



TECHNICAL CHARACTERISTICS OF COAL AND THEIR RELATIONSHIP WITH ORIGINAL CONDITION OF SOME COAL MINE IN NORTHEASTERN AREA, VIETNAM

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Abstract

This paper presents some statistical results of calculating the correlation coefficient of technical characteristics including content of gross calorific value, volatile matter, moisture, ash and sulfur among the coal mines of Na Duong (Lang Son), Ho Thien (Dong Trieu - QN); Khanh Hoa (Thai Nguyen); Thung Than (Nam Mau - QN); Mong Duong (Cam Pha - QN); Uong Thuong (Uong Bi - QN). The analytical results show that the correlation coefficient of technical characteristics of coals from various coal mines is not high. The correlation coefficient of gross calorific value R^2 is 0,83; the correlation coefficient of volatile matter R^2 is 0,50; the correlation coefficient of moisture R^2 is 0,17; the correlation coefficient of ash R^2 is 0,69 and the correlation coefficient of sulfur R^2 is 0,91. The value of the physical characteristics of coal at each coal mine clearly reflects the original conditions of ancient geography, biochemistry and tectonic activity of the Earth's crust.

Keywords: Calorific value; Volatile matter; Moisture; Ash; Sulfur.

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1. Introduction

Coal quality is assessed through their technical characteristics according to the criterion of Vietnamese. This paper considers the technical characteristics of coal, such as: calorific value, volatile matter, moisture, ash and sulfur [3]. These characteristics are classified according to the size of grain for the breeze, cobble, peat, etc. Technical characteristics are calculated separately for each different mine as follows:

- The absolute value of the calorification is calculated as calorie,

in the unit of solid fuel mass designated as a dry state and burned with oxygen in the bomb under standard conditions. The fired product consists of oxygen, nitrogen, carbon dioxide, sulfur dioxide and water (equivalent to the saturated carbon dioxide under reaction in bombs) and solid ash.

- Calorification material is the percentage of gases and vapors, subtracted by the moisture content, which is released from the fuel into the environment without air at standard conditions, compared with the fuel attributed dry.

- Moisture content is the percentage of outside water and water in dried samples compared to moisture content sample. Outside water is the water, which is released from the sample when dried under standard conditions to equilibrium with atmospheric moisture content. Water in the dried sample is the amount of capillary water, connected to the residual fuel when the sample is in equilibrium with the moisture content of the atmosphere environment.

- The ashes are the unburnt mineral part after burning the coal completely at specified conditions, calculated according to the percentage of the amount of coal attributed to the dry state.

- Synthesis of sulfur forms in dry coal samples is determined under standard conditions.

The value of the technical characteristics obtained is the basis for using reasonable coal and has been considered in previous studies [1, 2 and 4 - 8]. However, the comparative studies of these technical characteristics among coal mines or in different areas in relation to their origins have not been mentioned.

This study introduces an application of correlation method on technical characteristics among some coal mines in Vietnam, such as Ho Thien, Mong Duong, Than Thung, Uong Thuong, Na Duong, and Khanh Hoa, which are compared to each other to indicate their relationship to the formation origin.

2. Methods and material

2.1. Correlation analysis

Correlation analysis is used to express the relation between the coal technical characteristics of coal mines in the Northeastern, Vietnam and some other coal mines in the other areas. The correlation (R) value is calculated from the Excel program of Office 2010. The correlation value (R) has no unit, it is calculated from the encoded value of the linear transformation of X and Y. The R-value always changes within (-1) and (1). If the correlation coefficient (R) is positive, it will indicate that X and Y fluctuate in the same direction and negative is the opposite.

To express the degree of relationship between variables, the R-value is determined as below:

R = 1, the relationship between variables is completely tight.

R = 0, is unrelated variables.

2.2. Material

The technical characteristics of coal in terms of calorific value, volatile matter, moisture, ash, sulfur, and etc., were collected in synthesis reports of the coal mines in Mong Duong, Ho Thien, Than Thung, Uong Thuong, Khe Tam, Na Duong, and Khanh Hoa.

3. Results: Comparative studies of technical characteristics in some coal mines in the Northeast Mountains, Vietnam

3.1. Calorific value

Table 1 shows that the calorific value of the coal mines of Ho Thien, Mong Duong, Than Thung, Uong Thuong, Na Duong, and Khanh Hoa.

Table 1. Calorific values of coal at some coal mines in the Northeast Mountains, Vietnam

| Name of mines | Mines index | Calorific values (Kcal) | | | |
|----------------------------|-------------|-------------------------|-------|---------|-------|
| | | Min | Max | Average | DC |
| Na Duong (Lang Son) | ND | 3.750 | 6.998 | 5.374 | 3.248 |
| Ho Thien (Dong Trieu - QN) | HT | 4.314 | 6.060 | 5.687 | 2.746 |
| Khanh Hoa (Thai Nguyen) | KH | 3.096 | 8.503 | 5.800 | 5.407 |
| Than Thung (Nam Mau - QN) | TT | 3.844 | 7.935 | 5.890 | 4.091 |
| Mong Duong (Cam Pha - QN) | MD | 3160 | 8.654 | 5.907 | 5494 |
| Uong Thuong (Uong Bi - QN) | UT | 4.433 | 8.714 | 6.574 | 4.281 |

Calorific values of coal in Tab. 1 are plotted in the chart of Fig. 1.

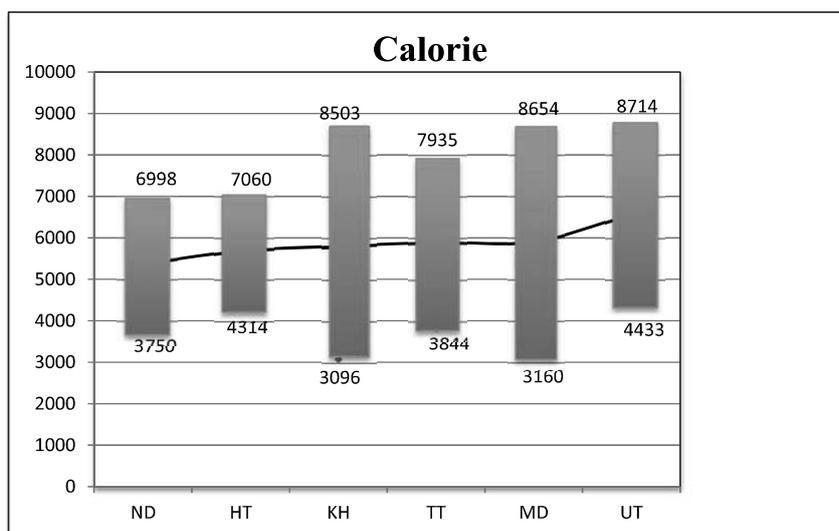


Figure 1: Chart of calorific values at some coal mines in the Northeast Mountains, Vietnam

Figure 1 shows that the calorific values among the coal mines are different. They vary from 2.75% at the Ho Thien (HT) coal mine to 5.49% the Mong Duong (MD). However, the average correlation coefficient among them is good ($R^2 = 0,83$), reflects clearly the upward trend in order among the mines (Fig. 2).

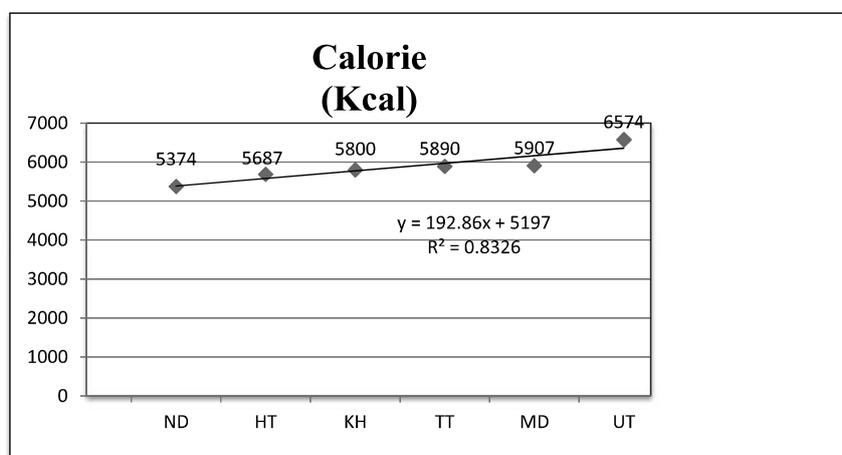


Figure 2: Correlation diagram of calorific values at some coal mines in Northeast Mountains, Vietnam

3.2. Volatile matter

Volatile matter values at some coal mines in the Northeast Mountains, Vietnam are listed in Tab. 2.

Table 2. Volatile matter value at some coal mines in the Northeast Mountains, Vietnam

| Name of mines | Mines index | Volatile matter | | | |
|----------------------------|-------------|-----------------|-------|-------|-------|
| | | Min | Max | Aver | DC |
| Na Duong (Lang Son) | ND | 18.32 | 78.33 | 48.33 | 60.01 |
| Ho Thien (Dong Trieu - QN) | HT | 2.95 | 11.29 | 7.12 | 8.34 |
| Khanh Hoa (Thai Nguyen) | KH | 2.03 | 49.17 | 25.60 | 47.14 |
| Than Thung (Nam Mau - QN) | TT | 1.10 | 11.84 | 6.47 | 10.74 |
| Mong Duong (Cam Pha - QN) | MD | 3.00 | 11.98 | 7.49 | 8.98 |
| Uong Thuong (Uong Bi - QN) | UT | 1.10 | 11.84 | 6.47 | 10.74 |

The volatile matter values in Tab. 2 are plotted on the graph in Fig. 3.

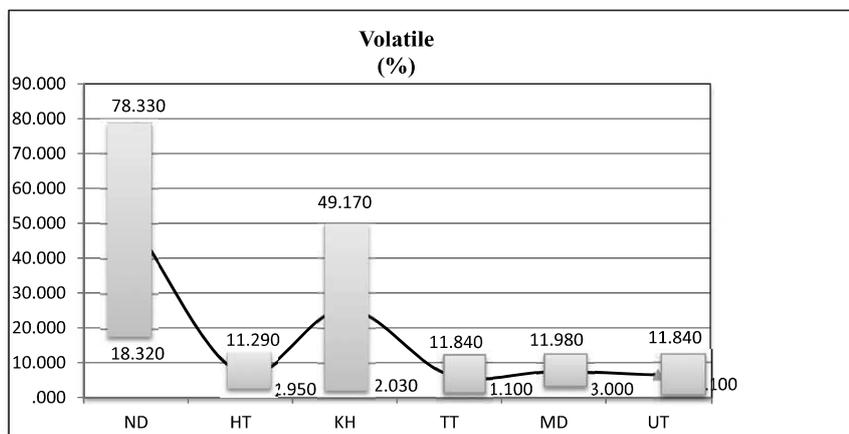


Figure 3: Chart of volatile matter at some coal mines in the Northeast Mountains, Vietnam

Fig. 3 shows that they have greatest variations at the coal mines of Na Duong (60,01%), Khanh Hoa (47,14%), and a minimum variation at Ho Thien (8,34%). The variation of volatile matter at the coal mines in the Northeast Mountains, Vietnam is not ruled, which made the correlation among them is only average ($R^2 = 0,50$) (Fig. 4).

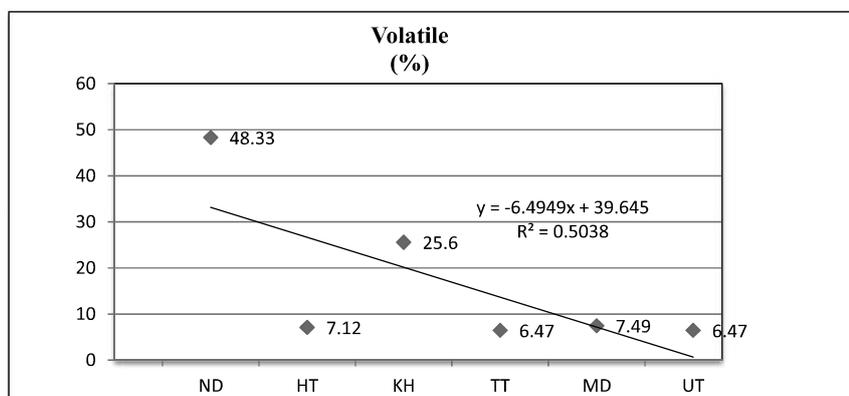


Figure 4: Graph of the correlation coefficient of volatile matter at some coal mines in the Northeast Mountains, Vietnam

3.3. Moisture

Moisture values at some coal mines in the Northeast Mountains, Vietnam are listed in Tab. 3.

Table 3. Moisture values at some coal mines in the Northeast Mountains, Vietnam

| Name of mines | Mines index | Moisture (%) | | | |
|----------------------------|-------------|--------------|------|------|------|
| | | Min | Max | Aver | DC |
| Na Duong (Lang Son) | ND | 4.44 | 5.98 | 5.21 | 1.54 |
| Ho Thien (Dong Trieu - QN) | HT | 1.64 | 5.27 | 3.46 | 3.63 |
| Khanh Hoa (Thai Nguyen) | KH | 0.1 | 3.5 | 1.80 | 3.40 |
| Than Thung (Nam Mau - QN) | TT | 1.3 | 5.87 | 3.59 | 4.57 |
| Mong Duong (Cam Pha - QN) | MD | 0.1 | 4.47 | 2.29 | 4.37 |
| Uong Thuong (Uong Bi - QN) | UT | 1.3 | 6.08 | 3.69 | 4.78 |

Moisture values at some coal mines are plotted in Fig. 5.

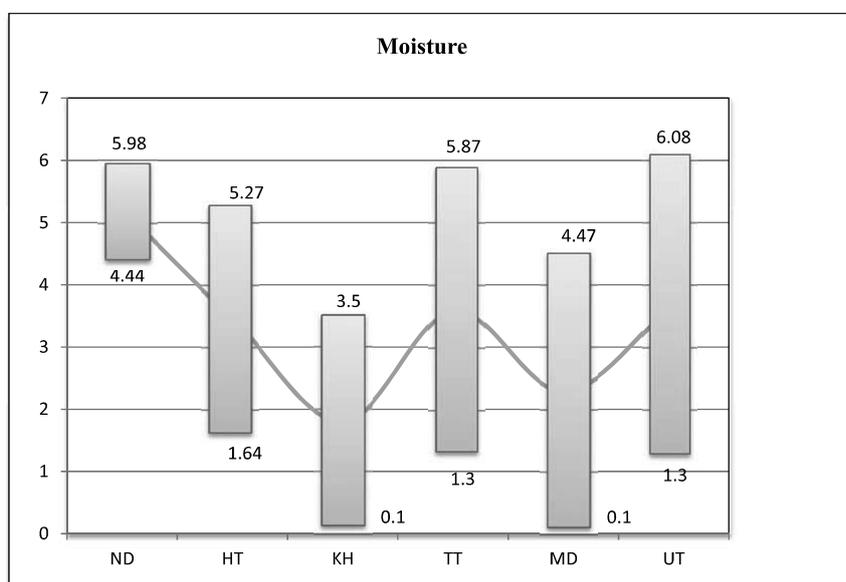


Figure 5: Chart of moisture at some coal mines in the Northeast Mountains, Vietnam

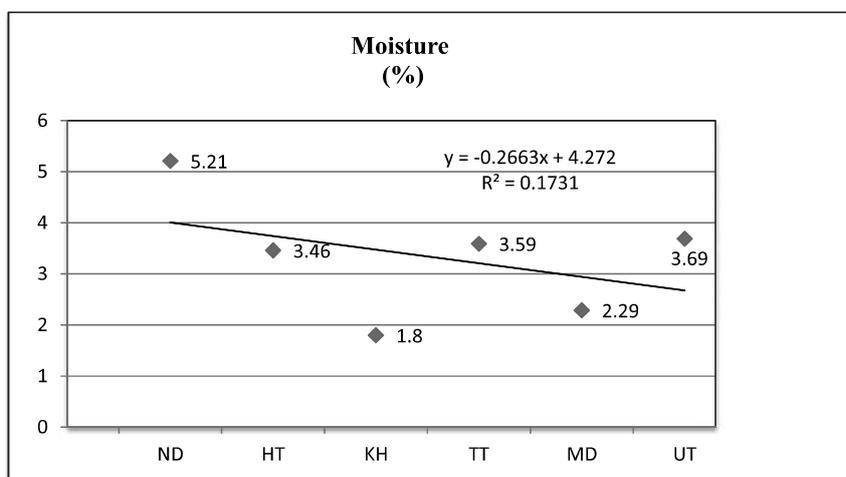


Figure 6: Graph of the correlation coefficient of moisture at some coal mines in the Northeast Mountains, Vietnam

Fig. 5 and figure 6 show that the moisture values change the maximum at Uong Thuong coal mine (3,78%) and minimum at Na Duong coal mine (1,54%). The correlation coefficient moisture is $R^2 = 0,17$. The greater the moisture content, the lower the quality of coal.

3.4. Ash

Ash value at some coal mines in the Northeast Mountains, Vietnam is listed in Tab. 4.

Table 4. Ash value at some coal mines in the Northeast Mountains, Vietnam

| Name of mines | Mines index | Ash (%) | | | |
|----------------------------|-------------|---------|-------|-------|-------|
| | | Min | Max | Aver | DC |
| Na Duong (Lang Son) | ND | 13.30 | 36.86 | 25.08 | 23.56 |
| Ho Thien (Dong Trieu - QN) | HT | 12.20 | 39.17 | 25.69 | 26.97 |
| Khanh Hoa (Thai Nguyen) | KH | 1.99 | 39.77 | 20.88 | 37.78 |
| Than Thung (Nam Mau - QN) | TT | 2.02 | 39.29 | 21.45 | 35.68 |
| Mong Duong (Cam Pha - QN) | MD | 1.11 | 39.96 | 20.54 | 38.85 |
| Uong Thuong (Uong Bi - QN) | UT | 2.02 | 39.53 | 20.78 | 37.51 |

The ash value of Table 4 is plotted in Fig. 7.

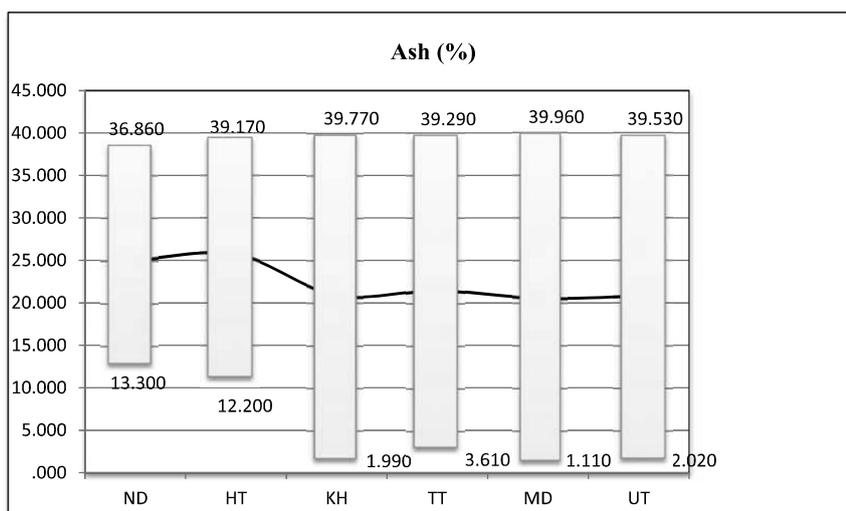


Figure 7: Chart of ash at some coal mines in the Northeast Mountains, Vietnam

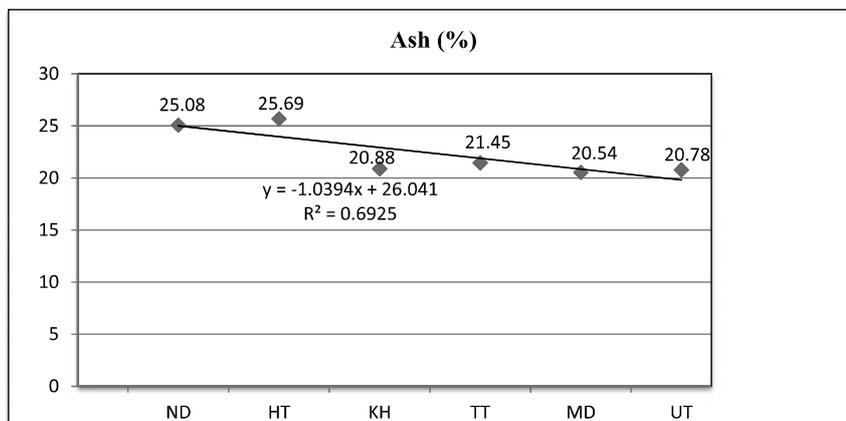


Figure 8: Graph of the correlation coefficient of ash in some coal mines in the Northeast Mountains, Vietnam

Fig. 7 show that the ash value fluctuates around 23 - 38%. The high ash value reduces the calorific value and quality of the coal. In the coal seams of these mines, there are usually clay layers: argillite, coal clay and siltstone, which will increase the ash value. The correlation coefficient between them is $R^2 = 0.69$ (Fig. 8).

3.5. Sulfur

The sulfur content of some coal mines in the Northeast area is listed in Tab. 5.

Table 5. The sulfur content of some coal mines in the Northeast Mountains, Vietnam

| Name of mines | Mines index | Sulfur (%) | | | |
|----------------------------|-------------|------------|------|------|------|
| | | Min | Max | Aver | DC |
| Na Duong (Lang Son) | ND | 1.20 | 9.93 | 5.57 | 8.73 |
| Ho Thien (Dong Trieu - QN) | HT | 0.33 | 9.63 | 4.98 | 9.30 |
| Khanh Hoa (Thai Nguyen) | KH | 0.44 | 6.56 | 3.50 | 6.12 |
| Than Thung (Nam Mau - QN) | TT | 0.30 | 4.94 | 2.62 | 4.64 |
| Mong Duong (Cam Pha - QN) | MD | 0.31 | 1.30 | 0.81 | 0.99 |
| Uong Thuong (Uong Bi - QN) | UT | 0.21 | 2.88 | 1.55 | 2.67 |

The sulfur value of Tab. 5 is plotted in Fig. 9.

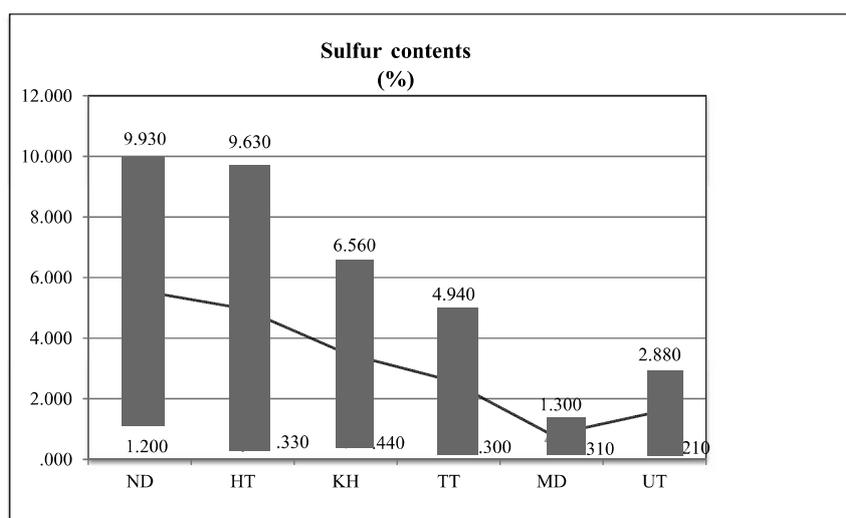


Figure 9: Chart of sulfur content at some coal mines in the Northeast Mountains, Vietnam

Fig. 9 show that the sulfur content fluctuations is quite large and different among the mines. The largest change in sulfur content is at Ho Thien (9.30%), Na Duong (8.73%) and lowest at Mong Duong (0.99%). The presence of sulfur will harm the mine because sulfur fires produce sulfur dioxide, SO_2 or SO_3 , which is soluble to create H_2SO_4 acid, causes metal corrosion. Coal mines in the Quang Ninh area and Bac Giang belong to the group of mines with low sulfur content which does not affect the quality of coal. The correlation value among them is very large with $R^2 = 0.91$ (Fig. 10).

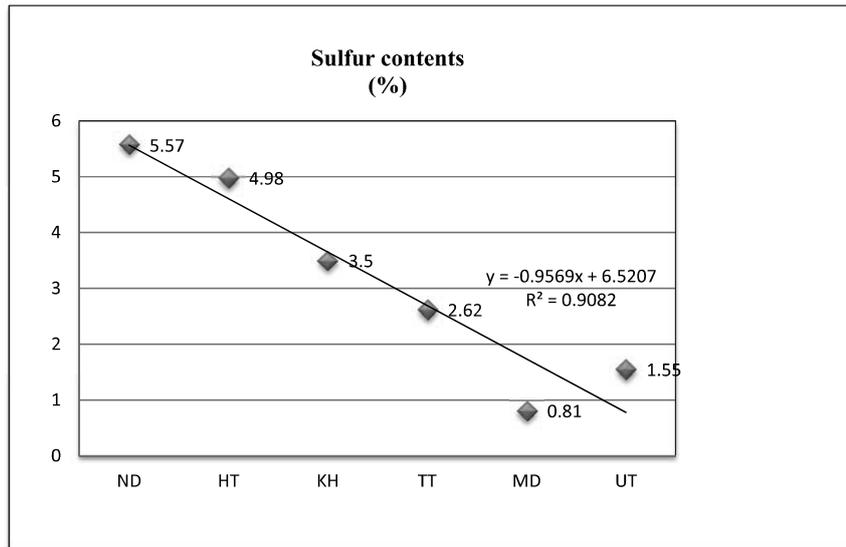
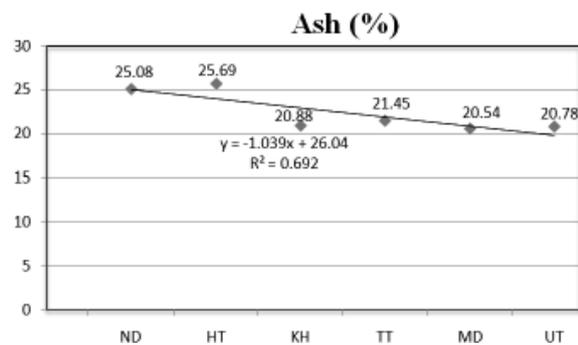
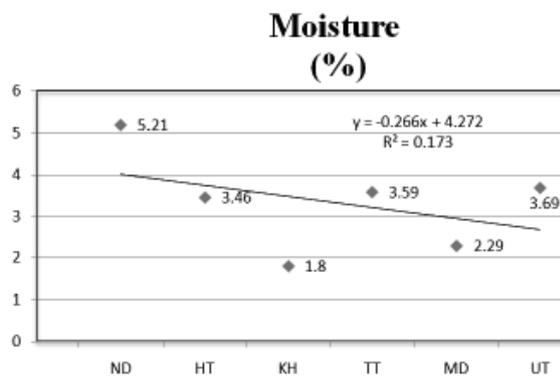
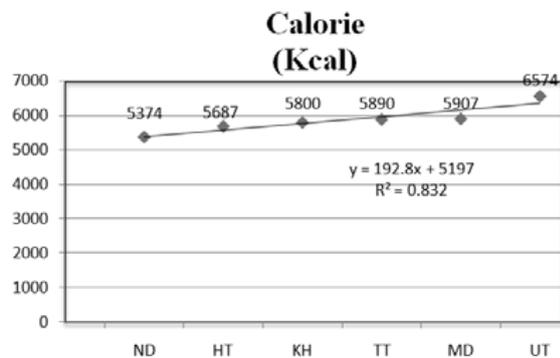
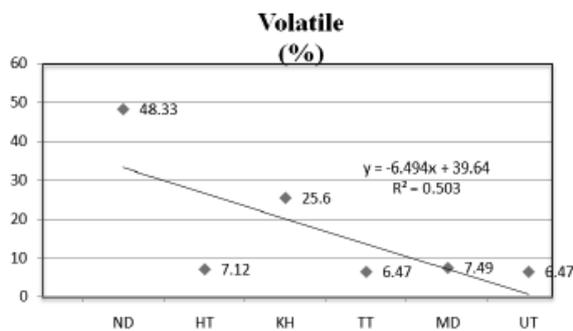


Figure 10: Graph of the correlation coefficient of sulfur at some coal mines in the Northeast Mountains, Vietnam

4. Conclusion and discussions

The comparative results of coal characteristics shows that the relative calorific values are the inverse ratio to the volatiles, moisture, ash, and sulfur, which reflects their relationship in practice (Fig. 11). This is to be explained

that the higher the carbon content, the higher the calorific value and the older formation, the higher the carbon content. The carbon content is strongly dependent on the degree of metamorphism of coal. The higher metamorphic coal, the bigger the carbon content.



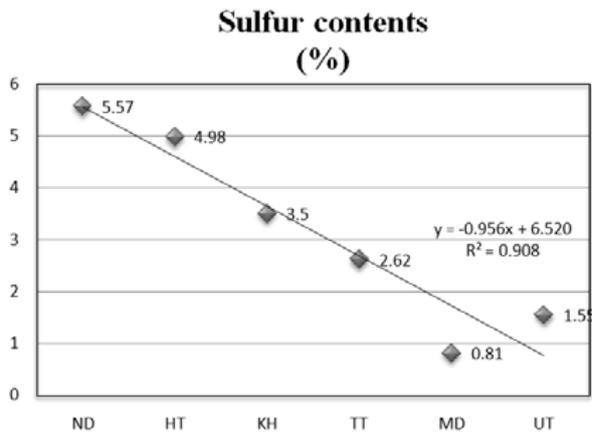


Figure 11: Graph of the correlation coefficient of technical characteristics at some coal mines in the Northeast Mountains, Vietnam

In addition to the above reasons, the changes in technical characteristics are also influenced by the formation age, such as the Na Duong coal mine being formed at the Neogene age, which is younger than the Triassic formations of the mines in the Northeast Mountains, Vietnam so their volatiles content is high. Northeastern coal mines, Triassic-formed, which is mainly anthracite coal, have increased levels of metamorphism towards the center of the coal basin. While the Na Duong coal mine was formed in the age of Neogene and is mainly lignite coal, some mines due to higher metamorphism, reached the pitch coke level. This coal quality is bad due to the high amount of ash and sulfur. The difference between the Na Duong coal mine and the Northeast coal mines, Vietnam is the sulfur content.

These two areas have the same forming environment, but the sulfur content is distinctly different. The coal in the Na Duong coal mine belongs to the high sulfur coal (5.57%) and the mines in the Northeast Mountains, Vietnam. The sulfur content is small and ranges from 0.81 to 2.62%.

The metamorphic process changed all the properties of coal. Metamorphism level can be expressed by various criteria of both physical and chemical categories. Belonging to the group of chemical

criteria, including, the content of carbon, hydrogen, volatile matter, moisture, etc., and the group of physical criteria, including, hardness, density, light, and etc. Variable speed of the indicators is not the same between the stages.

Many coal metamorphic processes in different coal basins in the world show that the coal has varied levels of metamorphism, distributed according to certain rules.

Some research results show that the degree of metamorphism of coal in each area depends on their stratigraphy and depth. The coal seams in the Northeastern area are undergone many various stages of metamorphism. This coal layer is deeply submerged under the high temperature and pressure, which causes an increase of the level of coal metamorphism according to the depth of stratigraphy. In addition, the displacement of the big faults with high amplitude can significantly change the metamorphic law of coal.

5. Conclusions

The statistical results and comparison of technical characteristics of coal mines in the Northeast region show that the content of volatile matter, moisture, ash, sulfur at coal mines: Na Duong (Lang Son); Ho Thien (Dong Trieu - QN); Khanh Hoa (Thai Nguyen); Thung Than

(Nam Mau - QN); Mong Duong (Cam Pha - QN); Uong Thuong (Uong Bi - QN) has a large difference and the correlation coefficient among them is not high.

- Calorific values are not similar among coal mines. They are 2.75% at Ho Thien (HT) and 5.49% at Mong Duong (MD) coal mine. Their correlation coefficient of average among coal mine is relatively high ($R^2 = 0.83$).

- The value of volatile varies greatly in Mong Duong coal mine (60.01%), Khanh Hoa coal mine (47.14%) and Ho Thien coal mines (8.34%). The fluctuation of volatile value causes the correlation coefficient which is $R^2 = 0.50$.

- The highest variety of moisture content in coal mines in the Quang Ninh coal basin (3.63 - 4.78%) and lowest in Na Duong coal mine (1.54%) cause the correlation among them of $R^2 = 0.17$.

- The ash value varies in the range of 23 - 38%. The high ash values will reduce the calorific value and the quality of coal. In the coal seams of these mines, there are usually clay layers: argillit, coal clay, siltstone, which cause the ash of coal increasingly. The correlation coefficient among them is $R^2 = 0.69$.

- The sulfur content varied between the largest at Ho Thien coal mine (9.30%) and the lowest at Mong Duong (0.99%). The largest correlation coefficient among them is 0.91.

Each period creates one type of coal that is produced by the coal material, condition of ancient geography, environment and tectonic activities of the Earth's crust and etc.

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