International Journal on Emerging Technologies 11(3): 507-509(2020)

ISSN No. (Print): 0975-8364
ISSN No. (Online): 2249-3255

Effect of Mineral matter on Ash Combustion Behavior of Indian Coal

Priya Ranjan Mishra[1], Rina Sahu[2] and Sanchita Chakravarty[3]
[1]Research Scholar, Department of Metallurgical and Materials Engineering, National Institute of Technology, Jamshedpur (Jharkhand), India.
[2]Assistant Professor, Department of Metallurgical and Materials Engineering, National Institute of Technology, Jamshedpur (Jharkhand), India.
[3]Sr. Principal Scientist, ANC Division, CSIR-NML, Jamshedpur (Jharkhand), India.

(Corresponding author: Priya Ranjan Mishra)
(Received 05 March 2020, Revised 28 April 2020, Accepted 30 April 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Coal has played a significant role for the development of modern civilization and the resources of high grade coal vanquishing at rapid rate due to its high demand. India has vast amount of high ash coal resources for which the assessment should be done in boiler operation conditions for effective operation and efficiency of thermal power plants. In present study, the ash fusion characteristics and liquid phase formation of the coal ash samples collected from Talcher coalfield, Orissa were investigated in boiler operation conditions. Chemical analysis shows that silica and alumina are the major components present in all four ash samples. Thermodynamic results show that alumina and silica reacts with each other forms high temperature stable sillimite phase, which is responsible for high AFT temperatures in Indian coal samples. XRD results obtained from the quenched ash samples also support the thermodynamic results. The complete liquidus phases formed at temperatures above 1500°C in all four coal ash samples, phosphorus forms $AlPO_4$ phase which is stable at high temperatures (>1500°C). AFT analysis approximately match with the thermodynamic results.

Keywords: AFT, Mineral matter and Coalfield (Orissa).

I. INTRODUCTION

In India, more than 60% of the power generation is produced through the thermal power sectors. The quality of the coal used in the thermal power plants has a direct effect on the operation cost, life, and efficiency of boilers. The inorganic matter or ash content in coal creates problems like fireside ash deposition, blinding the filter medium, slag depositions, and generation of hazardous air pollutants. The drift origin forms most of the Indian coals, hence they consist of high ash percentage [1-3]. The prediction of ash behavior relative to the boiler operation conditions is necessary for avoiding the ash or slag depositions. Traditional ASTM based ash characterization take lot of time, equipment cost, material waste, man power, and often fail to make a realistic behavior of highly heterogeneous coals [4].

The utilization of chemical thermodynamic computational methods is in progress for the effective prediction of ash fusion behavior at high temperatures. There are various thermodynamic database softwares are available for the accurate prediction of phase equilibrium conditions in complex coal ash slag. FactSage is one of the powerful thermodynamic tool box which has wide range of oxide component (FTOxid) thermodynamic database which can helpful in calculating the phase transformation of coal ash oxides in wide range of temperatures [5-6]. Kong *et al*., (2015) has successfully correlated the ash fusion and viscosity behavior using AFT analysis with FactSage thermodynamic calculations [7]. There are various works has presented the successful correlation of thermodynamic calculations with experimental ash fusion behavior in boiler operation conditions [8-10]. In present work, the ash fusion and viscosity characteristics of India origin (Talcher region) coal ash fusion behavior in boiler operation conditions. The slag tapping temperatures of coal ash collected from different seams of Talcher region has been predicted using the thermodynamic calculations. Thermodynamic calculations offer advantages like lowering the material wastage and cost of laboratory equipment operation.

II. MATERIALS AND METHODS

Samples for analysis were collected from four different boreholeD4, D5, CMTT025-C and CMTT026-C of Talcher coal mine, Orissa, India, were used in the present study. It was crushed and pulverized and made 212 micron size of fine powder. Chemical analysis of the ash was calculated by using XRF.Thermal properties of liquidus phase formation during the ash preparation was done by using FactSage.

III. RESULTS AND DISCUSSIONS

Proximate and Ultimate Analysis: Proximate and Ultimate investigation of the sample tests has appeared in Table 1. It shows that coals from different seams has shown variety in their chemical properties. CMTT025-C and CMTT025-D coal samples shown almost similar properties, while CMTT026-C coal shows higher moisture and ash content compared to others. Volatile matter in the CMTT026-C sample is lower compared to other samples. Sulfur content in the coal samples is lower in all three coal samples.

Table 1: Proximate and ultimate analysis data (air dried basis).

Borehole No.	Ash %	M %	VM %	FC %	C %	H %	N %	S %
MATT26 (D4)	54.59	7.25	20.16	18.00	35.10	2.25	0.93	0.43
MATT27 (D5)	51.44	7.98	21.47	19.11	35.35	2.30	1.01	0.43
CMTT025	50.90	6.81	23.47	18.82	34.66	3.36	0.99	0.6
CMTT026	43.11	8.87	24.26	23.76	34.56	2.33	0.95	0.41

Table 2: XRF data of coal ash (Equilibrated conditions).

Borehole No.	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	MnO %	TiO_2 %	P_2O_5 %	SO_3 %
MATT26 (D4)	64.7	23.37	4.73	1.57	0.96	0.04	1.22	0.77	0.29
MATT27 (D5)	66.7	23.44	2.1	1.82	0.88	0.01	1.29	1.00	0.42
CMTT025-C	65.4	23.69	3.01	1.91	0.91	0.02	1.26	0.99	0.46
CMTT026-C	64.3	26.45	3.22	0.83	0.67	0.02	1.56	0.68	0.12

Ash analysis: Chemical analysis of the ash prepared from D4, D5, CMTT025-C and CMTT026-C coal samples is shown in Table 2. Chemical analysis shows that silica and alumina are the major components present in the ash, iron, calcium, magnesium, titanium, manganese are minor components present in it.

XRD analysis: Fig. 1 indicate the mineral species present in coal ash as well as the mineral phases transformation behavior at temperature 815°C using XRD. Quartz and mullite are common minerals in all the coal ash. Sillimanite is also presence in abundance amount due to the presence of high amount of silica which is responsible for high Fusion temperatures.

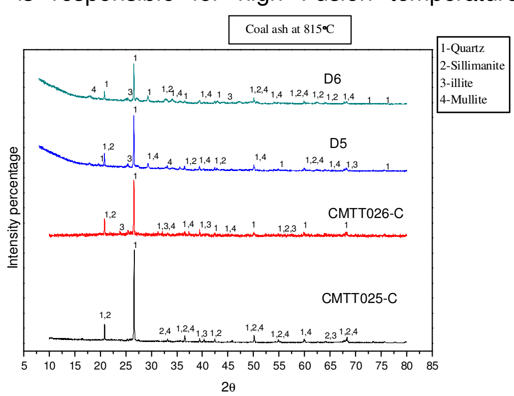

Fig. 1. XRD analysis of coal ash.

Ash Fusion Temperature Test: Ash fusion temperature tests for the three coal samples shown in the Table 3, it shows that CMTT025-C and D4 coal samples shows deformation temperature (DT) above 1400°C, which is very promising. While CMTT026-C coal shown deformation at lower temperature 1280°C but the fusion temperature is higher than the 1600°C.

Table 3: AFT of coal ash of different borehole sample.

Borehole No.	IDT(°C)	ST(°C)	HT(°C)	FT(°C)
MATT26 (D4)	1420	1480	>1600	>1600
MATT27 (D5)	1310	1370	>1600	>1600
CMTT025-C	1410	1410	>1600	>1600
CMTT026-C	1280	1350	>1600	>1600

Thermodynamic Analysis: Thermodynamic analysis of the phase transformation has shown below. FactPS, FactOxid, FTSteel databases are chosen for the thermodynamic calculation. Figs. 2, 3, 4 and 5 show the variation of the phases formed with temperature during the ash fusion. Al_2SiO_5 phase formation is the main reason for the high AFTs. Liquid phase started forming at 1100°C, but the liquid phase conversion rate increased drastically after 1200°C. As temperature increases silica phase transformed into quartz to tridymite. With an expansion in the temperature, there is a progress in the silica from quartz to tridymite stage. Presence of sillimanite is cause for increase of liquidus temperature, in light of high-temperature stability.

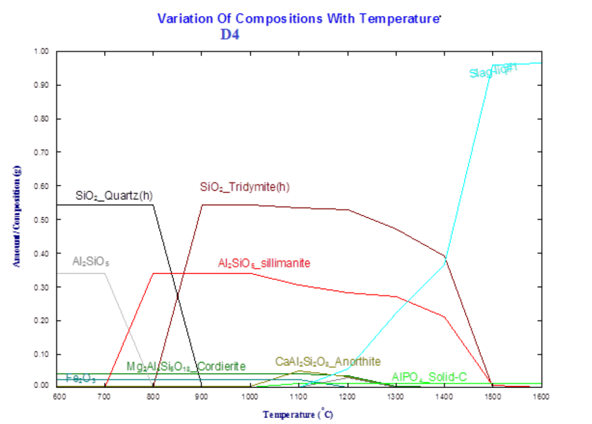

Fig. 2. D4 coal phase variations with temperature.

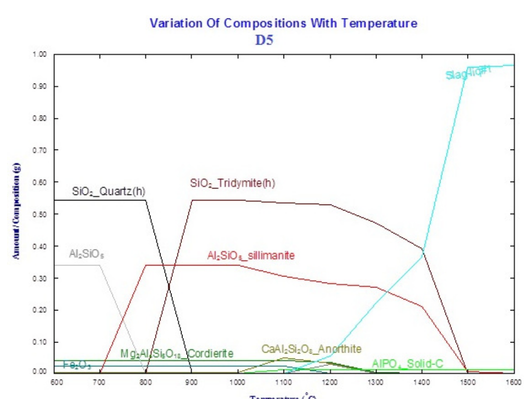

Fig. 3. D5 coal phase variations with temperature.

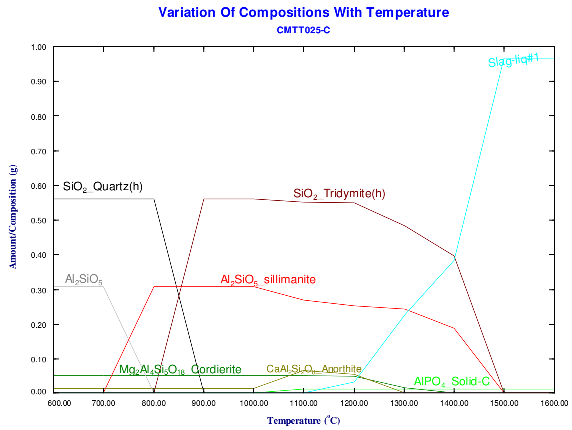

Fig. 4. CMTT025-C coal phase variations with temperature.

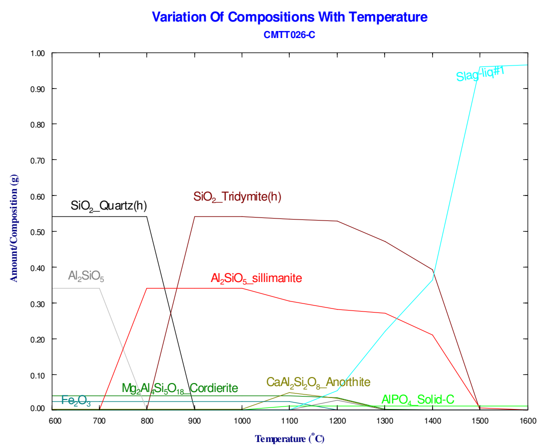

Fig. 5. CMTT026-C coal phase variations with temperature.

IV. CONCLUSION

– Ash fusion temperature of D4 and CMTT025-C is high demonstrating the obvious presence of quartz and silimanite.
– FactSage thermodynamic calculation indicates that melting point of silimanite is high whereas cordierite and rutile fully melts near about 1250-1350ºC respectively.
– The coals studied are similar in nature and possess almost negligible traces for slagging potential, therefore can find application in coal-fired thermal power stations.
– Ash fusion temperature of D4, D6, CMTT025 and CMTT026 is high indicating the appreciable presence of quartz and aluminosilicate.
– XRD figures (Fig. 1) showed us that the quartz is main mineral presence in coal.
–Present study has scope in understanding the phase transition behavior and in lowering the ash fusion temperatures in ash removal from boilers.

ACKNOWLEDGEMENT

The authors are thankful to the significant contribution and financial support provided by Dr. I. Chattoraj, director of CSIR - National Metallurgical Laboratory, Jamshedpur, India.

Conflict of interest. The author declares that there is no conflict between any organization and author.

REFERENCES

[1]. Mishra, U. C. (2004). Environmental impact of coal industry and thermal power plants in India. *Journal of environmental radioactivity*, *72*(1-2), 35-40.
[2]. Chakravarty, S., Mohanty, A., Banerjee, A., Tripathy, R., Mandal, G. K., Basariya, M. R., & Sharma, M. (2015). Composition, mineral matter characteristics and ash fusion behavior of some Indian coals. *Fuel*, *150*, 96-101.
[3]. Shaik, S., Chakravarty, S., Mishra, P.R., Sahu, R., & Chakravarty, K. (2019). Caking Ability Tests for Coal Blends in Process to Utilize the Indian Origin Coals. *Transactions of the Indian Institute of Metals*, *72*(12), 3129-3137.
[4]. Biswas, S., Choudhury, N., Ghosal, S., Mitra, T., Mukherjee, A., Sahu, S. G., & Kumar, M. (2007). Impact of petrographic properties on the burning behavior of pulverized coal using a drop tube furnace. *Energy & fuels*, *21*(6), 3130-3133.
[5]. Mishra, P. R., Sahu, R., & Chakravarty, S. (2020). Viscosity Analysis of Indian Origin Coal by Using FactSage at Different Temperatures. *Transactions of the Indian Institute of Metals*, *73*(1), 207-214.
[6]. Lee, S., Jung, B., Lee, N., Nam, W., Lee, S. J., & Yun, Y. (2018). Application of FactSage® thermodynamic modeling for predicting the ash transformation with temperatures under partial slagging entrained flow coal gasification condition. *Materials Testing*, *60*(2), 163-172.
[7]. Kong, L., Bai, J., Li, W., Wen, X., Li, X., Bai, Z., Guo, Z. & Li, H. (2015). The internal and external factor on coal ash slag viscosity at high temperatures, Part 1: Effect of cooling rate on slag viscosity, measured continuously. *Fuel*, *158*, 968-975.
[8]. Yuan, H., Liang, Q., & Gong, X. (2012). Crystallization of coal ash slags at high temperatures and effects on the viscosity. *Energy & fuels*, *26*(6), 3717-3722.
[9]. Zhou, J., Shen, Z., Liang, Q., Xu, J., & Liu, H. (2018). A new prediction method for the viscosity of the molten coal slag. Part 2: The viscosity model of crystalline slag. *Fuel*, *220*, 233-239.
[10]. Xin, D. A. I., Jin, B. A. I., Li, D.T., Ping, Y.U.A.N., Yan T. G., Kong, L. X., & Wen, L. I. (2019). Experimental and theoretical investigation on relationship between structures of coal ash and its fusibility for Al_2O_3-SiO_2-CaO-FeOsystem. *Journal of Fuel Chemistry and Technology*, *47*(6), 641-648.

How to cite this article: Mishra, P. R., Sahu, R. and Chakravarty, S. (2020). Effect of Mineral matter on Ash Combustion Behavior of Indian Coal. *International Journal on Emerging Technologies*, *11*(3): 507–509.