44	63.18	509	0.246	0.512
99.49	30.86	11.61	1.82	63.24	527	0.203	0.495

Tractor with rubber belts in plough-field provided maximum tractor efficiency coefficient of 0.540 at: Pv=108.54 kW, Fv=60.80 kN, v=6.43 km/h, δ=6.00%, Q=63.24 l/h, q=483 g/kWh and φ=0.400

Performance characteristics of wheeled tractor in stubble are shown in Table 5 and in plough-field in Table 6

Table 5 Performance of wheeled tractor at stubble ploughing

Parameters at P_{vmax}							
P_V (kW)	F_V (kN)	v (km/h)	δ (%)	Q (l/h)	q (g/kWh)	φ (-)	η_t (-)
67.53	80.50	3.02	24.36	54.50	669	0.700	0.341
97.02	71.42	4.89	18.66	54.42	465	0.621	0.490
119.99	61.52	7.02	14.03	54.42	376	0.533	0.606
131.67	51.75	9.16	10.58	54.48	343	0.450	0.665
130.09	42.50	11.02	7.94	54.45	347	0.370	0.657
124.15	32.48	13.76	5.02	54.51	364	0.282	0.627
119.21	26.62	16.12	3.84	54.50	379	0.231	0.602

The wheeled tractor in stubble provided maximum tractor efficiency coefficient of 0.665 at: Pv=131.67 kW, Fv=51.75 kN, v=9.16 km/h, δ=10.58%, Q=54.48 l/h, q=343 g/kWh and φ=0.450.

Table 6 Performance of wheeled tractor at harrowing ploughed soil

Parameters at P_{vmax}							
P_v (kW)	F_v (kN)	v (km/h)	δ (%)	Q (l/h)	q (g/kWh)	φ (-)	η_t (-)
40.99	55.89	2.64	33.00	54.44	1101	0.486	0.207
65.38	48.42	4.86	25.66	54.49	691	0.421	0.330
78.00	42.32	6.63	20.44	54.48	579	0.368	0.394
81.58	37.03	7.93	17.25	54.42	553	0.322	0.412
79.84	31.05	9.25	14.00	54.41	565	0.270	0.403
75.92	25.42	10.75	10.88	54.49	595	0.221	0.383
71.84	21.28	12.15	9.02	54.42	628	0.185	0.363

Wheeled tractor in plough-field provided maximum tractor efficiency coefficient 0.412 at: Pv=81.58 kW, Fv=37.03 kN, v=7.93 km/h, δ=17.25%, Q=54.42 l/h, q=553 g/kWh and φ=0.322.

Technical characteristics (Table 1.) show that tractor with rubber belts provides higher power by 1.51% as well as higher specific engine fuel consumption by 14.51%. Its mass is 32.48% higher and energy supply 23.35% lower compared to the wheeled one.

Comparison of drawbar characteristics at stubble ploughing and ploughed soil disc-harrowing at $\eta_{t\,max}$ shows the following:

- tractor with rubber belts achieved 61.6% higher drawbar force at stubble ploughing and 64.2% in disc-harrowing,
- velocity reduction due to surface type (stubble-plough-field) was lower with rubber belts tractor (3.9%) than with wheeled one (13.4%),
- 64.5% lower slip at stubble and 65.2% in ploughed-field was recorded with rubber belts tractor than with wheeled one,
- surface type caused η_t decrease by 30% with rubber belts tractor and by 38% with the wheeled one,
- tractor with rubber belts achieved 14.51% higher engine specific fuel consumption (q_m), 1.5% lower tractor specific fuel consumption (q_t) at stubble and 12.6% in plough-field,
- total fuel consumption of tractor with rubber belts (Q) is 16% higher,
- rubber belts tractor generated 1.2% more energy per one liter of fuel (E_Q) at stubble and 14% at ploughed-field.

Table 7 Rate of work, fuel and energy consumption of different tractor concepts in tillage

Tractor	F_V (kN)	b (cm)	W (ha/h)	1/W (h/ha)	Q_{ha} (l/ha)	E_{ha} (kWh/ha)	E_Q (kWh/l)
Stubble shallow ploughing							
C	53	442	4.42	0.226	14.34	33.33	2.32
T	47	392	3.92	0.255	13.90	33.33	2.39
C/T (%)	112.75	112.75	112.75	88.63	103.16	100.00	97.07
Ploughing							
C	105	263	1.32	0.758	48.01	111.11	2.30
T	71	178	0.89	1.124	61.21	111.11	1.81
C/T (%)	147.89	147.89	148.31	67.44	78.43	100.00	127.07
Plough-field disc harrowing							
C	42	382	3.44	0.291	18.42	30.55	1.66
T	32	291	2.62	0.382	20.79	30.55	1.47
C/T (%)	131.25	131.25	131.30	76.18	88.60	100.00	112.93
Disc harrowing							
C	42	840	7.56	0.132	8.38	13.89	1.66
T	32	640	5.76	0.174	9.46	13.89	1.47
C/T (%)	131.25	131.25	131.25	75.86	88.58	100.00	112.93
Seed-bed preparation							
C	37	822	8.22	0.122	7.71	12.50	1.63
T	28	622	6.22	0.161	8.76	12.50	1.43
C/T (%)	132.14	132.15	137.15	75.78	88.01	100.00	113.99
Total							
C	-	-	-	1.529	96.86	201.38	9.57
T	-	-	-	2.096	114.12	201.38	8.57
C/T (%)	-	-	-	72.95	84.88	100.00	111.67

Different tractor concept comparison regarding work rate and fuel/energy consumption in soil tillage (Table 7.) in particular working conditions (Table 2.) shows the following:

- consumption of technical energy per surface unit (E_{ha}) is the same for both tractors for all operations due to the same working conditions,
- in the stubble shallow ploughing the tractor with rubber belts provided 12.75% higher rate of work (W), 11.37% lower time consumption per hectare (l/W), 3.16% higher fuel consumption per hectare (Q_{ha}) and 2.93% lower energy exploitation per liter of fuel (E_Q) in comparison to the wheeled tractor,

- in ploughing at the depth of 40 cm the caterpillar tractor provided 48.31% higher rate of work (W), 32.56% lower time consumption per hectare (l/W), 21.57% lower fuel consumption per hectare (Q_{ha}) and 27.07% higher fuel energy exploitation (E_Q) in comparison to the wheeled one,
- in plough-field disc harrowing with heavy disc harrow 810 mm diameter, the rubber belts tractor provided 31.30% higher rate of work (W), 23.82% lower time consumption (l/W) , 11.40% lower fuel consumption per hectare (Q_{ha}) and 12.93% better fuel energy exploitation (EQ) in comparison to the wheeled one,
- in disc harrowing with the disc diameter of 610 mm the rubber belts tractor provided 31.25% higher rate of work (W), 24.14% lower time consumption per hectare (l/W), 11.42% lower fuel consumption per hectare (Q_{ha}) and 12.93% better fuel energy exploitation (E_Q) compared to the wheeled one,
- in seed-bed preparation the rubber belts tractor provided 37.15% higher rate of work (W), 24.22% lower time consumption per hectare (l/W), 11.99% lower fuel consumption per hectare (Q_{ha}) and 13.99% better energy exploitation per fuel liter (E_Q) in comparison to the wheeled one,
- for particular tillage technology the rubber belts tractor provided 27.05% lower time consumption per hectare (l/W), 15.17% lower fuel consumption per hectare (Q_{ha}) and generating 11.67% higher fuel energy (E_Q) than the wheeled one.

CONCLUSIONS

The following conclusions can be drawn from the testing of potential traction characteristics of the same power tractor with rubber belts and wheeled tractor types in tillage:

- rubber belts tractor achieved higher rate of work in all tillage operations, ranging from 112.75% - 148.31% in comparison to the wheeled tractor, thus providing 27.05% faster tillage per hectare,
- total fuel consumption per hectare of the rubber belts tractor in tillage was 15.12% lower in comparison to the wheeled one,
- rubber belts tractor generated 11.67% higher fuel energy per one liter of fuel consumed in tillage by than the wheeled one.
- The results obtained show higher tillage efficiency of the rubber belts tractor type.

REFERENCES

1. Chancellor, W., Zhang, N. (1989): *Automatic Wheel Slip Control for tractors*, Transactions of the ASAE, Vol. 32, No. 1, pp. 17-22, St. Joseph, Michigan, USA
2. Hillel, D. (1982): Introduction to soil physics, Academic press, New York.

3. Koolen, A.J., Kuipers, H. (1983): Agicultural Soil Mechanics, Springler Verlag, Berlin Heilderberg, Germany
4. Mileusnić, Z., Petrović, D., Đević, M. (2009): *Comparison Of Tillage Systems According to Fuel Consumption*, Energy, (doi:10.1016/j. energy.2009.09.12)
5. Nikolić R., Savin L., Furman T., Tomić M., Simikić M., Gligorić R., (2007), *Teorija vuče i koeficijent efikasnosti gumene gusenice*, Poljoprivredna tehnika Godina XXII, No 2, str. 15 – 23, Beograd.
6. Novaković, D. (1992): *Mogućnost uštede energije korišćenjem traktora guseničara*, Zbornik radova, Dan poljoprivredne tehnike, Beograd-Zemun
7. Novaković, D. (1993): *Primena traktora guseničara u primarnoj poljoprivrednoj proizvodnji,* doktorska disertacija. Beograd: Poljoprivredni fakultet Zemun.
8. Obradović, D. (1990) *Optimalni parametri traktorsko-mašinskih agregata za poljoprivredna gazdinstva,* Institut za mehanizaciju poljoprivrede Zemun-Beograd.
9. Ronai, Đ. (1986): *Sabijanje zemljišta kao posledica kretanja točka,* Monografija, Novi Sad.
10. http://www.oecd.org