The effect of working conditions on the selected parameters of duckfoot shares

M. FRÍD, J. ŠABATKA, I. CELJAK

Agricultural Faculty, South Bohemian University, České Budějovice, Czech Republic

ABSTRACT: We measured a series of six duckfoot shares in the years 1999–2000. The purpose of the research project resulted from the Grant EP7111 and the Research project MSM J06/98:122200002/I. We described forces affecting machine implements and we consequently calculated measuring resistances during the ploughing. The deeper the subterranean the higher the linear growth of forces. If the subterranean rises from eight to ten centimetres, it will appear an increase in forces of 59.61% in the horizontal plane and of 30.84% in the vertical plane. If the driving speed increases from 5.91 km/h to 11.38 km/h, i.e. 1.64 m/s to 3.16 m/s, the forces will intensify to 53.11% in the horizontal plane and to 25.8% in the vertical plane. We deducted an outstanding influence of soil moisture on the resistance of the duckfoot shares at all three stages.

Keywords: forces; resistivity of loosening; speed of operation; depth; soil moisture

To assure a good base for high and stable yields in future stubble plough under has to be done after the harvest as soon as possible. Currently used wheatland ploughs, shovel cultivators and rod weeders fulfil present high current agro-technical requests on stubble plough under in variant quality and at different costs. According to HŮLA and MAYER (1995) the rod weeders were more common in the past few years. The rod weeders were used especially for traditional soil processing that includes ploughing and which was also characteristic for stubble plough under of cereals and other crops that implicated stubble-field. But the rod weeders can be used for various working methods in which the ploughing is replaced with shallow loosening. Such cultivators are sufficient for soil conservation processing. Some of such working methods are even conditioned by using cultivators equipped with duckfoot shares.

These cultivators can be considered as an advantage for simplified soil processing with different degree of dampening of soil cultivation intensity. These cultivators can be used both for conventional and unconventional soil processing. Usage of such machines leads to a lot of studies evaluating the effects of the cultivators' tools on following parameters: energy intensiveness and the quality of cultivator work. The studies involve evaluation of effects of different soil quality on the same parameters. ANKEN et al. (1993) clarified the requirement of the detailed study of modern tillers with cultivator beams in their comparative study. JÄGER and FUNK (1994) came to same conclusions.

The aim of our work was to analyse and to verify the forces affecting working instruments of the tillers within soil processing. We compared the results under different conditions: variant designs of duckfoot shares, various driving speeds, varied sinking in and various physical soil characteristics.

MATERIAL AND METHODS

We recorded the forces affecting the duckfoot shares both in the vertical and horizontal planes under different depth of cultivation and driving speed. We used the measuring frame MV-97. Fig. 11 shows total view on MV-97. We noted down measured figures thanks to electronic frame comprising software and a computer. Our system was based on experience with constructions of similar devices (xx), (yy), (zz) of ADÁMEK (1994, 1999), FRÍD et al. (1998, 1999a,b).

We examined the transverse profile of the processed soil by measuring. The transverse profile can be counted from the equation (1). For detailed data see Fig. 1. The resistivity of cultivation k_o was counted from equation (2).

$$S = b \,.\, h + c \,.\, h \qquad (\mathrm{m}^2) \qquad (1)$$

where: b – mesh of the duckfoot share (m),
h – the average value of the working depth (m),
c – soil bulkage to the duckfoot share's edges (m).

$$k_o = \frac{F_{x2}}{S} \qquad (\mathrm{Pa}) \qquad (2)$$

where: F_{x2} – the force affecting the resistivity of the duckfoot share in the horizontal plane (N),
S – the surface of the transverse profile of the cultivated soil (m^2).

Recorded values were processed by the program Microsoft Excel 97 and evaluated by the program Statis-

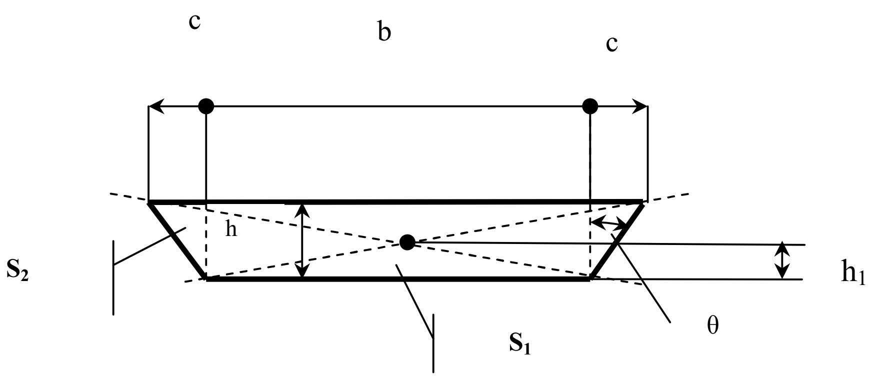


Fig. 1. Worked transverse profile

tics. We sampled soil profile by physical rings and we specified the type of soil in order to get the core physical soil characteristics (Table 1). We used the penetrometer P-70 to obtain penetration index. We measured the resistivity of penetration of exploring element in order to obtain the degree of soil compaction. For our research we used the standard type cone with an inside diameter of basis D = 12.8 mm and vertical angle α = 30°.

During the survey we used duckfoot shares equipped with cultivator beams. The overview of technical parameters and different shapes of working tools shows Table 2 and Fig. 2 and 10. We evaluated the impact of sinking in on the magnitude of forces. We recorded these forces at the depth of 8, 10, 12 cm and the average speed v_p = 3.11 m/s, i.e. 11.18 km/h. In order to obtain the influence of the driving speed on the magnitude of forces we set the depth of ploughing to 8 cm and we were altering the driving speed in the extend of v_p = 1.64 m/s – 3.16 m/s, i.e. 5.91–11.18 km/h. To be able to evaluate the influence of the soil moisture and the construction of the duckfoot shares on the resistivity of cultivation we set the depth of cultivation to 8 cm and the driving speed to 1.59 m/s, i.e. 5.71 km/h.

RESULTS AND DISCUSSION

The impact of the sinking in the duckfoot share on the magnitude of forces

We carried our researches during the year 1999 on the site number 1 after the harvest of a winter_wheat. We reviewed obtained data by the Friedman's test and by the Nemeny's method. On the significance level α = 0.05 we proved statistical evidential variance in an average value of the duckfoot shares' resistance in the horizontal plane F_{x2}. This was valid for all measured duckfoot shares under the given sinking-in of 8, 10, 12 cm. We also proved statistical evidential variance in the values of the vertical force F_z at the duckfoot shares 1, 3, 6 and under the given sinking-in of 8, 10, 12 cm. At the duckfoot shares number 2 and 4 we proved statistical evidential variance in average values F_z under the given sinking-in of: 8 and 12 cm. We stated linear dependence of the forces for all the duckfoot shares in the valuated range of 8–12 cm, which we expressed by equation $y = bx + a$. The deeper the sinking-in the higher the force F_{x2} for all duckfooot shares. We proved similar character of the vertical force F_z at the duckfoot shares 1, 4, 5, 6. At the duckfoot share number 3 we established diminishing character of the force F_z.

Figs. 3 to 8 show the forces affecting the duckfooot shares both in the horizontal and vertical planes.

The impact of driving speed on the magnitude of forces

We measured a series of six duckfoot shares on the site number 1 under the given sinking-in of 8 cm. We focused on four driving speeds in the range of 1.64–3.16 m/s, i.e. 5.91–11.18 km/h. We processed the data by the Friedman's test and by the Nemeny's method. We proved the driving speed significantly affected the magnitude of the horizontal force that influenced the duckfoot share by the given sinking-in. We used the F-test for evaluation of the vertical force and established significant differences in the average value of the vertical force affecting the duckfoot share on 100% significance level. Subsequently we used the Nemeny's test on the confidence level α = 0.05 in order to test the significance of the group's contrast. We proved significant differences at all tested duckfoot shares. The obtained data were used to define the regress function and the indexes of determination. We stated the linear dependence of the forces on the driving speed under the given range of 1.64–3.16 m/s, i.e. 5.91–11.18 km/h. We expressed this relation by equation $y = bx + a$. The higher the driving speed the greater the magnitude of the forces F_{x2} that was valid for all surveyed duckfoot shares. The progressive character of forces was also characteristic for the duckfoot shares number 2, 3, 4, 5. The diminishing character of forces was typical of the duckfoot share number 6. This difference was caused by the error of measurement. We surveyed the station after the harvest. Soil on this site got compacted due to the traffic of the harvest machinery. We did not succeed in keeping the given depth of processing at the duckfoot shares number 1 and 6. Under the driving speed varying from 1.64 m/s to 3.16m/s we established the average increase of the

Table 1. Soil properties

Site	Soil texture	Grain content below 0.01 mm (%)	Physical properties at the depth of 80 to 120 mm					Penetration index (MPa)
			M_z (t/m)	O_r (t/m)	W_{mom} (%)	P_c (%)	K_{vz} (%)	
1	loam soil	33.4	2.64	1.66	9.83	37.04	19.46	2.2
2	sandy loam soil	24.2	2.64	1.591	12.20	39.73	14.71	1.41
3	loam soil	34.1	2.62	1.35	7.54	48.92	28.66	1.27

M_z – specific density, O_r – bulk density of soil after drying to constant weight, W_{mom} – soil moisture, P_c – total porosity, K_{vz} – air capacity

Table 2. Survey base of parameter shares

Denotation	Width *b* (mm)	Size of angle (°)				Length *r* (mm)	Distance *q* (mm)
		β	2γ	α1	α2		
1	230	25	70	15	31	110	175
2	270	28	68	13	33	120	180
3	300	32	76	10			180
4	350	32	74	5°30´´			180
5	320	25	66	15		150	210
6	400	40	66	23		100	210

forces of 53.11% in the horizontal plane and of 25.8% in the vertical plane. Figs. 12–17 show forces affecting each duckfoot share both in horizontal and vertical plane and the development of forces affected by driving speed.

The resistivity of cultivation k_o in relation to the used machinery

We used during the research new duckfoot shares with cultivator beams, which differed in the construction. We carried on our comparative surveys on the station number 1 after the harvest of the main crop. We excluded the places that were extremely compacted, i.e. headlands and tramlines, at the given sinking-in of 8 cm and four driving speeds in the range of 1.64–3.16 m/s, i.e. 5.91–11.18 km/h. Fig. 9 shows the results of the comparative measurements of the resistivity of cultivation**.** We proved statistical significant higher resistances at the duckfoot share number 1 and 2 under the speed 1.64 m/s in comparison to other duckfoot shares.

Compared to other duckfoot shares we stated statistical highest resistance at the duckfoot share number 1 and number 2 under the driving speed 1.64 m/s. Under the driving speed 2.08 m/s we proved by Nemeny's test statistical important differences between the duckfoot shares number 1, 2 and duckfoot share number 3, 4 on the significant level α = 0.05. We stated the statistical difference between duckfoot share number 3, 4 and duckfoot shares number 5, 6 as well to be statistical substantial. We did not prove any other statistical significant differences.

We proved statistical important variances between the average value of k_o at the duckfoot share number 1 and number 2 and the duckfoot share number 4 on the significant level α = 0.05. We did not state any other differences between other duckfoot shares.

We did not prove the difference in variance under the speed 3.16 m/s, i.e. 11.38 km/h by the verification of variance fit of cultivation resistance k_o.

We stated high value of resistance of cultivation (k_o) at the duckfoot share number 1 and 2 both under the minimal and maximal driving speed. We stated the highest k_o = 35,249.69 Pa at the duckfoot share number 2 under the highest driving speed.

We proved low value of k_o at the duckfoot share number 3, 4, 5 under the low driving speed. The lowest k_o value was proved at the duckfoot share number 5. We backed up the difference between the duckfoot shares number 1, 2 and other duckfoot shares by our survey results. We discovered the highest statistical differences under the lowest driving speed. We detected the highest difference between the duckfoot share number 1 and duckfoot share number 5 – 89.85%, but under the highest driving speed we detected only difference of 7.02%. The higher the driving speed the lower the difference in the magnitude of k_o between the duckfoot shares. We validated that the higher the driving speed the higher the increase in k_o. Our result was in accord with the conclusion of LINKE (1993), GEBRESENBET and JÖNSSON (1993) and HŮLA and MAYER (1995).

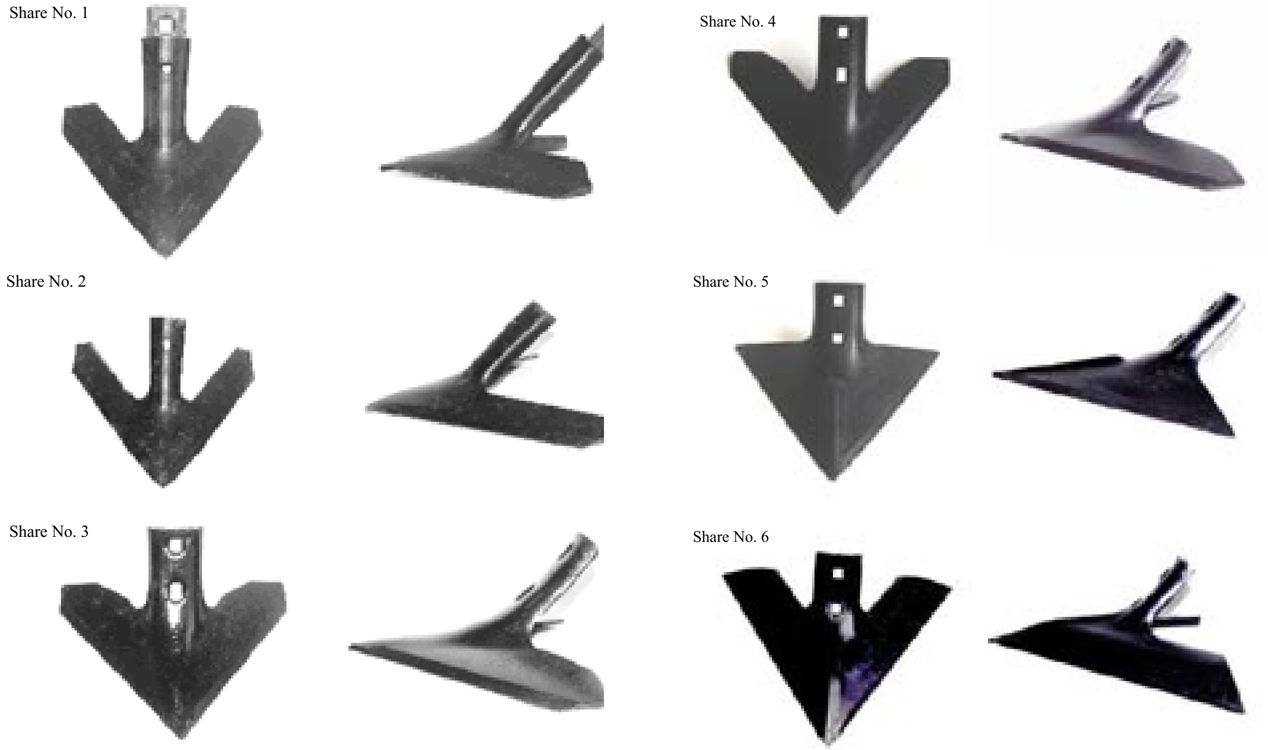
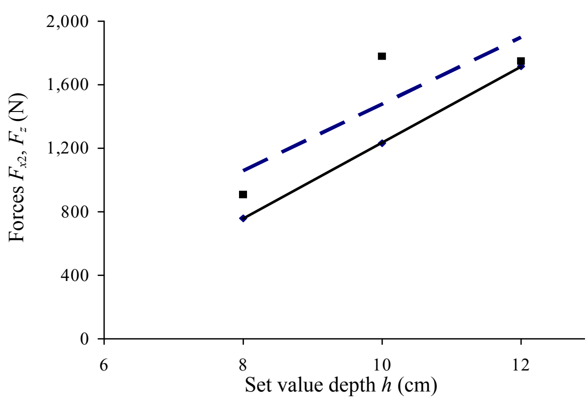
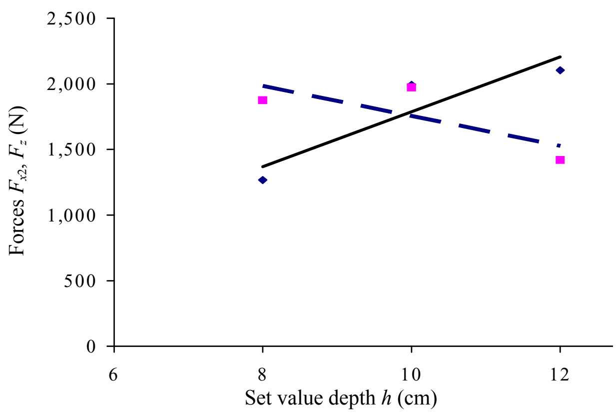


Fig. 2. Evaluation of the duckfoot share No. 1–6

We proved minimal sensitivity to the driving speed at duckfoot shares number 1 and 2. The minimal increase in k_o was found at duckfoot share number 1 – 5,051.47 Pa, i.e. 17.45%. The main increase in k_o was proved at the duckfoot share number 5 – 16,516.46 Pa, i.e. 108.35%. The obtained values at duckfoot share number 1 and 2 were similar to the surveys of HŮLA and MAYER (1995), who stated an increase in the range from 20 to 31.6%. We stated an increase in k_o in the range of 48.49% to 108.35% at other duckfoot shares.

Our results were affected by the construction of the duckfoot shares and the magnitude and development of the angle α. We proved that at the duckfoot shares number 3–5 the basic values of α were reaching extension from 5°30′ to 15° and that these values were continuously increasing up to 46°. We stated the lowest values of k_o at the duckfoot share number 3 and 4 under the whole range of driving speed. The higher the driving speed the lower the sensitivity to the elevation angle α. The working surface of the duckfoot share cultivated the soil only for a short period and that caused minimal differences in k_o at the driving speed closed to 3.3 m/s, i.e. 12 km/h. The duckfoot share number 1 and 2 had different characteristic – especially the development of the elevation angle α – than the other duckfoot shares had. We found out that at these duckfoot shares the eleva-





For Figs. 3–8: ● F_{x2} (N) ■ F_z (N) — Linear F_{x2} – – Linear F_z

Fig. 3. Dependence ot the magnitude of measured forces (N) on the given sinking (in cm) at the duckfoot share No. 1

Fig. 4. Dependence ot the magnitude of measured forces (N) on the given sinking (in cm) at the duckfoot share No. 2

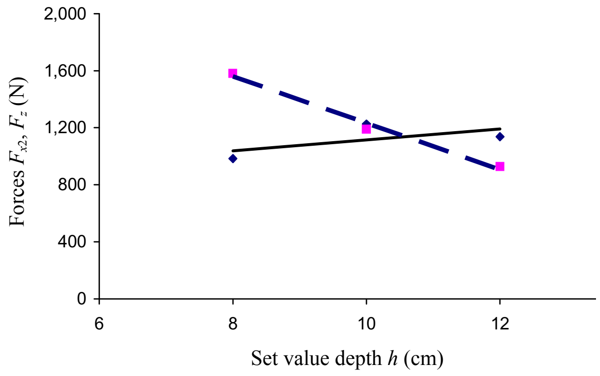


Fig. 5. Dependence ot the magnitude of measured forces (N) on the given sinking (in cm) at the duckfoot share No. 3

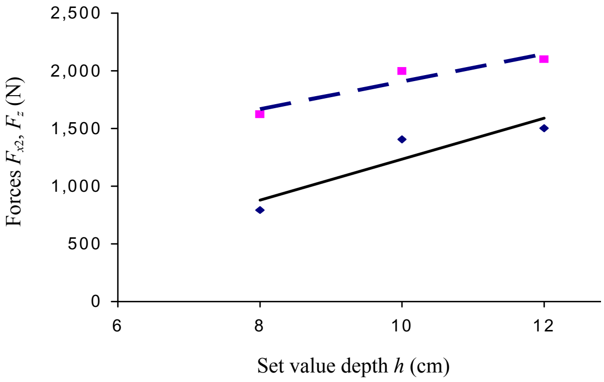


Fig. 6. Dependence ot the magnitude of measured forces (N) on the given sinking (in cm) at the duckfoot share No. 4

tion angle α was steeply increasing – the duckfoot share number 1 from 15 to 46° and the duckfoot share number 2 from 13 to 46°. Table 2 and Fig. 10 show the shapes of the duckfoot shares. We stated the highest k_o value at these duckfoot shares under the whole range of driving speeds, i.e. 1.64–3.16 m/s. This status was influenced by higher ability of cultivation. We proved the influence of the development of the elevation angle α at the duckfoot share number 1 and 5, where the elevation angle reached the same value of 15°. We stated statistical lower value of k_o under the speed 1.6 m/s at the duckfoot share number 1 compared to the duckfoot share number 5. The higher the driving speed the lower the differences in k_o at the duckfoot shares. We proved that duckfoot share number 6 differed extremely from other duckfoot shares. We stated maximal elevation angle α = 23° and even that did not measured the maximal value of k_o. We explained this result by the development of the elevation angle α at a small part of the duckfoot share (100 mm), after which the elevation angle α was decreasing. This duckfoot share cultivated soil intensively in the first stage but than calmed down.

We stated the angle γ ranging only by 5° and even by 1° at the duckfoot shares number 1 and 2. We were not allowed to state clear results of the influence of this angle on k_o.

We proved significant differences at the duckfoot shares number 1–5, where the angle β was altering in the range of 7°. Out of run surveys it was not possible to state clearly the influence of the angle β on k_o. This documented the values of angle β at the duckfoot shares number 1 and 2 in the range of 25 to 28° compared with the values at the duckfoot shares number 3–5, that reached values in the range of 32° and 25°. At the duckfoot shares number 3 and 4 we stated the higher the value of β and the lower the values of k_o – in comparison to the duckfoot shares number 1 and 2.

We proved the main influence of the mesh of the duckfoot share on the magnitude of k_o. The duckfoot share shifts the soil to the duckfoot share's edges and forward.

Following WICHA (1957) the slope of processed profile was given by the angle θ ranging from 45 to 55°. The processed profile S is represented by Fig. 1. The profile of this scheme is given by its dimensions $b \times h$ and is separated by the duckfoot share edge. Moving of separate soil components reciprocally processes the profile S_2 that is given by dimensions $c \times h$. When the separate planes of processed profile were being compared, we found that out of the processed profile S created the percentage of S_2 41.43% at the duckfoot share number 1 and 35.30% at the duckfoot share number 2. The greater the value

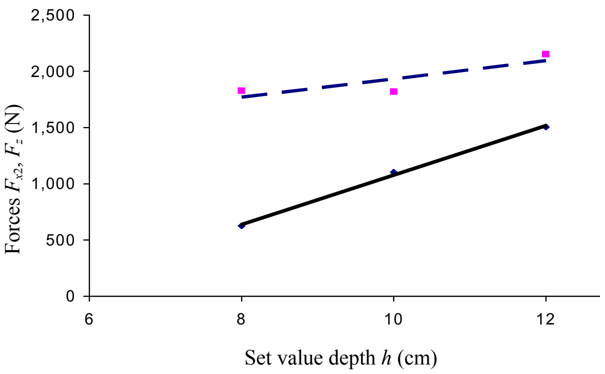


Fig. 7. Dependence ot the magnitude of measured forces (N) on the given sinking (in cm) at the duckfoot share No. 5

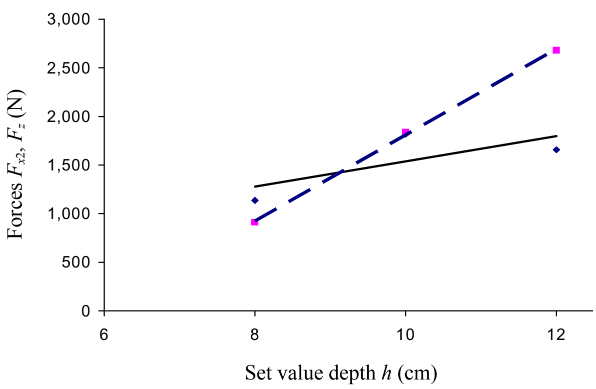


Fig. 8. Dependence ot the magnitude of measured forces (N) on the given sinking (in cm) at the duckfoot share No. 6

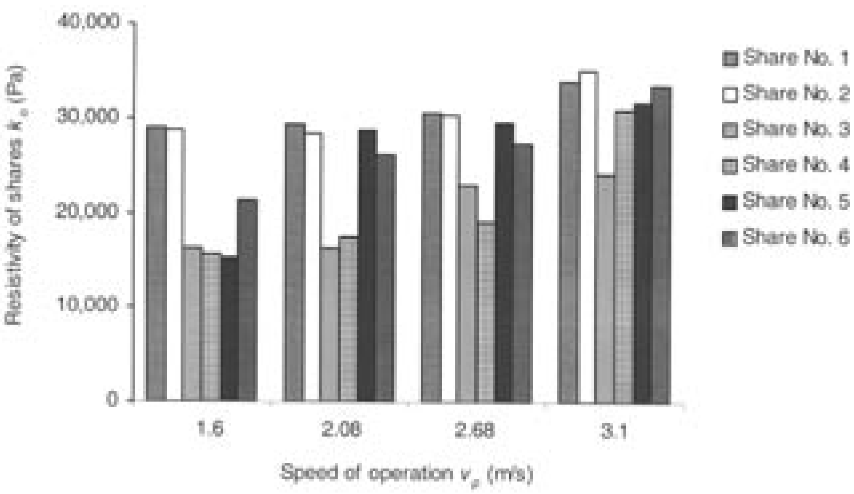


Fig. 9. Resistivity of shares (denotation of shares in Table 2)

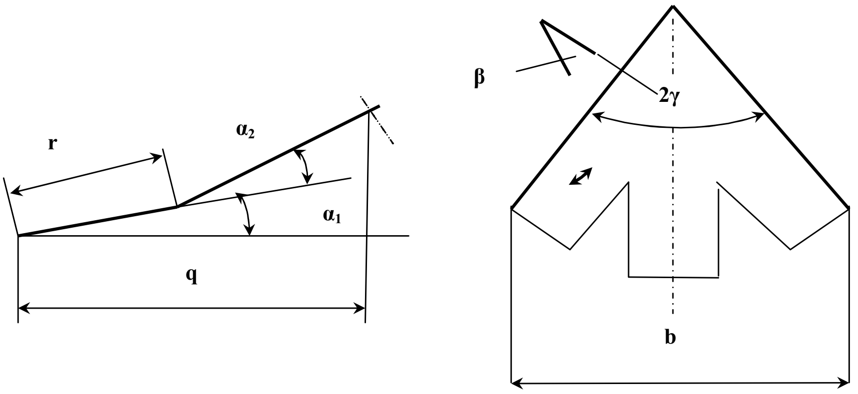


Fig. 10. View of a duckfoot share

of b the more decreasing the percentage of the share S_2. The share was 23.83% at the duckfoot share number 6. The coefficient of friction of steel and sandy clay soil (*f*) was $f = \text{tg}\ \theta = 0.341$. If the soil components moved in-between, the energy intensiveness was higher in case the soil was moved by steel machine components. This we proved by values of k_o at the duckfoot share number 6, where greater values of α and β appeared as compared to other duckfoot shares. We proved the values of k_o to be lower at all duckfoot shares except for the duckfoot shares number 1 and 2, in the whole extent of values of k_o although the values of α and β were higher.

The influence of the soil moisture on the duckfoot share resistivity

The resistivity of the duckfoot share was mainly influenced by the momentary soil characteristics especially by the soil moisture and by soil compaction. These parameters influenced crucially energy intensiveness within soil cultivation. In order to judge the impact of the soil physical characteristics on the duckfoot share resistivity we chose the plot, where the first measurement was under the way in 1999. The soil moisture reached 9.83%. The measurements on the site number 2 were under way after downfall in September 1999, when the soil moisture increased up to 12.2%. We measured the average value of moisture at the site number 3 in August 2000. In order to evaluate the impact of physical soil characteristics on the soil resistivity of cultivation we used the duckfoot shares number 1–6.

First of all we considered the difference between the values of soil resistivity of cultivation k_o separately for all duckfoot shares. We proved disparity of samples at the

Fig. 11. Measuring frame MV-97

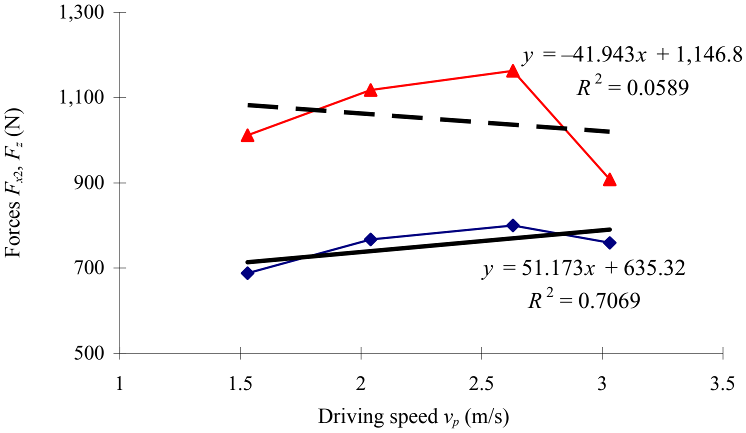


Fig. 12. Dependence of magnitude of forces on the driving speed under the depth 8 cm at duskfoot share No. 1

For Figs. 12–17: —◆— F_{x2} (N) —▲— F_z (N)

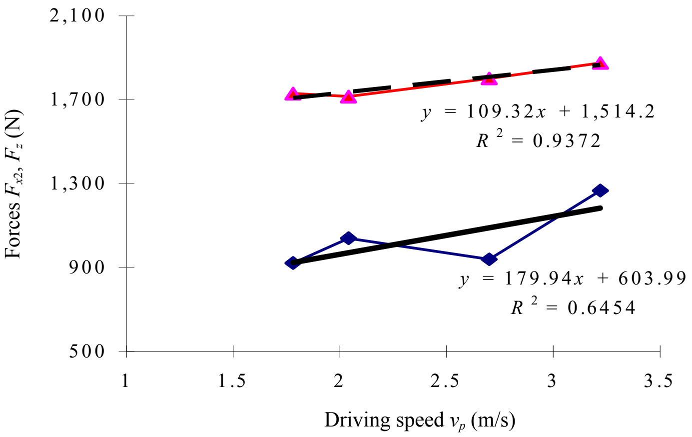


Fig. 13. Dependence of magnitude of forces on the driving speed under the depth 8 cm at duskfoot share No. 2

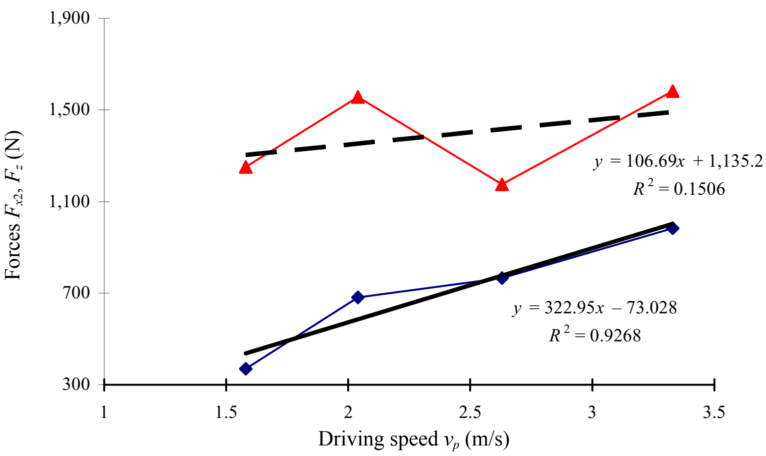


Fig. 14. Dependence of magnitude of forces on the driving speed under the depth 8 cm at duskfoot share No. 3

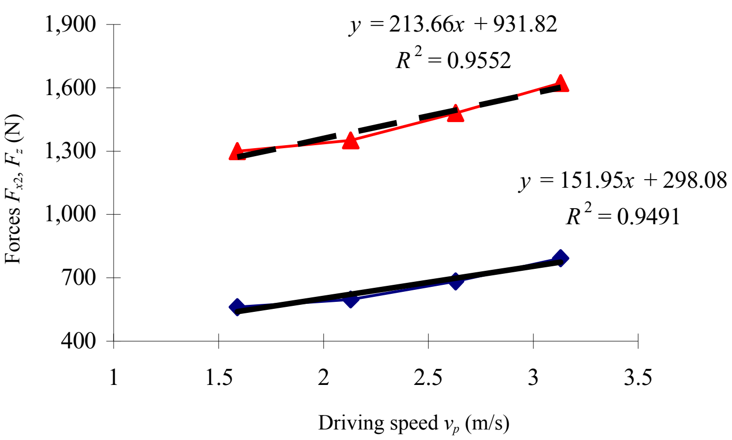


Fig. 15. Dependence of magnitude of forces on the driving speed under the depth 8 cm at duskfoot share No. 4

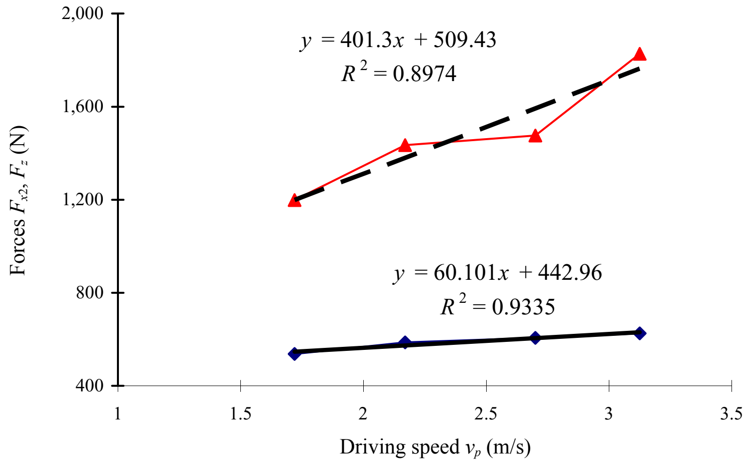


Fig. 16. Dependence of magnitude of forces on the driving speed under the depth 8 cm at duskfoot share No. 5

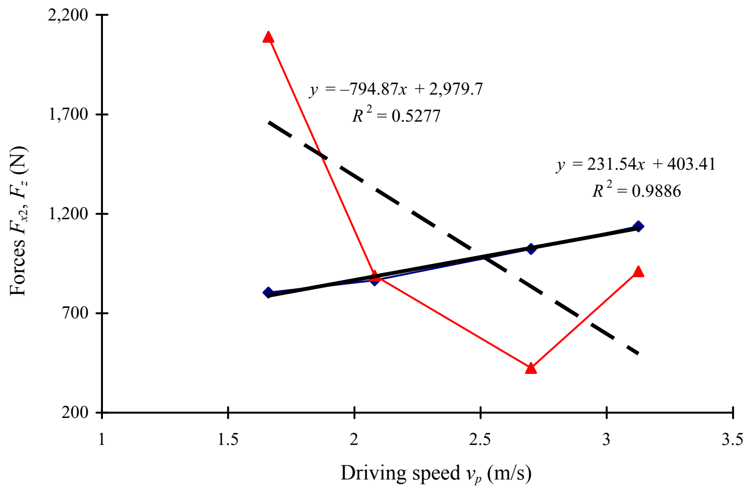


Fig. 17. Dependence of magnitude of forces on the driving speed under the depth 8 cm at duskfoot share No. 6

duckfoot shares number 1–5. We did not prove statistical significance of the measurement k_o at the duckfoot share number 6. We proved statistical significant contrast by the Saffe's test amongst the given sites. At the duckfoot share number 1 and 5 we stated statistical significant impact of the physical soil characteristics amongst the site number 1 and sites number 2 and 3 on the significant level $\alpha = 0.05$, but we did not prove the significant difference between the station number 2 and number 3.

We stated statistical difference between the site number 1 and 2 on the significant level $\alpha = 0.05$ at the duckfoot shares number 2 and 3. We did not prove significant differences between other sites.

We proved the impact of the physical soil characteristics on the resistivity of cultivator's tools at the station number 1 and 2. At the duckfoot share number 1 and 2 we demonstrated the slump of k_o by 7,204.14 N, i.e. by 24.89% at the duckfoot share number 1 and by 3,695.3 N at the duckfoot share number 2, i.e. by 12.87%, when the moisture increased. The higher the moisture the higher the resistivity k_o at other duckfoot shares.

We stated lower differences between the sites than HŮLA and MAYER did (1995). They proved the differences in the resistivity of cultivation influenced by the soil moisture in the magnitude of 114.6%. They followed the measurements in heavy soil with the resistivity k_o = 70–110 kPa. In light soil, where k_o = 16–30 kPa, such differences did not appear.

We did not prove significant differences between sites number 2 and 3.

At the duckfoot shares number 1 and 2 we established, that k_o was on the decline when the moisture was increasing. These duckfoot shares processed soil much more intensively. The higher the moisture the lower the resistivity of cultivation. The bigger the working surface of the duckfoot share the higher the increase of k_o. The rise of k_o was caused by higher soil adhesiveness of the duckfoot shares' working component.

We deducted that the changes in the resistivity of cultivation, which were affected by soil moisture, were lower than we had assumed. We are going to arrange other measurements in order to find out other physical soil characteristics that affect the resistivity of cultivation.

References

ADÁMEK P., 1999. Vybavení školních laboratoří měřicí a výpočetní technikou. In: Modernizace výuky v technicky orientovaných oborech a předmětech. Olomouc, Univerzita Palackého: 293–295.l

ADÁMEK P., 1994. The High-Speed Measuring System for the Probe Diagnostics of the Plasma. In: Proc. of Contribution Papers, Physica of Plasmas and Ionized Media. Prague, Charles University, Faculty of Mathematics and Physics: 60–65.

ANKEN T., HEUSSER J., SARTORI L., 1993. Stoppelbearbeitung, FAT-Berichte. Schweiz. Landtechn., *55*: 23–32.

FRÍD M., FROLÍK J., ADÁMEK P.,1998. Stanovení parametrů pohonných jednotek pásových dopravníků. In: Ekologické aspekty výzkumu, vývoje a provozu zahradnické techniky. Brno, MZLU, ZF, Ústav zahradnické techniky, Břeclav: 59–62.

FRÍD M., ŠABATKA J., ADÁMEK P., 1999. Měření orebního odporu pracovních orgánů pro zpracování půdy. In: Zemědělská technika na přelomu 20. a 21. století. Praha, ČZU, TF: 22–26.

FRÍD M., FROLÍK J., ADÁMEK P., BLAŽEK V., 1999. Systém pro měření energetické náročnosti strojů. In: Zemědělská technika na přelomu 20. a 21. století. Praha, ČZU, TF: 27–30.

GEBRESENBET G., JÖNSSON H., 1992. Performances of seed drill coulters in relation to speed, depht and rake angles. J. Agric. Eng. Res., *52*: 121–145.

HŮLA J., MAYER P., 1995. Faktory působící na měrný odpor pracovních orgánů radličkových kypřičů. Zeměd. Techn., *41*: 151–156.

JÄGER P., FUNK M., 1994. Gezogene Geräte arbeiten kostengünstig. DLZ, *45*: 72–81.

LINKE CH., 1993. Zugkraftbedarf von einfachen Bodenbearbeitungswerkzeugen bei hohen Arbeitgeschwindigkeit. Landtechnik, 8/9: 486–487.

WICHA A., 1957. Maschinen und Geräte für die Bodenbearbeitung. Leipzig, Fachbuchverlag: 35–45.

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Vliv pracovních podmínek na vybrané parametry šípových radliček

ABSTRAKT: V souvislosti s řešením grantu EP 7111 a výzkumného záměru MSM J06/98:122200002/I. byl založen pokus, při kterém byla v průběhu let 1999–2000 posuzována série šesti radliček. Byly zaznamenávány síly působící na pracovní nástroj a následně počítány měrné odpory kypření. Při podmítce docházelo k lineárnímu nárůstu sil se stoupajícím zahloubením. Při zvýšeném zahloubení z 8 na 10 cm došlo k nárůstu sil o 59,61 % ve vodorovném směru a o 30,84 % ve svislém směru. Při zvyšování pojezdových rychlostí z 5,92 km/h na 11,38 km/h (resp. z 1,64 m/s na 3,16 m/s) byl zaznamenán nárůst sil ve vodorovném směru o 53,11 % a ve svislém směru o 25,8 %. Na třech stanovištích byl zjištěn významný vliv vlhkosti půdy na měrný odpor radliček.

Klíčová slova: síly; měrný odpor kypření; pracovní rychlost; hloubka; vlhkost půdy

Corresponding author:

Ing. MILAN FRÍD, CSc., Jihočeská univerzita v Českých Budějovicích, Zemědělská fakulta, 370 05 České Budějovice, Česká republika
tel.: + 420 387 772 635, fax: + 420 387 772 630, e-mail: frid@zf.jcu.cz