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An Assessment of Chemical Properties and Hardgrove Grindability Index of Punjab Coal

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Abstract. This paper deals with the determination of chemical properties and hardgrove grindability index (HGI) of coal samples collected from three different coal fields of Punjab; Eastern Salt Range, Central Salt Range and Makerwal coalfields. The chemical properties of Punjab coal reveal that most of the Punjab coal belongs to sub-bituminous category except coal of Tunnel C section of Makerwal Collieries and Iqbal Mineral coal mine of Dalwal, which are high volatile bituminous and lignite, respectively. The results of the research show that the HGI values of Punjab coal vary from 57 to 92.The eastern salt range coals are found to be the softest coals among that of three coalfields. It was further observed that the HGI values of the Punjab coal decrease with increasing moisture content, fixed carbon and sulphur contents, while it has a positive relation with volatile matter, ash content and gross calorific value. It was concluded that moisture content at its lower range has negligible effect on HGI of the Punjab coal.

Keywords: chemical properties, coal, hardgrove grindability index

Introduction

Coal has prime importance among fuels in meeting the energy requirements of the whole world. It is by far the largest source of energy available to world economies today (Sanders *et al.,* 2002). Its utilisation through several technologies like carbonisation, combustion, coal water slurry, fluidised combustion beds, gasification, liquefaction and beneficiation requires grinding of coal to finer size (Sengupta, 2002). Grindability of coal is a central characteristic of coal, which is closely related to pulverizer performance and mill capacity (ACARP, 1998) and is defined as ease of grinding of coal which is, in turn, linked to coal tenacity, fracture and hardness (Rubiera *et al.,* 1999).

Grindability of coal is generally estimated by two indices: (a) work index in which energy consumption for obtaining product of constant fineness is measured; and (b) grindability index in which fineness of final product is measured for same grinding work of the standard samples. Determination of work index is time and labour consuming therefore, grindability index, most commonly known as hardgrove grindability index (HGI) is preferred for predicting the grinding behaviour of coal and energy consumption requirements of mill (Tichánek, 2008). HGI of coal is influenced by various factors including coal rank, composition and petrography, type and distribution of mineral matter particles and experimental conditions like temperature and pressure etc. Various physical and chemical properties of coal influence the value of HGI, including moisture contents, ash, volatile matter and fixed carbon, presence and proportion of various macerals and microlithotypes and composition and distribution of mineral matter (Jorjani *et al.*, 2008; Hills, 2007; Sengupta, 2002). Blending of coal is also an important factor which affects the grindability of a given coal. Generally, blending of coal does not show weighted average or additive relation among the HGI values of individual coal component (Vuthaluru *et al.,* 2003).

Rank of coal is an important factor which influences the grindability of coal. Generally, ease of coal grindability increases with the increase of rank but higher rank coals anthracite and lower rank coals lignite show more resistant to grinding than bituminous and sub-bituminous coals (Ozbayoglu *et al.,* 2008). Sengupta (2002) performed HGI tests on more than 300 coal samples collected from all coalfields of India and investigated the effects of ash, moisture, volatile matter and fixed carbon on HGI values. Positive relation of HGI with moisture content and ash content of coal was observed, while the relation with volatile matter and fixed carbon was negative.

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Earlier researchers have investigated the effects of maceral and microlithotypes on grindability of coal (Jorjani *et al.,* 2008; Trimble and Hower, 2003; Hower, 1998; Hower and Calder, 1997; Gray and Patalsky, 1990; Hower and Wild, 1988). Generally, softness of coal increases with increasing vitrinite content and decreasing micronite and liptinite macerals. Ural and Akyildiz (2004) studied the effect of mineral matter on grindability of low-rank coals. They found a positive relation of grindability with mineral matter content especially with quartz.

This study deals with the assessment of hardgrove grindability index of Punjab coal reserves in relation to their chemical properties. Coal deposits of Punjab are located in two coalfields; salt range coalfield, and Makerwal coal field (Fig. 1).

The total coal reserves of Punjab are found to be 235 million tonnes of which 213 millions are deposited in salt range and 22 millions in Makerwal (Warwick and Husain, 1990). At present most of the mined coal from Punjab coalfields is utilised in brick making industry while part of it is being used in cement sector which needs comminution of these coals before their usage. Normally imported coal is blended with the local coal to acquire permissible limits of coal properties for their effective utilisation in cement industry.

Materials and Methods

Materials. A total of eight representative coal samples were collected from different coalfields of Punjab. Among these, three samples were taken from three different areas (Ara, Mahinwal-Basharat and Dalwal) of the eastern salt range and three from different coal mines situated in the Bhadrar area of the central salt range (Fig. 2), while the remaining two were collected from different sections of Makerwal coalfield.

Methodology. Proximate, analysis was performed on each sample of coal in accordance with ASTM standards (ASTM, 2004 D3173, 3174, 3175). All tests were conducted on air-dried basis. Total sulphur

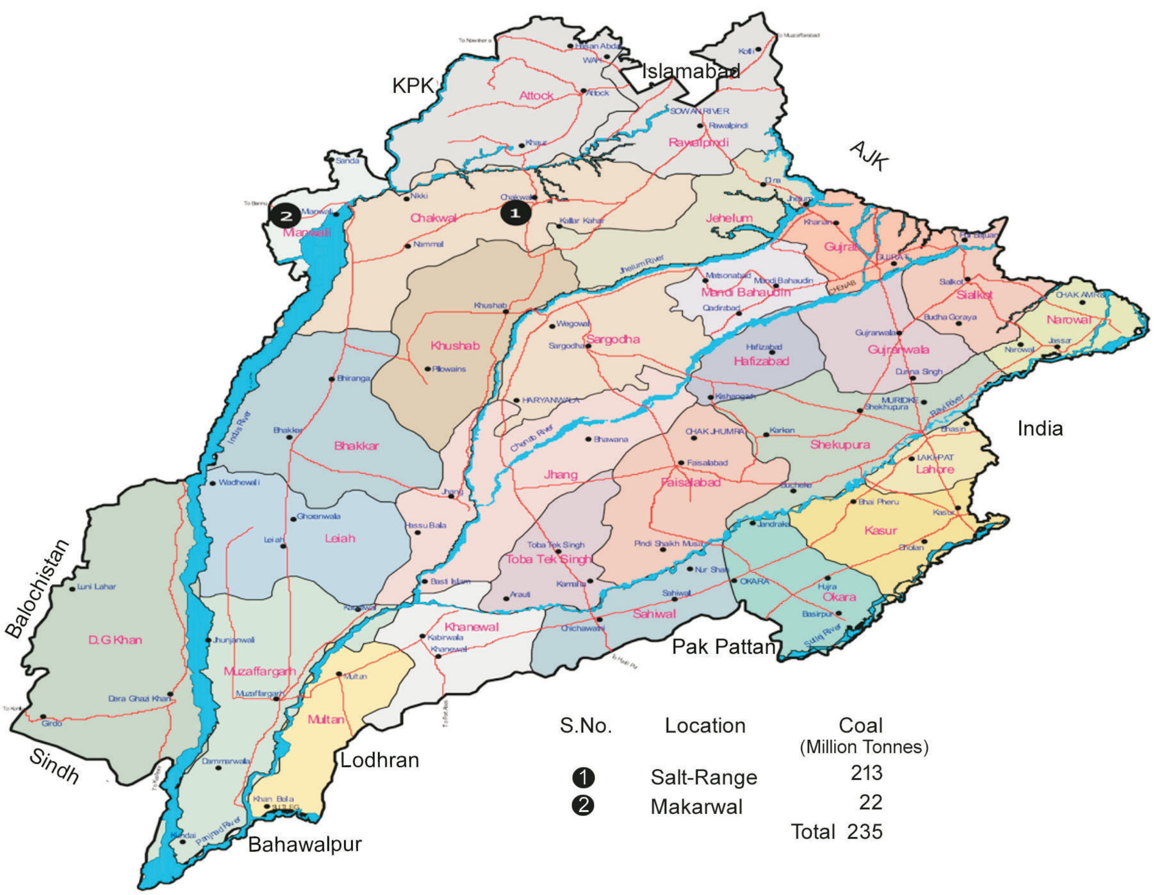


Fig. 1. Map showing locations of coalfields of Punjab, (Pakistan Coal Power Generation, 2004).

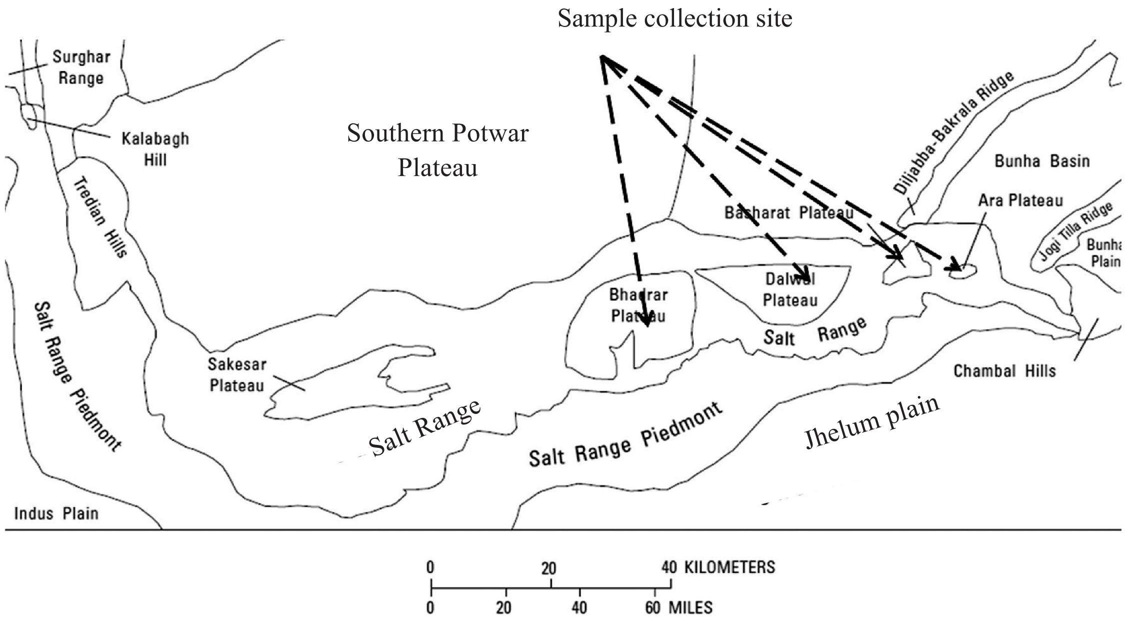


Fig. 2. Map showing the sample collection sites in the Salt Range (Warwick, 2007).

was determined using Eschka method (ASTM, 2004 E775-87). ASTM, 2004 (D409-02) was followed for determining hardgrove grindability index of coal samples. Each sample was crushed and screened to obtain a fraction of sample having size less than 4.75 mm, which was subsequently ground and screened to get an analytical sample of grain size of 0.6 to 1.18 mm. A charge of 50 g ± 0.01 g of coal was taken from analytical sample for performing grindability test in Hardgrove grindability machine (Fig. 3). After 60 revolutions of HGI grinder, the ground coal was screened for 10 min on 75 micron sieve. The weight of undersize was measured and HGI was calculated by following relation:

HGI = 13 + 6.93 (mass of -75 µm fraction).

Results and Discussion

The results of proximate analysis and hardgrove grindability tests are shown in Table 1.The proximate analysis performed on eight coal samples collected from three different coal fields of Punjab reveal that most of the Punjab coal belongs to sub-bituminous category except the Tunnel C section coal of Makerwal and Iqbal Mineral coal of Dhalwal, which are high volatile B bituminous and lignite A category, respectively.

Fig. 3. Hardgrove grindability machine.

Table 1. Proximate analysis and Hardgrove grindability index of Punjab coal

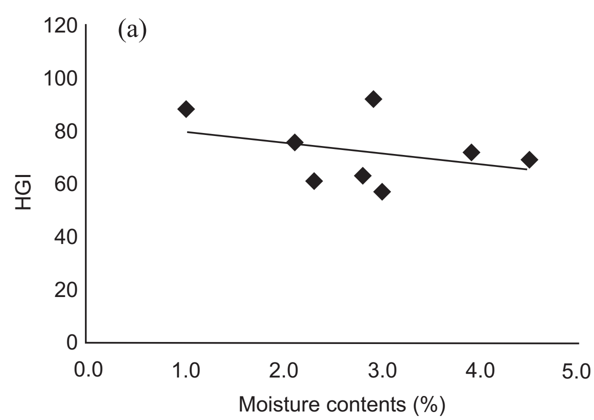
Coal type	Moisture contents (%)	Ash contents (%)	Volatile matter (%)	Fixed carbon (%)	Total sulphur (%)	Gross calorific value (Kcal/kg)	HGI	Coal class*
Eastern Salt Range coal								
Modern Engineering Coal Mine, Ara	3.9	30.6	34.8	30.7	3.82	5262	72	Sub-bituminous C
Hassan Kishor Coal Mine, Basharat	2.1	31.1	36.9	29.9	3.93	5431	76	Sub-bituminous B
Iqbal Mineral Coal Mine, Dalwal	1.0	50.4	29.1	19.5	5.66	3597	89	Lignite A
Central Salt Range coal (Bhadrar)								
PUNJMIN Coal Mine	3.0	31.9	33.8	31.3	8.24	4750	57	Sub-bituminous C
Sangha Coal Mine	2.3	25.4	38.8	33.5	6.24	5090	61	Sub-bituminous C
K. D. Well Coal Mine	2.8	18.5	43.2	38.3	6.77	5350	63	Sub-bituminous B
Makerwal coalfield								
Aslam Karandi section	4.5	28.7	43.9	22.9	4.51	4840	69	Sub-bituminous C
Tunnel-C section	2.9	13.0	48.7	35.4	1.52	7466	92	High volatile B Bituminous

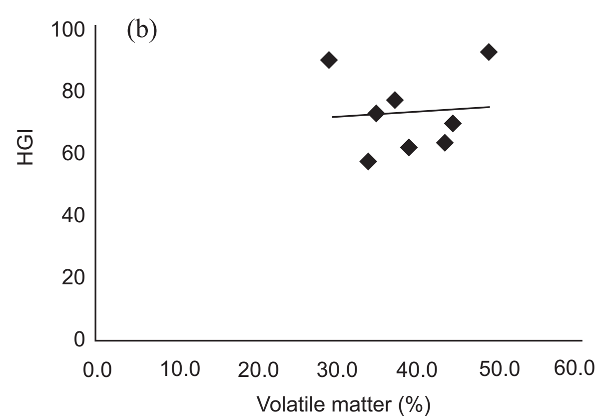
* = based on ASTM classification (ASTM D388).

The outcome of HGI tests indicate that Makerwal and eastern salt range coals are softer coals while central salt range coals are relatively harder. It is interesting to note that Tunnel C section coal of Makerwal which has the highest heating value and volatile matter and the lowest total sulphur contents among the tested coal samples shows the highest value of HGI. It is due to the fact that bituminous coals are easier to grind (Özbayoghu *et al.,* 2008). PUNJMIN coal of Central Salt Range having the highest total sulphur content reveals the lowest value of HGI, indicating the hardest coal among the eight coal samples. This is probably due to the presence of most of the sulphur in the pyritic form in PUNJMIN coal.

Although, lignite coals show resistance to grinding (Özbayoghu *et al.,* 2008) but lignite coal of Dalwal presents higher value of HGI i.e., softer coal. This is due to the presence of higher ash content which increase the softness of Dalwal coal (Sengupta, 2002).

Figure 4 shows the various graphs drawn between HGI *versus* moisture content, volatile matter, ash contents, fixed carbon, total sulphur and gross calorific value. The general trends show positive relation with ash content, volatile matter and gross calorific value, while the relation is negative with moisture content, fixed





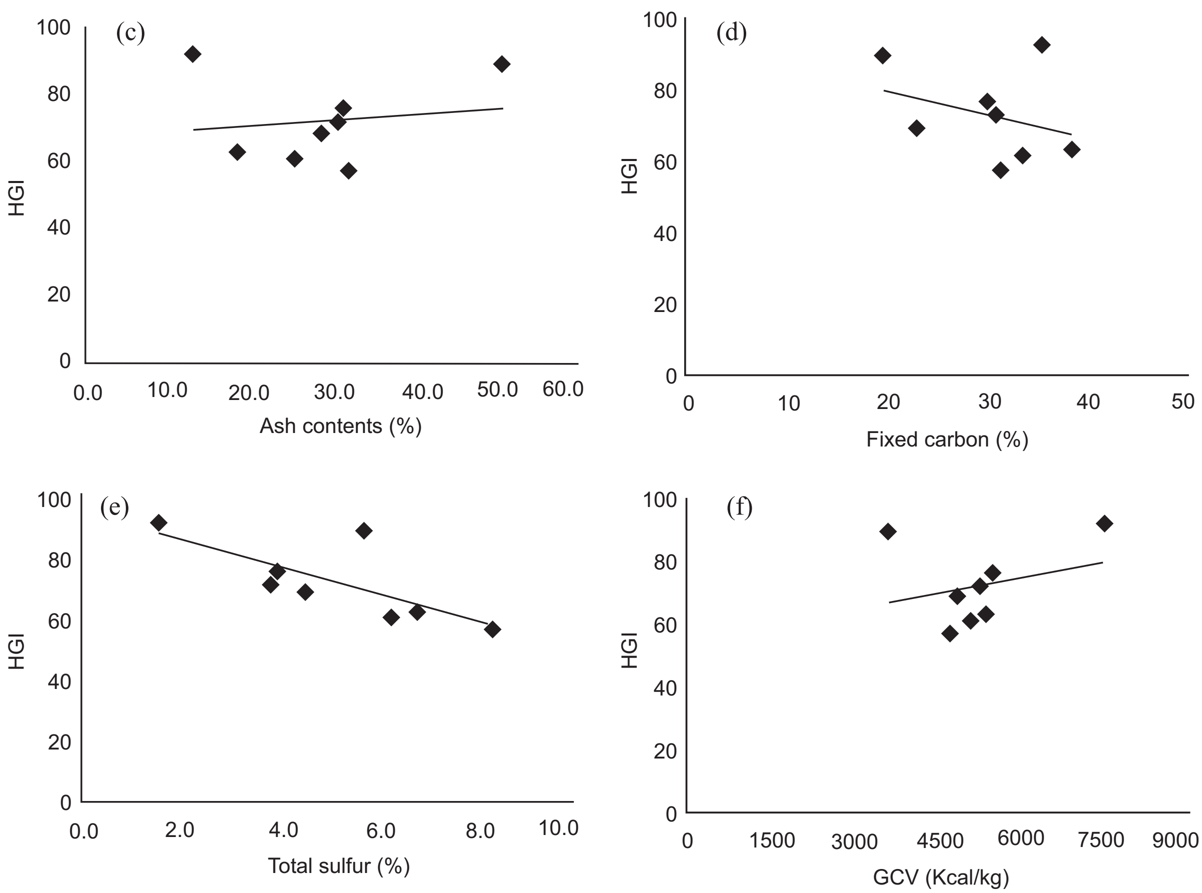


Fig. 4. Graphs showing HGI *versus* (a) moisture content, (b) volatile matter, (c) ash content, (d) fixed carbon, (e) total sulphur and (f) gross calorific value GCV (Kcal/kg).

carbon and total sulphur. The trend for volatile matter and ash content and fixed carbon is in accordance with that found by Sengupta (2002) but it is opposite for moisture content. The main reason for this difference is the range of moisture content in coal from 0.7 to 19%, while for Punjab coal it is from 1.0 to 4.5%, which indicates that effect of moisture on HGI vanishes at lower values of moisture and other parameters play prime role in determining HGI.

Conclusion

Chemical properties and hardgrove grindability index of various coal types of Punjab were determined. It was found that most of the Punjab coal belongs to sub-bituminous category and the HGI values vary from 57 to 92. HGI is frequently utilised in development design of grinding circuits for coal breakage. The results obtained from this study apparently indicate that grinding of Punjab coals is very smooth because its HGI values exceed 50 i.e., value at which most of the grinders are designed. Makerwal coal of Tunnel-C section is the most suitable coal for utilisation in cement sector and power industry as it has relatively high value of HGI with least total sulphur and ash contents. It was concluded that ash contents and volatile matter significantly, affect HGI of coal with moisture content less than 3% and fixed carbon less than 30%.

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