Thermal imaging is vital

The importance of reducing harmful emissions and improving combustion efficiency in reheat furnaces

Among the most pressing issues for the iron and steel industry is the need to reduce its environmental footprint. Worldwide, air pollution control regulations require producers to measure emissions of control emissions of species, such as carbon monoxide (CO) and oxides of nitrogen (NOx), and particulate matter, from the smelting process and downstream operations, such as rolling mills.

In addition, the widespread public awareness of climate change has put pressure on the supply chains of many consumer goods producers to reduce their emissions of greenhouse gases, such as carbon dioxide (CO2). Fortunately, there are a number of technologies that can be used to improve combustion efficiency and reduce pollution emissions.

Two measurement techniques for improving the efficiency of reheat furnaces that are used to bring a metal to the correct temperature for rolling or extrusion processes, are radiometric thermal imaging and oxygen-convertible measurement. Their benefits include reducing emissions of toxic gases, such as CO and NOx, reducing fuel costs, and reducing the emissions of greenhouse gases, such as CO2.

These techniques focus on optimising the temperatures within the reheat furnace and on maximising combustion efficiency by balancing the airflow ratio within the furnace. Given the amount of fuel used in a reheat furnace, even modest improvements in fuel operation can result in large reductions in cost.

Temperature measurements within a reheat furnace have traditionally been made by using thermocouples mounted on the roof and walls of the furnace, or by means of a single-point infrared thermometer. These methods both have limitations. Thermocouples measure the temperature of the furnace walls rather than the flame itself, so models are used to estimate its temperature. These tend to be conservative, so there is a tendency to overheat the billet, which results in significant amounts of wasted fuel.

A single-point infrared thermometer can be used to measure billet temperature directly, saving fuel and improving product quality. An accurate measurement requires a correction for the background temperature. Without this, reflections from the billet surface can result in a significant error in the measured temperature.

Radiometric thermal imaging inside a reheat furnace places specific requirements on a thermal imaging system. The high temperatures within the furnace mean that a short-wavelength imager is preferred, as the intensity of infrared radiation would overwhelm an imager designed for ambient-temperature applications. A short-wavelength sensor also gives more accurate temperature measurements, because it is less dependent on an accurate determination of emissivity. Use of a radiometric thermal imager is important because less-expensive, non-radiometric imagers are available. Although these imagers allow a user to visualise the hotter and cooler portions of a scene, they do not give accurate temperature measurements.

It is impractical to place an imager inside the furnace, but there is a need for a method that allows an imager mounted outside the furnace to view the inside. This can be done using a borescope that allows a wide-angle view of the inside of the furnace even though it requires only a small diameter penetration through the furnace wall. Because it is an optical device, the borescope must be protected from the harsh environment so it is usually mounted in a water-cooled and air-purged jacket. A borescope will suffer catastrophic damage if the cooling water fails, so it is usually mounted in a water-cooled and air-purged jacket.

The image processor can also measure the temperature of the furnace walls, so it can compensate for reflected radiation without the need for an additional temperature input.

A near-infrared device does not respond to radiation coming from a clean flame, such as that from a natural gas burner, so it is able to view the entire scene within the furnace. While liquid or solid fuels are used, the radiant flames are visible to the imager. This can be useful, because the flame temperature is key to controlling NOx. Thermal NOx formation occurs rapidly at temperatures above 1600°C through the Zel’dovich mechanism, so maintaining a flame temperature below that point minimises NOx. A longer wavelength sensor operating around 3.9μm can be used, if it is necessary to produce a flame-free image in a furnace with radiative flames.

The amount of fuel burned in a reheat furnace means that efficiency improvements give large benefits. A gas-fired furnace typically has a reliable retraction system that can withdraw the probe even if the mains power fails; this will typically include a spring-loaded or pneumatic system that does not require electric power to operate. See Figure 1.

Thermal imaging provides a wealth of information that is not readily accessible using traditional temperature measurement techniques, such as thermocouples or single-point infrared thermometers. Most important is the ability to measure the temperature of the entire blitet surface. See Figure 2. Image processing software can determine maximum, minimum and average temperatures across the zone of interest. Not only does this minimise fuel wastage, it also allows for increased throughput and improved product quality.

Combustion efficiency can also be improved by optimising the fuel-to-air ratio within the furnace. For a furnace burning natural gas under ideal conditions, the fuel and oxygen from the air would be consumed and the only products would be water vapour (H2O) and carbon dioxide (CO2). This is known as stoichiometric combustion. Real combustion processes are inevitably more complicated and stoichiometric conditions cannot be achieved in practice.

In addition to the CO2 and H2O, carbon monoxide is formed from the incomplete oxidation of fuel. Fuel-rich conditions, with very little oxygen in the flue gases, are an obvious source of loss because not all of the fuel is burned. Excess air allows the fuel to burn completely, but the additional air carries a lot of heat out of the furnace. The green line shows the total loss. Under ideal operating conditions there is a very small amount of excess air, though the need for flame stability means that it is preferable to operate with an additional safety margin. See Figure 3.

It is clear that the oxygen concentration is an essential parameter for efficient furnace operation, as it allows the selection of the correct fuel-to-air ratio. Not only does excess air cause a reduction in efficiency, it results in additional NOx formation. That is because the reactions which form NOx depend on the availability of oxygen molecules. Reducing the oxygen concentration also reduces the formation of NOx. However, adjusting the furnace on the basis of oxygen concentration alone consumes 25% of fuel per metric ton of steel processed. Improved temperature measurement can reduce fuel consumption by up to 10%, saving money and reducing emissions. For a large furnace, the savings can be considerable, saving money and reducing emissions. For a large furnace, the savings can be considerable.

A combined analyser measuring both oxygen and carbon monoxide simplifies installation, calibration and maintenance.

A combined analyser measuring both oxygen and carbon monoxide simplifies installation, calibration and maintenance. It isn’t generally possible to place sensors within a high-temperature furnace, so an extractive analyser is preferred. The user must choose between full-extractive and close-coupled extractive analysers, each of which has its advantages and drawbacks.

A close-coupled unit, such as the AMETEK Thermox WDG-VC (See Figure 5), has a probe that inserts into the furnace. The analyser is located some distance away. This allows it to remain cool, so there is less stress on the electronic components and it is easier to service, even when the process is in operation. A true carbon monoxide measurement is possible using either infrared or electrochemical sensors. The drawback is that it has a slower response time, typically between 45 and 60 seconds, which makes it less convenient to adjust the combustion controls in real-time.

In conclusion, the use of the latest techniques for measuring process conditions within a reheat furnace, allows the operator to reduce harmful emissions of carbon dioxide and oxides of nitrogen, improve product quality and reduce fuel costs.

Author
Derek Stuart, Global product manager – Power
AMETEK Land
www.ametek-land.com

The advantage of this approach is its fast response time, with a T90 of less than 10 seconds for oxygen and 20 seconds for CO2. This allows for a very fast indication of changes in combustion conditions and makes it easier for the operator to correctly adjust the combustion controls. Drawbacks include difficulty of maintenance. The instrument is mounted close to the furnace, so maintenance is only practical when the furnace is not operating, and it is not possible to remove the instrument while the furnace is hot.

A full-extractive system, such as the AMETEK Land FGAS60E (See Figure 5), has a probe that inserts into the furnace. The analyser is located some distance away. This allows it to remain cool, so there is less stress on the electronic components and it is easier to service, even when the process is in operation. A true carbon monoxide measurement is possible using either infrared or electrochemical sensors. The drawback is that it has a slower response time, typically between 45 and 60 seconds, which makes it less convenient to adjust the combustion controls in real-time.