Abstract

Stringent SO_2 emission regulations have placed immense pressure on coal-fired power plants to desulfurize exhaust flue gas. Wet Flue Gas Desulfurization (WFGD), using limestone with forced oxidation (LSFO), is a common FGD process where limestone reacts with SO_2 to produce gypsum ($CaSO_4.2H_2O$). Eskom's Kusile Power Station (Kusile) receives high-grade limestone (96% $CaCO_3$) from Idwala Lime's Danielskuil mine site at a top size of 19 mm and work index of 12 kWh/t. The limestone is stockpiled and conveyed to a feed preparation area where conventional wet ball milling (in closed circuit with a classifier cyclone cluster) is used to reduce the limestone particle size to 95% passing 45 µm. The Kusile ball mill specific energy is 26.5 kWh/t.

The dry vertical roller mill (VRM) is a novel grinding technology that dries, grinds and classifies ore within a single unit. Testwork was conducted using a pilot-scale Loesche VRM to determine the energy consumption required to grind 100 t/h of the Danielskuil limestone to 85% and 95% passing 45 µm. The specific energy for these two conditions is 13.7 kWh/t and 16.1 kWh/t, respectively. A wet ball mill locked cycle test was conducted at Mintek to grind the limestone to 85% passing 45 µm and resulted in a circuit specific energy of 15.4 kWh/t (compared to 13.7 kWh/t from the dry Loesche VRM testwork).

The testwork data and information received from Kusile were used to set up flow diagrams and generate mass balances for equipment sizing. Various suppliers provided budgetary quotations for the different milling technologies and ancillary equipment. The total installed power for the wet ball mill circuit (including ancillary equipment) is 3,802 kW compared to 1,893 kW for the dry Loesche VRM circuit. The absorbed power for the wet and dry circuit is 2,734 kW and 1,703 kW, respectively. The mechanical cost of the wet ball milling circuit is R48,328,000 compared to R59,185,000 for the dry Loesche VRM circuit (increase of 22.5%). The different components of the capital expenditure (CAPEX) were calculated as a percentage of the mechanical cost. The CAPEX for the wet ball milling circuit and dry Loesche VRM circuit (including ancillary equipment) is R239,960,400 and R265,042,900, respectively (10.5% increase).

A hot gas generator (HGG) is required in the dry Loesche VRM circuit if the moisture content of the limestone feed is higher than 6.0%. Data provided by Kusile indicated that the feed moisture content is less than 1.0%. Therefore, the HGG was not included in the main cost comparison. The stockpile and conveying areas at Kusile are large enough so that the maximum rainfall in Delmas (where Kusile is situated) should not increase the moisture content of the limestone feed to more than 6%. With the HGG included, the CAPEX of the dry

Loesche VRM circuit is R286,283,200, which is 8.0% more expensive than the dry circuit without the HGG, and 19.3% more expensive than the wet ball milling circuit.

No water saving is realized for this application (even though the dry Loesche VRM circuit does not require water) because a 30% solids concentration limestone slurry is required for the FGD process to be sprayed into the scrubber. The operating factor for both milling circuits is 89.8%, because the limestone consumption is dependent on the SO_2 concentration in the flue gas. Therefore, the annual raw material (limestone cost) and water cost are the same for both circuits. The annual operating cost for the wet ball milling circuit and dry Loesche VRM circuit is R254,819,200 and R238,890,700, respectively. The reduced OPEX is as a result of the reduced power consumption (decrease of 37.8%) and no grinding media used for the Loesche VRM. Revenue from gypsum sales (R267/t) is estimated to be R361,304,200 for both circuits.

The net present value (NPV) of the wet ball mill circuit is R348,407,000 based on an assumed 20-year plant life, 12% interest rate, and 35% corporate income tax. The corresponding interest rate of return (IRR) is 20.2% with a discounted payback period (DPBP) of 4.1 years. The return on investment (ROI) is 39.9%. In comparison, the NPV of the dry Loesche VRM circuit is R408,573,000 which is 17.3% higher than for the wet ball mill circuit. An increased IRR of 21.3% is observed with a slightly reduced DPBP of 3.8 years. The ROI is 8.6% higher at 48.5%.

An alternative option is for the limestone to be milled off-site (dry VRM circuit at the limestone mine) so that the dry, milled limestone is delivered to site without further grinding and/or processing required. This could result in a significantly reduced CAPEX and OPEX for the FGD process at any coal-fired power plant.

It should be noted that the results obtained from this study are specific to this project and characteristics of the Danielskuil limestone ore. The aim of the study is to compare the different circuits, and not to provide an accurate overall project cost estimate. A detailed engineering study is required to increase the accuracy of the cost estimate.