Oxygen fuel combustion and its application in reheating furnaces

Oxygen-rich combustion and its application in reheating furnaces

Steel reheating is an energy-intensive process that requires uniform temperature distribution within the reheating furnace. Historically， heat exchangers have been used to preheat the combustion air and thus save energy. Recent innovations include oxygen enrichment (O2) and the use of regenerative burners， which provide higher preheating air temperatures than heat exchangers. These processes have limitations such as aging equipment， decreasing energy efficiency over time， high maintenance costs， and increased NOx emissions as the air preheat temperature increases unless special equipment is used.

Three things are necessary to start and maintain combustion. They are fuel， oxygen and sufficient energy for ignition. The efficiency of the combustion process is highest if the fuel and oxygen can meet and react without any restrictions. However， in heating practice， in addition to efficient combustion， heat transfer is also a practical consideration.

The common air used for combustion contains nitrogen (N2) and argon (Ar) in addition to oxygen. In an air-fuel burner， the burner flame contains nitrogen from the combustion air. A large amount of fuel energy is used to heat this nitrogen. The hot nitrogen leaves through the chimney， resulting in energy loss. As a result， the air does not provide optimal conditions for combustion and heat transfer. The heat absorbed by the nitrogen is either wasted or recovered to achieve energy savings. Currently， the best air-fuel heating systems in reheat furnaces require a minimum of 310 megacalories per ton of steel to reach the proper temperature for rolling steel products.

Historically, the primary use of oxyfuel combustion has been for welding and cutting metals, especially steel, because oxyfuel combustion allows higher flame temperatures than can be achieved with air-fueled flames. The introduction of the innovative oxyfuel burner technology (using 100% oxygen) for reheating steel is a very new phenomenon. The concept of oxyfuel combustion was introduced by Abraham in 1982 to provide carbon dioxide (CO2) rich flue gas. Because of its potential benefits, the Argonne National Laboratory (ANL) has conducted several research activities, including techno-economic studies and pilot scale studies on the subject.

Oxyfuel is the practice of completely replacing air with industrial-grade oxygen as the oxidant source for combustion. Industrial grade oxygen is defined as a liquid oxygen supply vaporized into a gas or generated on-site. The purity of the liquid oxygen supply typically exceeds 99.99%, while the purity of the on-site generated oxygen typically ranges from 90% to 93%. The advantage of using on-site generated oxygen is that it is less expensive because the product does not need to be liquefied or transported and is delivered at a lower pressure to minimize power consumption. In integrated steel plants with steelmaking air separation plants, high purity oxygen (99.99%) can be supplied from the air separation plant via pipeline.

When industrial grade oxygen is used to avoid nitrogen, as in the case of oxyfuel combustion, not only is the combustion itself more efficient, but so is the heat transfer. Oxyfuel combustion affects the combustion process in several ways. The first obvious result is the increased thermal efficiency due to the reduced amount of exhaust gas, which is a fundamental result and is valid for all types of oxy-fuel burners. In addition, the concentration of highly emitted combustion products - carbon dioxide and water - increases in the furnace atmosphere. For heating operations, these two factors lead to higher heating rates, fuel savings, lower CO2 and NOx emissions and, if the fuel contains sulfur, lower sulfur oxide emissions. Figure 1 shows the oxygen-fuel and air-fuel combustion processes.

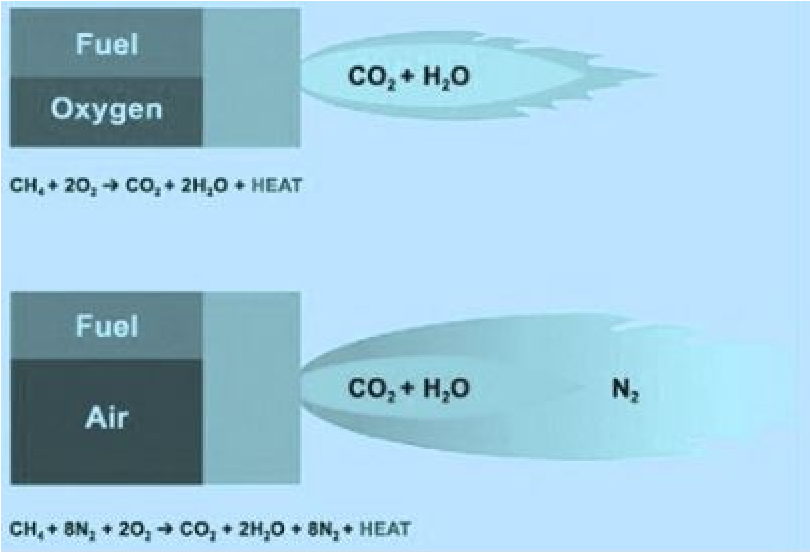

Figure 1 Oxyfuel and air-fuel combustion processes

Oxy-fuel combustion has been found to differ from air combustion in many ways, including reduced flame temperature and delayed flame ignition. Many of the effects of oxy-fuel combustion can be explained by the difference in gas properties between CO2 and N2, which are the primary dilution gases in oxy-fuel and air, respectively. CO2 has different properties than N2, which affects heat transfer and combustion reaction kinetics. These differences are explained below.

Density - CO2 has a molecular weight of 44 compared to N2's molecular weight of 28, resulting in a higher density of flue gas in oxy-fuel combustion.

Heat Capacity - CO2 has a higher heat capacity than N2.

Diffusivity - The oxygen diffusivity of CO2 is 0.8 times higher than that of N2.

Radiative properties of furnace gases: - Oxyfuel combustion has higher levels of CO2 and H2O, both of which have higher emission capacity.