

Paper Number: 1453

Mineralogical Reactions in Low and High Ash South African Coals during Pulverised-fuel Combustion

Matjie, R.H.¹, Ward, C.R.², French, D.², Li, Z.³

¹ North-West University, Potchefstroom 2520, Republic of South Africa

² University of New South Wales, Sydney, NSW 2052, Australia (c.ward@unsw.edu.au)

³ CSIRO Energy Flagship, North Ryde, NSW 2113, Australia

The mineralogical changes produced during pulverised-fuel (pf) combustion of a Highveld Coalfield coal from South Africa, partitioned into fractions with low (13.5%) and high (39.6%) ash percentages, have been investigated using a pilot-scale combustion test facility[1]. The petrology, chemistry and mineralogy of the feed coals, and also of the ashes produced from each coal in different parts of the combustion system have been investigated using optical and electron microscopy, X-ray diffraction (XRD) and X-ray fluorescence (XRF) spectrometry, integrated with observations from the test program, and combined with other research [2-4], to evaluate the mineralogical reactions occurring in South African and similar coals under pf combustion conditions.

The mineral matter of both coals contained abundant kaolinite, with lesser proportions of quartz, ankerite and calcite, and minor proportions of pyrite and several other minerals. A small proportion of non-mineral Ca was also indicated in the organic matter. The mineral matter of the low-ash coal contained a greater proportion of carbonate minerals, due mainly to the occurrence of calcite and ankerite as cleat infillings in the more abundant vitrinite components. Quartz was more abundant in the mineral matter of the high-ash material.

Quantitative XRD analysis of the ashes collected from different parts of the test facility indicates that most of the quartz and rutile in both coals passed through the combustion process without alteration, suggesting that these phases are essentially non-reactive under pf conditions. The kaolinite was altered to metakaolin and then to mullite, with mullite formation initiated at around 900 °C. Calcium, derived from both the carbonate minerals and the organic matter of the feed coals, reacted with the aluminosilicate residues of the kaolinite and other clays at higher temperatures (around 1350 °C) to form an anorthite-rich feldspar phase, probably by solid-state reaction. Feldspar did not form in the cooler sections lower in the combustion chamber, but feldspar-bearing ash became detached from the upper sections and fell to the bottom of the test rig, especially when the high-ash coal was used as the feedstock.

Some of the Ca released from both coals also combined with SO₂ in the combustion gases to form anhydrite. This phase is more abundant in the products of the low-ash coal, due to the greater availability of Ca from the mineral matter. Lime (CaO) and periclase (MgO) were also identified in some of the ashes, especially those from the low-ash coal, suggesting that insufficient sulfur was available from that particular feedstock to convert all of these oxides to sulphate material.

The study provides an example of how quantitative mineralogical analysis, in conjunction with microscopy and ash chemistry, can be used to provide a more complete understanding of the processes associated with ash formation from different coals in pulverized-fuel combustion systems. Although

significant slagging or fouling problems are not indicated for either of the coals tested, the study provides a framework from which the more generic impact of variations in feed coal mineral matter or furnace operating conditions can be evaluated using geological principles and techniques.

References:

- [1] Matjie R et al. (2015) Energy & Fuels 29: 8226-8238.
- [2] Matjie R et al. (2011) Fuel Processing Technology 92: 1426-1433
- [3] Matjie R et al. (2012) Coal Combustion and Gasification Products 4: 45-54
- [4] Creelman R et al. (2013) Energy & Fuels 27: 5714-5724

