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Gross Calorific Value of Indian Coals and its Correlation with Ash Content

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Abstract

The Indian coals are a sub-bituminous variety, high in ash content and low in calorific value. The high ash content in Indian coals makes Indian coals more heterogeneous. The moisture and the ash content have a direct impact on the calorific value of the coals. In the present work the moisture, ash content and GCV have been analyzed for the coals obtained from various locations in India and the relationship between ash content and GCV was established on a dry basis. The variation in GCV to ash content was statistically quantified for the coals from each mine and overall mines.

Keywords: Ash Content, Correlation Equations, Gross Calorific Value

1. Introduction

The maximum proportion of the power generation in India is from coal-based thermal power plants. The Indian coals are of sub-bituminous variety and high in ash content. The high ash content in Indian coals is due to the drifted origin of Indian coals. There are numerous publications[1-9] on the inter-correlation of various coal properties. These researchers have established statistical equations correlating the properties like elemental compositions, proximate, ultimate parameters and GCV. It has been found that the relationships are mostly unique to the coal types, the level of heterogeneity and the rank of the coals. Among the various properties, the moisture and ash content is the non-combustible portion of the coal and have a direct impact on the Gross Calorific Value (GCV). Priya Kumari *et al.*,[10] have published the relationship of moisture and ash content with GCV on 756 coal samples taken from three coal basins in Raniganj, India regions.

The GCV is the heat released per unit mass of the coal during the combustion of coal. The combustion of coal is an exothermic reaction and the enthalpy change is generally not only due to the quantity of combustible matter present in the coal but also to the qualitative aspects of combustible matter and the bond linkages. This will make some variations in GCV between the coals with the same quantity of combustible matter. In India, there are many coal mines which are classified by Coal India Ltd (CIL) as Northern Coal Fields Ltd (NCL), Central Coal Fields Ltd (CCL), Western Coal Fields Ltd (WCL), South Eastern Coal Fields Ltd (SECL), Bharat Coking Coal Ltd (BCCL), Eastern Coal Fields Ltd (ECL), Mahanadi Coal Fields Ltd (MCL), etc., based on the geographical locations. The GCV and other coal properties vary for these mines. In the present work, the moisture, ash content and GCV were analyzed for the coals obtained from various locations in India and the relationship between ash content and GCV was established on a dry basis to nullify the effect of moisture. The variation in GCV with respect to ash content was statistically quantified for the coals from each mine and for overall mines.

2. Experimental Work

A total of 3764 samples obtained from NCL, BCCL, MCL, WCL, CCL and CCL have been subjected to moisture and ash analysis as per ASTM D7582 and GCV analysis as per ASTM D5865 standards. The experimentally determined ash content and GCV have been correlated on dry basis to nullify the effect of moisture. The number of samples from different mines subjected for the present study are given in Table 1. The range of ash content and GCV determined experimentally on dry basis, and the correlation equations with R^2 values are given in Table 2. The standard deviation for the difference in the experimentally obtained GCV

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value and the theoretically predicated GCV value from the correlation equation has been calculated statistically as follows:

$$\text{Standard Deviation } (\sigma) = \sqrt{\frac{\Sigma(X_i - X)^2}{n-1}}$$

where, X = Average of the difference of experimental and predicted GCV, X_i = Difference of experimental and predicted GCV for the coal sample i, and n is the total number of coal samples. The values of the standard deviation for the coals obtained from various mines are given in Table 2. The plots of the ash content vs. GCV on dry basis and the ash content vs. Difference in Experimental and Predicted GCV are given in Figures 1 and 2.

3. Results and Discussion

Table 2 indicates that the R^2 value varies between 0.9213 (MCL) to 0.9833 (BCCL). The higher value of R^2 indicates a better correlation between ash content and GCV value. WCL, BCCL and NCL have R^2 in the range of 0.98. This emphasizes that the GCV of the coals from these collieries are relatively more predictable with their ash content compared to other regions. Also, coals from these regions show a relatively low standard deviation (44.2 to 59.6 kcal/kg) on the difference in the experimental and predicted GCV.

The CCL, SECL and MCL coals have relatively low R^2 values (0.9490, 0.9751 and 0.9213) and high standard deviation (128.6, 96.3 and 72.1) compared to WCL, BCCL and NCL coals. The standard deviation of the difference between the experimental and the predicted GCV with respect to the ash content is attributable to many reasons that include, high heterogeneity in the qualitative aspects of coal like the chemical structure of combustible matter, its reactive and non-reactive maceral contents, etc.

Table 1. Number of coal samples from different mines

Sl. No	Coal Mines	Number of Coals
1	Western Coal Fields Limited (WCL)	531
2	Bharat Coking Coal Limited (BCCL)	131
3	Mahanadi Coal Field Limited (MCL)	1260
4	Northern Coal Field Limited (NCL)	156
5	Central Coal Field Limited (CCL)	464
6	South Eastern Coal Field Limited (SECL)	1222
7	**Total Coal**	**3764**

Table 2. Range and Correlation Parameters of GCV with Ash Content for the coals from different mines

Sl. No	Coal Mines	Ash Content Range (%) Dry Basis	GCV Range (kcal/kg) Dry Basis	Correlation Equation	R^2 value	Standard Deviation (± kcal/kg)
1	WCL	17.3 - 69.5	1687 - 5919	GCV_d = -82.734 x Ash_d + 7469.2	0.9829	59.6
2	BCCL	19.3 - 57.4	3780 - 6710	GCV_d = -95.467 x Ash_d + 8608.4	0.9833	45.1
3	MCL	24.3 - 63.8	2352 - 5419	GCV_d = -79.453 x Ash_d + 7438	0.9213	72.1
4	NCL	14.7 – 52.2	3353 - 6315	GCV_d = -81.766 x Ash_d + 7559.6	0.9844	44.2
5	CCL	12.4 – 65.7	2061 - 6868	GCV_d = -92.838 x Ash_d + 8105.8	0.9490	128.6
6	SECL	17.4 – 68.0	1757 - 6005	GCV_d = -93.22 x Ash_d + 8096.5	0.9751	96.3
7.	Over all	12.4 - 69.5	1687-6868	GCV_d = -89.456 x Ashd + 7911.2	0.9466	124.9

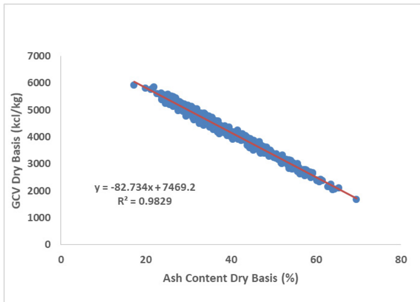
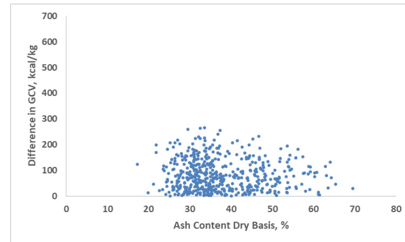
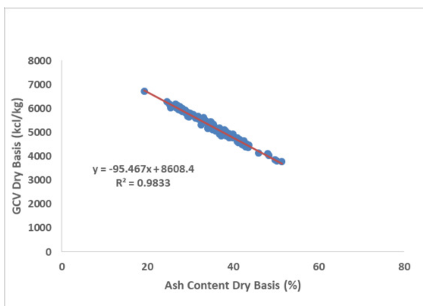
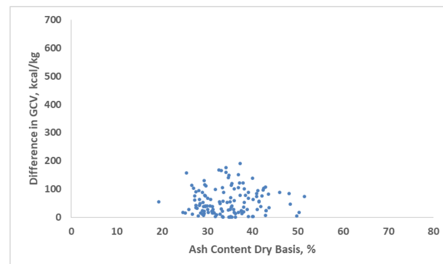
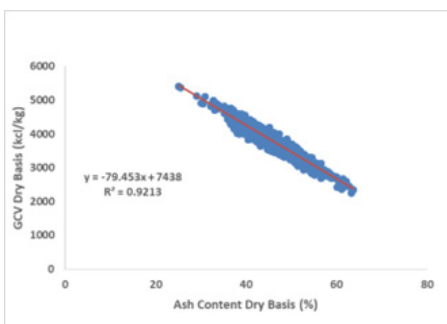
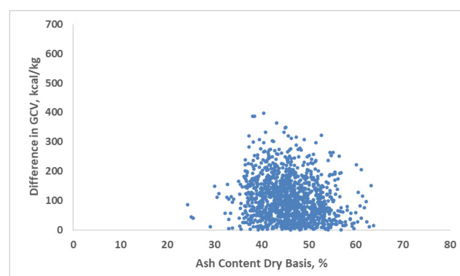
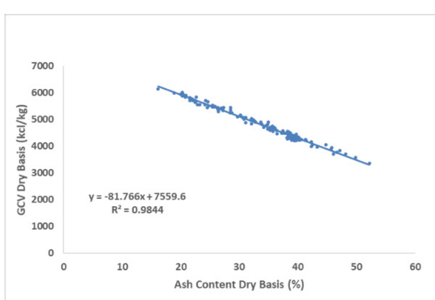
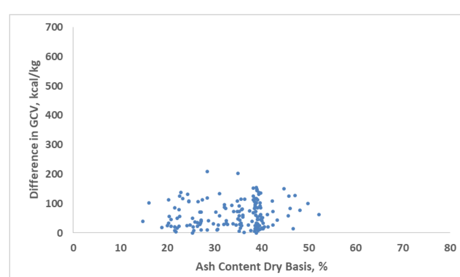
Mines	GCV Vs. Ash Content on Dry Basis	Difference Experimental GCV and Predicted GCV Vs. Ash Content
WCL		
BCCL		
MCL		
NCL		

Figure 1. Correlation plots for GCV vs. ash content.

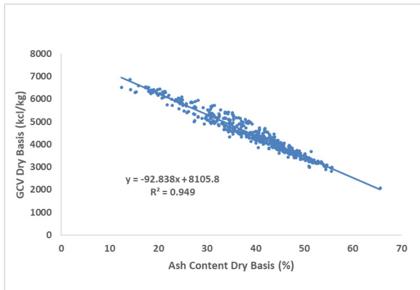
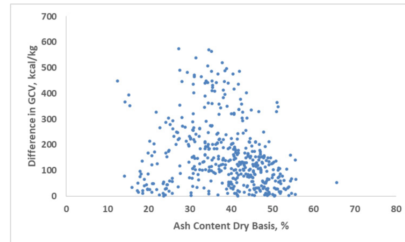
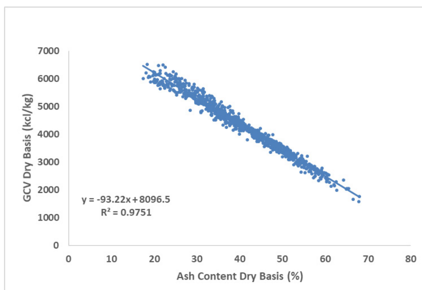
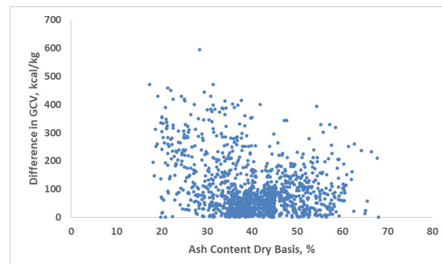
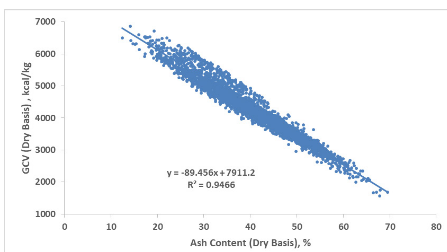
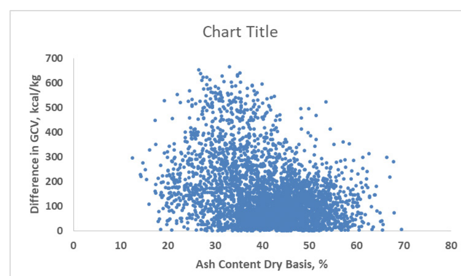
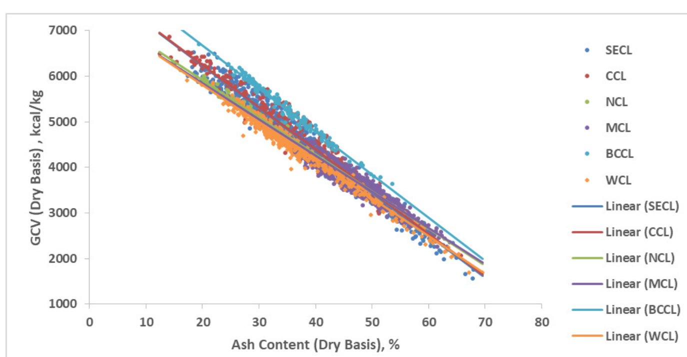
<table>
<tr><th>Mines</th><th>GCV Vs. Ash Content on Dry Basis</th><th>Difference Experimental GCV and Predicted GCV Vs. Ash Content</th></tr>
<tr><td>CCL</td><td>
</td><td>
</td></tr>
<tr><td>SECL</td><td>
</td><td>
</td></tr>
<tr><td>All coal mines</td><td>
</td><td>
</td></tr>
<tr><td>All coal mines</td><td colspan="2">
</td></tr>
</table>

Figure 2. Correlation plots for GCV vs. ash content.

The coals from the same mines with a wide difference in qualitative parameters may show differences in GCV with the same ash content. The coals with quantitatively equal amounts of combustible matter but qualitatively different maceral contents may show differences in GCV due to the reason that the coal with a high proportion of non-reactive maceral content may not completely combust and leave out a mild portion of non-combusted residue during the GCV experiments which may go unnoticed. This may give a difference in GCV. Also, the coals have quantitatively equal amounts of combustible matter but are chemically different in composition and may also give different GCV values for the same ash content due to the difference in the enthalpy content of the chemicals constituting the combustible portion. This shows that the prediction of GCV with ash content is only indicative. The correlation equation involves both combustible and non-combustible matters such as C, H, N, S, O and Ash on a dry basis will give much better predictions compared to ash content alone.

4. Conclusion

The ash content of coal samples from different mines was correlated with the GCV on a dry basis, and the correlation equations were established. The standard deviations for the difference in the experimental GCV and the GCV predicted through the correlation equations were calculated statistically. The results indicate that the WCL, BCCL and NCL coals showed better R2 value and standard deviation compared to other coals like CCL, SECL and MCL. The standard deviation is attributable to many reasons that include, high heterogeneity in the qualitative aspects of coal like the chemical structure of carbonaceous matter, its reactive and non-reactive maceral contents, etc. The prediction of GCV with the ash content is only indicative, and better predictions can be achieved involving both combustible and non-combustible matters like C, H, N, S, O and Ash in the correlation equations.

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6. References

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