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Jinlong Copper Co. Ltd. implemented Praxair's dilute oxygen combustion (DOC)-JL oxy-fuel technology on anode furnace #3 in August 2009 to reduce energy consumption and pollutant emissions. Later, the same system was implemented on anode furnace #1 for scrap melting.

Jinlong Copper Co. Ltd. is one of the largest primary copper producers in the People's Republic of China, and its plant is located in Tongling City, Anhui Province. The plant was started up in 1993, and the current annual production is 350,000 metric tons (t) of high-grade cathode and 1.1 million t of sulfuric acid.

Praxair® DOC technology uses separate high-velocity fuel and oxygen jets to generate strong in-furnace gas recirculation, producing combustion between the fuel and a highly diluted oxygen and furnace-gas mixture. These very low-NOx oxy-fuel burners have been developed and commercially demonstrated in copper, glass, aluminum and lead melting furnaces and steel reheating furnaces among others. DOC technology meets industry needs for increased productivity and lower operating costs with minimal capital expense and low maintenance.

DOC (Dilute Oxygen Combustion) Technology

Traditional oxy-fuel burners produce very intense high flame temperatures that can potentially cause hot spots, leading to concern regarding refractory damage, oxidation (such as in aluminum melting) and volatilization (such as in glass melting).

DOC technology is a low-peak temperature and low-NOx oxy-fuel combustion process using in-furnace recirculation of flue gas. The in-furnace recirculation technique, or the aspirating burner, demonstrated that the peak flame temperature of oxy-fuel flames could be reduced even below those promoted by conventional air-fuel burners (Fig. 1).

DOC technology design is based on deep staging using separate high-velocity fuel and oxygen jets to generate strong in-furnace gas recirculation, producing combustion between the fuel and a highly diluted oxygen and furnace-gas mixture

(Fig. 2). The rich primary-zone stoichiometry produces high-luminosity flame for high heat-transfer efficiency, and the separate secondary-oxygen-controlled injection provides the flame adjustability. Due to the flame adjustability feature, DOC technology promotes optimized flame coverage and heat transfer. DOC technology meets industry needs for productivity increases, low operating costs with minimal capital expense and low maintenance.

Drivers for Anode-Furnace Conversion to Oxy-Firing Technology

Jinlong's program for energy consumption and pollutant emission reduction led it to select the anode furnace as a potential unit for oxy-fuel technology implementation. The main issues identified by Jinlong to be tackled in the anode furnace were:

- High energy consumption via fossil fuel
- High power consumption with the

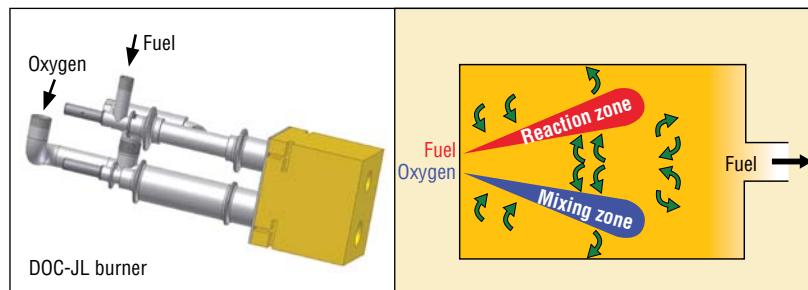
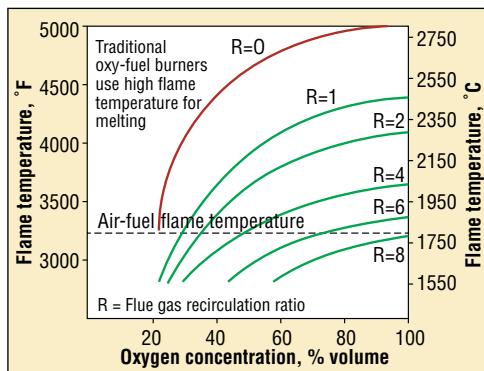


Fig. 2. (Above) Schematic of dilute oxygen combustion (DOC) technology

Fig. 1. (Left) Impact of the aspiration technique on peak flame temperature.



Fig. 3. Anode furnace #3

combustion-air supply system (blower) and exhaust system (ID fan)

- Heavy smoke generation, mainly during the reduction period, due to the incomplete combustion of the gases generated from the liquid bath

DOC-JL technology was selected due to the uniform flame temperature profile, uniform heat distribution, multiple fuel capability (heavy fuel oil, gaseous fuel and solid fuel) and low maintenance. The significant reduction of the flue-gas volume allows the exhaust system to be operated at lower power load.

The control system was designed to allow the introduction of additional oxygen through the staging lance to complete the combustion of the partial oxidized species generated in the liquid bath, mainly during the reduction phase. The complete combustion is a result of the combination of the reduction of combustion gases generated by the DOC technology, which led to higher residence time of the gases in the furnace and oxygen being injected at high momentum to promote enhanced mixing.

Anode-Furnace Description and DOC System

The nominal holding capacity of Jin Long anode furnace #3 is 450 t (500 tons) of liquid metal with about 12 meters (39.5 feet) internal length (Fig. 3). The anode furnace's original combustion system was a dual-fuel air burner rated at 7-MW (24 MM Btu/h) nominal firing rate.

The air-fuel burner was removed, and a dual-fuel DOC-JL burner rated at 2.5-MW (9 MM Btu/h) nominal firing rate was installed in the same port at anode furnace #3 in August 2009. The same system was installed in anode furnace #1 in May 2010 in order to allow scrap and return melting. Vertical orientation of the DOC-JL burner, fuel and oxygen injection velocities, and de-

gree of staging were determined to promote uniform heat distribution over the bath.

A full automatic combustion-control system (Fig. 4), with all safety interlocks required for oxy-fuel operation, was installed in the copper anode furnace and integrated to the existing anode furnace-control system. The control system designed for the DOC-JL allows adjustments of fuel-to-oxygen ratio as well as the degree of staging in such a way that the oxy-fuel system can be operated at the stoichiometric ratio required for each phase throughout the heat. This feature promotes the combustion of partially oxidized gaseous phases coming out of the liquid bath, minimizing pollutant emissions.

Anode furnace #3 is charged with liquid blister in two steps with a heating phase in between, while anode furnace #1 is charged with solid scrap and returns. The DOC-JL burner firing rate is maintained steady throughout those phases. Firing rate is adjusted for the oxidizing phase, and the stoichiometric ratio is raised for the reduction phase. The firing rate, stoichiometric ratio and degree of staging is remotely adjusted from the control room based on the requirement of each step throughout the heat.

DOC-JL System Performance

From an energy standpoint, in spite of the low-purity oxygen stream supplied by an on-site air-separation plant, the fuel consumption in the refining process in anode furnace #3 was reduced by over 65%, from 209 kWh/t to 77 kWh/t (0.65 MM Btu/ton to 0.24 MM Btu/ton), and no impact on the quality of the cast anodes was observed. The overall reduction in energy consumption via fuel was around 6.6 MWh/t of oxygen (20.3 MM Btu/ton O₂).

Historical data shows a typical 10-hour cycle for charging, heating, oxidizing and reduction phases of the anode furnace.



Fig. 4. DOC-JL burner and oxy-fuel control system valve rack

Although the main goal of the DOC-JL system is energy savings, this cycle was shortened by about 30 minutes due to accurate flow control and fuel-to-oxygen settings during the reduction phase. Flow rates of oxidizing and reducing agents were kept unchanged.

For the scrap and return melting in anode furnace #1, the specific energy consumption firing fuel oil was reduced by over 60%, from 1,115 kWh/t (3.5 MM Btu/ton) with air-fuel to 409 kWh/t (1.3 MM Btu/ton) with DOC-JL system.

The 75-kW blower used to supply combustion air to the anode furnaces has been shut down, and the load on the ID fan was significantly lowered, promoting additional power savings.

In regard to emissions in both cases, flue-gas volume was reduced by about 75% and CO₂ emission expected to be reduced at about the same rate as the reduction in fuel consumption. Since the DOC-JL is an ultra-low-NO_x emission burner, the NO_x emission rate is also expected to be substantially reduced. Smoke emission due to unburned organics generated during the reducing phase was solved with the oxy-fuel system installed in the anode furnace.

Summary

A DOC system has been successfully implemented in anode furnace #3 for refining and anode furnace #1 for scrap and return remelting at Jinlong's plant. The system has delivered significant fuel savings, power savings and CO₂ emissions reductions without any additional requirement on the furnace operators. Anodes cast from the anode furnace operated with DOC technology show no difference in properties compared to the anode furnaces equipped with air-fuel firing systems.

DOC technology offers energy savings, emission reduction and cost reduction in the copper industry. **IH**