COMBUSTION, THE HIDDEN SIDE OF QUALITY ROD

Cathodes charging operation

To most of the CCR producers, the word "combustion" immediately invokes images of a complex network of piping, burners and troughs that transforms the metal from solid to liquid by burning very expensive fuel to feed the casting machine. Everyone is aware of how combustion affects production costs, however, not everyone knows how combustion influences the final rod quality.

We would like to very briefly discuss with our readers how important combustion control is to product quality and why it may cut costs as well.

COMBUSTION THEORY

Combustion is the fast oxidation process of a fuel. The reaction generates the physical phenomenon known as "flame" and releases energy in the form of heat and some by-products.

For simplicity, if we assume the use of natural gas, which only contains CH_4, the combustion reaction will be:

$$CH_4+2O_2 = CO_2+2H_2O+Heat$$

Since combustion oxygen is normally supplied to the mixture as air, we then assume the combustion air to be 21% oxygen, 78% nitrogen, 1% argon, plus traces of other components. Therefore, in short, we need 10 m^3 of air per 1 m^3 of natural gas, or:

$$CH_4+2O_2+8N_2= CO_2+2H_2O+8N_2+Heat$$

This combustion is complete and the 1/10 ratio is known as "stoichiometric". It is also important that the gases are thoroughly mixed.

The inert nitrogen plays no role in the combustion chemistry, other than absorbing some heat. However, the stoichiometric proportion enables the highest release of heat, or the highest flame temperature.

The stoichiometric mixture is the most advantageous in terms of thermal efficiency.

However, in an industrial process such as the shaft melting furnace, it is practically impossible to obtain the perfect mixture required to facilitate complete combustion. Therefore, we have to deal with two opposite combustion conditions:

REDUCING RATIO

If we have an excess of fuel or a lack of oxygen (air) we assume the combustion mixture to be "rich". The resulting flame will be longer, yellowish and smoky. Such combustion is also known as "incomplete" as some of the fuel particles will have no matching oxygen to react completely. The incomplete combustion generates a toxic gas know as carbon monoxide (CO), which is normally used as an indicator of the combustion ratio.

The generated flame will be "reducing" and colder.

In a CCR shaft furnace, an incomplete combustion can generate the following issues:

a Waste of fuel, as a number of particles will not take part in the reaction, thus decreasing furnace efficiency.

b Dissolved hydrogen (H_2) in copper. The gas may combine with impurities in the cathodes, producing hydrates which weaken the intergranular bonds thereby making the cast bar more brittle. Furthermore, the dissolved H_2 may evolve in excessive water vapor as solidification begins, originating gas porosity and splashes in the casting pit.

c Pollution. The unburned particles will boost carbon dioxide (CO_2) in the flue gases to levels which may not match local environmental regulations.

In addition to the CO analyzer readings, the furnace operator can detect a highly reducing flame by making observations through the burner eyepiece the color may appear purple to red, with darker slicks forming in front of the burner. In some extremely reducing conditions, close to or over 5% CO, the flame can partially or completely extinguish thereby promoting the opposite effect, causing oxidation to soar.

OXIDIZING RATIO

If we have excess oxygen in the mixture, we assume the combustion to be "lean". The resulting flame will be blue and very short. This combustion is also known as "oxidizing", as not all the oxygen takes part in the chemical reaction and remains free.

The "free" oxygen will absorb part of the generated heat, therefore, the flame will also be colder.

The induced CO will be, or close to, zero. However, the free O_2 will affect the combustion in the CCR shaft furnace in the following manner:

a The free oxygen will oxidize some impurities in the raw material, reducing, to some extent, the deleterious effect on quality. However, the copper will be rapidly oxidized as well, increasing the O_2 concentration in the final product, sometimes to unacceptable limits.

b The furnace lining material, silicon carbide (SiC), may be severely damaged as it gets easily oxidized at high temperatures. SiC shapes, especially in the burner area, could literally dissolve thereby extensively reducing the refractory life. More slag, and therefore more inclusions, may be generated by this process.

Again, the furnace operator can detect an oxidizing flame by looking into the burner eyepiece; the color will be greenish, clearly indicating the oxidation of copper. Some darker spots may also appear. The flame, lacking fuel, may eventually extinguish, quickly raising O_2 in the copper.

RECOMMENDED CO SETTINGS, MELTING FURNACE

As stated before, it is not possible to obtain perfect combustion. Consequently, it will be necessary to determine a CO setting, or ratio, which will be a compromise to minimize the issues from either "rich" or "lean" combustion in order to enable the most effective copper melting.

A slightly reducing ratio, from 0.5 to 1% CO, is therefore recommended in the melting furnace. This range has been considered a common practice for many years by most of the operators.

The flame in the eyepiece will appear bright orange-yellow.

The lower limit of 0.5% CO may, in fact, keep the oxidation on the safe side, preventing the copper and the SiC lining from being affected during the firing rate variations and mitigate any counter-pressure due to the shifting of the charge.

The upper limit of 1% CO may still allow the flue gases to remain within some of the local environmental emissions specifications.

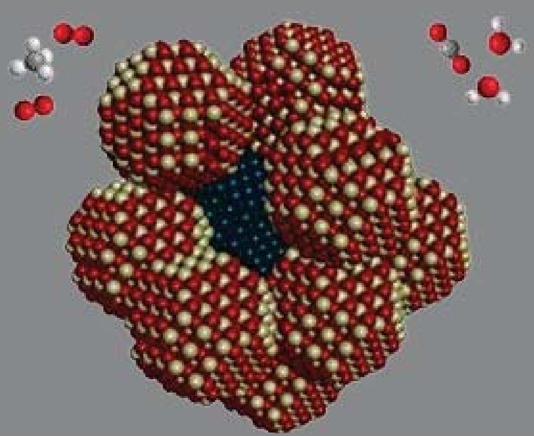
With this CO range setting, the resulting O_2 in the molten copper should be from 50 to 100 ppm, depending on charge composition and combustion control equipment accuracy.

It must be noted that overall results can easily be impaired by a single burner malfunction. Thus, the ideal CO range should be carefully maintained on all the burners in the shaft furnace.

NON-MELTING BURNERS

A different approach should be taken for the non-melting

Combustion principle



$$CH_4+2O_2 = CO_2+2H_2O+Heat$$

units, like launders, holding furnace and tundish. Even though it is less crucial in these areas, the CO setting still plays a significant role in the final rod quality.

Launders

The design, length and burner number may vary widely from plant to plant. The burners' main purpose is to keep the molten metal from freezing while it is being transfered. However, the CO setting should be adjusted so that the copper flow remains protected from the surrounding atmosphere by non-oxidizing combustion products; a typical setting would be 1.5 to 2% CO. In the lower (or second) launder, the setting may gradually be slightly decreased in order to bring the O_2 in copper to the higher, desired levels.

It might be noted that cooler spots along the metal path may induce the dissolved iron in copper to segregate thereby generating potential inclusions. Make sure the temperature in the launders remains consistent by suitably regulated burners.

Holding Furnace and Tundish

The combustion system should maintain and control the copper temperature and prevent the metal from being uncontrollably oxidized. Non-oxidizing flue gases should fill these almost closed environments. Depending upon the design, a higher CO setting may be required: normally from 2 to 3%.

COMBUSTION CONTROL

It is clear, though, that keeping such relatively narrow CO ranges in all the burners requires dedicated, skilled practice. However, the state-of-the-art combustion equipment that Continuus-Properzi can supply will enable the furnace operator to full attain optimum results. This equipment includes:

Automatic Ratio Control

The system automatically maintains the pre-set combustion ratio on the burners, rapidly adjusting the gas flow at each firing rate change, thus keeping consistent combustion quality. This system, as designed by Continuus-Properzi, makes it possible to safely stay closer to the more efficient 0.5% CO limit. This arrangement also allows the O_2 setting to be quickly reduced during start-ups by easily altering the ratio to a reducing stage.

Automatic CO Control

Although the Automatic Ratio Control is very accurate, uncontrolled changes in fuel quality may affect the results. The fast CO analyzer will therefore override the pre-set ratio values by the amount strictly necessary to maintain a constant CO level.

The equipment design provided by Continuus-Properzi enables the correct proportioning and optimal mixing of the gases.

CONCLUSION

The convenient control of the combustion system enables the copper to be melted and cast into a sound, quality bar, while significantly reducing fuel and refractory costs.

A slightly reducing environment is recommended. A setting of 0.5% CO is the best compromise between quality and expenses.

We hope this information has been useful and we would like to point out that Continuus-Properzi can provide the equipment, engineering and expertise necessary to achieve optimal combustion control in your process. *by Andrea Peviani*

Combustion quality is always a very important factor