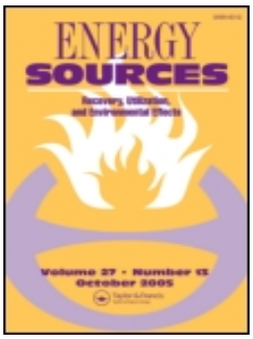

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Prediction of the Calorific Value of Coal Deposit Using Linear Regression Analysis

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Coal quality has prime importance in the production of energy, and thus determining the quality is useful in planning of coal deposit. The prediction of coal quality, especially calorific value, is one of the important parameters. The estimation of calorific value is a complicated problem in coal deposits. In this study, the prediction of calorific value was investigated using linear regression analysis, including simple linear regression analysis and multiple linear regression analysis, and prediction models were developed. Afterward, the developed models were verified with statistical tests. It was concluded that calorific values can reliably be estimated using a multiple linear regression model. The model has practical and economical advantages for mining planning.

Keywords: ash content, calorific value, coal, linear regression analysis, moisture content

1. INTRODUCTION

Energy consumption is one of the important problems for the whole world (Oktay, 2009). While the world population today is four times more than that of the 20th century, the primary energy consumption has grown about 10 times, up to 10,345 mtoe in 2002. In the same year, this amount of energy was mainly achieved from fossil fuels (Ozgur, 2008).

Fossil fuels will continue to dominate the energy supply systems for much of this century. In particular, coal is projected to remain the mainstay of electricity generation in many major economies—especially where coal is the main indigenous, and economically viable, source of energy (Garg and Shukla, 2009). On the eve of the 21st century, Turkey was unable to meet its energy requirement with its limited sources as a result of the increasing population and industrialization and, thus, the deficit between the energy production and energy consumption increased rapidly. Under such conditions, utilizing its own resources more effectively had become more increasingly important day by day. Turkey becomes more dependent on imports year to year. It still supplies about 70% of its primary energy consumption from imported energy sources. It is now vital for Turkey to attach importance to coal and renewable energy sources, which are the largest domestic energy sources of Turkey, in order to meet this increasing energy deficiency (Yilmaz, 2008).

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Coal is one of the most abundant energy resources in the world and its importance as an energy source is increasing as petroleum and gas resources decline. The two most important attributes of coal as an energy resource are quality and quantity (Heriawan and Koike, 2008). Calorific value is the most useful parameter for assessing coal quality. A quick and accurate estimation of the calorific value of coal deposit is of great importance. In this article, the prediction of calorific value using linear regression analysis was investigated. Finally, calorific value was predicted by considering the multiple linear regression model.

2. MATERIAL AND METHOD

2.1. Regression Analysis

The goal of regression analysis is to determine the values of parameters for a function that causes the function to best fit a set of data observations provided. In linear regression, the function is a linear equation. When there is more than one independent variable, multiple linear regression analysis is used to get the best fit equation (Khandelwal and Singh, 2010). The best prediction model is selected while being based on the highest coefficient of determination (R^2) and the probability value (p-value).

2.1.1. Simple Linear Regression Analysis

Simple linear regression analysis attempts to explain the relationship between the dependent variable, y, as a linear function of one independent variable, x. The mathematical equation of the simple linear regression model is in the general form:

$$y = \beta_0 + \beta_1 x, \tag{1}$$

where β_0 donates the regression line intercept, the y axis, and β_1 is the regression coefficient representing the slope of the regression line (Aczel, 1995).

2.1.2. Multiple Linear Regression Analysis

Multiple linear regression analysis explains the relations between the independent variables and dependent variable. The mathematical form of the multiple linear regression is given by Eq. (2):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n, \tag{2}$$

where y is the dependent variable, $x_1, x_2, \ldots, x_n$ are the independent variables, n is the number of independent variables, β_0 is the intercept, and the regression coefficient of descriptors is β_n (Green and Carroll, 1996).

2.2. Study Area

Western Turkey is an area of active continental extension that is characterized by E-W, NE-SW, and NW-SE trending grabens (Kocyigit et al., 1999). Approximately, E-W trending grabens with their intervening horst are the most prominent neotectonic features of western Turkey. These grabens were the sites of detrital sedimentation and pyroclastic accumulation (Gorur, 1998; Yavuz and Nagy, 1997; Turkmenoglu and Isik, 2008).

Kutahya graben is one of the largest and best developed E-W trending grabens of Western Turkey, consisting of Tavsanli and Seyitomer basins (Turkmenoglu and Isik, 2008). Today, Seyitomer basin is rich in coal deposits. The study area is located in the Seyitomer basin in Kutahya (Turkey).

TABLE 1
Descriptive Statistics of Coal Quality Parameters

	Calorific Value	*Ash Content*	*Moisture Content*
Mean	1,822.00	11.35	7.38
Median	1,489.00	8.61	5.54
Minimum	10.00	0.03	0.04
Maximum	4,276.00	28.30	20.73
Std. deviation	235.07	5.12	3.42

2.3. Dataset

In this article, coal quality parameters, such as calorific values, ash content, and moisture content, were obtained from 79 borehole samples. Afterwards, the coal deposit parameters were evaluated by using the linear regression analysis including simple linear regression analysis and multiple linear regression analysis. Descriptive statistics of coal quality parameters were presented in Table 1.

3. RESULTS AND DISCUSSION

The predicting of value by using the linear regression analysis is the most important aspect in mining issues. In this study, linear regression analysis, including simple linear regression analysis and multiple linear regression analysis, was applied to determine the relationship between dependent variable calorific value and independent variables ash content, and moisture content. First, a simple linear regression procedure was applied for ash content versus calorific value. After that, the procedure was carried out for moisture content versus calorific value. The regression line is drawn to show the relations between ash content versus calorific value and moisture content versus calorific value (Figures 1 and 2). The simple linear regression equation is given by Eqs.

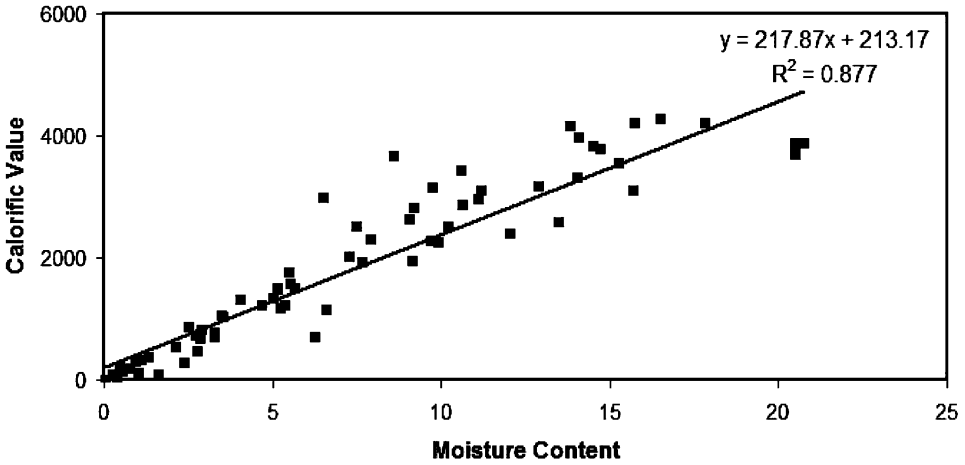

FIGURE 1 Moisture content versus calorific value.

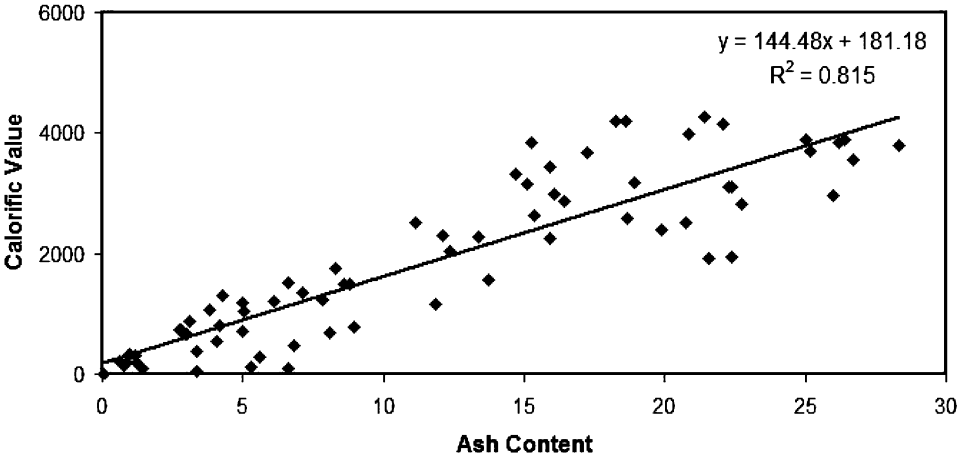

FIGURE 2 Ash content versus calorific value.

(3) and (4). The statistical significance and validity of the equations were checked by using the test statistics:

$$\text{Calorific value} = 213.17 + 217.87 \text{ moisture content}, \tag{3}$$

$$\text{Calorific value} = 181.18 + 144.48 \text{ ash content}. \tag{4}$$

The coefficient of determination (R^2) is a descriptive of the proportion of variance in the dependent variable, which should be estimated from the independent variables. The R^2 calculated for Eq. (3) indicates that 87.7% of the variance in calorific value can be estimated from the moisture content. The probability value (p-value) is the observed level of importance for the test statistic. The analysis of variance of the model gives a p-value of 0.11, which is equivalent to p-value ≥ 0.05. Since this p-value is higher than 0.05, it was concluded that the model is not valid.

R^2, calculated for Eq. (4), shows that 81.5% of the variance in calorific value can be predicted from the variable ash content. The p-value of the model is 0.00, which is equivalent to p-value ≤ 0.05. Since p-value is less than 0.05, it is concluded that there is a statistically significant relation between variables at the 95% confidence interval; thus, the derived model is valid.

Multiple linear regression analysis is applied to produce an alternative model. In this article, multiple linear regression analysis was applied to determine the relationship between dependent variable calorific value and independent variables ash content, and moisture content. The produced model is given by Eq. (5). R^2 value for this model is calculated to be 89.2%. This value is good and indicates a strong relation between the dependent variable and independent variables. In addition, p-value of the model is 0.00, which is equivalent to p-value ≤ 0.05; thus, the model is statistically valid.

$$\text{Calorific value} = 140.00 + 46.40 \text{ ash content} + 156.00 \text{ moisture content}. \tag{5}$$

A comparison of the above models has shown that Eq. (5) is highly superior to that of the other models. Therefore, it is suggested that the model can be used as a determination of the other coal quality parameters, such as ash content and moisture content. For this reason, the regression analysis models may be considered as an effective tool because of their dynamic calculation

feature. This study should be considered to determine the applicability of the multiple linear regression analysis model to examine the coal quality parameters; further improvements should be made for other coal quality parameters.

4. CONCLUSION

Coal is one of the most important fossil fuels in the world. A quick and accurate prediction of calorific values is significant in the determination of coal quality and planning of deposit. An accurate prediction of calorific values helps to make the regression analysis.

In this study, calorific value, ash content, and moisture content were evaluated using regression analysis, such as simple linear regression analysis and multiple linear regression analysis. Regression analysis results showed that the multiple regression model is seen as the best model. The determination R^2 of the multiple regression model is 89.2%. This value is good and identifies the valid model. This result reveals the usefulness of a multiple linear regression model in the prediction of calorific value. These models are decision makers that examine coal deposit parameters, such as calorific value, ash content, and moisture content, in order to manage the coal deposit.

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