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INVESTIGATION OF THE *DRAFT-AND-POWER*, AND AGREOTECHNICAL INDICATORS OF THE WORK OF A PLOUGHING AGGREGATE, CREATED ACCORDING TO THE SCHEME «*PUSH-PULL*»

Summary

The article expounds the research results of two ploughing machine and tractor aggregates (MTA). One of them consisted of a tractor HTZ-16131, a front-mounted double-furrow and a rear-mounted four furrow ploughs (the scheme «push-pull» «2+4»), but the other - of the same tractor and a five furrow rear-mounted plough (the scheme «0+5»). The obtained experimental data indicate that the working width of the aggregate assembled according to the scheme «2+4» was by 20.9% greater than that of the aggregate created according to the scheme «0+5». Although the operating velocity of travel of the first MTA turned out to be by 1.5% lower, its efficiency, due to a greater working width, was by 19.5% higher. Therefore the specific fuel consumption by the aggregate created according to the scheme «2+4» turned out to be by 11.5% lower. The mean root square deviation in the depth of ploughing by both the compared aggregates did not exceed the agrotechnical requirements (± 2 cm); however the use of a ploughing aggregate, created according to the scheme «push-pull» «2+4», ensures soil cultivation with more uniform plough travel by depth.
***Key words**: ploughing, aggregate, «push-pull», front-mounted plough*

BADANIA «DRAFT-AND-POWER», I AGREOTECHNICZNYCH WSKAŹNIKÓW PRACY AGREGATU UPRAWOWEGO UTWORZONEGO WEDŁUG SCHEMATU «PUSH-PULL»

Summary

Artykuł prezentuje wyniki badań agregatów ciągnikowych z dwoma maszynami uprawowymi (MTA). Jeden z nich zawierał ciągnik HTZ-16131, pług dwuskibowy zawieszony z przodu oraz pług czteroskibowy zawieszony z tyłu ciągnika (schemat «push-pull» «2+4»), a drugi – ten sam ciągnik i pług pięcioskibowy zawieszony z tyłu ciągnika (schemat «0+5»). Otrzymane wyniki badań eksperymentalnych wskazują, że szerokość robocza agregatu utworzonego według schematu «2+4» była o 20,9% większa niż agregatu utworzonego według schematu «0+5». Chociaż prędkość robocza pierwszego agregatu (MTA) okazała się o 1,5% mniejsza, jego wydajność, z powodu większej szerokości roboczej, była o 19,5% większa. Dlatego jednostkowe zużycie paliwa przez agregat utworzony według schematu «2+4» okazało się o 11,5% mniejsze. Odchylenie kwadratowe głębokości orki w obydwu porównywanych agregatach nie przekroczyło wymagań agrotechnicznych (± 2 cm); jednakże użycie agregatu uprawowego, utworzonego według schematu «push-pull» «2+4», zapewnia uprawę gleby z bardziej niezmienną głębokością orki.
***Key words**: orka, agregat, «push-pull», pług zawieszany z przodu ciągnika*

1. Introduction

One of the most important tasks of agricultural production is diminishing power losses in ploughing. The first step in the solution of this problem is raising the towing properties of the tractor by raising its adhesion weight.

Within a machine-and-tractor ploughing aggregate (MTA) this aim can be achieved using ploughs connected according to the scheme «push-pull». As the theoretical investigations indicate, owing to the vertical component of the draft resistance of the front-mounted plough there increases additional loading of the front wheels, consequently, the adhesion weight of the tractor. As a result, this leads both to a certain lessening of its towing and lower specific fuel consumption by the ploughing aggregate, on the whole [4-6].

However, if the front-end plough is not connected correctly to the source of power, there may be not additional loading but, vice versa – unloading of the front wheels and an inevitable loss of the travel control and stability of the entire ploughing MTA. In order to avoid this, it has been established by theoretical research that, using a tractor with a rated tractive force 30-32 kN, the front-mounted plough must have two bodies but the rear plough – 4 (the scheme «2+4») [7]. In this case the right-side wheels of the tractor move along the furrow, the front-end plough is connected to it in a horizontal plane, but the support (balancing) wheel of this tool is placed outside of the furrow.

The aim of this article is to expound and analyse the results of the experimental estimation of the paths, draft-and-power, as well as agrotechnical indicators of the work of the ploughing aggregate created according to the scheme «push-pull» with the number of bodies «2+4».

2. Materials and methods

The ploughing aggregate created according to the scheme «2+4» consisted of a tractor HTZ-16131, a front-mounted double-furrow and a rear-mounted four furrow plough (Fig. 1a).

A ploughing aggregate, created according to the scheme«0+5», was tested for comparison, consisting of the same tractor and a rear-mounted five furrow plough PLN-5-35 (Fig. 1b).

a)

b)

Source: own work

Fig. 1. Ploughing aggregates, created according to the schemes «2+4» (a) and «0+5» (b)

During the field tests, the following parameters were recorded: humidity and density of soil, the longitudinal-vertical profile of the field, the draft resistance and working width (B_p) of the ploughs, velocity of travel (V_p), towing of the wheels (δ), and the hourly fuel consumption by the tractors (G_h), the depth of ploughing.

The density of soil was determined according to a well-known method of hot drying. The density measurement of the agricultural background was made with the help of a special method developed by us and an appliance on its basis [3].

Table 1. Technical specifications of the ploughing aggregates

The engine capacity of the tractor HTZ-16131, kW	132
Weight, kg	8100
Track of the tractor, mm	2100
Longitudinal base of the tractor, mm	2860
Size of the tyres of the front and rear axles of the tractor	16.9R38
Working width of the front-mounted plough, m	0.70
Working width of the rear-mounted plough, m	1.40
Working width of the ploughing MTA, scheme «2+4», m	2.10
Working width of the ploughing MTA, scheme «0+5», m	1.75

Source: own work

The amplitude and frequency fluctuations of the irregularities of the field profile in a longitudinal direction were measured by means of a special profilograph.

The draft resistance of the ploughs was recorded using a tensometric sensor, designed for tractive forces up to 40 kN. The velocity of travel of the ploughing aggregate was fixed by means of a track measuring wheel, mounted on the tractor. On the hubs of its front and rear axles there were mounted the revolution counters the electric signals of which were detected with the help of current collectors.

In order to measure the hourly fuel consumption by the investigated tractor, an impulse-type fuel meter was used. The electric signals produced by the profilograph, the tensometric sensor, the track measuring wheel, the revolution counters and the fuel meter were recorded on the computer, were transmitted through the analog to digital converter (ADC).

The towing of the wheels of the tractor δ was calculated according to the formula:

$$\delta = 1 - \frac{n_{xx}}{n_p} \cdot \frac{V_p}{V_{xx}}, \tag{1}$$

where n_{xx}, n_p – the rotation frequency of the tractor wheels when the ploughing aggregate moves respectively without the tractive load and with it, s^{-1};

V_{xx}, V_p – the travel velocity of the aggregate without a load and with it, $m \cdot s^{-1}$.

The movement of the tractor aggregates without a load presupposed their movement across the field with ploughs raised in a transport position.

The efficiency of the ploughing aggregate MTA (W_a, $ha \cdot h^{-1}$), and its specific fuel consumption (G_u, $kg \cdot ha^{-1}$) were determined in the following way [1]:

$$W_a = 0.1 \odot B_p \odot V_p, \tag{2}$$

$$G_u = \frac{G_h}{W_a}. \tag{3}$$

The repeatability of the conducted measurements of all the parameters was not less than 5.

The laboratory-field testings were carried out on the field the soil humidity of which was 16.5%, and density − 1.26 $g \cdot cm^{-3}$.

3. Results and discussion

Fluctuations of the field profile were high-frequency ones, as the length of the correlational link of the ordinates of the particular process shows, which does not exceed 0.3 m (Fig. 2). More than that, it follows from the estimate of the normalised autocorrelation function that the fluctuations of the amplitude of the longitudinal profile of the field contained a hidden periodic component with a period, approximately equal to 0.75 m.

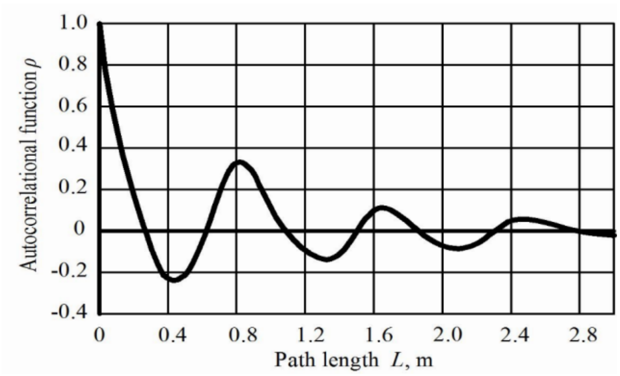

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Fig. 2. A normalised autocorrelation function (ρ) of the fluctuations of the field profile as a function of the track (path length) L

Dispersion of the fluctuations was also as low (1.21 cm^2), and it was concentrated within a frequency range 0…12 m^{-1}. At the travel velocity of the ploughing aggregate 1.98 $m \cdot s^{-1}$ it constitutes 0-24 s^{-1}, or 0-4 Hz.

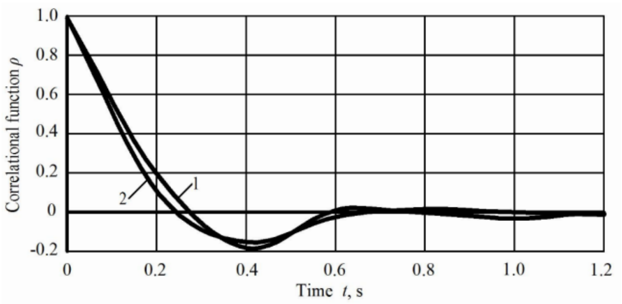
One can draw a conclusion from the above correlational spectral analysis that the relatively high frequency and the low fluctuation dispersion of the irregularities of the longitudinal-vertical profile of the field cannot be generators of more or less essential fluctuations in the draft resistance of the front- and rear-mounted ploughs aggregated with the tractor HTZ-16131. The basic changes in this parameter (i.e. the draft resistance) will be provoked and, as a rule, they are provoked by the internal structure of the soil environment acted upon by the operating elements of the ploughing tools.

The ploughs of the machine-and-tractor aggregates created according to the schemes «0+5» and «2+4» were designed for the same ploughing depth – 25 cm.

The draft resistance of the plough in the aggregate, created according to the scheme «0+5», varied within the limits 26.6 – 28.4 kN. The mean root square deviation of this parameter was ± 4.0 – 4.8 kN. As a result, the coefficient of variations in the draft resistance varied within the limits 14.0 – 18.0%, which points to average variability of the present process [6].

In contrast to the ploughing aggregate PLN-5-35, the summary draft resistance of the front-mounted and the rear-mounted ploughs of the aggregate, composed according to the scheme «2+4», at the same value of the mean root square deviation (± 5 kN) constituted 31.5 − 34.7 kN, the time of the correlational link for the given processes varying within the limits 0.24 − 0.26 s (Fig. 3).

It follows from the analysis of the practice of using similar aggregates that such a length of the correlational link (in time) characterises the process as a high-frequency one [2]. A real proof for this is the dispersion spectrum of the fluctuations in the draft resistance of the ploughs. For the investigated machine-and-tractor aggregates it is concentrated within a range of frequencies 0 − 25 s^{-1}, or 0-4 Hz.



Source: own work

Fig. 3. Normalised correlational functions of fluctuations of the draft resistance of ploughs of the ploughing aggregates created according to the scheme «0+5» (curve 1) and «2+4» (curve 2)

The results of the measurements show that the actual working width of the machine-and-tractor aggregate created according the scheme «push-pull» (i.e. «2+4») was by 20.9% greater than that of the machine-and-tractor aggregate created according the scheme «0+5». As regards the working velocity of travel, for the MTA with one five furrow plough this velocity was greater by 1.5% due to a smaller working width, consequently, a smaller draft resistance of the aggregated tool (Table 2).

As a result, it turned out that labour productivity per hour of the aggregate, created according to the scheme «2+4», was by 19.5% higher than that of the machine-and-tractor aggregate with one rear-mounted five furrow plough.

As the draft resistance of the ploughs of the ploughing MTA, created according to the scheme «2+4», was greater than that of the aggregate composed according to the scheme «0+5», it, naturally, had greater towing of the tractor wheels (Table 2). In absolute measurements, − by 0.6%, but in relative measurements − by 4.3%.

Meanwhile, at the expense of greater labour productivity, the specific fuel consumption by the aggregate, created according to the scheme «push-pull», was by 11.5% lower. This economy, in our view, takes place due to more efficient application of the tractive properties of the front axle of the tractor. Their improvement occurs owing to a front-mounted tool, correct aggregation of which ensures extra loading of the frontal propulsion devices of the source of power.

One of the basic agrotechnical indicators of the work of the ploughing MTA is uniformity of the ploughing depth. According to the experimental data, the mean root square deviation of this parameter for both the compared aggregates did not exceed the agrotechnical requirements (± 2 cm), and they were separately: for the MTA (scheme «0 + 5») – ± 1.98 cm, and for the aggregate assembled according to the scheme «2+4» – ±1.52 cm.

It follows from the results of the dispersion analysis that, on the statistical level of significance, the 0.05 difference between these mean root square deviations is not random since, in compliance with the Fisher's F-criterion, the null hypothesis about the equality of the compared statistical estimates does not deviate [2].

In other words, with confidence probability 95% one can confirm that the aggregate created according to the scheme «2+4» carries out soil ploughing with a higher stability in depth control. One of the reasons for such a result may be the circumstance that the front axle of the tractor HTZ-16131without a front-mounted plough performs less vertical oscillations while moving along the furrow. As a result, just this is the positive effect on the smooth travel of both the front-mounted and the rear-mounted ploughs.

It should be underlined that the normalised correlational functions and spectral densities of fluctuations in the ploughing depth for the compared machine-and-tractor aggregates differ little from each other (Fig. 4). For both the variants of the MTA the length of the correlational link is less than 21 m.

By the way, the depth fluctuations themselves do not contain any hidden periodic component. Such a result can be explained by the fact that the agricultural background before ploughing was levelled out by means of a dick harrow. A proof of this is the small dispersion of fluctuations in the field irregularities, which was only 1.24 cm^2.

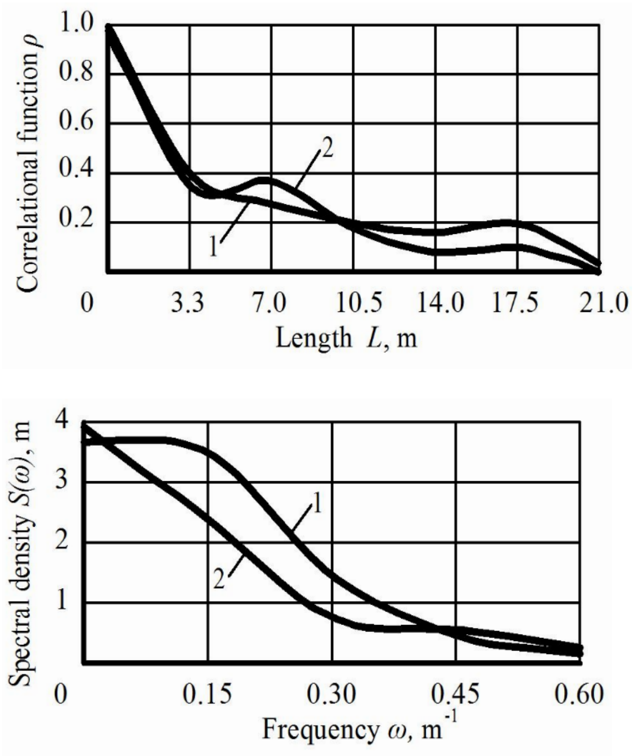
More than that, during the working movement of the tractor wheel there takes place certain towing. And, since this process is accompanied by cutting of the soil by the grousers of the propulsion devices, there occurs additional levelling of the path of the source of power. In addition to it, the amplitude of its vertical oscillations diminishes, which ensures diminishing of the vertical oscillations of the ploughs aggregated with the tractor. The final consequence of this is increased stability of the ploughing depth of the aggregate composed according to the scheme «push-pull».

Table 2. Results of experimental investigations of the ploughing MTA on the basis of the tractor HTZ-160

Scheme MTA	V_p[1), $m \cdot s^{-1}$	B_p[2), m	W_a[3), $ha \cdot h^{-1}$	h[4), cm	δ[5), %	$P_{кр}$[6), kN	G_h[7), $kg \cdot h^{-1}$	G_u[8), $kg \cdot ha^{-1}$
«0+5»	2.01	1.77	1.28	24.9±0.3	13.8	27.4	21.2	16.5
«2+4»	1.98	2.14	1.53	25.1±0.1	14.4	33.1	22.3	14.6

Source: own work

1) – the working velocity of travel;
2) – the working width;
3) – labour productivity of the aggregate in 1 hour;
4) – the depth of ploughing;
5) – towing of the tractor wheels;
6) – the draft resistance of the plough;
7) – the hourly consumption of fuel;
8) – the specific consumption of fuel by the aggregate.



Source: own work

Fig. 4. Normalised correlational functions (ρ) and spectral densities [S(ω)] of the fluctuations in the ploughing depth for the aggregates created according to the scheme «0+5» (curves 1) and «2+4» (curves 2)

4. Conclusions

Advantages of the frontal aggregation of agricultural tools with a tractor allow creating highly efficient machine-and-tractor aggregates on its basis according to the scheme «push-pull».

In contrast to a MTA, consisting of a tractor HTZ-16131 and a rear-mounted five furrow ploughing tool («0+5»), the ploughing aggregate of such a scheme, consisting of a tractor HTZ-16131, a double-furrow front-mounted and a four furrow rear mounted ploughs («2+4»), has greater (by 19.5%) labour productivity and lesser (by 11.5%) specific fuel consumption.

The use of a ploughing aggregate created according to the scheme «2+4» allows soil cultivation with a higher travel stability of the ploughs in depth.

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