Hardgrove Index Estimation of Coal, Using its Characteristics and Sink-Float Data

Mohammad Noaparast¹; Hadi Hendizadeh²

ABSTRACT

The grindability of ores is a very significant parameter which is used in size reduction equipments design and selection. The Hardgrove Index (HGI) is a normal approach for measuring the coal sample grindability, which is calculated using hardgrove machine. The coals specification such as humidity, ash content, volatile matter and heating value are analytical parameters which could change the HGI amount of coal samples. In this study it has been attempted to define the coal HGI values, on the basis of sink-float experimental data. An empirical equation was defined with applying regression technique on the data of above parameters to estimate HGI values.

KEYWORDS

Hardgrove Index, Coal Characteristics, Sink-Float.

1. INTRODUCTION

Run-off-mine coals are usually washed as a final and sellable product to be achieved. This process could easily be size classification, comminution and sizing, washing (cleaning), and/or further chemical treatment. Comminution is an essential stage in any type of ore processing practices. Therefore, size reduction equipments could usually be implemented in coal cleaning plants, coal conditioning, and coke furnaces.

One of the most significant properties of coal is its grindability, which is widely applied in size reduction equipment design and selection, and estimating of size distribution of coal products, as well. Hardgrove index is a parameter which defines the coal grindability, and is experimentally calculated. The variation of raw coal grindability is very important in performance of crushers, and accordingly it is usually attempted to prepare homogenous materials, to be used in size reduction equipments (as feed) which is certainly very complicated. Therefore, it is important to estimate the hardgrove index of coals prior to their crushing and/or cleaning steps.

In previous studies the effects of individual coal physical and chemical characteristics on their hardgrove index was considered. However in this work the effects of the whole parameters on coal hardgrove index was investigated. It should be noticed that these parameters are analytically measured. The data obtained from sink-float experiments are normally used in order to estimate coal yields/recoveries. Therefore it was applied in this study which is presented in other parts.

2. MAJOR ANALYTICAL COAL CHARACTERISTICS

In order to correlate the coal Hardgrove index with its different specifications such as coal composition, heating value, many researches have been done. However any of these studies did not lead to the complete and satisfactory results, due to coal complexity and its specifications variation. Thus, it has been concluded that the relation of coal characteristics and its hardgrove value is not performed, due to the lack of smooth understanding of coal specifications variation [6]. Therefore, researchers defined a relation between (some) coal specifications such as i) humidity, ii) ash content, iii) volatile matter, and iv) the carbon percentage, and with its grindability using regression approach on the analytical data. This grindability index is calculated which is here called “statistical grindability index (SGI)” [3, 5].

More than 300 coal samples with wide range of HGI equal to 35-115 were tested which their analytical specifications were as following:

Humidity percent: 0.7 to 0.9.
Ash percent: 3 to 65.

¹ASSOCIATE Professor, Mining Engineering Department, Faculty of Engineering, University of Tehran, E-mail: mnoaparast@yahoo.com, Tel./Fax: 88088838
²M.Sc. of Mining Engineering, Mining Engineering Department, Faculty of Engineering, University of Tehran.
Volatile matter percent: 16 to 45.
Carbon percent: 15 to 66.
Equation 1 was defined to estimate SGI, using data regression method [3, 5]:

\[ SGI = 93.25 + M(0.256 + 0.196M) + 3A(1.097 - 0.009A) - 3/M(1.165 - 0.029M) - SC(1.103 - 0.0166) \]  

where,
M= Humidity,
VM= Volatile matter percent,
FC= Carbon percent.

The correlation factor of this equation is about 0.93 which is very remarkable. Figure 1 presents the results obtained from equation 1 versus HGI values. The estimated standard deviation (st.d.) is about \( \pm 3 \) units and it is rarely more than \( \pm 5 \) units. As it was explained, the results of previous studies did not present a perfect relation of coal specifications with its grindability, so that to yield a good correlation factor. However, in this method all four mentioned parameters were included which the variation of results was accordingly reduced.

![Figure 1: The relationship between estimated HGI (SGI) and experimental HGI.](image)

**3. Estimating HGI with Sink-Float Data**

The results of investigations indicate that the coal grindability is determined on the basis of specific gravity of coal compositions and their weight percentage. If the grindability is varied, it is then possible to define the type of coal (according to the coal types). The results of sink-float tests could be implemented to determine the coal grindability. There is certainly some relations between specific gravity and HGI of float mass [2].

The variation of grindability with specific gravity particularly in certain SG fractions has been investigated to specify the HGI based on the type of coals and its composition [2].

**A. Experimental Studies**

The results obtained from the studies in past 30 years on the decrease of coal’s HGI values with increase of specific gravity reveals some interesting comments. It was shown that for the tested coals, the HGI of combined coal sample (a sample which is produced by combining some other coals) could be calculated using fractional HGI values. For these tests, the HGI and ash content of each individual sample were primarily measured. Then each
sample was used in sink-float test with 6 specific gravity fractions. The heavy liquids used were zinc-chloride and tetra-chloride carbon, and the ash content and HGI values were determined [2].

**B. HGI Variation with Specific Gravity**

Table 1 presents HGI values and weight distribution obtained in different size fractions. The experimental HGI are in good fit with estimated HGI. It could be presented that the experimental HGI for all specific gravity fractions, using B1 coal sample are approximately equal, except for the lightest fraction which is 0.5-1% of the whole coal sample. This discrepancy using L1 coal sample is about 10% or even more (Table 1).

A certain trend is observed in the HGI variation versus specific gravity for both B1 and L1 samples. The HGI values are decreased with the consistent increase of SG, until the minimum is achieved which is related to SG 1.8. Then the HGI for heavier fractions up to SG 2.3 are increased [2]. It is obvious that the comminution process, liberate the locked particles, and therefore after size reduction, it is possible to estimate HGI values of crushing unit feed. The variation of HGI with SG for L1 sample is similar to those of B1 [2].

**C. The HGI Estimation**

The HGI values of various specific gravity fractions, using B1 sample are steadily decreased, but in the last fraction is increased (Table 1). As the HGI values decrease is varied for heavier fractions, therefore it is hard to define an equation to be fitted to data. The defined equation is more convenient for L1 sample, as HGI values decrease is not varied. However, the data are very scattered and HGI estimation is not valid (Figure 2) [2, 6].

According to the sink-float results, which were prepared during the sampling campaigns in mineral processing plants, it is recommended that the HGI values to be determined for the ascending specific gravity fractions, as for the float part, the ash content is measured (Figure 2). These amounts are then plotted versus specific gravities which straight lines are produced. On the contrary, when based on the sink-float data, the average specific gravity and the HGI values are calculated and plotted, it is observed that a linear relationship is produced between two coal types (Figure 3). These equations are as following [2]:

\[
\text{HGI}_{\text{cum}} = -65.5582SG_{\text{cum}} + 172.6564 \\
\text{HGI}_{\text{cum}} = -27.6325SG_{\text{cum}} + 116.6265 \\
\text{HGI}_{\text{cum}} = -83.1395SG_{\text{cum}} + 243.5456
\]

Figure 2: The HGI values versus specific gravity [5].

Equations 3 and 4 are used for the B1 sample. The first equation was prepared, concerning all specific gravities (Table 1), and in equation 4 float material lighter than 1.3 is mixed with material with SG of 1.4 and the lightest fraction is then considered to be equal to 1.4. This is based on the fact that the HGI values in SG of 1.3 is very different with other SG fractions, and its weight distribution is also negligible. In addition the object of this study is to develop an equation which is to be able to estimate the grindability index of B1 coal sample. It is observed in Figure 2 that the equation 3 is more acceptable, if the float material in SG of 1.3 is neglected.

The correlation factor, \( r \), in equations 3, and 4 are 0.9036 and 0.9187 respectively. It is observed in Figure...
3. that the best relationship for the L1 coal sample is achieved equal to 0.9988 [2].

4. CONCLUSIONS

Estimation of the HGI values for two types of coal samples were studied, using statistical method which has some advantages. Any change in the specific gravity distribution of coal might result in change of grindability and through the sink-float experiments it is possible to determine any change in HGI values.

Since the sink-float experiments are conventional in coal preparation plants, to evaluate the washability of the ore, the data obtained by these tests could be used to estimate the grindability, without performing the tests. Therefore it is possible to reduce the cost and time.

The products of coal washing of B1 and L1 samples in the steel & power plants would go for further grinding, therefore the data obtained from analysis of sink-float data of washed coal and its middling products, could be to determine grindability of samples.

### Table 1

<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th>B1 Coal Type</th>
<th>Product</th>
<th>L1 Coal Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feed Weight (%)</td>
<td>HGI</td>
<td>Weight (%)</td>
</tr>
<tr>
<td>&lt;1.3</td>
<td>1.0</td>
<td>95</td>
<td>0.5</td>
</tr>
<tr>
<td>1.3-1.4</td>
<td>22.2</td>
<td>78</td>
<td>11.0</td>
</tr>
<tr>
<td>1.4-1.5</td>
<td>28.1</td>
<td>76</td>
<td>42.3</td>
</tr>
<tr>
<td>1.5-1.6</td>
<td>20.8</td>
<td>73</td>
<td>18.3</td>
</tr>
<tr>
<td>1.6-1.7</td>
<td>14.3</td>
<td>70</td>
<td>11.6</td>
</tr>
<tr>
<td>1.7-1.8</td>
<td>6.2</td>
<td>69</td>
<td>6.9</td>
</tr>
<tr>
<td>&gt;1.8</td>
<td>7.4</td>
<td>71</td>
<td>9.4</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>74</td>
<td>100.0</td>
</tr>
<tr>
<td>Calculated Average</td>
<td>-</td>
<td>76</td>
<td>-</td>
</tr>
<tr>
<td>Index</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Specific Gravity (SG)</th>
<th>Average</th>
<th>Cumulative Amounts of Cruiser feed</th>
<th>Cumulative Amounts of Cruiser Product</th>
<th>Cumulative Amounts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Weight (%)</td>
<td>SG</td>
<td>HGI</td>
</tr>
<tr>
<td>&lt;1.3</td>
<td>1.25</td>
<td>1.0</td>
<td>125</td>
<td>95</td>
</tr>
<tr>
<td>1.3-1.4</td>
<td>1.35</td>
<td>23.2</td>
<td>1.35</td>
<td>79</td>
</tr>
<tr>
<td>1.4-1.5</td>
<td>1.45</td>
<td>51.3</td>
<td>1.40</td>
<td>77</td>
</tr>
<tr>
<td>1.5-1.6</td>
<td>1.55</td>
<td>72.1</td>
<td>1.45</td>
<td>76</td>
</tr>
<tr>
<td>1.6-1.7</td>
<td>1.65</td>
<td>86.4</td>
<td>1.48</td>
<td>75</td>
</tr>
<tr>
<td>1.7-1.8</td>
<td>1.75</td>
<td>92.6</td>
<td>1.50</td>
<td>75</td>
</tr>
<tr>
<td>&gt;1.8</td>
<td>1.95(B1), 2.21 (L1)</td>
<td>100</td>
<td>1.53</td>
<td>74</td>
</tr>
</tbody>
</table>

---

*Amirkabir Vol.16/No.62-C/(Civil Engineering)/Summer-Fall 2005*
It seems that the calculated values of HGI for B1 and L1 samples is determined by the HGI values for specific gravity components and weight percent distributions. The distinct types of trends could be assigned for HGI-specific. The linear correlation observed for the both types of coal samples, which presents the relationship between the cumulative average of specific gravity and the HGI for the float part of that component. Therefore, careful estimation of HGI for both coal types should be considered using the empirical relationship.

5. REFERENCES


