A CORRELATION STUDY OF GROSS CALORIFIC VALUE WITH PARAMETERS OF PROXIMATE ANALYSIS OF COAL

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ABSTRACT

A correlation study of gross calorific value of coal with parameters of proximate analysis (the content of ash, moisture, volatile matter and fixed carbon) was studied on more than 200 samples of coal from different mining areas across India. Gross calorific value is increased with the decrease of the content of ash, moisture respectively, and gross calorific value is also increased with the increase in the content of volatile matter and fixed carbon respectively. The relevant experimental data and graphs are very useful for industries to estimate the quality of coal.

Keywords: Moisture, Ash, Volatile Matter, Fixed carbon, Gross Calorific Value

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INTRODUCTION

Coal is one of the best non-renewable energy sources and abundantly available in India and used as the main fuel for the industrial process as well as household use in some parts of the country. India is the second-largest producer and importer of coal in the world.³ India's electricity generation highly depends on coal only.³ It is used as fuel for power generation for thermal power plants, steel making industries, and cement manufacturing industries, etc., Every country are having coal with different physical/chemical properties. The ash of coal is one of the pozzolanic material used in the manufacturing of cement. Indian coal is having a variety of grades which is dependent on the gross calorific value. Chemical analysis of coal is very important concerning the correlation of gross calorific value with the parameters of proximate analysis which are very useful for the industries to estimate the quality of coal.

EXPERIMENTAL

Sampling

Coal samples were pulverized and passed through a sieve 212 micron¹ as per Indian standard. Estimation of moisture, ash, volatile matter, and fixed carbon was analyzed by Eltra thermogravimetric analyzer (TGA) model Thermostep and results are recorded. Initially we are loading the sample in Eltra thermogravimetric analyzer, within 1.5 hours, we got the results of moisture, ash, volatile matter and fixed carbon respectively.

Gross Calorific Value (GCV)

Gross calorific value was determined by using a digital bomb calorimeter and results are recorded.² According to environmental condition, we are going to find out water equivalent of a standard benzoic acid, based on that one, find out the calorific value of certified reference material. The calorific value of standard reference material is used for calibration of the digital bomb calorimeter. Then we are going for sample analysis. More than 200 Samples were analyzed and data recorded as follows in Table-1.

Table-1

S. No.	Moisture % by mass	Ash% by mass	GCV, Kcal/kg	Volatile matter % by mass	Fixed Carbon % by mass
1	5.87	13.14	6300	33.22	47.77

2	6.00	13.06	6270	33.11	47.83
3	6.09	11.92	6370	34.46	47.53
4	6.11	11.89	6380	34.47	47.53
5	5.56	13.41	6280	34.12	46.92
6	5.57	13.44	6260	33.84	47.15
7	5.56	13.11	6270	33.83	47.50
8	5.50	13.36	6250	33.53	47.61
9	5.49	13.36	6280	33.94	47.20
10	5.61	13.45	6300	34.01	46.93
11	5.72	13.14	6240	33.38	47.76
12	5.59	13.34	6230	33.42	47.65
13	6.09	13.20	6260	33.88	46.83
14	5.74	13.46	6250	33.51	47.28
15	5.65	13.46	6300	33.68	47.20
16	5.89	13.06	6340	33.22	47.83
17	5.70	13.42	6330	33.51	47.37
18	5.88	13.13	6210	33.30	47.69
19	5.99	13.03	6310	33.36	47.62
20	5.79	20.33	5730	31.80	42.08
21	5.77	13.45	6260	34.69	46.09
22	5.94	12.98	6380	34.51	46.57
23	6.23	13.10	6240	34.61	46.06
24	5.99	13.00	6270	34.32	46.69
25	5.96	13.65	6270	33.98	46.41
26	6.92	11.80	6350	34.63	46.65
27	6.73	11.88	6360	34.60	46.78
28	6.64	11.91	6310	34.73	46.72
29	0.75	12.82	6210	36.67	49.77
30	6.08	13.21	6390	34.33	46.37
31	5.90	13.09	6400	34.60	46.42
32	5.98	13.46	6190	34.57	45.98
33	5.90	13.10	6310	33.49	47.51
34	6.01	13.37	6300	33.83	46.79
35	5.97	13.14	6300	33.67	47.22
36	6.25	22.05	5560	30.19	41.52
37	5.67	13.37	6240	34.43	46.53
38	6.42	11.80	6360	35.23	46.55
39	5.77	11.77	6380	36.60	45.86
40	4.97	13.47	6350	35.61	45.95
41	5.82	12.72	6280	36.51	44.95
42	4.96	14.42	6060	34.03	46.58
43	5.05	13.49	6280	34.50	46.95
44	5.49	13.60	6040	35.47	45.44

45	5.38	13.61	6270	35.45	45.56
46	5.19	13.47	6260	34.80	46.54
47	4.55	28.24	4800	29.18	38.03
48	6.27	11.82	6390	35.56	46.35
49	6.24	15.00	5920	34.39	44.37
50	6.11	12.75	6140	36.28	44.86
51	5.66	13.58	6320	34.83	45.93
52	6.21	12.71	6240	35.34	45.73
53	6.38	11.89	6350	34.99	46.74
54	5.61	21.28	5520	33.23	40.88
55	5.89	13.06	6420	35.14	45.91
56	5.81	12.94	6420	34.32	46.93
57	5.63	12.10	6350	36.50	45.77
58	6.08	12.79	6360	34.18	46.95
59	6.11	12.78	6210	34.08	47.04
60	5.97	14.41	6050	33.88	45.74
61	6.21	12.74	6360	33.87	47.18
62	6.30	12.76	6260	33.89	47.05
63	6.21	12.75	6300	33.89	47.15
64	6.27	12.74	6320	33.93	47.06
65	6.19	12.82	6290	34.03	46.96
66	6.16	14.38	6040	33.50	45.96
67	6.01	11.15	6290	34.37	48.47
68	6.56	12.76	6190	33.53	47.15
69	6.51	12.75	6360	33.73	47.01
70	6.60	12.77	5950	33.68	46.95
71	6.60	12.71	6180	33.53	47.12
72	6.66	12.80	6240	33.34	47.20
73	6.52	12.73	6090	33.19	47.56
74	6.31	21.28	5830	30.44	41.97
75	6.74	12.74	6270	33.37	47.15
76	5.81	11.98	5910	34.47	47.75
77	5.99	11.81	6040	34.07	48.13
78	5.94	11.81	6240	34.13	48.13
79	5.36	13.38	6260	33.73	47.53
80	5.37	13.36	6120	33.64	47.63
81	5.46	13.40	6150	33.79	47.35
82	5.34	13.28	6290	33.36	48.02
83	5.76	13.11	6210	33.73	47.40
84	6.44	14.00	5860	32.27	47.29
85	5.65	13.22	6340	33.27	47.86

86	6.50	12.73	6270	32.91	47.85
87	6.03	12.29	6170	33.22	48.46
88	6.38	11.54	6050	33.39	48.69
89	6.33	12.08	6240	33.65	47.93
90	5.88	12.42	6330	32.73	48.96
91	5.97	13.48	5940	32.70	47.85
92	6.51	11.45	6080	33.25	48.79
93	5.89	14.44	5960	32.22	47.45
94	6.21	12.34	6320	33.05	48.40
95	5.89	11.87	6390	34.18	48.07
96	5.76	12.98	6280	33.75	47.50
97	5.39	12.55	6370	33.97	48.09
98	6.15	14.38	6000	33.43	46.04
99	5.91	12.06	6250	35.45	46.58
100	6.06	12.02	6340	35.47	46.44
101	5.65	13.93	6070	33.93	46.49
102	6.08	11.42	6050	34.30	48.20
103	5.32	14.21	6280	34.02	46.45
104	6.15	11.84	6210	34.99	47.02
105	6.27	14.49	6000	33.01	46.24
106	6.29	11.86	6250	35.02	46.82
107	6.31	11.88	6040	34.70	47.10
108	6.26	13.34	6270	33.81	46.59
109	6.47	11.79	6230	34.75	46.98
110	6.42	13.37	6340	33.63	46.58
111	6.55	13.32	6230	33.50	46.63
112	6.62	11.83	6120	34.38	47.77
113	6.58	15.16	6050	32.72	45.54
114	5.65	12.78	6150	35.51	46.07
115	5.52	12.08	6330	34.62	47.77
116	5.18	13.33	6380	33.46	48.04
117	5.21	13.02	6350	33.79	47.97
118	5.40	13.05	6360	33.57	47.98
119	5.68	12.04	6390	34.77	47.51
120	5.60	12.34	6420	33.25	48.80
121	5.59	13.91	6140	33.04	47.46
122	6.15	13.90	6010	32.91	47.05
123	6.30	13.48	6230	32.75	47.46
124	5.65	12.94	6340	33.93	47.49
125	6.00	12.16	6300	34.32	47.53
126	6.08	11.47	6380	34.00	48.45

127	5.42	13.07	6330	33.42	48.09
128	5.87	12.58	6380	33.29	48.26
129	5.49	13.37	6420	33.43	47.71
130	5.47	13.48	6360	33.34	47.71
131	6.34	12.04	6380	34.09	47.53
132	6.25	11.98	6310	33.87	47.91
133	6.39	11.45	6410	33.40	48.76
134	5.53	13.88	6390	33.67	46.92
135	5.98	17.15	5690	33.78	43.09
136	6.19	12.08	6340	34.85	46.89
137	6.20	12.13	6320	34.59	47.08
138	6.28	12.07	6340	35.04	46.61
139	6.21	12.04	6200	35.35	46.40
140	6.27	12.06	6120	35.20	46.47
141	5.58	14.11	6100	33.21	47.10
142	6.46	13.94	6020	33.47	46.13
143	6.37	12.08	6300	34.65	46.89
144	5.59	13.59	6160	34.27	46.55
145	6.45	11.99	6260	34.97	46.58
146	6.78	14.03	5870	32.73	46.47
147	6.54	12.04	6230	34.42	47.01
148	6.54	12.03	6350	34.40	47.03
149	6.67	12.60	6140	33.52	47.21
150	8.57	16.15	5920	31.66	43.62
151	5.81	13.42	6210	33.67	47.10
152	6.11	11.36	6180	34.22	48.31
153	6.86	14.42	6100	33.00	45.72
154	5.63	13.00	6030	34.53	46.85
155	5.68	12.73	6300	35.34	46.24
156	4.82	13.55	6160	33.84	47.78
157	5.35	13.22	6270	34.46	46.97
158	5.45	13.59	5870	34.97	46.00
159	6.06	13.94	6240	33.66	46.34
160	5.16	18.56	6360	32.12	44.16
161	5.91	12.74	6150	35.48	45.86
162	6.24	12.09	5920	34.21	47.46
163	5.49	13.06	6020	33.95	47.50
164	5.77	13.93	6180	33.51	46.79
165	5.83	13.00	5920	34.30	46.87
166	5.70	13.31	6320	33.83	47.15
167	6.22	12.14	6310	34.98	46.65

168	7.45	18.58	6340	30.60	43.36
169	6.33	14.04	6320	33.36	46.27
170	6.15	12.07	6150	35.24	46.54
171	5.87	12.49	6120	33.62	48.02
172	6.91	15.56	5850	31.88	45.66
173	5.56	12.03	6080	34.45	47.96
174	4.91	13.59	6230	34.09	47.41
175	5.61	12.12	6360	34.32	47.95
176	7.36	15.64	6200	31.76	45.23
177	5.89	12.06	6160	34.31	47.74
178	4.97	13.58	6340	33.98	47.46
179	5.90	11.92	5840	34.16	48.02
180	5.89	11.97	5440	34.22	47.92
181	5.77	13.01	5950	32.56	48.66
182	5.29	13.15	5700	33.01	48.55
183	5.88	12.13	5960	33.22	48.77
184	5.08	13.75	6180	32.20	48.97
185	6.29	12.75	6280	32.97	47.98
186	5.65	12.98	6260	32.27	49.10
187	6.24	14.41	5990	31.79	47.56
188	5.45	13.13	6210	33.02	48.40
189	8.86	13.39	6120	31.07	46.68
190	6.24	12.02	6250	33.87	47.87
191	5.69	11.93	6150	36.17	46.21
192	5.61	12.97	6050	35.70	45.72
193	7.35	15.44	6130	33.13	44.08
194	6.24	16.20	5820	33.21	44.34
195	5.83	13.46	6230	35.00	45.71
196	5.00	12.97	6270	35.13	46.89
197	5.18	15.34	6060	34.48	45.01
198	5.14	13.40	6150	35.81	45.65
199	6.10	11.96	6280	35.80	46.14
200	5.33	13.26	6210	34.89	46.52
201	5.45	13.35	6260	34.09	47.10
202	5.52	13.36	6250	34.42	46.70

RESULTS AND DISCUSSION

Data have compiled an interval of 10 points to draw the graphical representation and correlation of Gross calorific value (GCV) with parameters of proximate analysis of coal.

Gross calorific value is one of the important parameters as per the requirements of IS 1350 (part-2) for coal² samples to determine the quality. The above (proposed) correlation studies are based on the data of thermogravimetric analysis¹ (TGA) and bomb calorimeter.² Already correlation studies were done based on the experimental data of coal to calculate the approximate calorific value by formula and Artificial

Neural Network (ANN) models.⁴⁻⁶ The proposed correlation studies are showing that the content of gross calorific value (GCV) is increased with the decrease of the content of moisture and ash respectively (Figs.-1 and 2). The content of ash of coal is an impurity that will not be burned. The gross calorific value (GCV) is also increased with the increase of the content of volatile matters and fixed carbon respectively (Figs.-3 and 4). Volatile matters are hydrocarbons such as methane and other gases etc., Fixed carbon is carbon in the free state that does not combine with other elements. This study of gross calorific value correlated with the parameters of proximate analysis is useful for determination of the quality of coal and also it may be useful for cement industries, thermal power plants, steel making industries, etc.

Moisture VS Gross Calorific Value (GCV)

The Gross calorific value was decreased with the increase in moisture content.

Fig.-1: Graph between Moisture VS Gross Calorific Value (GCV)

Moisture always lowers the heating value of coal, when moisture increases automatically gross calorific value decreases.

Ash VS Gross Calorific Value (GCV)

The Gross calorific value was increased with the decrease of ash content.

Fig.-2: Graph between Ash VS Gross Calorific Value (GCV)

Ash is an impurity will not burn. It is usually consists of silica, alumina, iron oxide, lime and magnesia etc., when high ash content, gross calorific value always decreases.

Volatile Matter VS Gross Calorific Value (GCV)

The Gross calorific value was increased with the increase of volatile matters. It consists of a complex mixture of gaseous and liquid products from thermal composition of coal. Volatile matter increases, gross calorific value also increases.

Fig.-3: Graph between Volatile Matter VS Gross Calorific Value (GCV)

Fixed Carbon VS Gross Calorific Value (GCV)

The Gross calorific value was increased with the increase of fixed carbon.

Fig.-4: Graph between Fixed Carbon VS Gross Calorific Value (GCV)

Fixed carbon calculated from 100 - (moisture + ash + volatile matter) etc., Fixed carbon is free state does not combine with any other elements. Gross calorific value increases with the increase of the high fixed carbon content.

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