Why is CSR Important?

Many coke plants and blast furnaces around the world use CSR as a specification just as important as cold strength, size, and chemistry. Researchers have studied reactivity and its influence on blast furnace performance and productivity. The use of both physical and mathematical models of the various blast furnace zones, the monitoring and sampling of heavily-instrumented blast furnaces, and the quenching and subsequent sampling of commercial furnaces have aided in determining the effect of changes in coke reactivity on furnace operating parameters such as fuel rate, furnace permeability, and hot metal production. It has been widely reported in the literature that increases in CSR have led to decreases in blast furnace fuel rates. The magnitude of fuel rate reductions varies for different blast furnaces and operating parameters. The exact effect of coke reactivity on blast furnace performance is not completely clear; however, most furnace operators agree that the coke should not readily react at lower temperatures in the upper zone of the furnace to avoid wasted carbon. Also, highly reactive coke may become substantially weakened so that it cannot properly support the burden during its descent through the blast furnace. By the time the coke works its way to the high temperature combustion zone, or raceway, the coke may become so weak that it causes major upsets to occur in raceway performance. Poor raceway behavior restricts both gas and liquid permeability in the blast furnace, reducing overall furnace efficiency.

As a result of major changes in blast furnace operating parameters and practices through the 1990's such, as increased usage of auxiliary fuels and improved operating efficiency, coke rates to the blast furnace have dropped well below 1000 pounds per ton of hot metal. Thus, the need for strong and consistent coke properties has become greater than ever. Ideally, cokes should be high in CSR and low in corresponding reactivity. The optimum CSR will depend on the particular blast furnace, its associated practices, and overall production goals.

Such as carbon dioxide, oxygen, air, or steam. The rate of reaction depends upon the character of the coke surfaces, the surface area exposed, and the chosen test conditions (gas composition, velocity, concentration, and temperature). The various reactivity tests are empirical in nature and are determined for prescribed conditions as to the amount and size of coke, geometry and dimensions of the reaction chamber, duration of reaction, and the gas composition, pressure, and temperature. Although there is no universally accepted standard procedure for measuring coke reactivity, the Japanese method (Nippon Steel) reactivity test is widely recognized both domestically and abroad. ASTM officially adopted this test method as its standard procedure in 1993. the test determines both the coke reactivity Index, or CRI, and the coke strength after reaction, or CSR, of a given sample of coke.

The standard ASTM test method D 5341 for measuring CRI and CSR requires reacting 200 grams (0.44 pounds) of 19 by 21 mm (¾ by 7/8 inch) dry coke with carbon dioxide, adjusted to a flow rate of 5 liters per minute (0.18 cubic feet per minute), for two hours at a temperature of 1100 degrees Centigrade (2012 degrees Fahrenheit). The CRI is reported as the percent weight loss of the coke sample after reaction. The cooled, reacted coke is then tumbled in an I-drum for 600 revolutions at 20 rpm. The cumulative percent of plus 10 mm (3/8 inch) coke after tumbling is denoted as the CSR. Generally, cokes with high CRI values have low CSR's and cokes with low CRI values have high CSR's. It should be noted that "hot" strength, as measured by CSR, does not correlate with "cold" strength, as measured by the ASTM tumbles test.
Factors Affecting CSR

Coke properties that affect reactivity include:
Texture (carbon forms)
Structure (Porosity, pore size, and pore wall thickness)
Ash composition (Alkalies, sulfur, iron, etc)

These coke properties can be readily traced to the parent coals making up the blend composition. The rank, type, and grade of the constituent coals determine the characteristics of the resultant coke. It has been shown that coke with isotropic texture derived from weakly-coking high-volatile (HV) coal is chemically weak and easily attached by the gasification reaction with carbon dioxide. Better coking HV and medium-volatile (MV) coals produce coarse circular and lenticular carbon forms with lower reactivity, whereas, low-volatile (LV) coals produce ribbon-like carbon forms with intermediate reactivity.

Reactivity increases as coke porosity increases. The carbonization of different coal ranks and types produces varying coke structures which, in turn, affect reactivity. Cokes produced from low rank HV coals exhibit thicker walls and less pore area. LV coals produce cokes similar in porosity to those produced from the lower rank HV coals. Coal type, or the relative proportion of inert and reactive macerals, also affects coke structures. For example, coals that are high in inerts produce thick-walled cokes, while similar rank coals with low inerts produce thinner walled cokes. Porosity is also influenced by carbonization conditions such as bulk density, heating, and pulverization.

In addition to the properties of coke carbon texture and structure, another factor that affects reactivity is the composition of the ash (or minerals) in the coke. For example, the presence of alkalies (sodium and potassium), iron, calcium, and magnesium can lead to an increased rate of reaction with carbon dioxide.

Coke Reactivity

Traditionally, chemistry, size and cold strength (tumbler stability and hardness) have been considered the most important properties for evaluating coke for use in the blast furnace. However, coke reaction with carbon dioxide (CRI) and coke strength after reaction (CSR) have also been reported by many companies to be important indices in evaluating coke. Accepting the premise that CSR is a critical property when assessing blast furnace performance, this newsletter presents practical and theoretical techniques for measuring and predicting CSR's of cokes produced from individual coals and coal blends. Once this data is generated, coal blends maximizing CSR, while at the same time maintaining or increasing stability and not negatively impacting oven pushing and coking pressures, can be designed. Constraints on coal availability, existing contracts, costs, and coke plant operating variables will all impact the maximum achievable coke quality.