Challenging the unseen with CFD

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discuss how CFD simulation can provide important and otherwise unseen insights into a combustion environment, and how it ultimately helped optimise the performance of a new burner design for Cemmac.

Cemmac is a cement plant operating with nearly 70% refuse derived fuel (RDF) in its kiln burner. This type of fuel is known to be challenging to burn due to its high moisture content and particle size, and in this case, the RDF substitution target added to the challenge. For quite some time, Cemmac experienced low retention of sulfur in clinker caused by fuel particles hitting the kiln wall and material bed, thus generating a localised reduction zone as well as excessive build-ups in the kiln due to the high sulfur volatility.

Original setup

The original 30 MW burner was from another supplier based in Europe.This original arrangement was modelled using computational fluid dynamics (CFD) techniques, including a section of the cooler, the burner and the whole kiln. The numerically obtained trajectories of the fuel particles are seen to accurately reproduce the RDF flight behaviour observed during site survey as demonstrated in Figure 1a and 1b (the red arrows on Figure 1a indicate some burning fuel particles). The trajectory of the RDF particles hitting the inside of the kiln and clinker bed close to the burner tip could not be easily explained by the burner design and operating parameters.

Generally, a common assumption would be that secondary air will match the direction of kiln rotation due to the cooler off-set relative to the kiln. However, during the development of the modelling project, it was noted that the rotation direction of the secondary air in the hood, and in the first couple of metres within the kiln, was the opposite to what was expected. Figure 2 presents a sketch of kiln and air flow rotation directions on this project. Figure 3 shows cross sections of velocity magnitude contours with vectors superimposed on the field for four axial positions, two in the hood and two in the kiln, with the latter cross section just few centimetres from the burner tip. On all sections, it is clearly seen that secondary air flow predominantly rotates counter clockwise instead of clockwise as expected.

A different approach

The common approach to set the rotation direction of the burner swirl primary air is by matching the kiln rotation – and supposedly the secondary air rotation as well. It is rare for the secondary air and the kiln to rotate in opposite directions. However, the result for assuming that secondary air was also rotating in the same direction as the kiln led to a non-matching rotation between primary and secondary air flows in the early stages of combustion, largely explaining the disastrous flight behaviour of the fuel particles. Reversing the swirl direction in another CFD simulation with the existing burner (i.e. with swirl primary air matching the secondary air rotation) showed much improved trajectories with no particles being shot at the kiln wall. In addition to this unexpected condition of primary and secondary air opposing swirl, the original burner design was not well suited to the existing kiln conditions, being relatively low momentum and therefore not capable of overcoming the secondary air flow rotation direction or keeping injected fuel in suspension long enough to burn. Figure 4 shows the RDF trajectories, clipped by 5% residual volatile content and coloured by particle mass, for the original burner with non-matching and matching rotations of primary and secondary air flows. In addition, Figure 4c also includes the tracks numerically obtained for

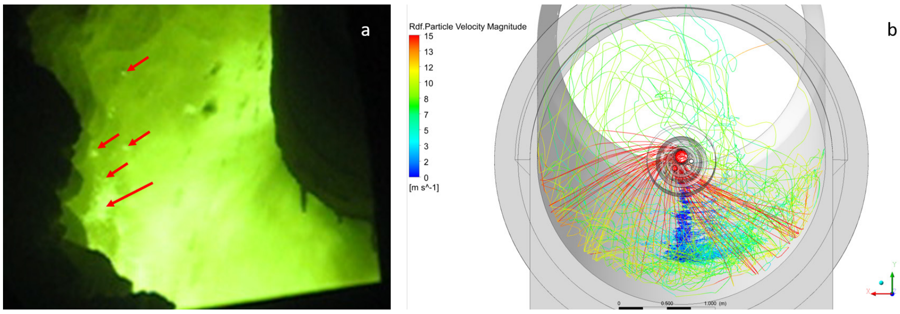

Figure 1. a) Picture taken during the site survey showing fuel particles hitting the kiln wall and b) fuel particle tracks obtained via CFD modelling.

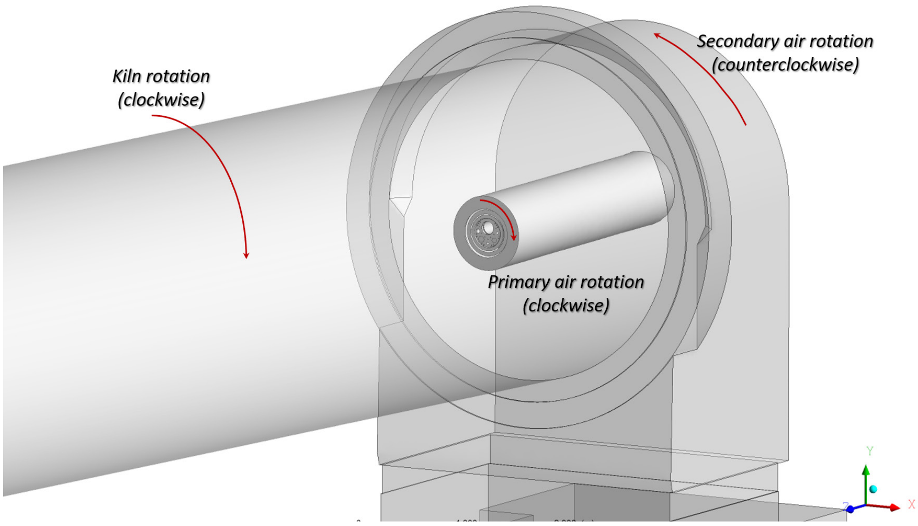

Figure 2. Sketched rotations of kiln, primary and secondary air.

FCT Combustion's Turbu-Flex™ burner, with matching air flows already considered. Note that in the first case in Figure 4a, RDF particles are shot at the kiln wall right after they emerge from the burner, with many hitting the wall even before they start to dry. Just by changing the direction of the swirl primary air, and absolutely nothing else, the fuel particles describe completely different trajectories. The difference is demonstrated in Figure 4b, where there are no particles shot at the wall, but instead they land on the bottom due to gravity. However, the burner performance in this instance would still be problematic, as the fuel particles still fall into the clinker bed, creating local reducing conditions in the clinker and therefore volatising any sulfur. Due to the high momentum and optimised secondary air entrainment of the Turbu-Flex, RDF particles are kept in suspension for greater distances, maximising the in-flight combustion of fuel particles. The Turbu-Flex burner also performed very well under adverse conditions, and, thanks to its high momentum, it was capable of keeping the RDF particles away from the kiln walls.

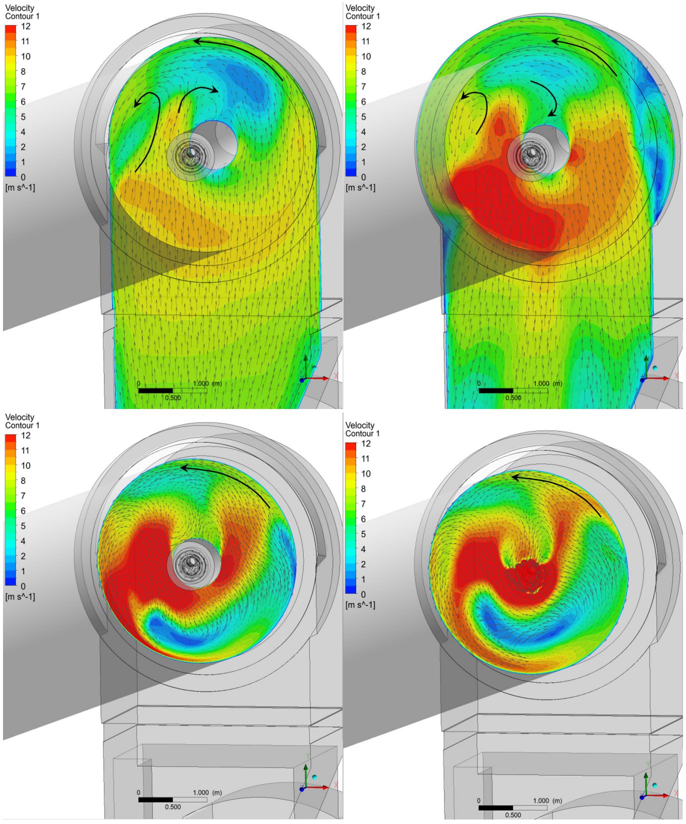

Figure 3. Velocity vectors and contours coloured by velocity magnitude on four cross sections within firing hood and kiln.

The CFD simulation was carried out by FCT Combustion as part of a burner replacement programme. The results of the simulations were used to optimise the performance of the new burner design. In addition to correcting the swirl direction and RDF trajectories, FCT Combustion's new FCT Turbu-Flex burner also provided increased rate of secondary air entrainment and heat release from the RDF. Figure 5 compares the reaction rate for the RDF volatiles obtained for the Turbu-Flex and with the original burner. Figure 5a demonstrates the intense projection of part of the volatiles onto the kiln wall close to the discharge end (original burner) creating a reduction zone in this region which is then adjusted to be kept well centralised and away from the bottom for greater distances with Turbu-Flex in Figure 5b.

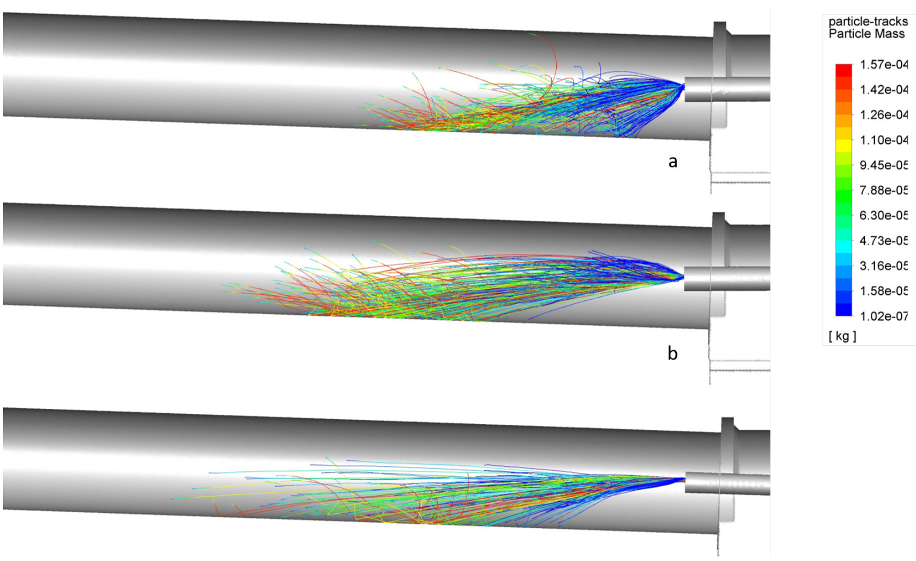

Figure 4. RDF particle tracks clipped at 5% residual volatile amount and coloured by particle mass. a) Original burner with non-matching flows; b) original burner with matching flow; c) Turbu-Flex with matching flows.

This project shows the strength of this modelling tool in giving important insights into what is happening in a combustion environment, identifying the root cause of problems and helping to design a burner to optimise the entire process. Simply relying on the common, or generic, approach cannot account for individual environments, and in

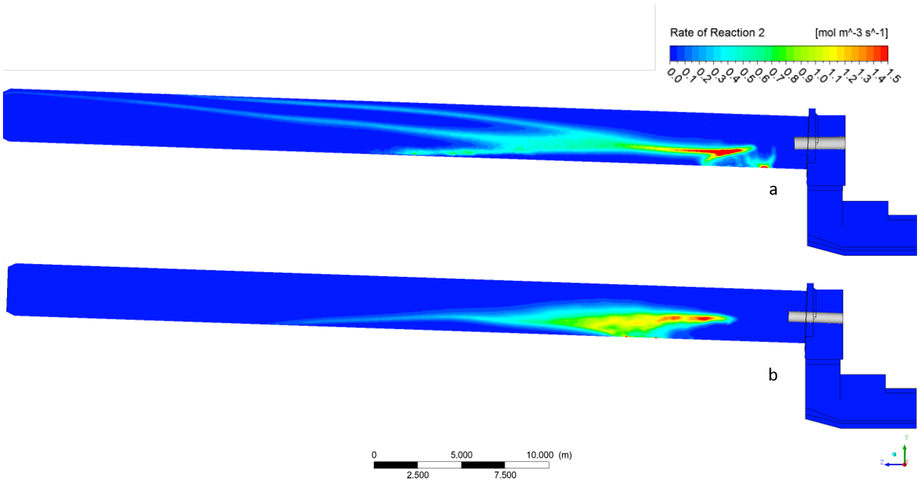

Figure 5. Rate of RDF volatile reaction obtained with a) The original burner and b) Turbu-Flex on the kiln centre line plane.

some cases, further investigation is necessary to reveal the hidden issues. Studying the kiln aerodynamics in combination with the burner results in reduced risk, and the ability to avoid negative consequences such as increased fuel costs, reduced RDF substitution, reduced capacity, build-ups, emissions and reduced clinker quality.

Summary

Following this project, Cemmac increased its alternative fuel split in the kiln using Turbu-Flex to exceed 80% of AF firing rate, cementing a move towards the future of sustainable production. The ability to increase the alternative fuel firing rate further than 80% was restricted in this particular case because the current coal dosing system started to pulsate and become unstable with lower coal flows. ■

About the authors

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