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OPEN

Arch. Min. Sci., Vol. 60 (2015), No 1, p. 143–156

Electronic version (in color) of this paper is available: http://mining.archives.pl

DOI 10.1515/amsc-2015-0010

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INFLUENCE OF THE PLOW FILLING AND THREAD ANGLE ONTO THE PLOW HEAD EFFICIENCY

WPŁYW WSPÓŁCZYNNIKA WYPEŁNIENIA ORGANU ORAZ KĄTA NAWINIĘCIA PŁATA ŚLIMAKA NA SPRAWNOŚĆ ŁADOWANIA FREZUJĄCYMI ORGANAMI ŚLIMAKOWYMI

Laboratory examinations on the plow heads at various filling rate and material grain-size, as well as various values of worm thread angle of the plow head have been executed. Influence of the worm thread angle and plow head filling onto optimal loading efficiency, has also been tested.

Keywords: plow heads, longwall shearer, laboratory examinations

Eksploatacja węgla kamiennego w Polsce odbywa się przy zastosowaniu kompleksów ścianowych kombajnowych jak również kompleksów strugowych. Ten drugi z kompleksów jest znacznie mniej rozpowszechniony w Polsce i stosowany do pokładów o miąższości poniżej 1,5 m. Do głównych maszyn i urządzeń ścianowego kompleksu kombajnowego należy zaliczyć maszynę urabiająco – ładującą jaką jest kombajn ścianowy, obudowę zmechanizowaną oraz przenośnik ścianowy. Elementami roboczymi w kombajnie ścianowym są frezujące organy ślimakowe, które mocowane są na ramionach kombajnu. Zadaniem frezujących organów ślimakowych jest realizacja jednocześnie dwóch procesów. Pierwszym z procesów jest frezowanie czyli oddzielanie kawałków węgla od calizny. Drugi proces to proces ładowania urobku, polegający na ciągłym odprowadzaniu urobku na przenośnik ścianowy. Równoległość realizacji pracy tych dwóch procesów, uniemożliwia w warunkach rzeczywistych przeprowadzenie obserwacji procesu ładowania i dokonania jakichkolwiek pomiarów i analiz.

Dlatego też, przeprowadzane badania i pomiary opisywane w literaturze zwykle miały charakter modelowy lub stanowiskowy, gdyż tylko takie warunki umożliwiały rozdział tych funkcji organu (Chodura, 1992; Hyong Jong Gol, 1990; Jaszczuk & Tomaszewski, 2004; Krauze, 1997). W związku z powyższym, chcąc bliżej poznać prawa rządzące procesem ładowania, zdecydowano się na rozdzielenie tych dwóch procesów i przeprowadzenie badań laboratoryjnych. Przedmiotowe badania zostały przeprowadzone w laboratorium Katedry Maszyn Górniczych, Przeróbczych i Transportowych AGH. W badaniach uwzględniono wpływ jednego z parametrów konstrukcyjnych organu, a mianowicie kąta nawinięcia płata ślimaka α_2 na sprawność ładownia, a także jaki wpływ ma współczynnik wypełnienia organu k_w i współczynnik rozluzowania urobku k_r na sprawność ładowania (Wydro, 2011).

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Po przeprowadzonych badaniach wstępnych przyjęto, że kryteria oceny procesu ładowania będą różne dla organu wyposażonego w ładowarkę kryterium oceny procesu ładowania będzie pobór mocy silnika organu i posuwu, natomiast dla organu bez ładowarki kryterium jego oceny będzie sprawność ładowania.

Za sprawność ładowania uznano stosunek pola przekroju pryzmy urobku załadowanego do pola przekroju całkowitego pryzmy urobku przemieszczonego, co szerzej zostało opisane w dalszej części artykułu (Wydro, 2011).

Przedmiotowe badania miały na celu, sprawdzenie w jakim stopniu wybrany parametr konstrukcyjny, kąt nawinięcia płatów ślimaka α_2 oraz współczynnik wypełnienia organu k_w i współczynnik rozluzowania k_r urobku mają wpływ na sprawność ładowania i przy jakich ich wartościach organy ślimakowe uzyskują największą sprawność ładowania. Wartości i zakresy tych współczynników, zostały określone na podstawie badań empirycznych. Jak podaje literatura (Hamala & Wydro, 2005; Krauze, 1997) współczynniki przyjmowane są w granicach $k_w = 0 \div 1$, $k_r > 1$ na podstawie doświadczenia konstruktora dla nowo projektowanych organów ślimakowych.

Parametr konstrukcyjny, który został przyjęty do badań, to kąt nawinięcia płatów ślimaka α_2 i według literatury (Bednarz, 2003; Krauze, 2000) przyjmuje optymalną wartość w zakresie 19°, a 23°. W związku z powyższym, w przedmiotowych badaniach chciano sprawdzić jaki wpływ na proces ładowania mają kąty poniżej i powyżej wspomnianego zakresu, a także sprawdzenia, czy można określić jakie wartości współczynników k_w i k_r należy przyjmować podczas określania parametrów konstrukcyjnych i kinematycznych nowego organu nie opierając się tylko na doświadczeniu projektanta. Do badań, został przyjęty model analityczny procesu ładowania frezującymi organami ślimakowymi, który został opisany już wcześniej w literaturze (Krauze, 1994, 2000; Hamala & Wydro, 2005).

Zgodnie z przyjętym celem pracy, określono również założenia i wytyczne do badania procesu ładowania frezującym organem ślimakowym (Wydro, 2011), mianowicie:

- konieczność rozdzielenia procesu skrawania (frezowania) od procesu ładowania,
- rozdzielenie powyższych procesów może nastąpić tylko w warunkach laboratoryjnych,
- badaniom zostaną poddane zarówno organy bez ładowarek jak i z ładowarkami,
- do badań zostaną użyte organy o różnym kącie nawinięcia płata ślimaka,
- do badań zostanie użyty urobek o różnym współczynniku k_r.

Mając na uwadze powyższe wytyczne i założenia, przeprowadzono badania procesu ładowania frezującymi organami ślimakowymi bez ładowarek i z ładowarkami. Badania zostały przeprowadzone, na specjalnie do tego celu przygotowanym stanowisku badawczym, na którym możliwy był pomiar oporów i sprawności procesu ładowania. Urobek wykorzystany do badań, został odpowiednio dobrany pod względem własności i klasy ziarnistości do rzeczywistych parametrów zastosowanych organów. Do badań wykorzystano specjalnie zaprojektowane ślimakowe organy urabiające, o określonych kątach nawinięcia płata ślimaka. Kąty te, zawierały się w przedziale pomiędzy 15°, a 26°. Specjalnie zaprojektowany układ pomiarowy pozwolił określić pobór mocy i wielkości niezbędne do obliczenia sprawności ładowania. Zaproponowana metodyka i plan badań pozwoliły uwzględnić zakres współczynników k_w i k_r mających wpływ na proces ładowania.

Parametrami mierzonymi podczas badań były:

- pobór mocy N_l mierzony na silniku organu ładującego w funkcji
- sprawność ładowania η_l,
- pobór mocy oporów posuwu N_p mierzony na silniku posuwu w funkcji sprawność ładowania η_l.

Uzyskane wyniki i ich analiza pozwoliły stwierdzić, że badane organy wykazywały bardzo zróżnicowane sprawności ładowania, w zależności od zmiennych parametrów ruchowych, czyli prędkości posuwu v_p i obrotów n, a także przy różnym kącie nawinięcia płata ślimaka.

Również istotnym wnioskiem z badań, który może w praktyce zostać wykorzystany, jest fakt, że dla stałych obrotów organu n i zwiększanej prędkości posuwu v_p spadała sprawność ładowania η_l (dla pracy organu bez ładowarki). Fakt ten jest ważny, ponieważ w warunkach dołowych w trakcie eksploatacji kombajnu ścianowego istnieje tylko możliwość regulacji jego prędkości posuwu.

Istotnym dla wykorzystania w praktyce, może być również fakt, iż przy pracy organu z ładowarką występuje wzrost poboru mocy organu przy wzroście współczynnika wypełnienia k_w. Jest to istotne z punktu widzenia ekonomi eksploatacji i dążenia do minimalnego zużycia energii.

Zrealizowane badania laboratoryjne sprawności procesu ładowania, pozwoliły uzyskać szeroki zakres wyników, które mogą pomóc przy doborze parametrów ruchowych kombajnu ścianowego w trakcie jego eksploatacji, a nawet wcześniej, na etapie projektowania organów ślimakowych (Wydro, 2011).

Słowa kluczowe: organy urabiające, kombajn ścianowy, badania laboratoryjne

1. Introduction

Worm-type plow heads are the main mining elements of longwall shearers. Their role is simultaneous realization of two processes, i.e. plowing the rock body and loading of the separated material onto longwall conveyor. The mentioned two processes are not separable in natural conditions and existing models of the material loading describe this process only through theoretical relations between constructional parameters of the plow head and operational parameters of the shearer. High cost of underground examinations as well as exploitation and machine operations limitations does not allow to determine suitable assessment criteria of the processin question in natural conditions, and just few examinations executed on models of worm-type plow heads are also insufficient to solve all aspect of the examined problems. Limited knowledge of the phenomena occurring during loading process in particular referes to worm-type plow head selection with respect to geological mining conditions of the exploited longwall. Thus we should take under consideration not only dominant plowing process but also parallel loading process. It is accompanied by number of processes because efficiency of both mentioned processes depends on inverse parameters of the longwall shearer. That is why laboratory examinations of the loading process with use of worm-type plow heads is reasonable. That allowed better recognition of phenomena and parameters responsible for the process in question. Examinations of the loading process with use of worm-type plow head have been executed in laboratory of Katedry Maszyn Górniczych, Przeróbczych i Transportowych. Test stand examinations were chosen because separation of two parallel processes, i.e. plowing and loading, was possible only in laboratory conditions (Wydro, 2011).

2. Purpose and assumptions of the laboratory examinations

Executed examinations were aimed at determination how ration of the material loose coefficient k_r and plow head filling k_w influence loading efficiency η, both in case of plow head without and with loader. Moreover, the problem how the mentioned ratios influence the loading of the plow head with and without loader. Role of the worm thread angle α_2 has also been tested.

In the designing phase such coefficients as k_r and k_w are selected on the basis of the designer's knowledge and experience ($k_w = 0 \div 1$, $k_r > 1$), and their values and range have been determined on the basis of empirical experiments.

Analytic model has been chosen which assumes that internal volume of the plow head must be bigger than the volume of the material produced during plowing, what was previously described in the literature (Krauze, 2000; Krauze et al., 2009).

According to the assumed target, the following assumptions and testing procedures of the loading process with use of worm-type plow head have been determined:

- Necessity of the separation of plowing and loading functions, which in natural conditions are realized in parallel,
- Assumption mentioned above can be satisfied only for conditions of laboratory examinations.

3. Research plan and testing procedure

Relation describing influence of coefficients k_w and k_r onto loading process was examined. This means that internal volume of plow head V_o is bigger than volume of plowed material V_u for one or two plow heads. These relations have been described in literature (Krauze, 2000) for operations of plow heads with and without loaders. In these inequalities (described by Krauze, 2000) occur such parameters as plow volume of frontal and rear plow head, what can be described with following relations:

Volume of material plowed by frontal plow head:

$$V_{up} = V_u \frac{D_s z v_p k_r k_L}{n} \tag{1}$$

and volume of material plowed by rear plow head:

$$V_{ut} = \frac{\left(H - D_s\right) z v_p k_r k_L}{n} \tag{2}$$

where:

V_u — plow head efficiency,
D_s — plow head diameter,
H — height of plowed longwall,
Z — plowing depth,
k_r — material loose ratio,
k_L — factor determining volume of loaded material without head participation.
k_w — plow head filling ratio.

Thus according to the assumption mentioned above only frontal plow head was taken into consideration because it plows the material on its whole diameter. I was assumed that factor k_L is equal to 1, because it has been assumed that whole material will be loaded by worm-type plow head. Thus:

$$k_w \geq \frac{D_s \cdot z}{v_o} \cdot \frac{v_p}{n} \cdot k_r \tag{3}$$

where:

$\frac{D_s \cdot z}{v_o}$ — plow head construction parameters,
$\frac{v_p}{n}$ — kinematic parameters.

It results from the formula (3) that according to required conditions one can determine (select) plow head structural parameters, however without cutting pick system. Thus production of the material of suitable grain-size and suitable material loose ratio k_r was needed in this case. In such conditions of determined ratio and constant structural parameters, plow head worm thread angle k_r, plow head filling ratio k_w can be controlled (regulated) via suitable change of advance speed v_p or plow head rotational speed n.

Thus material loose ratio k_r was constant during loading process. The radio k_r was determined by suitably prepared material (winning), and it was calculated according to standard procedure (PN-EN 1097-6 and PN-EN 1097-3:2000). The plow head filling coefficient k_w was the second constant parameter. This coefficient was controlled via regulation of advance speed v_p and plow head rotational speed n. Lift angle of plow worm-type screw α_2 was the third constant parameter (Table 1).

TABLE 1

Structural parameters of plow heads used in examinations

No.	**Plowing depth without cutting disc Z_U [m]**	**Plow head drum diameter D [m]**	**Plow head hub diameter d [m]**	**Worm thread thickness b [m]**	**Number of threads i**	**Worm thread angle α_2 [°]**	**Plow head internal volume V_o [m^3]**
1	0,133	0.334	0.2	0.012	4	15,35	0,00618
2	0.133	0.334	0.2	0.012	4	18,29	0,00639
3	0.133	0.334	0.2	0.012	4	19,81	0,00647
4	0.133	0.334	0.2	0.012	4	24,66	0,00666
5	0.133	0.334	0.2	0.012	4	26,20	0,00670

During the examinations, suitable selection of the rotational speed n, and advance speed v_p, allowed controlling the plow head filling ratio, i.e. determination of the value of the coefficient k_w. Range of the rotation speed n and advance speed v_p has been determined on the basis of real structural and kinetic parameters of worm-type plow heads used in the examinations. Values of these parameters are gathered in tables prepared for each plow head (ex ample – Table 2). Relation (3) was used for the table making. Each table comprise values of plow head filling coefficient k_w, depending on advance speed v_p and plow head rotation n for various coefficients of the material loose k_r. Such tables allow easy and fast selection of the advance speed and the plow head rotation speed in order to obtain required plow head filling coefficient.

The examinations were conducted on the basis of parameters marked in Table 2, and analysis of these results allowed assessment of the influence of coefficients k_w and k_r onto loading efficiency expressed in function of the plow head rotational speed and advance speed.

Examinations of the loading process comprised testing of five plow heads having different worm thread angle. Influence of coefficients k_w and k_r onto load of the plow head for operations with and without loader. Moreover, influence of worm thread angle onto quality of loading process has also been determined.

When all parameters needed for the examinations were completed, a research plan has been developed.

It was decided that the examinations will comprise two stages. The first stage comprised checking if the testing stand and measuring system operational property, including setting of the number of experiments, which should be repeated. The second stage comprised execution of the experiments.

It was assumed that the experiments will be conducted according to the same procedure for plow heads both with and without loaders.

TABLE 2

Values of the plow head filling coefficient k_w and coefficient of material lose k_r for plow head with worm tread angle amounting for 15°33', (plow head no. 1)

Lp.	**Material loose coefficient k_r (grain-size)**	**Rotation [r.p.m.]**	**Filling coefficient k_w**							
			Advance Speer v_p [m/min]							
1	1,55 (0÷10 mm)	40	0,27	0,55	0,83	1,11	1,39	1,67	1,94	2,22
2		80	0,13	0,27	0,41	0,55	0,69	0,83	0,97	1,11
3		120	0,09	0,18	0,27	0,37	0,46	0,55	0,65	0,74
4	1,8 (10÷25 mm)	40	0,32	0,64	0,97	1,29	1,61	1,9	2,26	2,58
5		80	0,16	0,32	0,48	0,64	0,80	0,97	1,13	1,29
6		120	0,10	0,21	0,32	0,43	0,53	0,64	0,75	0,86
7	1,8 (20÷45 mm)	40	0,32	0,64	0,97	1,29	1,61	1,94	2,26	2,58
8		80	0,16	0,32	0,48	0,64	0,80	0,97	1,13	1,29
9		120	0,10	0,21	0,32	0,43	0,53	0,64	0,75	0,86

The first step comprised preparation of the material needed for the experiments. Hard coal was used as the experimental material because in natural conditions such type of winning is loaded by worm-type plow heads. Coal for experiments has been suitably selected with respect of its properties and grain-size.

The material was prepared by the Rock and Stoneware Testing and Research Laboratory of the AGH University of Mining and Metallurgy In Krakow – Poland. Winning preparation comprised separation of three material fractions, as well as determination of their tap density in loose state. It was made on the basis of bulk density of coal grains (lumps), as well as tap density of different coal fractions. On this basis material (winning) loose coefficient k_r was determined. The material bulk volume was determined according to Polish standard PN-EN 1097-6, whereas tap density was calculated according to Polish standard PN-EN 1097-3:2000. Geometrical parameters of tested plow heads has also been taken into consideration in calculations of the coefficient k_r. Results of examinations completed by the Rock and Stoneware Testing and Research Laboratory allowed selection of three material fractions of given grain-size, which were characterized with the following loose coefficients:

k_r =1,55 0÷10 mm and k_r = 1,8 two fractions of the grain-size 10÷25 mm and 20÷45 mm. These values of the loose coefficient k_r, will be used for determination of the influence of this coefficient onto the loading process.

4. Testing stand and measuring system used in the laboratory examinations of the loading process with use of worm-type plow heads

Laboratory examinations of the loading process with use of worm-type plow heads have been conducted in suitably designed testing stand. This testing stand shown in Fig. 1 and 2 is described below and it consists of the following elements:

- Stationary frame with basal elements of the testing stand: slidable frame, plow head arm, plow head body and curtain loader.

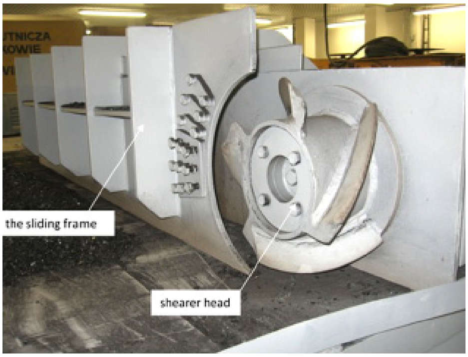

Fig. 1. Testing stand for loading process examinations (view from loading head side)

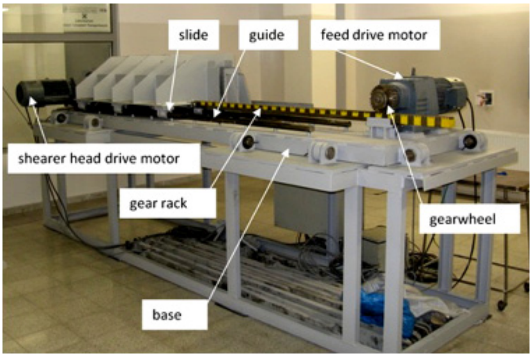

Fig. 2. Testing stand – view from the side of advance system motor and toothed strip

- Shearer advance driving system comprises: toothed gear wheel with strip, which allow frame sliding along guides, what results in the shearer movement. Advance system driving motor (three-phase motor 4,0 kW, voltage 400V) allows regulation (controlling) of the linear speed within the range from 0 to 10 m/min.
- Two guides allowing frame sliding along a distance of 1200 mm.
- Arm being one of the obstacles during material loading. Change of the arm position with respect to plow head surface is possible.
- Plow head driving motor (Tyree-phase motor of voltage 5,5 kW). Allows rotation direction changing and control of the plow head rotational speed.
- Curtain loader pulled by the moving frame aiding the material loading (Fig. 3).

Construction of the movable frame allows formation of material prism between frame shields.

Fig. 3. Plow head equipped with curtain loader

Testing stand was also equipped with a control system allowing regulation of basal kinematic parameters (Fig. 4):

- Plow head advance speed,
- Linear speed of the frame (advance speed),
- Direction of the plow haed rotation.

Measuring system mounted on the testing stand allows measurement of the following parameters:

- Plow head rotational speed,
- Motor power consumption – motor responsible for the plow head drive,
- Rotational speed of the advance motor (the rotations can be re-calculated onto advance system linear speed thanks to known number of teeth of the driving wheel and toothed strip,
- Power consumption of motor responsible for advance driving system.
- In order to make suitable measurements the special measuring system was developed, which consists of the following elements:
  - encoders (pulse meters),
  - inverters (frequency inverters),
  - active power transducers,
  - current transformers,
  - docking station with measuring card,
  - measuring computer with softeware ESAM – 3000.

Fig. 4. Testing stand measuring system, control system cabinet at the left side and measurement computer with docking station at the right side

5. Realization of the examinations

The examinations were conducted according to previously developed plan and testing procedure. Five worm-type plowing heads having various worm thread angle α_2 have been used In examinations.

The first step comprised preliminary examinations. This examinations were aimed at check out if the measuring system is operated properly, if the assumptions are satisfied, including determination of needed number of repeated measurements.

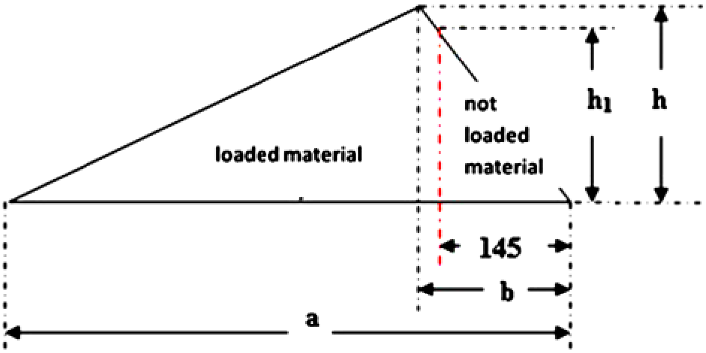

Fig. 5. Scheme of the winding prism

No increase of power consumption was proved during plow head operations without loader, whereas such increase was visible during operation of the plow head with curtain loader. However it was noted that in case of operation of the plow head without loader that increase of the value of coefficient k_w was accompanied by change and location of the material prism (Figs 6 and 7), what was not visible in case of the operation of plow head with loader (Fig. 8).

Thus it was assumed that criteria of the loading process will be diversified. In case of plow head equipped with loader, power consumption of the motor plow head and advance system, whereas in case of the plow head without loader loading efficiency will be considered as the criterion in question.

Ratio of prism cross-section area of loaded material and total area of dislocated material prism was considered as loading efficiency. Cross-sections are triangle-shaped, as seen in Figs 6 and 7.

Fig. 6. Winning prism – operation without loader and $k_w = 0,29$

Fig. 7. Winning prism – operation without loader and $k_w = 0,58$

Thus it was assumed that prism cross-section will be illustrated by a triangle (Fig. 5), for which values a, b, h will be measured, what allows calculation of loading process efficiency for

Fig. 8. Winning prism – operation with loader

given measurement. Dimension in Fig. 5 amounting for 145 mm result from plowing depth (web) and the dimension is considered as limit between loaded and not loaded winning (Wydro, 2011).

Next step of preliminary examinations comprised calculation of the minimal number of repeated measurements, which should be executed during fundamental examinations.

Thus three measurements have been made for plow head with angle $\alpha_2 = 15{,}3°$, grain-size 0÷10 mm ($k_r = 1{,}55$) and rotational speed = 120 r.p.m. and advance Speer $v_p = 6$ m/min.

The results have been statistically processed according to Stein's method (Krysicki et al., 1999) and it was assumed that 2 measurements are quite sufficient.

After completion preliminary examinations the fundamental examinations have been started. The fundamental examinations have been completed for plow head operations both without and with loader.

Examinations of the operations of plow head without loader was conducted according to assumed plan and testing procedure. The testing procedure was as follow:

- Winding of determined grain-size corresponding to coefficient k_r, was dosed in chosen section if the mobile frame
- Suitable kinematic parameters (advance speed v_p, and plow head rotational speed n according to tables – see example of Table 2 – were set,
- then plow head rotation and advance movement were switched ON,
- after a distance of 1200 mm the plow head arm was stopped, and then volume of loaded winding was measured according to Fig. 5 (prism geometry measurement). When the mentioned activities were completed the testing procedure was repeated for various values of parameters from tables (advance speed v_p, plow head rotational speed n see ex ample of Table 2).

Examinations of the plow head with curtain loader were conducted according to the same procedure with one exception that winding prism was not measured and only power consumption of plow head and advance system were measured. It resulted from the fact that the winning prism was the same – independently on change of the parameters (v_p, n).

6. Testing results (Wydro, 2011)

Results of conducted examinations have been processed on the basis of statistical analysis, according to Stein's method (Krysicki et al., 1999). Values of individual parameters registered during measurements for the plow head without loader have been gathered in Tables. Tables were made for each tested plow head and all grain-sizes, see example Table 3.

Length of the triangle base (illustrating the prism cross-section) amounting for 145 mm results from the plow head web allowing calculation of the triangle height imaging not loaded winning h_1 (Fig. 5). This high is needed for calculation of area of the loaded winning prism P_z.

TABLE 3

Testing results for plow head 1 without loader for k_r = 1,55

v_p [m/min]	n [r.p.m.]	k_w	a [mm]	b [mm]	h [mm]	h_1 [mm]	P_z [cm^2]	P_c [cm^2]	η_l [%]
2	40	0,557	370	235	143	113,08	183,09	265,07	70,31
2	80	0,278	372	237	149	115,18	194,15	277,66	74,56
2	120	0,186	373	230	141	106,98	185,95	263,51	71,41
4	40	1,114	380	243	140	111,88	184,68	265,79	70,92
4	80	0,557	386	228	133	96,08	187,26	256,9	71,91
4	120	0,371	375	225	130	98,39	171,86	243,19	66,00
6	40	1,670	358	239	235	126,06	174,02	265,41	66,83
6	80	0,835	370	228	136	105,38	174,84	251,24	67,14
6	120	0,557	382	228	133	98,14	183,64	254,79	70,31
P_c mean [cm^2]								260,39	

Differences in values of the winning prism cross-section area P_c for individual measurements resulted from inaccuracy resulted from the winning prism linear measurements (geometrical).

Loading efficiency η_l is calculated from the following relation:

$$\eta_l = \frac{P_z}{P_{c\ average}} \cdot 100\% \tag{4}$$

Measurement of the power consumption of the motor driving the plow head N_o and the motor driving the advance system N_p in case of plow head working with curtain loader has been made in the second part of fundamental examinations. These measurements allowed making courses of the power consumption signals of plow head and advance system motor. Than the diagrams of given measurement series were statistically processed what allowed making tables, in which minimal, maximal and mean values were mentioned. Mean values were mentioned in tabular form – for ex ample see Table 1. In further analysis, mean values of the motor power consumptions were used and gathered in tables, see example Table 4. Each table refers to other plow head and various winning loose coefficients k_r.

On the basis of the loading process examinations conducted with use of plow heads without curtain loader, loading efficiency for various kinematic parameters (v_p and n) and various worm thread angles α_2 it, have been determined

It was proved that in case of material loose coefficient amounting for k_r = 1,55 and grain-size 0 mm ÷ 10 mm the highest loading capacity was obtained for plow heads having lowest worm thread angle α_2, independently on kinematic parameters such as advance speed v_p and head rotational speed n. No essential influence of the filling coefficient k_w onto loading process was observed.

Other situation was observed for coefficient k_r = 1,8 and grain-size from 10 mm to 25 mm. In this case it was observed that loading efficiency is influenced by kinematic parameters (head rotational speed n) and geometric parameters as well (head worm thread angle α_2). At constant advance velocities v_p = 2, 4, 6 m/min the maximal loading efficiency was obtained for maximal rotational speed of plow head n = 120 r.p.m., independently on the value of the plow head filling coeffocient k_w.

TABLE 4

Measurement results for plow head 1, material loose coefficient k_r = 1,55,Grain size 0÷10 mm

k_r	v_p [m/min]	n [rpm]	k_w	N_p [kW]	N_o [kW]
1,55	2	40	0,55	0,28	0,22
	2	80	0,27	0,31	0,32
	2	120	0,18	0,28	0,29
	4	40	1,11	0,30	0,19
	4	80	0,55	0,29	0,22
	4	120	0,37	0,33	0,28
	6	40	1,67	0,45	0,28
	6	80	0,83	0,38	0,21
	6	120	0,55	0,39	0,22

In this case the best loading efficiency was obtained for plow heads having the lowest value of worm tread angle α_2.

Another situation was observed in result of comparing plow heads were working with material loose coefficient k_r = 1,8 and grain-size from 20 mm to 45 mm. In this case the better performance was obtained for plow heads having big values of the worm thread angle α_2. In this case the best efficiency was obtained for plow heads operated with the highest rotational speed (120 r.p.m.) independently on the advance speed v_p, and head filling coefficient k_w (0,2 to 0,6).

On the basis of results of executed loading efficiency examinations we may conclude that the loading efficiency increased with growing grain-size of loaded material. Thus we can assume that taking under consideration the output of coarser material with respect to loading process, plow heads having greater worm thread angle α_2 of the value close to 26° should be used.

Information important for the analysis of testing results related with plow heads with curtain loader have been obtained already in the preliminary examination phase. It was observed that in case of the operation of the plow head without the loader, change of the value of coefficients k_w and k_r is not accompanied by power consumption changes of any motor. However, change of shape and location of the winning prism was observed, what proves influence of coefficients k_w and k_r

onto volume of not loaded material. During preliminary examinations, influence of coefficients k_w and k_r onto motor power consumption was also observed in case of operation of the plow heads with curtain loader. Changes of shape and location of the winning prism depended on the value of plow head filling coefficient k_w, including loose coefficient k_r, have not been observed. The fundamental examinations confirmed information obtained during preliminary experiments.

Graphical comparison of the data obtained in fundamental examinations has been made, and the power consumption of both advance and plow head rotation motor was discussed. The comparisons comprise operation of plow head in conditions of different values of kinematic parameters (v_p and n), geometrical parameters (α_2) and different values of coefficients k_w and k_r. Analysis of the prepared diagrams showing power consumption of plow head motor proved that the coefficient k_r had no essential influence onto growth of power resistances, however increase of the coefficient k_w over 0,5 results in increase of power consumption of advance and plow head rotation motor. It was also observed that plow head loading efficiency was better form coarser material of the (20 mm ÷ 45 mm) and increased rotation speed of the plowing head.

7. Summary

On the basis of the analysis of the examinations we may draw conclusions, which can be very useful in practice. Based on results of fundamental examinations it can be stated that in case of constant head rotational speed and increased shearer advance speed loading efficiency is reduced, if the plow head was equipped with curtain conveyor. It is important because in natural conditions only shearer advance speed can be controlled.

Suitable selection of the plow head filling coefficient k_w was obtained via regulation of the shearer advance speed v_p and plow head rotational speed n, whereas value of the material loose coefficient k_r was matched via using material of definite grain-size matched with respect to the plow head constructional parameters. Possibility of coefficients k_r and k_w matching allowed broader attitude to the process of loading with use of worm-type plow heads and also determination of their influence on the process in question. In natural conditions such experiment would be difficult or even impossible for realization because of the fact that the shearer advance speed is the only parameter, which can be controlled.

To summarize the testing results we can state that in case if too large filling of the plow head with the winning, material is left on the floor, what was reflected by change of the shape and location of the winning prism.

Plow heads operated with constant rotational speed n and bigger advance speed v_p perform lower loading efficiency η_l, and in case of constant advance speed v_p and bigger rotational speed n perform higher loading efficiency η_l. However winning loose coefficient k_r has no unique influence on loading efficiency η_l, because for the same value of the coefficient $k_r = 1{,}8$, but various grain-size (10 mm ÷ 25 mm or 25 mm ÷ 45 mm), increase of the grain-size influences the loading efficiency. In case of coarse grain-size (25 mm ÷ 45 mm) improvement of loading efficiency was observed.

In case of the plow head with worm thread angle α_2 ranging between 15° and 24°, selected values of the head filling coefficient k_w should be ranged between 0,2 and 0,7, because with such values of this coefficient plowing heads performed the highest efficiency independently on kinematic parameters v_p and n.

It was observed that in case of the plow head equipped with curtain loader increase of the material filling coefficient k_w and constant head rotational speed n, power consumption of the plow head motor N_o, was increased.

In case of plow head with the worm thread angle α_2 ranging from 15° to 19,8°, values of the coefficient k_w ranging from 0,3 to 0,5 at material loose coefficient amounting for 1,55 are suggested, because for such parameters the motor power consumption was minimized. However, in case of the same parameters plowing resistances were minimized for heads having worm thread angles α_2 ranging from 24° to 26°.

Inverse situation was observed if value of the coefficient k_r was changed from 1,55 onto 1,8. That is why in case of plow heads having worm thread angle α_2 ranging from 15° to 19,8° we recommend values of the coefficient k_w ranging from 0,3 to 0,5, what results in plowing resistance minimization, and for heads in mentioned range of the angle α_2 values of the coefficient k_w ranging from 0,3 to 0,6 are suggested with respect to advance resistance minimization.

The executed laboratory examinations on the loading process efficiency allowed obtaining the broad range of results, which can be very useful in selection of the shearer operational parameters during its exploitation in designing phase, or even earlier.

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Received: 30 March 2014