Influence of Concentrating Table Deck Inclination Angles on Energy Reclamation Potential from Fine Coal Particles Based on Laboratory and Statistical Studies

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Abstract

The article presents the results of research on enrichment of fine, raw coal grains using concentrating table. The reference point was a change of inclination of a table on actual value of separated products. Laboratory research that had been conducted, shown that with proper choice of technological parameter of a table, which was its inclination, produced coal concentrates having ash content of a few to a dozen percent, as well as waste with ash content of over an 80%. Second part of the article is the static analysis of conducted laboratory research, which has proved the correctness of the process performed and also a relation between technological parameters of concentrating table and obtained enrichment products.

Keywords: gravitational enrichment, concentrating table, hard coal, enrichment accuracy, ANOVA

Introduction

Excavated mining material obtained due to operation of hard coal deposits consists of a mixture of size differentiated grains that include coal, gangue and coal shale interlayers. Excavated material is classified as unsorted and at this moment, because of its quality parameters, it is not subject of trade on the sales market. Adjusting quality parameters offered on coal market takes place by separating gangue from excavated material, coal-rock interlayers, pirite and others. Technological processes conducted to increase quality of excavated coal material are collectively named as enrichment. Enrichment processes are usually performed in devices that use density difference of useful extracted grains and gangue. This type of enrichment is called gravitational. Most often, the gravitational enrichment is done in water medium, however, there is currently significant interest in air medium enrichment [7, 8, 9, 13]. Trials like these have been done on so called air tables with positive results for Polish hard coals [1, 2, 3]. Gravitational enrichment is most often performed for grains that are above 10 mm. Fine grains below 1 mm can be enriched using floatation method, applied mainly to coking coals production. This method is also used, in very rare cases, for reclamation grains of pure energetic coal [2, 12, 14, 17]. Considering poor floatation properties of energetic coals and significant loss of fine grained classes of material (slurry) going into water-slurry circulation, proper method of reclamation of energetic potential has to be found for slurry going into dumping grounds or to so called sedimentation ponds. Concentrating table enrichment is one of the most economically beneficial and one of the most accurate processes for fine grains enrichment. It is based on the difference in raw grains density difference, as well as difference in their shape and decreasing size of water stream running down on the surface of the table. One of the most important factors, influencing separation of material on concentrating table is lateral inclination of the deck. This factor has significant impact on the moving speed of material grains on the deck in direction lateral to its axis. This speed is the result of movement of water that is running down, additional water and grains of material. It has to be noted that inclination issue of concentrating table deck should be considered for smooth and grooved decks. Critical inclination angle should not be exceeded during enrichment process using smooth table deck, i.e. when exceeding angle results in movement cease of a grain in lower part of the table deck. Critical inclination angle is determined according to a formula:

$$\frac{\frac{9}{2}k\frac{\delta'}{\delta-\delta'}\frac{H}{r}-\frac{27}{8}k\frac{\delta'}{\delta-\delta'}+1}{\varphi_s}=ctg\alpha crit \qquad (1)$$

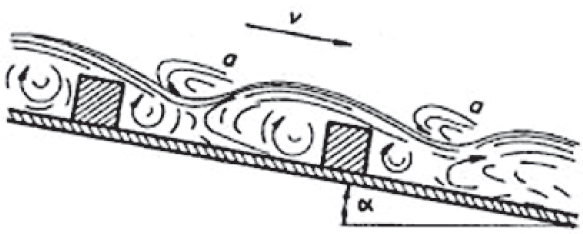

Fig. 1. Diagram of water stream movement that occur in grooves between strips on the surface of concentrating table, source [5]

Rys. 1.Schemat ruchu strug wody w rowkach utworzonych przez listwy na powierzchni stołu koncentracyjnego, źródło: [5]

where:
ctgαcrit – critical inclination angle of the deck [°],
k – proportionality coefficient that takes into account non spherical shape of grain, *r* – average radius of a grain [mm],
H – water layer height [mm],
δ – grain density[kg/m3],
δ' – water density [kg/m3],
φ_s – friction coefficient.

Analysis of above formula proves that critical inclination angle of the deck depends on mutual relations between water density, grain size, coefficient of deck friction and height of water layer. Different situation occurs for process performed on grooved deck. Use of barriers prevents adverse grain deposition occurrence on the deck. It is a result of turbulent movements (tangential) in deck's grooves, which lead to carrying the grains to further zones on concentrating table deck. This situation is shown on Figure 1.

The figure above and the occurrence presented by it, leads to conclusion that speed of lateral water movement (result of deck inclination) does not influence fluctuation in grain differentiation, when it comes to their density and it also allows movement of smaller density grains in lateral direction to the deck. Thus, while using high lateral inclination angle, both high density and light grains are washed away. That is why lateral inclination angle should be chosen accordingly to grain sizes of material used in the enrichment process. It is recommended to use following lateral inclination angles of concentrating table deck for: coarse grains characterized by high density grains, inclination should fall into ranges between 6° and 10°, materials similar in grain size to sands should be enriched using inclination between 4° to 8°; for fine grained sand like material, inclination should be 2,5° to 3,0°; for the finest grained material lateral inclination should be between 1° and 2,5°. Incorrect choice of the inclination angle considering grain sizes and density may lead to disturbance of the whole separation process leading to increased loss of useful material as it is wasted. Because of that studies on inclination angle influence on coal grain class separation, which vary in size and density, have been conducted for the purposes of this article.

Feed Characteristic

Research has been performed on fine coal grains class between 3–0 mm, which have been sampled directly from technological chain of processing plant. The sample was 90 kg. Additional samples have been taken in order to perform granulometric and densometric analyses. To uniform granulation of the material, it has undergone initial sieving on vibrating screen. Upper product that was left on the mesh has been directed to laboratorial mill crusher and sieved again. The lower product has been a subject to granulometric and densometric analysis to describe its quality and quantity characteristic. Table 1 shows obtained results from granulometric analysis of studied material with consideration of ash content in different grain classes. On the other hand, Table 2 shows obtained products and ash content of studied coal related to them, which has been created by separation in heavy liquid ($ZnCl_2$) in following density ranges: <1,45 g/cm³; 1,45–1,8 g/cm³; >1,8 g/cm³.

Granulometric analysis of raw coal has shown that grain classes of 3,0–2,0; 0,3–0,2 i 0,2– 0,102 constitute only marginal percentage of mass in relation to total mass of studied sample. There is a similar relation in case of other grain classes, where ash content is high, 65,39% on average. Densometric analysis has shown that there are 60,39% of concentrate grains present, which have relatively low ash content, of around 11,52%. During separation in heavy liquid with density

Tab. 1. Results of quality and quantity analysis of raw coal in 3–0 mm grain class [source: own research]

Tab. 1. Wyniki analizy ilościowo-jakościowej węgla surowego w klasie 3–0 mm [źródło: własne]

Grain class d [mm]	**Product** *γ[%]*	**Ash content** A^a*[%]*
3,0–2,0	2,46	58,99
2,0–1,0	22,49	67,16
1,0–0,5	28,81	67,12
0,5–0,3	10,82	72,65
0,3–0,2	8,03	70,74
0,2–0,102	4,2	71,02
-0,102	23,19	50,05
Suma	100	

Tab. 2. Physicochemical composition of feed material in 3–0 mm grain class [source: own research]

Tab. 2. Skład fizykochemiczny nadawy – węgiel surowy klasa 3–0 mm [źródło: własne]

Separation density [g/cm^3]	**Product γ [%]**	**Ash content A^a [%]**
< 1,45	60,39	11,52
1,45–1,8	10,01	42,35
>1,8	29,6	83,4
	100	

of <1,45 g/cm³, amount of semi-product grains obtained was 10,01% while their corresponding amount of ash was 42,25%. During separation in heavy liquid with density of 1,45 to 1,8 g/cm³, while during separation in heavy liquid with density of >1,8 g/cm³ amounted 29,6% and its ash content was 83,4%.

Research Methodology

Research have been conducted in laboratory scale, on the Wilfrey type concentrating table. Main technological parameter of the table used for the studies was inclination angle of its deck. Values of inclination for research purposes were set at: 4°, 3,5°, 3°. Prior to the main studies, initial control studies had been conducted that aimed at choosing the best possible table parameters for researched material. Based on that, the decision was made to conduct research with following technological parameters set:

– vibration frequency of concentrating table deck: 270, 280, 290 1/min,
– density of feed material: 350, 400 g/dm³,
– makeup water: 1,25 dm³/min.

Taking products out of the table took place 60 seconds after opening the valve feeding the material. That time was necessary to form stable range that differentiated the material in terms of size and density. Products of enrichment process have been put into 8 containers. Then, obtained products have been dried using dryers and after that they have been subjected to quality and quantity analysis. The results have been shown in Tables 3 and 4, while Table 5 and 6 present the final distribution of obtained enrichment products mass. Abbreviations have been placed at respective number of product and their explanations goes as follows: *O* – waste [odpad], *Pp* – semi-product [półprodukt], *K* – Concentrate [Koncentrat].

Research on Concentrating Table Technological Parameters Influence on Increase of Quality of Enrichment Products Based on Chosen Statistical Analyses

The situation where there is a need for comparison of quantitative features between more than two populations, occurs very often for empirical research. To study the results of such research, analy-

Tab. 3. Ash content in products obtained from raw coal enrichment process, class 3–0 mm in relation to chosen technological parameters of concentrating table [source: own research]

Tab. 3. Zawartość popiołu otrzymanych produktów wzbogacania węgla surowego w klasie 3–0 mm w zależności od wybranych parametrów technologicznych stołu koncentracyjnego [źródło: własne]

	ρ=400 g/dm^3								
	α=4°			α=3,5°			α=3°		
	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]
	A^a[%]								
Product									
1 (O)	83,62	82,57	82,40	84,05	83,91	83,76	84,79	84,64	84,09
2(O)	82,22	79,74	78,74	78,74	75,02	67,82	77,17	76,50	72,34
3(Pp)	42,16	35,2	34,13	56,47	59,38	51,42	48,4	53,28	62,28
4(Pp)	31,15	32,5	36,53	31,7	34,08	36,45	28,94	34,45	35,50
5(Pp)	24,04	28,48	31,84	23,75	27,03	31,77	21,11	23	30,31
6(K)	15,32	18,64	22,38	14,67	17,02	19,26	13,04	15,18	16,96
7(K)	14,16	14,29	15,04	12,09	12,14	13,45	10,45	11,86	13,04
8(K)	12,55	13,83	14,95	11,42	11,81	13,35	8,88	9,91	10,68

Tab. 4. Ash content in products obtained from raw coal enrichment process, class 3–0 mm in relation to chosen technological parameters of concentrating table [source: own research]

Tab. 4. Zawartość popiołu otrzymanych produktów wzbogacania węgla surowego w klasie 3–0 mm w zależności od wybranych parametrów technologicznych stołu koncentracyjnego [źródło: własne]

	ρ=350 g/dm^3								
	α=4			α=3,5°			α=3°		
	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]
	A^a[%]								
Product									
1 (O)	82,57	82,35	81,62	84,32	82,91	81,76	85,79	82,64	79,74
2(O)	79,50	78,34	67,82	78,74	78,09	75,02	82,22	81,17	79,74
3(Pp)	39,85	39,50	38,46	53,69	44,65	34,50	48,83	47,74	35,60
4(Pp)	32,23	32,72	41,90	34,50	35,03	35,55	24,48	32,00	33,90
5(Pp)	21,62	24,90	32,57	23,70	26,04	28,37	20,67	21,67	22,05
6(K)	15,81	18,19	20,27	13,42	14,29	15,35	12,05	13,22	14,09
7(K)	12,41	13,68	14,33	9,65	11,18	12,71	8,36	9,53	9,83
8(K)	11,6	12,47	14,09	8,92	9,05	10,42	7,15	8,25	8,75

sis of variance is often used, described in literature as "ANOVA". Variance analysis ANOVA is one of the most popular and used methods of statistical analysis [15]. To be precise - variance analysis is a group of analyses, used for research on influence of factors (independent variables, in this case, angle, speed) on dependent variable - ash content.

Variance analysis is a ratio of variance, calculated between studied groups and average variance, which is observed inside groups. This analysis is a statistical method that allows for division of observed variability (variance) of results into separate parts [6]. One of the basic issues in variance analysis is calculation of so called mean squares (MS). Ratio of mean squares calculated for each factor to mean square error allows for estimation of influence of individual factors on value of dependent variable separately.

In comparison to other, simpler, methods of data analysis such as student t-test and non-parametric tests, variance analysis ANOVA allows for comparison between variables with more than 2 levels (groups), but also analysis of simultaneous influence of several factors (MANOVA) and interaction between these factors. It is simultaneous change of influence of density, inclination angle

Tab. 5. Obtained products from raw coal enrichment process, class 3–0 mm in relation to chosen technological parameters of concentrating table [source: own research]

Tab. 5. Wychody produktów wzbogacania węgla surowego w klasie 3–0 mm w zależności od wybranych parametrów technologicznych stołu koncentracyjnego [źródło: własne]

	ρ=400 g/dm^3								
	α=4°			α=3,5°			α=3°		
	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]
	Y[%]								
Product									
1 (O)	2,02	6,47	8,02	9,41	11,47	15,53	6,34	9,66	10,74
2(O)	8,29	11,05	13,80	6,67	9,78	11,73	10,31	11,80	12,78
3(Pp)	2,68	8,29	13,75	11,13	11,15	11,17	9,89	9,77	12,83
4(Pp)	6,22	7,86	15,44	4,73	6,37	7,99	2,02	2,98	2,49
5(Pp)	22,03	18,78	13,49	10,60	11,73	12,88	12,82	12,16	11,73
6(K)	8,13	8,08	7,96	14,76	13,46	10,49	24,40	22,77	21,15
7(K)	27,90	21,94	15,84	26,58	23,03	17,46	24,32	23,23	22,92
8(K)	22,73	17,53	11,70	16,12	13,03	12,75	9,90	7,63	5,36

Tab. 6. Obtained products from raw coal enrichment process, class 3–0 mm in relation to chosen technological parameters of concentrating table [source: own research]

Tab. 6. Wychody produktów wzbogacania węgla surowego w klasie 3–0 mm w zależności od wybranych parametrów technologicznych stołu koncentracyjnego [źródło: własne]

	ρ=350 g/dm^3								
	α=4°			α=3,5°			α=3°		
	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]	f=290 [1/min]	f=280 [1/min]	f=270 [1/min]
	Y[%]								
Product									
1 (O)	2,10	1,63	3,25	8,65	8,11	6,11	10,67	2,76	2,64
2(O)	6,64	8,62	12,47	11,80	10,34	8,88	11,12	10,02	8,94
3(Pp)	8,50	18,05	3,54	6,51	8,40	12,32	6,81	7,76	8,67
4(Pp)	1,94	2,54	13,78	2,82	6,89	11,25	2,40	12,85	13,55
5(Pp)	2,72	8,98	19,12	10,60	13,35	16,11	5,07	9,97	14,21
6(K)	22,65	17,22	11,4	12,95	12,29	10,62	16,15	14,59	8,75
7(K)	32,15	21,19	18,71	25,63	23,33	21,06	22,00	20,75	21,55
8(K)	23,30	21,77	17,73	21,04	17,30	13,65	26,34	21,30	21,69

and speed that makes quality improvement of analyzed material possible.

Choice of statistical test for estimation of importance of calculated parameters can be made according to algorithm [16].

Assumed null hypothesis was that the change of parameters of technological process influence increase of quality of products 6,7,8 (concentrates). To verify this hypothesis, thesis has been made that the products have the same expected value for alternative hypothesis that is contradiction to null hypothesis. If it was possible to reject null hypothesis formulated like that it would be proof for quality increase of products. If rejection was baseless it would mean that the whole study did not make any sense. To verify this hypothesis, ANOVA tool from Statistica10 PL has been used. Calculation results have been shown on fig. 3.

Completed analysis shows that density of feed material, inclination angle of a deck and jig frequency of a deck are parameters that significantly influence changes in ash content in individual products of enrichment process, while interactions between these parameters are not statistically important (probability lower than 0,05).

Observation can also be made that increase in

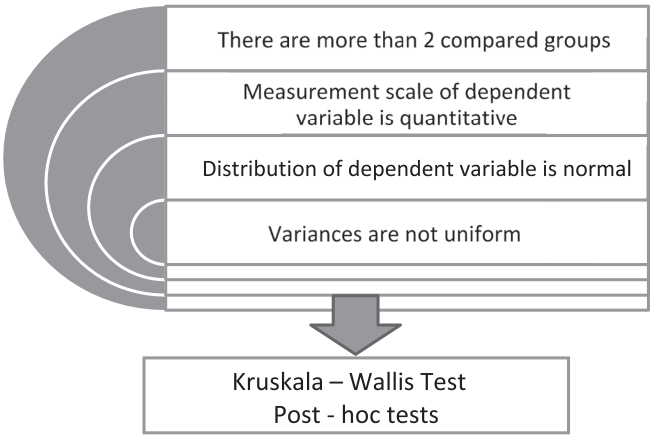

Fig. 2 Choice algorithm of statistical test for estimation of parameters importance, source [16]

Rys. 2 Algorytm wyboru testu statystycznego do oszacowania istotności parametrów, źródło [16]

Fig. 3. Calculation results for ANOVA, source own

Rys. 3. Wyniki obliczeń ANOVA, źródło: badania własne

	Single dimensional importance test for Ash A^a[%] Parametrization with sigma-limitations Decomposition of effective hypotheses				
Effect	SS	Degrees of Freedom	MS	F	p
Free Term	12547,13	1	12547,13	1956,020	0,000000
Density of feed material [g/cm^3]	40,76	1	40,76	6,354	0,014392
Angle [°]	294,31	1	294,31	45,882	0,000000
Jig Frequency of deck of the table [1/min]	88,83	2	44,41	6,924	0,001970
Density of feed material [g/cm^3]* Angle [°]	6,08	1	6,08	0,948	0,334013
Density of feed material [g/cm^3]* Jig Frequency of deck of the table [1/min]	1,92	2	0,96	0,150	0,861048
Angle [°]* Jig Frequency of deck of the table [1/min]	3,10	2	1,55	0,242	0,786112
Density of feed material [g/cm^3]* Angle [°]* Jig Frequency of deck of the table [1/min]	0,25	2	0,12	0,019	0,980712
Error	384,88	60	6,41		

density of feed material directed to enrichment leads to decrease in quality of separated products (fig. 4), decrease of inclination angle increases quality of separated products, while in case of jig frequency of the deck, better products can be obtained with increase of this parameter.

It was also assumed that within the group the parameter is normal fig.5.

To verify the hypothesis, Levenev's variance uniformity test has been used [11]. Prior to variance analysis there has to be a check of methods assumptions. Checking assumption of variance uniformity in groups defined by levels of factors is especially important:

- H0: Variance of dependent variable in factor groups is identical
- H1: Variance of dependent variable in factor groups is different

Test results indicate that null hypothesis should be rejected, which means that variance in groups is not identical, that in turn proves that conducted experiment allows for development of method for choosing technological parameters of the enrichment process.

Statistical analysis of usable grains (coal) has also been conducted for the waste material. The influence of the deck on the lowest content of usable grains (loss) in the waste has been studied. To statistically verify importance of conducted study, t-student test has been used.

Null hypothesis has been established that conducted experiment has led to production of waste burdened by ballast (ash) that amounted 80%. This value of ash content in product informs about its lack of usefulness for energetic purposes or for coke, what has been proved multiple times in different laboratory research, in comparison to alternative hypothesis, which contradicts null hypothesis.

- H0: mo=80,00
- H1: mo≠80,00

To verify assumptions, statistic of t-Student for α = 0,05 and n-1 = 35, this critical value is 2,0301 [10].

Empirical statistic has been designated using following formula [10]:

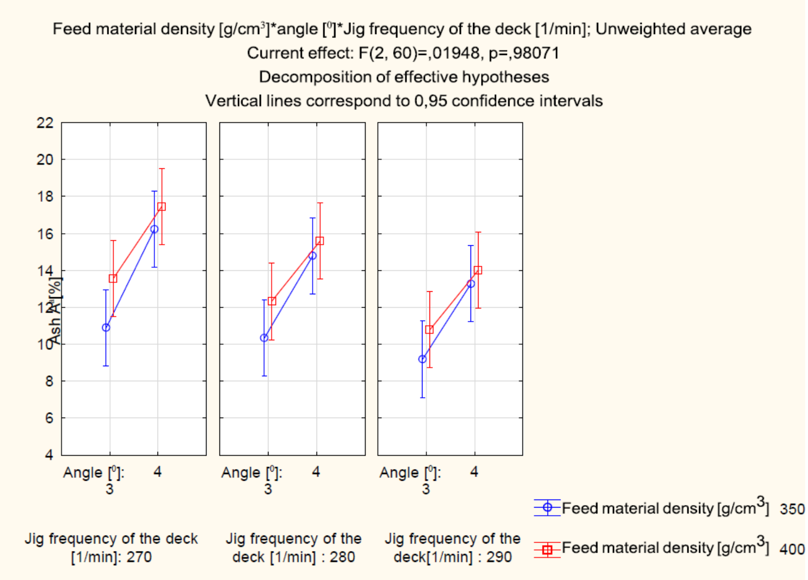

Fig. 4. Graphs showing changes of expected value depending on technological parameters of enrichment process, source own

Rys. 4. Wykres zmiany wartości oczekiwanej w zależności od parametrów technologicznych procesu wzbogacania, źródło: badania własne

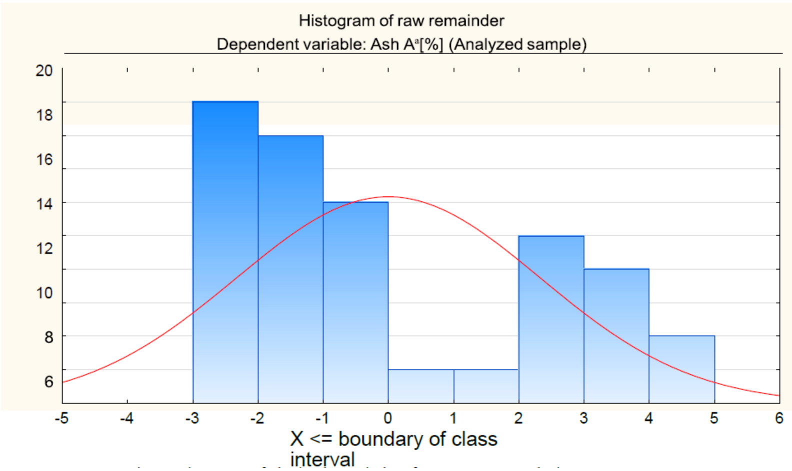

Fig. 5. Histogram of obtained remainders from ANOVA analysis, source own

Rys. 5. Histogram reszt uzyskanych z analizy ANOVA, źródło: badania własne

$$t = \frac{\overline{x} - m_o}{s^2}\sqrt{n-1} = \frac{80,1175 - 80,0000}{23,0865}\sqrt{36-1} = 0,0301 \qquad (2)$$

where:
$\overline{x}$ – arithmetic average of waste, m_o – assumed value, s^2 – variance, n – sample number.

Statistical analysis shows that empirical value is lower than critical, thus assumed null hypothesis should be accepted.

Conducted statistical analysis of choice of parameters of technological process has allowed to prove the legitimacy of laboratory experiment. Using precisely chosen parameters, obtained product is useful for energy and coke.

Results and Discussion

Based on analysis of data presented in tables 3-4, conclusion has been made that along with reduction of inclination angle of concentrating table deck, there is a reduction of ash content in each individual enrichment process products. This relation was present for feed material density of ρ = 400 g/dm³, as well as ρ = 350 g/dm³. The lowest ash contents in concentrates obtained in these studies were 7,15%, 8,25%, 8,75% respectively. These values have been achieved for deck tilt of 3°, jig frequency 290 1/min, 280 1/min, 270 1/min and density of feed material of ρ = 350 g/dm³. Similarly, in case of density of feed material of ρ

Fig. 6. Results of Levene's test, source own

Rys. 6. Wyniki testu Levene'a, źródło: badania własne

Levene's variance uniformity test (MichałMP.sta)
Highlighted effects are important with p< ,05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
Y	11,04613	11	1,004194	30,19817	24	1,258257	0,798083	0,640879

= 400 g/dm³, the lowest ash content of concentrates was achieved with 3° deck tilt. Likewise, there is an observable relation between reduction of deck inclination and quality of waste material (increase of ash content). The best waste has been obtained for deck tilt angle of 3°, density of feed material of ρ = 350 g/dm³ and deck jig frequency of 290 1/min, 280 1/min, 270 1/min. In other cases, conclusion can be made that waste obtained from the process (especially product designated as number 2) contain some amount of usable grains (coal). Thus it seems justified to conduct secondary enrichment of the waste to maximize coal grains reclamation. Semi products obtained with all studied inclination angles of the deck, are characterized with somewhat increased ash content, however, such ballast does not exclude them from further use. In this case it is necessary to perform dual stage enrichment or further decrease of tilt angle of the deck in pursue to increase usable value of analyzed products. These actions are burdened with certain economic issues, which occur as a result of conducting additional technological process, energy cost and media supplied to the system, as well as lower amount of obtained product from the final process. Such actions should be preceded with careful analysis of sales possibility of products from secondary enrichment with consideration for final balance informing about potential profit of loss, after eventual market sale. Data analysis presented in tables 5 and 6, clearly shows that the highest amount of obtained products for every analyzed inclination angle can be observed in concentrates (products 6–8), where their amount was in 50% range on average, while the lowest was in the wase (products 1–2) with 20%. Data shown in the tables above, clearly show the relation between quantity and quality changes in obtained enrichment products and studied technological process parameters. In this case inclination angle of concentrating table deck.

Conclusions

Research discussed in the article have been performed in laboratory scale on Wilfrey type concentrating table. The main technological parameter of concentrating table that has been basis of the studies, was inclination angle of the deck. Its respective values: 4°, 3,5°, 3°. Prior to conducting the main studies, initial, control studies have been performed. Their goal was the choice of the best parameters of concentrating table for researched material. Based on that, the decision has been made to conduct the research. Using the analysis included in this article, conclusion has been made that along with reduction of inclination angle of concentrating table deck, there is a reduction of ash content in each individual enrichment process products. This relation was present for feed material density of = 400 g/dm³, as well as = 350 g/dm³. The lowest ash contents in concentrates obtained in these studies were 7,15%, 8,25%, 8,75% respectively. These values have been achieved for deck tilt of 3°, jig frequency 290 1/min, 280 1/min, 270 1/min and density of feed material of = 350 g/dm³. Similarly, in case of density of feed material that has amounted =400 g/dm³, the lowest ash content has been obtained for inclination angle of the deck of 3°. Likewise, there is an observable relation between reduction of deck inclination and quality of waste material (increase of ash content). In other cases, conclusion can be made that waste obtained from the process (especially product designated as number 2) contain some amount of usable grains (coal). Thus it seems justified to conduct secondary enrichment of the waste to maximize coal grains reclamation.

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Badanie wpływu kąta nachylenia płyty roboczej stołu koncentracyjnego na odzysk potencjału energetycznego drobnych ziaren węglowych w ujęciu laboratoryjno-statystycznym

W artykule przedstawiono wyniki badań wzbogacania drobnych ziaren węgla surowego na stole koncentracyjnym. Jako punkt odniesienia obrano wpływ zmiany kąta nachylenia płyty roboczej stołu na wartość użytkową otrzymanych produktów rozdziału. Badania przeprowadzone w skali laboratoryjnej pokazały, iż przy odpowiednim doborze parametru technologicznego stołu jakim był kąt nachylenia można uzyskać koncentraty węglowe o zawartości popiołu rzędu kilku do kilkunastu procent jak i odpady przekraczające 80% popiołu. Drugim etapem artykułu była analiza statyczna przeprowadzonych badań laboratoryjnych, która udowodniła prawidłowość przeprowadzonego procesu jak i zależności pomiędzy parametrami technologicznymi stołu a uzyskanymi produktami wzbogacania.

Słowa kluczowe: wzbogacanie grawitacyjne, stół koncentracyjny, węgiel kamienny, dokładność wzbogacania, ANOVA