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Analysis of relationships between the qualitative parameters of brown coal

Introduction

The qualitative parameters of coal decide its utility, hence they should also affect its prices. This fact is used in pricing formulas. It is common practice to use formulas in relations between producers (coal mines) and users (power plants) in mutual settlements for the supplied coal.

In developing the formulas, it is necessary to have a knowledge of the relationships between individual price-related parameters, the levels of such parameters, and the range in which they vary over time. This issue involves the necessity of selecting price-related parameters and basic parameter levels, and determining the functional dependencies between parameters and price. Such information is useful in developing pricing structures.

Pricing structure is a component of the sales formula which expresses the influence of selected parameters on price. The structure determines an increase or decrease in coal price depending on the improvement or worsening of its quality.

Results of the analysis of relationships between the basic qualitative parameters of coal are given below. The analysis was carried out in order to check whether or not such dependencies may be found based on the parameters of coal from domestic brown coal mines.

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1. Discussion of the input data

The input data for the analysis were taken from information on the qualitative parameters of brown coal delivered to power plants. The coal originated from four mines (Adamów, Bełchatów, Konin and Turów) and is supplied to five power plants (Adamów, Bełchatów, Konin, Pątnów and Turów). Konin is the only mine which supplies coal to two power plants: Konin and Pątnów.

Brown coal is characterised by four parameters: calorific value, sulphur content, ash content and moisture content. All parameters are given as received.

The analysis was carried out based on averaged daily data on the quality of deliveries between 2004 and 2006. In case of the Adamów mine, the author had data only from 2006.

See Table 1 for average annual qualitative parameters for individual mines. Based on the data presented, the following conclusions can be made:

— Coal from the Turów mine has the greatest calorific value (above 10,000 kJ/kg). This coal also has the lowest moisture content (42.6–43.9%), but the highest ash content (14.9–16.6% depending on the year). According to the average values, the parameters of the coal worsened to some degree, as compared to 2004: average calorific value decreased and ash and moisture content increased. The sulphur content increased by 0.12% but, compared with other mines, its level is still relatively low.

— Coal from the Konin mine also has a high calorific value – above 9000 kJ/kg. The qualitative parameters in this mine worsened too, especially as regards the sulphur content (this increased by more than 0.2%, i.e. by 27% from 2004). This coal has the highest sulphur content in the entire sector.

— Coal from the Adamów mine lies in the middle of the range in the sector as regards calorific value and ash content. An important and highly positive feature of this coal is its very low sulphur content.

— Average parameters from the Bełchatów mine have recently improved. As compared to 2004, the calorific value has increased (by 4%), and the sulphur and ash contents have decreased.

In (Grudziński 1999a, b), studies of the quality of brown coal carried out in the mid ‘90s are described (based on data from 1992 to 1995). As compared to the results of those studies, it may be stated that the average parameters of coal from the Adamów and Bełchatów mines have virtually not changed (a slight increase in calorific value occurred at the Adamów mine). The most favourable situation appeared at Turów where, as compared to the years 1992–1995, all parameters clearly improved; calorific value increased by from 700 to almost 1000 kJ/kg (depending on the year), ash content decreased by around 4%, and sulphur content decreased by 0.2–0.3% (the average value from 1992–1995 was around 0.7% S). At Konin, on the other hand, the increase of calorific value by around 100–400 kJ/kg was accompanied by an increase in ash content of over 1% and in sulphur content of around 0.3–0.4%.

TABLE 1

Average annual parameters of brown coal from individual mines
(based on daily deliveries to the power generation sector between 2004 and 2006)

TABELA 1

Średnie roczne parametry węgla brunatnego z poszczególnych kopalń
(na podstawie dostaw dziennych do energetyki z lat 2004–2006)

Mine	Year	Q_i^r	S_t^r	A^r	W_t^r
		kJ/Mg	%	%	%
Adamów	2006	8 490	0.29	9.4	53.1
Bełchatów	2004	7 870	0.61	10.6	53.0
	2005	8 094	0.57	8.9	53.7
	2006	8 169	0.58	8.8	53.6
Konin	2004	9 361	0.84	8.2	52.1
	2005	9 425	0.92	8.3	51.9
	2006	9 149	1.07	8.8	52.6
Turów	2004	10 069	0.34	15.5	43.9
	2005	10 387	0.35	14.9	43.2
	2006	10 104	0.46	16.6	42.6

Comparisons of parameters from previous studies are cited here because, in the paper of 1999, an analysis was also carried out on the fluctuations of quality parameters of coal in deliveries to the power generation sector, based on the data from the same mines.

Changes in average (for the sector) qualitative parameters of brown coal in a multi-year perspective (1995–2006) are presented in Fig. 1. In the years presented, the average

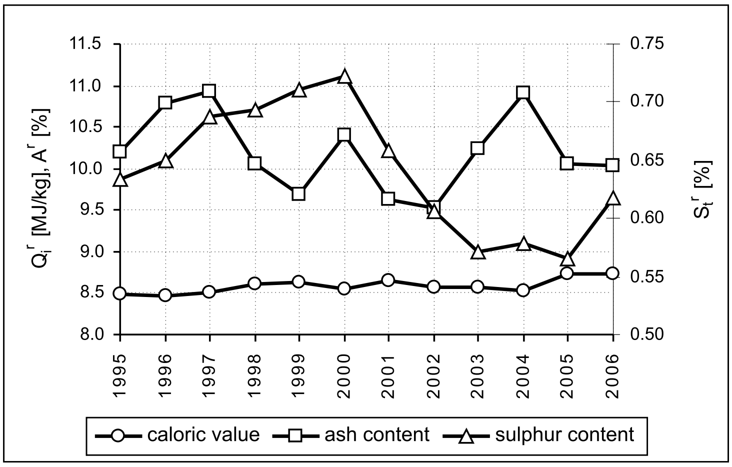

Fig. 1. Changes in average (for the sector) parameters of brown coal 1995–2006
Source: Emitor

Rys. 1. Zmiany średnich (dla branży) parametrów węgla brunatnego w latach 1995–2006 parameters for all coal combusted by the power plants did not change considerably. The calorific value improved by 3%. The sulphur content had smaller fluctuations in this period. After a growth trend up to 2000, there followed a fall, and then growth in 2006. Despite this, the current value is lower by 15% than that of 2000 (taking the content in 2000 as 100%). The ash content oscillates around 10%. The graphs in Figs. 2 and 3 allow us to compare the levels of average qualitative parameters (in pairs: A(Q) and S(Q)) between individual mines with average parameters for the sector.

In determining pricing structures, it is also extremely important to know the range of fluctuations of qualitative parameters of coal supplied to power plants, since large fluctuations in quality cause similarly large fluctuations in price. It is worth mentioning that brown coal mines have little influence on the parameters of the coal, but they can – with proper exploitation – influence the stability of the parameters. A mine's costs may to a small degree depend on the quality of coal sold.

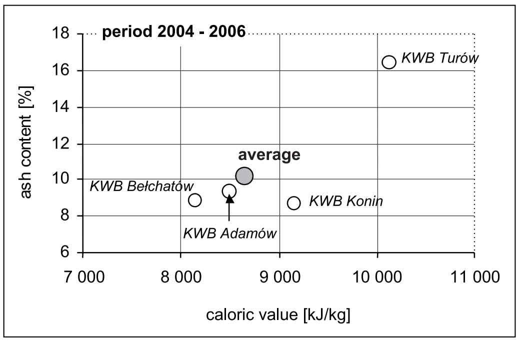

Fig. 2. Relationship between caloric value and ash content in brown coal of individual mines (average parameters 2004–2006)

Rys. 2. Związek wartości opałowej i zawartości popiołu w węglach brunatnych z poszczególnych kopalń (parametry średnie za okres 2004–2006)

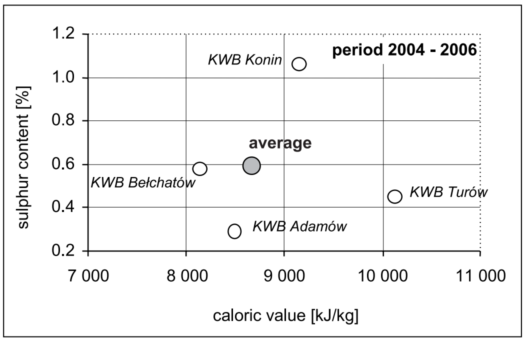

Fig. 3 Relationship between calorific value and suphur content in brown coal of individual mines (average parameters 2004–2006)

Rys. 3. Związek wartości opałowej i zawartości siarki w węglach brunatnych z poszczególnych kopalń (parametry średnie za okres 2004–2006)

2. Studying the relationship between the qualitative parameters of brown coal from individual mines

The basic objective of the analysis has been to determine the relationships between the qualitative parameters: calorific value (Q), sulphur content (S) and so-called ballast (A + W) which refers to total ash (A) and moisture (W) content. All parameters have been given as received. In addition, the maximum and minimum fluctuations of qualitative parameters have been determined for coal supplied to power plants in the given periods.

The daily data on the quality of coal supplied from mines to power plants were cleared of any incomplete data sets, i.e. those missing even one parameter.

Sometimes, in such statistical analysis, missing data are replaced with average values. This applies, in particular, when little data is available. Here, however, the number of data seta was always over 200, so there was no need to apply such a procedure. In the case of the Adamów mine daily data was available for only 9 months of 2006.

All relationships were studied for potentially observable and statistically important correlations. All calculations were made with StatSoft's STATISTICA program (Statistica PL 2006). The analysis was carried out by the multiple regression method.

Calculations were carried out in two stages:

— in the first – all combinations of parameters were analysed to determine the significant dependencies,
— in the second stage, following the specific requirements of the procedure for calculating regression, equations were determined which depict the dependencies between the qualitative parameters.

The basic criterion for evaluation of the dependencies occurring between parameters was the R-square regression coefficient (R^2). The value of this coefficient refers to the match between the regression equation and a given set of data.

The analyses were extremely detailed; calculations referred to daily data for individual years, then for individual months; an attempt was also made to find correlations for all coal for the period 2004–2006.

Each analysis was carried out in multiple stages:

— first, the raw data was analysed,
— then, analysis of the distribution of residual values was carried out, in order to eliminate incomparable data,
— following the residual analysis, the correlations were studied once more in order to calculate the equation parameters.

While calculating the correlations, no important links between sulphur content and other parameters were found. For sulphur, the correlation square R^2 exhibits the largest values in studying the dependency of sulphur content on calorific value. However, even for this data set, the results are not at all satisfactory: the highest R^2 value achieved was of 0.3 for Bełchatów in 2006. For coal from other mines, the best values reached only 0.2. It was thus impossible to find reliable dependencies between sulphur content and other qualitative parameters. Determining such relationships involved too great a risk of errors. In similar studies carried out for hard coal (Lorenz L. et. al. 2002), it was also difficult to find a significant correlation between sulphur content and calorific value. The prevailing tendency is: the higher the calorific value, the lower sulphur content. This is related to the formation of sulphur presence in coal.

The most significant relationships were found between calorific value and ballast, i.e. concisely ash and moisture content (A + W). These relationships had a high R^2 value and were subjected to more detailed analysis.

Regressive calculations were performed for the Q = f(A + W) and (A + W) = f(Q) dependencies, which allowed for evaluation of how a change in some parameters affects others. Calculation of the reverse function of Q = f(A + W), i.e. (A + W) = f(Q) (in the case of each calculation), was also carried out by the regression method – this equation is not a mathematical transformation of the equation Q = f(A + W).

In the first stage, as already mentioned, so-called raw data was analysed. As in the initial analysis, the R^2 had a high value: a minimum of over 0.7. Only in case of coal from Bełchatów did the correlation coefficient for the 2006 data had a relatively low value, of approx. 0.57. In studying the dependencies for daily data in an annual perspective, this was the lowest result.

The R^2 value serves as an indicator of the quality of the match between the regression equation and the data model: the higher the coefficient, the more variability is explained by the equation. Should $R^2 = 1$, the whole variability, e.g. of calorific value, would be explained by variables (A + W). Such a situation did not occur, yet the results obtained in further calculations are quite satisfactory.

In practice, it appears that $R^2 < 1$, i.e. some of the data deviates from the determined regression line. In the next stage, these deviations were analysed.

The deviations may disturb the regression equation, which causes the regression line to be inclined in a different direction, and the values of the regression coefficients to be inappropriate. Residual analysis was performed in all tests. Standard deviation σ (sigma) was adopted as the main criterion. For this type of calculations, it is assumed that data outside the $\pm 2\sigma$ range should be deleted. In the next stage, the calculations are repeated without the so-called deviating data. Analysis is carried out in a sufficient number of cycles in order to ensure the proper level of all regression coefficients.

Tables 2–5 present the final regression equations. The minimum and maximum data values which were included in the calculations are also given. It was determined how given parameters change with a change of a specific value in others, and the quantity of data analysed is also described.

Calculated regression coefficients fluctuate in the range of 0.85–0.92. Correlation coefficients for the given equations may be regarded as very high. Thus the equations quite reasonably depict the relations which appear between calorific value and ballast content (A + W).

The lowest coefficient values achieved were for the Bełchatów mine. As already mentioned, for the raw (initial) data, the correlation square was only 0.57. This unimpressive

TABLE 2

Results of regression analysis of coal from the Adamów mine

TABELA 2

Wyniki analizy regresji węgla z KWB Adamów

Year 2006		
Q = –228.73 (A + W) + 22778	229 kJ/kg na 1% (A + W)	$R^2 = 0.87$
(A + W) = –0.00382 Q + 94.92	3.82% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 7665–9069 kJ/kg	S_{min}–S_{max} = 0.16–0.54%	
A_{min}–A_{max} = 6.1–15.4%	*Number of data – 242*	

TABLE 3

Results of regression analysis of coal from the Bełchatów mine

TABELA 3

Wyniki analizy regresji węgla z KWB Bełchatów

Year 2004		
Q = –203.74 (A + W) + 20836	204 kJ/kg na 1% (A + W)	$R^2 = 0.85$
(A + W) = –0.00415 Q + 96.31	4.15% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 7306–8533 kJ/kg	S_{min}–S_{max} = 0.35 – 0.90%	
A_{min}–A_{max} = 5.3–16.5%	*Number of data – 332*	
Year 2005		
Q = –199.77 (A + W) + 20614	200 kJ/kg na 1% (A + W)	$R^2 = 0.82$
(A + W) = –0.00409 Q + 95.80	4.09% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 7394–8667 kJ/kg	S_{min}–S_{max} = 0.32 – 0.83%	
A_{min}–A_{max} = 4.6–13.6%	*Number of data – 360*	
Year 2006		
Q = –219.43 (A + W) + 21873	219 kJ/kg na 1% (A + W)	$R^2 = 0.85$
(A + W) = –0.00387 Q + 94.12	3.87% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 7423–8813 kJ/kg	S_{min}–S_{max} = 0.30 – 1.03%	
A_{min}–A_{max} = 4.2–15.0%	*Number of data – 261*	
2004 – 2006		
Q = –213.25 (A + W) + 21460	213 kJ/kg na 1% (A + W)	$R^2 = 0.86$
(A + W) = –0.00405 Q + 95.53	4.05% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 7306–8813 kJ/kg	S_{min}–S_{max} = 0.30–1.03%	
A_{min}–A_{max} = 4.2–16.5%	*Number of data – 953*	

TABLE 4

Results of regression analysis of coal from the Konin mine

TABELA 4

Wyniki analizy regresji węgla z KWB Konin

Year 2004		
Q = –252.67 (A + W) + 24606	253 kJ/kg na 1% (A + W)	R^2 = 0.92
(A + W) = –0.00365 Q + 94.47	3.65% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 8693–9885 kJ/kg	S_{min}–S_{max} = 0.60–1.08%	
A_{min}–A_{max} = 5.4–12.5%	*Number of data – 354*	
Year 2005		
Q = –251.07 (A + W) + 24520	251 kJ/kg na 1% (A + W)	R^2 = 0.90
(A + W) = –0.00358 Q + 93.87	3.58% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 8535–9929 kJ/kg	S_{min}–S_{max} = 0.62–1.15%	
A_{min}–A_{max} = 5.6–12.7%	*Number of data – 361*	
Year 2006		
Q = –254.03 (A + W) + 24739	254 kJ/kg na 1% (A + W)	R^2 = 0.90
(A + W) = –0.00356 Q + 93.90	3.56% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 8119–9768 kJ/kg	S_{min}–S_{max} = 0.71–1.44%	
A_{min}–A_{max} = 5.7–15.9%	*Number of data – 363*	
2004 – 2006		
Q = –232.40 (A + W) + 23376	232 kJ/kg na 1% (A + W)	R^2 = 0.89
(A + W) = –0.00385 Q + 96.34	3.85% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 8119–9929 kJ/kg	S_{min}–S_{max} = 0.52–1.44%	
A_{min}–A_{max} = 4.9–15.9%	*Number of data – 1443*	

result was caused by a low level of correlation in March, July and August 2006. After removing a considerable part of the data from these months, correlation of 0.85 was achieved. Such a result, however, was achieved after removing as much as 25% of the data. In the other analyses, the quantity of rejected data, not meeting the requirements of the analysis, did not exceed 10%.

The best results of fit the regression line to the set of data was achieved for Konin mine. The correlation square received is the highest here. The calorific value in coal can be described using those equations with accuracy of lower than 50–60 kJ/kg. The similar analyses but conducted on the data on coal quality from bore holes (in Konin deposit) were described in the work (Kasztelewicz, Mazurek 2004). The authors have achieved inter alia the correlation equations between calorific value and ballast with a high accuracy (r = –0.99).

TABLE 5

Results of regression analysis of coal from the Turów mine

TABELA 5

Wyniki analizy regresji węgla z KWB Turów

Year 2004		
Q = –331.60 (A + W) + 29744	332 kJ/kg na 1% (A + W)	R^2 = 0.92
(A + W) = –0.00276 Q + 87.15	2.76% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 8089–11731 kJ/kg	S_{min}–S_{max} = 0.22–0.53%	
A_{min}–A_{max} = 8.5–23.8%	*Number of data – 355*	
Year 2005		
Q = –321.17 (A + W) + 29048	321 kJ/kg na 1% (A + W)	R^2 = 0.91
(A + W) = –0.00283 Q + 87.53	2.83% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 8353–12288 kJ/kg	S_{min}–S_{max} = 0.22–0.82%	
A_{min}–A_{max} = 8.3–24.3%	*Number of data – 361*	
Year 2006		
Q = –320.05 (A + W) + 29027	320 kJ/kg na 1% (A + W)	R^2 = 0.87
(A + W) = –0.00273 Q + 86.72	2.73% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 8223–12100 kJ/kg	S_{min}–S_{max} = 0.25–0.89%	
A_{min}–A_{max} = 8.7–24.5%	*Number of data – 353*	
2004 – 2006		
Q = –319.49 (A + W) + 28990	319 kJ/kg na 1% (A + W)	R^2 = 0.90
(A + W) = –0.00282 Q + 87.63	2.82% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = 8089–12288 kJ/kg	S_{min}–S_{max} = 0.22–0.89%	
A_{min}–A_{max} = 8.3–24.5%	*Number of data – 1069*	

The received dependencies allow for predicting calorific value with adequacy 20–25 kcal/kg. It is especially important while predicting the quality of coal (directed to power plant) from the part of deposit before the exploitation as well as from a new deposits. Such information should also be used in the works on price system for the system mine- power plant.

The average accuracy of calculated equations for coal from individual mines is presented in Table 6. The maximum deviations found are of around 300 kJ/kg, and only for the coal from Turów mine the deviations slightly exceed 500 kJ/kg.

Dependencies between the qualitative parameters of brown coal from all mines as delivered to the power generation sector in the studied year of 2006 are presented in Figs. 4 and 5.

Fig. 4 illustrates well why it was impossible to find a correlation of sulphur with other qualitative parameters. In case of coal from the Turów mine, the data is highly 'dispersed'

TABLE 6

Average regression accuracy

TABELA 6

Średnia dokładność równań regresji

Mine	Year	Average regression accuracy kJ/kg
Adamów	2006	77
Bełchatów	2004	75
	2005	78
	2006	76
Konin	2004	51
	2005	57
	2006	58
Turów	2004	147
	2005	150
	2006	173

along the x-axis (calorific value). This means that, e.g. a sulphur content of some 0.3% may occur in any coal from of a calorific value in the range of 9000–11500 kJ/kg.

A similar data distribution is present at the Konin mine. Here, there is even a slight growth trend noticeable in the sulphur content with the increase in calorific value. Yet, in this mine too, correlations for this pair of parameters (S and Q) are statistically insignificant. It is possible, for example, that for a calorific value of 9000 kJ/kg, the sulphur content may vary in the range from 0.8 to even 1.4%. Only in the case of Bełchatów (as already mentioned), can a slightly higher correlation be observed and, moreover, the increase in calorific value is accompanied by a decrease in sulphur content. However, even for these data, it was impossible to find reliable linear dependencies. The graph below shows well how low sulphur content is in the coal from Adamów mine and how this parameter appears in relation to other mines.

In the case of the dependency between calorific value and ballast, the situation is completely different. The aforementioned Tables 2–5 present precise numerical values, and the graph in fig. 5 depicts very well these dependences (on the basis of data from 2006). Straight lines created on the basis of the regression equations are also presented in the graph.

The regression lines for the coal from three mines – Adamów, Bełchatów and Konin – are more or less parallel, and the differences between the equations result mainly from the constant in the equation. From the equations presented, it appears that a change in ballast (A + W) of 1% results in a change in calorific value of around 220 kJ/kg for both Adamów and Bełchatów. In the case of the coal from Konin mine, that value is slightly higher (around 250 kJ/kg).

The regression line for coal from the Turów mine is different, as it is inclined at greater angle, since for this coal, a change in ballast of 1% changes the calorific value by around 320 kJ/kg.

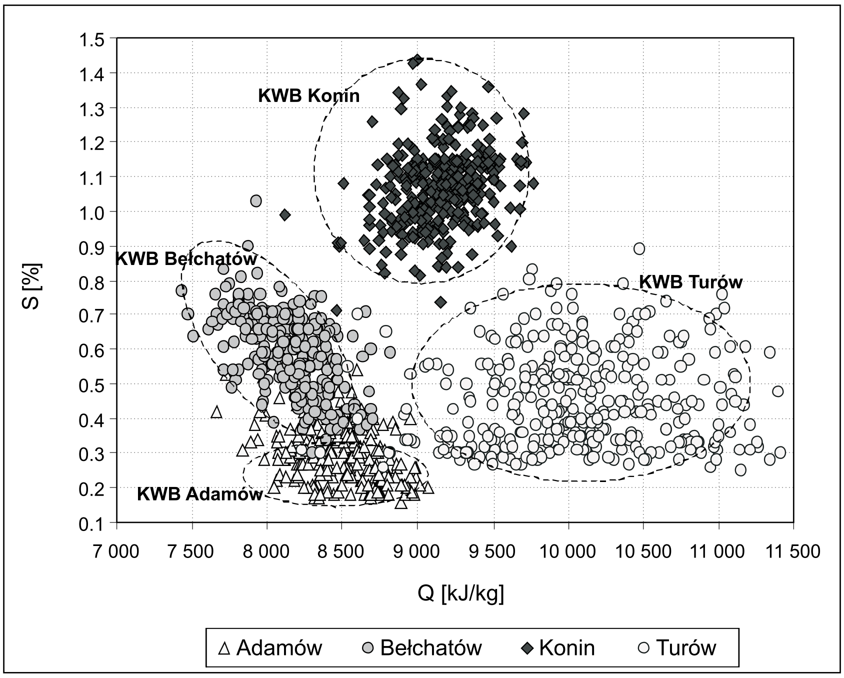

Fig. 4. Dependency between sulphur content and calorific value of brown coal from individual mines in 2006

Rys. 4. Zależność zawartości siarki od wartości opałowej w węglu brunatnym z poszczególnych kopalń w 2006 r.

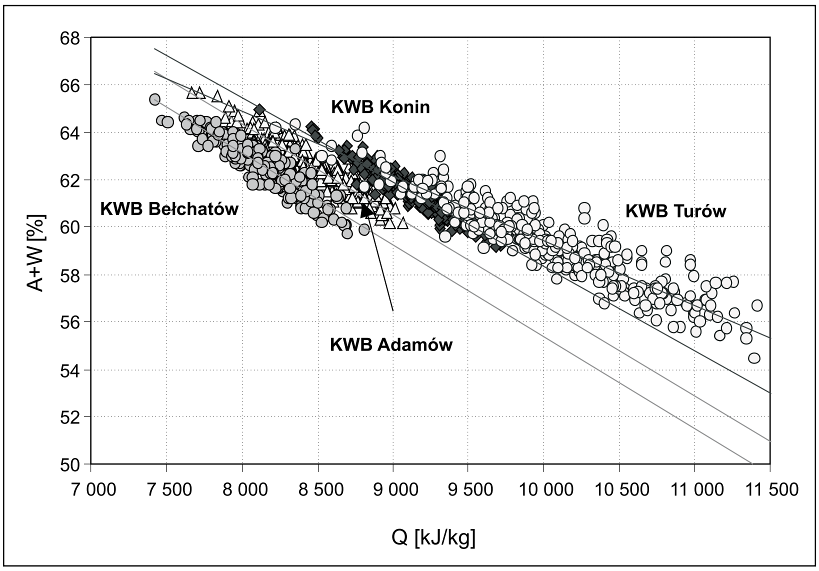

Fig. 5. Dependency between ballast content and calorific value of brown coal from individual mines in 2006.

Rys. 5. Zależność zawartości balastu od wartości opałowej w węglu brunatnym z poszczególnych kopalń w 2006 r.

The reversed dependency, i.e. change of the ballast (A + W) as a function of calorific value is as follows:

- for the Adamów, Bełchatów and Adamów mines, a change in calorific value of 1000 kJ/kg results in a change in ballast content of 3.5–4.2%. In case of all coal, the direction of change exhibits the expected trends, i.e. an increase in calorific value is accompanied by a considerable fall in ballast content;
- for the Turów mine, a change in calorific value of 1000 kJ/kg results in a change in ballast content of around 2.8%.

Certainly, all the equations Q = f(A + W) and (A + W) = f(Q) exhibit the expected trend, i.e. an increase in calorific value with a simultaneous decrease in ballast content. These trends are also evident in the case of hard coal, but they are usually much stronger. For many types of coal from a given mine, equations may be elaborated with an accuracy of over $R^2 > 0.95$ (Lorenz et. al. 2002; Lorenz, Grudziński 1998).

For brown coal, an attempt was also made to calculate the regression equation for the data from all mines. The results are given in Table 7. Correlation is relatively high, as the result for 2006 was $R^2 = 0.86$, and for 2004–2006 – as much as 0.90.

Applying these equations to determine the calorific value will involve an average error of some 270 kJ/kg, whereas the maximum error is almost 1100 MJ/kg. In analysing the dependencies in Fig. 5, it appears more appropriate to use separate equations for the coal from each mine. Although the data for the Konin mine apparently lie in series with those for Turów mine, the correlation calculation results indicate that the coals from these mines have different dependencies of parameters.

In such tests for hard coal, it has also been concluded that the dependencies Q = f(A) are different for coal in individual mines. In one mine, a change of calorific value of 1 MJ/kg

TABLE 7

Results of regression analysis of coal from all mines together

TABELA 7

Wyniki analizy regresji węgla ze wszystkich kopalń łącznie

2004–2006		
Q = –414.43 (A + W) + 34376	414 kJ/kg na 1% (A + W)	$R^2 = 0.90$
(A + W) = –0.00217 Q + 80.69	2.17% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = *7306–12288 kJ/kg*	S_{min}–S_{max} = *0.16–1.44%*	
A_{min}–A_{max} = *4.2–24.5%*	*Number of data – 3714*	
Year 2006		
Q = –412.84 (A + W) + 34344	413 kJ/kg na 1% (A + W)	$R^2 = 0.86$
(A + W) = –0.00209 Q + 80.14	2.09% (A + W) na 1 MJ/kg	
Q_{min}–Q_{max} = *7423–12100 kJ/kg*	S_{min}–S_{max} = *0.16–1.44%*	
A_{min}–A_{max} = *4.2–24.5%*	*Number of data – 1219*	

results in a change in ballast content of around 1.2%, whereas in another, a change of as much as 3.9%. On the other hand, a change in ash content of 1% results in a change in calorific value of around 300 kJ/kg in one mine, and as much as 700 kJ/kg in another. There are sometimes considerable differences for mines exploiting coal from the same seam (Lorenz et al. 2002).

Conclusions

The results of dependencies between qualitative parameters of coal presented above indicate that only the relationship between calorific value and ballast content (i.e. the total ash and moisture content) is in the wider sense statistically significant. This only confirms the linear dependency between these two parameters long known to practitioners. However, as the calculations demonstrate, such dependencies are a little different for coal from each individual mine. It may thus be surmised that, in theory, separate sales formulas should be developed for each mine (for various Q = f(A) dependencies). The basic parameters should also be decided individually for each power plant – mine relationship.

As a result of calculations, equations were presented. Calculated regression coefficients fluctuate in the range of 0.85 to 0.92. Correlation coefficients obtained for the given equations may be regarded as very high. The equations quite reasonably depict the relations which appear between calorific value and ballast content (A + W).

The analysis carried out draws attention to the fact that in determining one parameter in contracts for the supply of coal, other qualitative parameters are determined.

The equations worked out can be a convenient tool for quick prognoses of a given qualitative parameter based on (an) other(s). This applies, in particular, to calorific value, which can quickly be found based on the measurement of ash and moisture content.

In determining pricing structures, it is also extremely important to know the range of fluctuations of qualitative parameters of coal supplied to power plants, since large fluctuations in quality cause similarly large fluctuations in price.

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ANALIZA ZWIĄZKÓW WYSTĘPUJĄCYCH MIĘDZY PARAMETRAMI JAKOŚCIOWYMI W WĘGLU BRUNATNYM

Słowa kluczowe

Węgiel brunatny, parametry jakościowe, zmienność parametrów

Streszczenie

W artykule przeprowadzono analizę zależności pomiędzy parametrami jakościowymi węgli brunatnych dostarczanych do elektrowni. Analizę przeprowadzono w oparciu o uśrednione dane dobowe o jakości dostaw w latach 2004–2006. Podstawowym celem analizy było zbadanie, jakie związki występują między parametrami jakościowymi (podanymi w stanie roboczym): wartością opałową (Q), zawartością siarki (S) oraz zawartością tzw. balastu (łączna zawartość popiołu i wilgotności – A + W)). Jak wykazała analiza nie zaobserwowano wiarygodnej zależności zawartości siarki z pozostałymi parametrami. Uwzględnienie wpływu tego parametrów wiązałoby się z możliwością popełnienia dużych błędów. Najbardziej istotne okazały się związki miedzy wartością opałową i balastem Znalezione relacje, w odniesieniu do wartości opałowej, potwierdzają tendencje, jakich należało oczekiwać i jakie wiążą się z użytkowymi właściwościami węgla brunatnego. Obliczenia regresji przeprowadzono dla zależności Q = f(A + W) oraz (A + W) = f(Q), co pozwoliło ocenić także wartościowo, jak zmiana jednych parametrów wpływa na pozostałe. Obliczenia przeprowadzono dla węgli z poszczególnych kopalń i dla poszczególnych lat oraz dla całej branży węgla brunatnego. W wyniku obliczeń opracowano równania, które z dużą dokładnością oddają związki między wybranymi parametrami jakościowymi.

ANALYSIS OF RELATIONSHIPS BETWEEN THE QUALITATIVE PARAMETERS OF BROWN COAL

Key words

Brown coal, qualitative parameters, changeability of parameters

Abstract

This article analyses the relationships between the qualitative parameters of brown coal supplied to power plants. The analysis was carried out based on averaged daily data on the quality of deliveries between 2004 and 2006. The basic objective of the analysis has been to determine the relationships between the qualitative parameters (as received): calorific value (Q), sulphur content (S) and so-called ballast (total ash and moisture content – [A + W]). As the analysis showed that no reliable relationship between sulphur content and the other parameters was observed. Considering the effect of this parameter would involve the potential for large errors. The most important relationships were found between the calorific value and ballast. The relationships discovered, with reference to calorific value confirm the trends that should be expected and are related to the operating properties of brown coal. Regressive calculations were made for the Q = f(A + W) and (A + W) = f(Q) dependencies, which allowed for the qualitative evaluation of how a change in some parameters affects the others. Calculations were performed for coal from individual mines and for individual years and for the entire brown coal sector. As a result of the calculations, equations were elaborated which, with great accuracy, depict the relationships between selected qualitative parameters.