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# Investigating the effect of coal macerals on the recovery rate of the flotation process- a case study

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# INVESTIGATING THE EFFECT OF COAL MACERALS ON THE RECOVERY RATE OF THE FLOTATION PROCESS- A CASE STUDY

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*Abstract*: Alborz-Sharghi coal washing plant is one of the most significant coal producers in Iran, which has a low recovery rate in the flotation process. This paper investigates the effect of coal macerals types on the flotation recovery rate. For this purpose, a comprehensive sampling procedure was conducted on the feed of the flotation system. Afterwards, the required polished sections of the samples were prepared for detecting the macerals. After conducting a series of flotation tests on the samples, the recovery rate results were compared based on detected macerals on the polished sections. The results revealed that the flotation recovery rate increased with the rising vitrinite contents. However, it decreased with increasing fusinite and liptinite contents.

## BACKGROUND

Alborz-Sharghi coal washing plant is one of Iran's most significant coal plants, established in 1974. It is located in northeastern Damghan, 57 km from Shahrood, between Tazareh and Mehmandoost. The coals extracted from coal mines in the area, including governmental mines such as Tabas, Tazareh, Razi, and other private mines, are transported to this plant for the washing process. The clean coal of this plant is the primary source of the produced coke needed by the Isfahan Steel Company, which is the largest in the Middle East (Jodeiri Shokri & Zare Naghadehi, 2018). **Figure 1** shows the current flowsheet of the processing circuit of the plant.

As seen from the figure, the jig and the flotation system are the two main processes for washing coal. First, the feed of flotation cells with a particle size of -1 mm is conducted in two conditioners where some frothers (Pine oil) and collectors (Fuel oil) are added. However, the MIBC is recently used instead of gasoline in the flotation circuit. Next, the flotation circuit consists of seven rows, including three cells involved in four scavenger cells and three rafer cells. Finally, the concentrate is sent to a conveyor of washed coals. Also, flotation tailings enter the tailings dam (Mejlej et al., 2015).

Along with environmental issues related to the Alborz-Sharghi coal washing plant, specifically on detecting, monitoring, and predicting contaminant plumes resulting from the Alborz-Shaghi coal washing process by applying various geochemical and geophysical methods (Moradzadeh et al. (2007); Doulati Ardejani et al. (2008) (a) and (b); Doulati Ardejani et al. (2011); Shafaei et al. (2016); Hadadi et al. (2021); Jodeiri Shokri et al. (2014) (a), (b), (c); Jodeiri Shokri et al. (2016) (a), (b), (c) and (d); Jodeiri Shokri et al. (2022)), several research works have been conducted on the circuit, due to the low rate of the coal washing process of the plant, less than 50%, in the last decade. For instance, Kor et al. (2010) studied particle size effects on the distribution of coal flotation kinetics. Ghasemi et al. (2014) examined the effect of different coal types on overall plant recovery. For this, fed, including five different coal mines of the region, were collected and studied. Then, five controllable operational parameters, such as collector dosage, frother dosage, solid percentage content and particle size, were chosen for further investigation. They found that the recovery rate increased by decreasing the solid contents. Mejlej et al. (2016) determined an optimum operational condition for the flotation process considering four different operational variables, including the collector dosage (Fuel oil), the frother dosages (MIBC), the pulp density percentage and the impeller speed. After collecting the required samples, a series of comprehensive experimental tests were examined based on the Taguchi method. They found that the total recovery rate increased with increasing the collector dosage and decreased with increasing pulp density consumption in the circuit. Finally, Jodeiri Shokri and Zare Naghadehi (2018) investigated the potential of applying spiral separators on the plant's circuit. After collecting the required samples, they considered four different operational variables, including the feed size distribution, the feed pulp density

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and the feed rate with three levels of low, base, and high values. Afterwards, they conducted 27 experimental tests based on the Taguchi method. They found that the optimum recovery of the spirals occurred at a high level of pulp density and low levels of feed size distribution and feed rate.

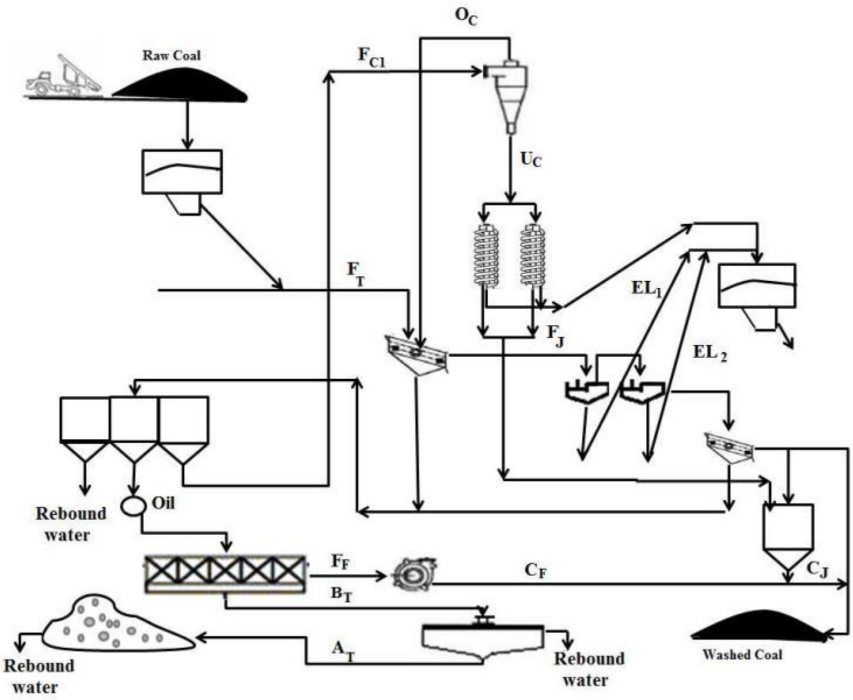



**Figure 1: Processing circuit of the Alborz-Sharghi coal washing plant (Fattahi Mejlej et al. 2015)**

Although several research works have been conducted on the modifying and increasing recovery rate of the Alborz-Sharghi coal washing plant circuit, the literature reviews revealed a necessity to study and investigate the role of the maceral types on the recovery rate of the flotation circuit. Therefore, the main objective of this paper is to answer the following question: how the types of macerals of the flotationcell feed can affect the recovery of the flotation process?

## MATERIALS AND METHODS

### CURRENT RECOVERY RATE OF THE ALBORZ-SHARGHI COAL PLANT

In the first step, several samples were obtained from the feeds of the overflow of the primary classifier, concentrate, and flotation circuit to determine the current recovery rate of the plant. The samples were collected on four different days. These samples were then transported to the Shahrood University of Technology laboratory for further investigations. The results of the different days are given in **Table 1**.

**Table 1: The results of the ash contents of the coal samples**

| Sampling location | Sample No. | Ash content (%) | Average (%) |
|---|---|---|---|
| **The feed of the flotation** | 1 | 43.30 | 41.05 |
| | 2 | 44.10 | |
| | 3 | 36.21 | |
| | 4 | 40.88 | |
| **Tailings** | 1 | 60.63 | 57.28 |
| | 2 | 58.90 | |
| | 3 | 53.81 | |
| | 4 | 55.78 | |
| **Concentrate** | 1 | 18.90 | 20.95 |
| | 2 | 21.84 | |
| | 3 | 23.08 | |
| | 4 | 19.97 | |

After determining the ash contents in samples, averaging and inserting them into the recovery equation, the values of recovery rates of concentration in the overflow, discharge, and total recovery were 59.91%, 77.20%, and 46.25%, respectively.

## SAMPLING PROCEDURE

One hundred coal samples, 2 kg each, were taken from the feed of the flotation circuit of the Alborz-Sharghi coal washing plant. Then, the representative samples were transported to the laboratory of mineral processing to determine the values of the variables, including ash content (A), volatile matter (V), and plasticity (P). The results of the primary analysis of the samples are presented in **Table 2**.

**Table 2: Results of analysis of the coal samples (in percentage)**

| Variable / Sample types | Ash content (%) with a 95% confidence level | Volatile matter (%) with a 95% confidence level | Plasticity (%) with a 95% confidence level |
|---|---|---|---|
| **Collected** | (40.77; 47.52) | (29.54; 32.83) | (14.25; 15.66) |

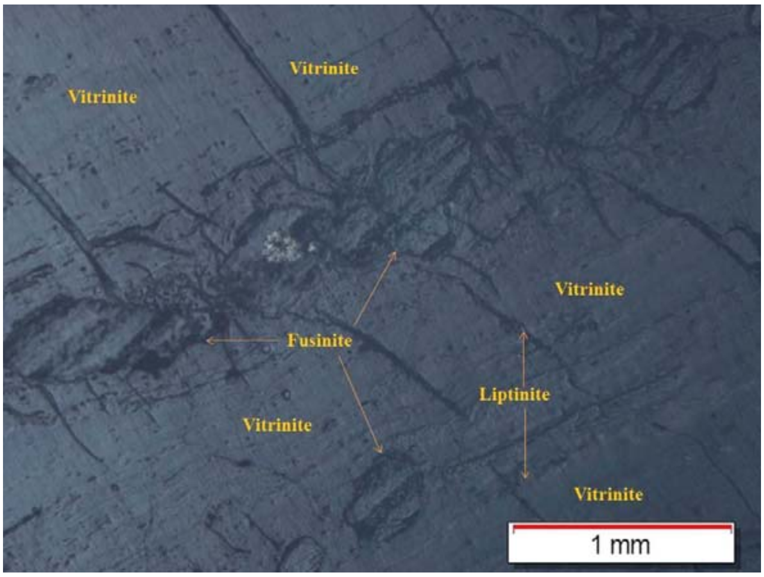
## RESULTS AND DISCUSSIONS

## DETECTING MACERALS IN THE SAMPLES

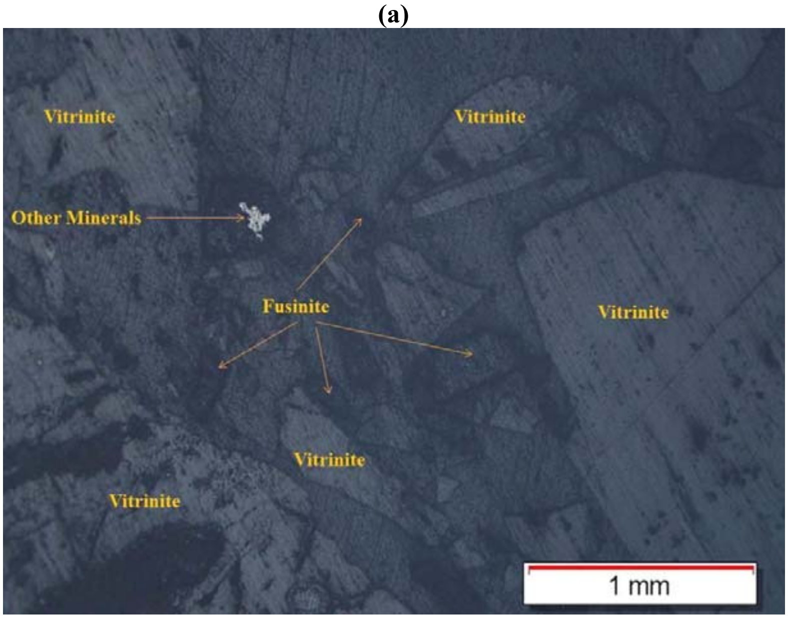
Before conducting flotation experiments, it was crucial to determine the macerals' types in the samples. For this purpose, the required standard polished sections were prepared from all collected samples. The sections were then examined by optical microscopy (reflected light microscope) to detect each section's macerals contents (%). Indeed, this procedure was necessary to find any likely relationship between the type of macerals and the flotation recovery rate. The measurements were based on the point count procedure (ISO 7404-3). This method counts on the block based on a total of at least 500 points. Then, the next block was examined by one step in the left-to-right direction. After that, the required images were taken by magnifying 1000 microns from each polished section to determine the macerals. Then, macerals were detected regarding various colour zones. Afterwards, the relative percentage of each maceral was determined based on the pointing count method. **Figure 2** shows the microscopical images of polished sections to study maceral types. The relative percentages of macerals in the samples are given in **Table 3**. Results revealed that the most abundant macerals in the samples were vitrinite, fusinite, and liptinite, respectively.

**Table 3: The relative percentages of macerals in the samples**

| Sample No. | Vitrinite (%) | Fusinite (%) | Liptinite (%) | Other minerals (%) |
|---|---|---|---|---|
| 1 | 67.7 | 11.8 | 4.3 | 16.2 |
| 2 | 59.5 | 22.3 | 2.5 | 15.7 |
| 3 | 56.1 | 19.6 | 5.6 | 18.7 |
| 4 | 50.4 | 24.2 | 8.4 | 17.0 |
| 5 | 54.3 | 20.9 | 7.7 | 17.1 |
| 6 | 53.8 | 23.6 | 8.6 | 14.0 |
| 7 | 61.1 | 15.7 | 3.4 | 19.80 |
| 8 | 53.9 | 19.9 | 6.8 | 19.4 |
| 9 | 49.6 | 24.8 | 7.3 | 18.3 |
| 10 | 63.4 | 13.9 | 8.1 | 14.6 |
| 11 | 68.5 | 12.8 | 5.2 | 13.5 |
| 12 | 57.0 | 20.1 | 4.2 | 18.7 |
| 13 | 59.50 | 23.4 | 7.5 | 9.6 |
| 14 | 56.3 | 14.6 | 6.3 | 22.8 |
| 15 | 48.7 | 19.2 | 5.8 | 26.3 |
| 16 | 53.4 | 13.7 | 8.3 | 24.6 |
| 17 | 49.7 | 27.3 | 9.1 | 13.9 |
| 18 | 55.4 | 16.8 | 6.0 | 21.8 |
| 19 | 63.1 | 25.9 | 7.5 | 3.5 |
| 20 | 52.6 | 24.2 | 9.3 | 13.9 |




(a)




(b)

**Figure 2: Three types of macerals, including vitrinite, fusinite, and liptinite in the polished sections**

## THE RELATIONSHIP BETWEEN FLOTATION RECOVERY AND MACERALS

After determining the flotation recovery rate in each sample, the relationship between floating ability and macerals types was suggested. **Figure 2** shows the relationships between flotation recovery rates and macerals type, including vitrinite, fusinite, and liptinite.

The relationships between the flotation recovery rates and vitrinite, fusinite, and liptinite are given in equations (1) to (3), respectively:

$$\text{Flotation Recovery (\%)} = 1.04 \times \text{Vitrinite (\%)} - 24.92 \quad (1)$$

$$\text{Flotation Recovery (\%)} = -1.45 \times \text{Fusinite (\%)} + 63.3 \quad (2)$$

$$\text{Flotation Recovery (\%)} = -2.73 \times \text{Liptinite (\%)} + 52.82 \quad (3)$$

The values of determination coefficients, R-squared, of the suggested relationships between the flotation recovery rate and vitrinite, fusinite, and liptinite are 0.57, 0.30, and 0.35, respectively

The comparison between the results described that the recovery rate increased with increasing vitrinite, and decreased with rising liptinite and fusinite contents. It is worth noting that the slope values of the liptinite contents were higher than the vitrinite and fusinite. The floating ability of the samples seemed dependent on this type of maceral.

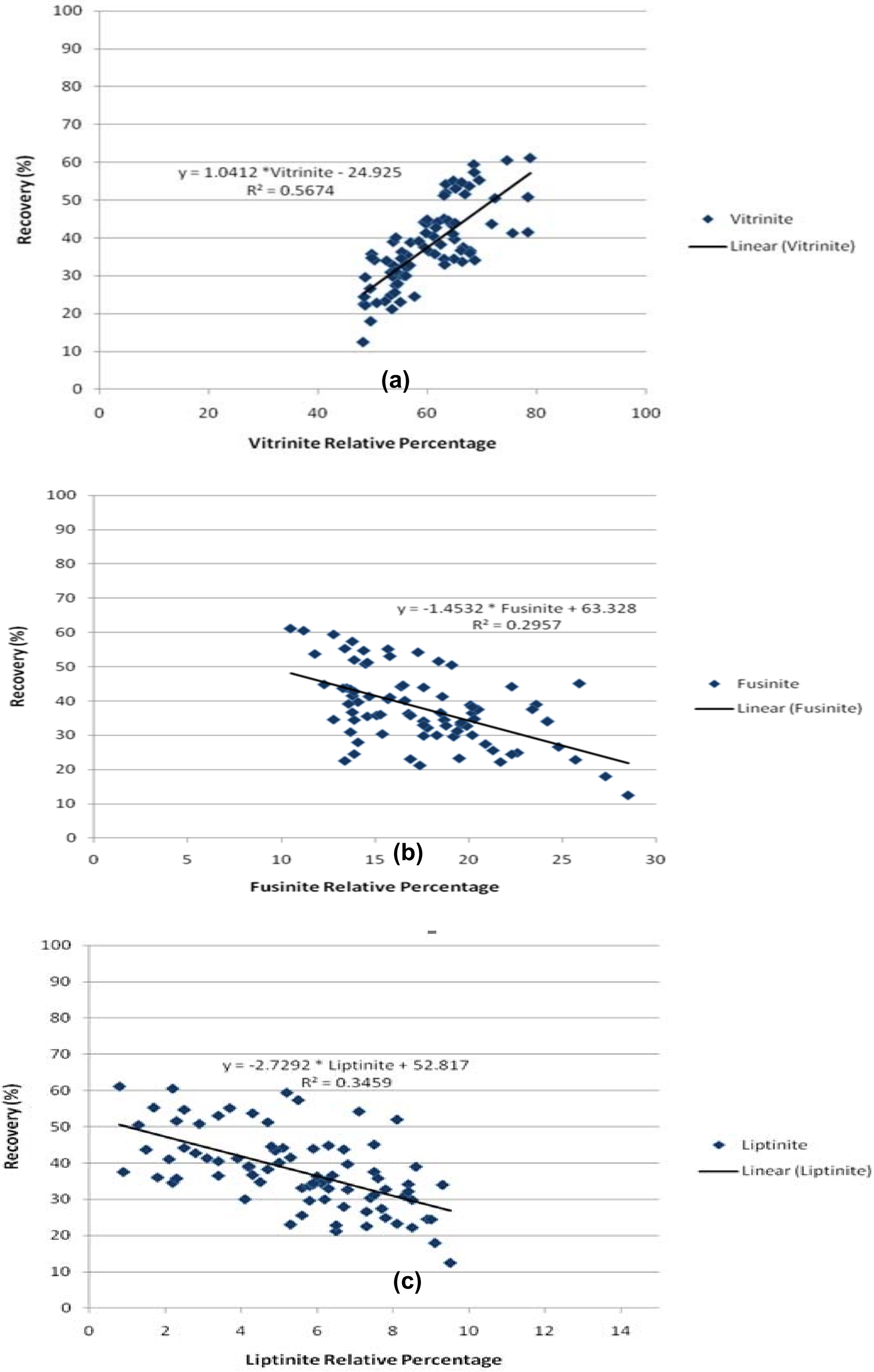



**Figure 3: (a) The relationships between flotation recovery rates and (a) Vitrinite, (b) fusinite, and (c) liptinite**

## CONCLUSIONS

This paper studied the effect of maceral types on the Alborz-Sharghi coal-washing plant's flotation recovery rate. For this, at the first step, the total recovery rate of the plant, 46.25%, was determined, based on collecting the required samples from feeds of the circuit. Then, as the feed was provided from different coal mines, a comprehensive sampling procedure, including 100 representative samples, was obtained over several months. Subsequently, the required polished sections of the samples were prepared and studied to detect the maceral types and their relative percentage in the samples. Finally, after conducting several flotation experiments, the relationships between the flotation recovery rate and the type of macerals were determined. The results revealed that the most type of macerals in the samples was vitrinite, which positively correlated with the recovery rates.

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