How a Dolomite kiln used modeling science to become one of the most efficient in the world

"The Thrislington kiln had its lowest fuel consumption and CO^2 per ton figure of the year last month with a waste fuel usage of 69%. The sooner you get me a new Turbu-Jet burner for Whitwell the better."

John Carlill
Steetley Plant in UK

Control over fuel costs, by taking efficiency to another level.

FCT Combustion's Engineer, Grant England, together with John Carlill, Managing Director of Steetley Dolomite Ltd, were published in World Cement magazine February 2013.

After an extensive search by Steetley Dolomite for a suitable burner supplier, FCT Combustion was selected for its strong technical ability and kiln modeling skills. The article provides an insight into the expertise used to achieve significant cost savings.

Introduction

Steetley Dolomite operates two dolomite lime plants with three kilns between them in Northern England. Here, the company produces three grades of lime for use in the steel and refractory industries. As a result of global market pressures, the company has needed to cut the cost of production. A number of initiatives were identified, but the one that showed the greatest potential for savings was to reduce fuel costs in the kiln. There were multiple ways that this could be achieved, but a decision was made to concentrate on reducing fuel consumption levels and maximizing the use of alternative fuels.

A review of the kilns indicated that the Thrislington Works kiln 3 would have the greatest potential for fuel reduction because of its unusually high primary air requirements. The burner designed and supplied to the plant some years earlier would not allow proper kiln operation at lower amounts of primary air. The burner was firing coal and could accommodate up to 40% of the required heat input as waste solvent.

Statutory regulations prevented more than 40% addition of waste solvents, so another alternative fuel (tyre crumb) was sourced. This provided the incentive to improve on the existing burner and improve efficiency with a better burner design. Oxygen was being used as the atomizing medium for the waste solvent for a number of reasons, so it was determined that any reduction in the amount of oxygen used would also be welcomed, given its high price.

After an extensive search for a suitable burner supplier, FCT Combustion was selected because of its strong technical ability and capacity to model the kiln under all of the firing conditions. This article discusses some of the expertise used to achieve significant cost savings.

Kiln assessment

For meaningful modeling, accurate data is needed, so an experienced engineer went to the site in order to collect information vital to the burner design. Apart from measuring fan flows, air temperatures and fuel data, a number of specialized measurements were taken.

These included secondary air temperature and kiln inlet gas concentrations, both of which are critical for analysing the performance of combustion in the kiln. Long-term data was collected from plant logs too, to assist in determining typical values and as a reference for assessing performance improvement. Drawings of the kiln and cooler were gathered for modeling purposes. Plant engineers and operators were consulted about their experiences with the operation of the kiln.

Modeling

FCT uses a number of modeling techniques when assessing a kiln combustion system. Each of them helps to build a picture of the process and includes various mathematic techniques, as well as physical modeling. The physical modeling technique focuses on the dominant processes that determine how well the fuels and air mix and, hence, how effectively combustion occurs in the process. The technique has been proven through its successful use in hundreds of applications over 25 years and is a primary tool for validating the burner design.

The physical modeling involved the construction of a 33:1 laboratory scale acrylic model of the kiln and cooler. Dilute acid and alkali solutions are introduced into the model through specialized nozzles to represent the air and fuel so that the flame shape can be visualized.

Thermodynamic scaling, validated from hundreds of studies, is applied to the results based on data collected from the site. Additionally, the aerodynamics can be observed in real time by following small beads placed in the water flow. Water-bead modeling was first used to investigate the aerodynamics of the cooler throat and kiln hood. In this technique, the secondary air is represented by water and neutrally buoyant polystyrene beads are added and illuminated with thin light sheet to enable the flow in that area to be visualized (Figure 1).

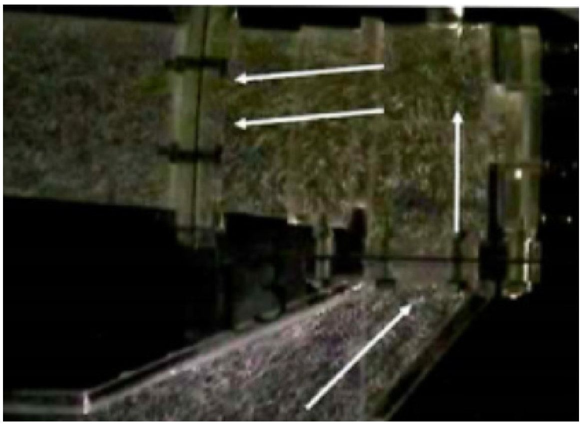

Figure 1

It was found that the flow of secondary air in the cooler throat and kiln hood was relatively uniform, with little to no swirl. However, as the hot air from the cooler bends to enter the kiln, it continues in a downward motion around the burner. The downward direction can cause the flame to be deflected onto the bed, often with detrimental effects to product quality and refractory life. In this case the downward motion could be adequately addressed using clever design and re-positioning of the burner within the kiln.

Acid-alkali modeling was used to simulate the combustion process in the kiln. With this technique, dilute acid is used to represent air and alkali is used to represent the fuel. The acid and alkali flows and concentrations are based on site measurements to reflect the flow of fuel, primary and secondary air.

By adding a pH indicator, phenolphthalein, unburnt fuel appears pink. This highlights the flame shape and how well the fuel mixing occurs.

Modeling of the original burner showed that the flame was excessively long, meaning that it was impinging on the bottom of the kiln (Figure 2a). This indicated that the fuel and air mixing was inadequate, leading to inefficient combustion. CO readings as high as 0.1% confirmed unburnt fuel was leaving the kiln. With the flame continually impinging on the kiln walls, the effects were lower product quality and shorter refractory life.

Figure 2a

The new, optimized flame can be seen in Figure 2b operating under the same conditions, i.e. same fuel rate and kiln oxygen, at 1.4%. The flame is now centered in the kiln and is significantly shorter. This is a direct result of the new burner improving the mixing of the fuel and air, increasing the burner angle by 3.5 degrees and adjusting the insertion slightly. As a result, the heat profile of the flame is shorter, and more heat will report to the burning zone, where it is needed. The centered flame will increase refractory.

Figure 2b

The modeling gave an insight into the impact of the flame that the plant engineers or operators could not have appreciated by other means. Typically, operators use a trial and error approach that will often jeopardies product quality and production.

Implementation

During a routine maintenance shutdown, a number of improvements were made around the kiln system, and the installation of the new burner system provide an opportunity to free up precious burner deck space and reduce and safety concerns. This was achieved by replacing the original format and trolley with an overhead one. The primary air fan was replaced with one of higher pressure to reduce the volume of ambient air injected. The primary air volume was reduced from 20% to 11% (on a stoichiometric basis). This represented a 45% reduction in primary volume.

The new Turbu-Jet burner is rated for 60 MW, either firing entirely pulverized coal with a combination of alternative fuels. The burner included FCT's proprietary lofting air channel to assist the dispersion of tired crime into the flame at more than three TPH. Figure 3 shows how the use of coal has reduced. There have been a number of significant improvements since the installation of the new burner. An alternative fuel substitution of 70% has been achieved, the specific heat consumption has dropped by 12%, primary use by 45% and pure oxygen has dropped by 10%.

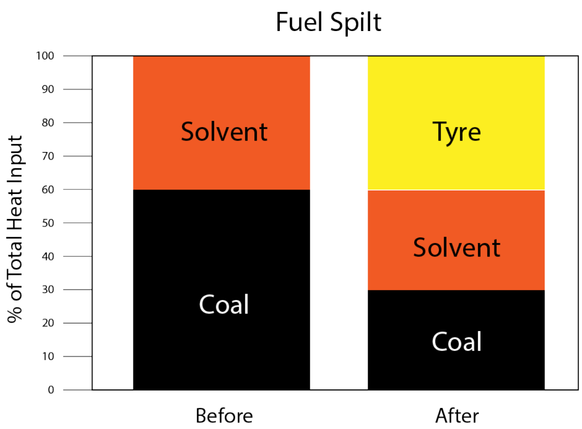

Figure 3

These effects are summarized in Figure 4. It is also expected that there will be an improvement in the refractory life, but it will take until the end of this campaign to confirm this.

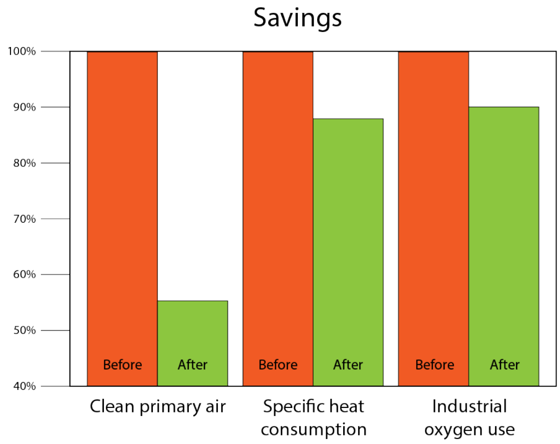

Figure 4

Conclusion

The installation of a fully optimized, multi-fuel burner in the Steetley Thrislington dolomite kiln has resulted in significant financial savings being achieved for the company. The burner is now firing up to 70% as well as improving overall feel consumption and fan power savings. At a time when there were significant market pressures, it is vitally important to improve efficiency and drive down operating costs.

This kiln has demonstrated the potential savings of this process, and as a result, kiln 2 at the Whitwell plant was upgraded in 2013.

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