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*Yakup Umucu*[*], *Vedat Deniz*[**]

# A STUDY SIMULATION AND MODELING ON THE PERFORMANCE OF THE HEAVY MEDIA CYCLONE IN COAL BENEFICIATION

## 1. Introduction

Coal is one of the world's most plentiful energy resources, and its use is likely to quadruple by 2020. Coal beneficiation is based on wet physical processes such as gravity separation and flotation. Beneficiation produces two waste streams: fine materials that are discharged as slurry to a tailings impoundment, and coarse material (typically greater than 0.5 mm) that is hauled away as a solid waste.

Dense medium cyclones (DMCs), also known as heavy medium cyclones, are versatile separators known to be efficient, high tonnage devices suitable for upgrading particles in the 50–0.5 mm size range. Their working principle has been well documented [5, 10]. DMCs have been widely used as separators in most of the modern coal plants and in a variety of mineral plants treating iron ore, magnetite, dolomite, diamonds, and lead-zinc ores.

The sink-float test is a routine exercise, especially in coal preparation and mineral processing plants to evaluate and cross-check the washability characteristics of coal and minerals. Data obtained from the float-sink tests are used to form a set of washability curves, which are then used to assess the degree of difficulty of gravity separation of raw minerals and to provide qualitative or quantitative data for the products of the separation at a selected relative density.

[*] Department of Mining Engineering, Süleyman Demirel University, Turkey
[**] Department of Chemical Engineering, Hitit University, Çorum, Turkey

In the literature, there are a few studies related to the evaluation of float-sink test results in the form of mathematical equations. Some of the studies are concerned with balancing of the weight and assay, whereas others describe interpolations and mathematical equations on float-sink data. However, as these techniques involve complicated mathematical equations, they have not been widely used in practice.

In this study, time-dependent performance of heavy-medium cyclone were determined with sink-float testing of the clean coal and the refused samples taken from cyclone feeding at Buruyar coal company located at Manisa-Soma Region. The samples taken from coal mines located at Denizli-Çivril region were firstly classified, and then subjected to float-sink test for washability assessment. Finally, hourly changes in the amount of clean coal and refuse recovered from processing of Denizli-Çivril coals with the dense media cyclone were determined using both classic simulation and modeling methods depending on performance values of the dense media cyclone. The results obtained from both methods were compared.

## 2. Materials and Experimental Methods

### 2.1. Material

Coal samples to be used in experimental study were taken from the deposits that belonged to Cantürk Mining in Denizli-Çivril (Turkey). Chemical properties and sieve size analyses of coal samples used in experiments were presented in Table 1.

TABLE 1
**Chemical properties and sieve size analyses of Denizli-Çivril coal**

| Sieve size, [mm] | Amount., [%] | Ash, [%] |
|---|---|---|
| –150 + 70 | 43.77 | 23.91 |
| –70 + 40 | 40.79 | 18.33 |
| –40 + 10 | 12.01 | 17.42 |
| –10 + 4.75 | 2.36 | 16.85 |
| –4,75 | 1.07 | 37.64 |
| Total | 100.00 | |

While size the fraction becomes smaller the ash content of coal decreases as given in Table 1. The reason for this, coal is more brittle than side rock (limestone, e.g.). However, the ash content is high in the smallest sieve size fraction because a small amount of clay minerals are found in the formation of coal.

## 2.2. Experimental

Gravity concentration is the most important unit operation in coal or mineral washing circuit. Normally, sink-float analyses of the representative coal or mineral samples to be washed is carried out in a laboratory to predict the theoretical yield and contents of clean product obtainable in an ideal gravity concentrator at different specific gravities. It is a common practice to plot a series of washability curves, from the sink-float data of a mineral sample in order to generate much useful information relating to its amenability for producing clean product at desired quality.

To ensure accuracy in the sink-float tests, the original samples were separately subjected to size analysis, maintaining a top to bottom ratio of about 1.3–1.8. A small head sample was collected from each size fraction for ash analysis to cross-check the accuracy of subsequent sink-float tests. Coal was subjected to sink-float tests with six specific gravity cuts. Zinc chloride was used as the medium. Each size specific gravity fraction thus obtained was then subjected to ash analysis by ASTM standart. In addition, the average specific gravity was determined for the final sink product of coal, by using specific gravity buckets.

Coal obtained from source, Denizli-Çivril, has been used for this investigation. The representative sample weighed about 250 kg. Sink-float curves for particle size fraction of –10 + 4.75 mm of coal sample were illustrated in Figure 1. It can be seen from Figure 1 that the sink float curves appear to be easy to wash.

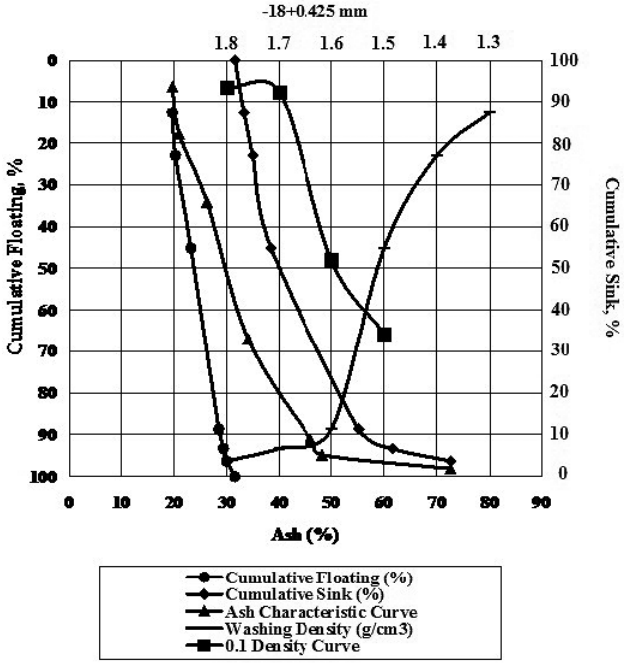


**Fig. 1.** Henry Reinhart curves of Denizli Çivril Coal at –18 + 0.425 mm

## 3. Optimization of Results with Simulation

### 3.1. Performance Measurement of Dense Media Cyclone

Shape of Tromp curves depend on separation precision at washing machines. With using this curve a comparison was made between the washing machines and at the same machines different washing conditions were tried as well [2].

Time-dependent performances of the second group studies of dense media cyclone were determined with sink-float testing of clean coal and refuse samples taken from cyclone feeding at Buruyar Coal Company located at Manisa-Soma Region. Tromp curves of these products is shown in Figure 2.

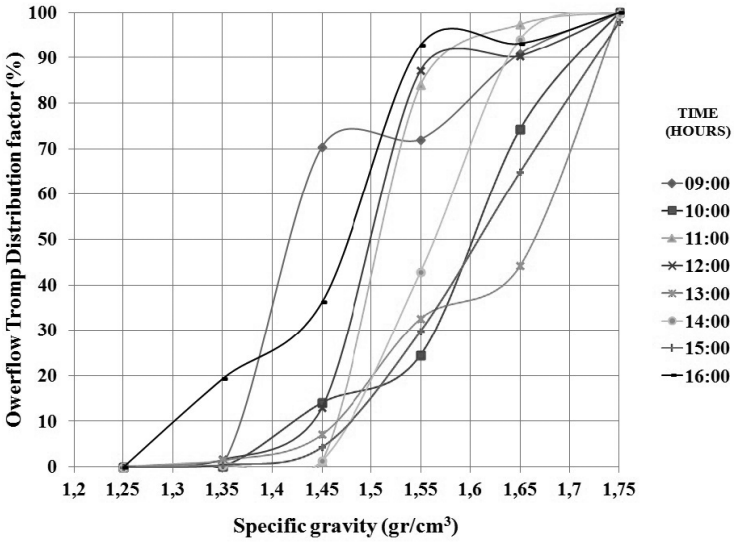


**Fig. 2.** Plot of the overflow Tromp distribution factor against density showing of the DMCs

The measured performances of the dense media cyclone were changed in time-dependent. Performance changes were not determined any caused mechanical problem of device. The performances of DMCs have negatively affected by change in working hours and meal break at the facility. Therefore, the separation density of device was determined by change in time-dependent.

### 3.2. Classic Simulation Methods

Conventional coal washability information is generally obtained in the laboratory by the tedious sink-float analysis using hazardous halogenated organic compounds in large

quantities [6]. The principle behind this procedure (sink-float) is nothing more than particle fractionation by specific gravity. Although knowledge of the washability characteristics of various streams within a coal preparation plant is of great utility for process control and optimization, up to now, on-stream utilization of washability data is limited because of the lack of any instrumental method for the rapid determination of the washability curve. Typically, the return time for coal washability analysis using conventional sink-float testing will be about one day [7].

Separation performance of coal beneficiation equipment depends on equipment structure, working conditions, the separation medium, the amount of feed, ash of fed coal, the sieve size and distribution of coal.

As a result of change separation density in the density heavy medium cyclone of Buruyar Company in Soma, obtained products were investigated in the terms of amounts and ash content. İf the device is rune in 1.60 g/cm$^3$ of separation with density, product specifications obtained clean coal amount and ash content will be calculated classical simulation method. As a result of this evaluation, the change weights rates of clean coal and ash content was obtained from the different density of heavy medium cyclone separation are shown in Figure 3.

In Figure 3, the obtained recovery performances of clean coals showed varied depending on the time in the dense media cyclone. In simulation studies, the samples are obtained from fed coal, clean coal and refuse should not be any time period. Because the samples must obtained from different time periods, simulation results is correct.

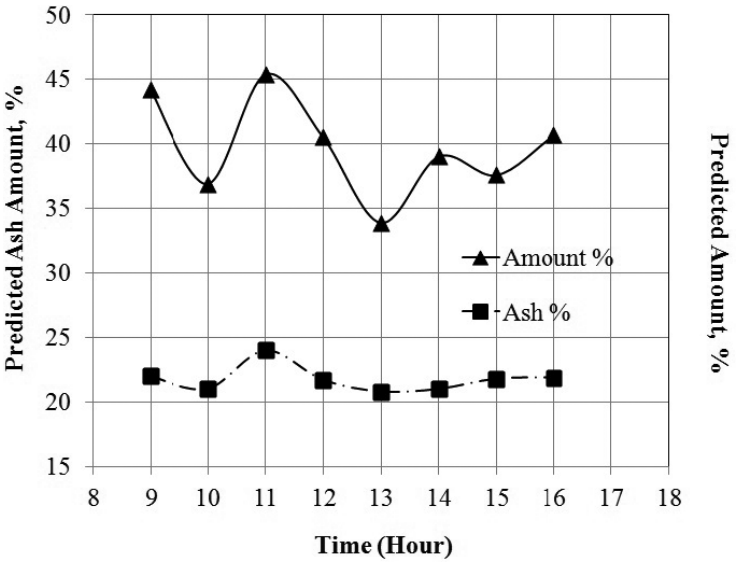


**Fig. 3.** Depending on the separation density conventional simulation result to be obtained the amount of clean coal ash (%) and the amount (%)

### 3.3. Modeling Method

In the literature, there are a few studies related to the evaluation of float-sink test results in the form of mathematical equations. Some of the studies are concerned with balancing of the weight and assay, whereas others describe interpolations and mathematical equations on float-sink data [7–9].

As these techniques involve complicated mathematical equations, they have not been widely used in practice. However these equations can be used for smoothing and interpolation of float-sink data.

In this modeling works, non-linear regression techniques are used and modeling. The base variables the considered washing density and the density of the heavy media cyclone separator are used. The resultant value is the ash value thought to be the washed density. The model, developed from the obtained float-sink test data and Tromp density separations are given below as:

$$OA = 24.32 \cdot (TDS)^{-0.899} \cdot (CDS) \tag{1}$$

where:

$OA$ — Obtained Ash,

$TDS$ — Tromp Density Separation,

$CDS$ — Considered Density Separation.

The results of modeling the relationship with classical simulation are given in Figure 5. The value of coal ash will be easily predicted from any separation density with modeling. Estimation of ash in a short time, with the help of the developed model can be made.

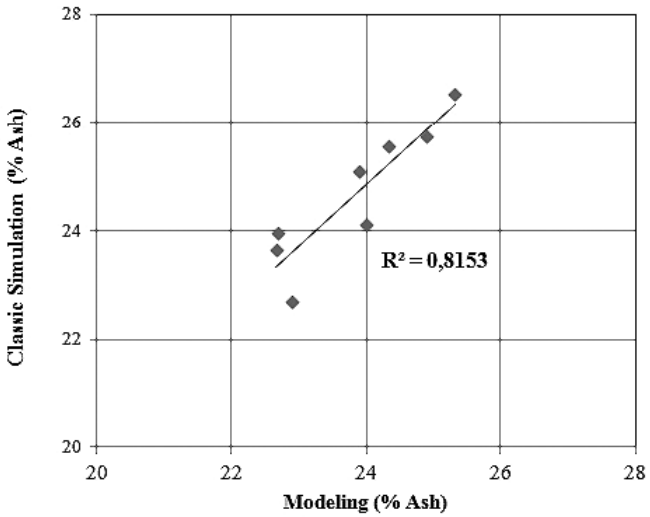


**Fig. 4.** The relations classical simulation results and modeling results

## 4. Conclusion

The float-sink washability test data of Denizli-Çivril coal is shown that medium-hard type. Ideal washing density of coal was found to be 1.6 g/cm$^3$. In the smaller size of coal, ash forming minerals becomes free, because enriching may make the negative impact.

In heavy media cyclone environment involving too much clay, thus magnetite is acted in similar manner with the clay and magnetite which moves away from the beneficiation. Therefore, the density of the media is slowly changing. However, the magnetite addition to the separator is uncertain and at long periods of time, the media densities certainly changes. Control of the density with irregular feeding is required continuously.

According to tests, the device performance was resulted in high costs of plant operation and great decrease the obtained quality of clean coal in this study. Heavy media devices are useful in making computerized control problems, instead of manually controlling. Searched a lot of insensitive work to be simulated succeed in to a computerized control of system. Thus, increased device performance, clean coal, with refuse interference is eliminated. Separation performance change of devices, the density change at the cleaning and precision of separation is usually seen to consist at shift breaks tea and meal times. Therefore, it is essential to control of separators by automatic control devices.

Compared with conventional simulation studies, performed by modeling predictions which will be more beneficial easily determine the quality of the product.

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