Joel Maia & Renata Favalli, FCT-Combustion (Austria & Australasia); Robert Jánsky, Cemmac (Slovakia)

MAXIMISING AF WITH CFD

A look at how computational fluid dynamics (CDF) and a new Turbu-Flex™ burner from FCT Combustion helped to increase Cemmac's alternative fuel substitution rate.

Kiln and calciner burner systems have a major impact on the bottom-line results for a cement plant. This means that customised optimisation of the flame is critical for any given kiln to achieve the best possible plant performance. In the quest to increase AF firing capabilities, a burner specialist can assist plants in finding an optimal design and tailored solution for their unique environment.

Computational Fluid Dynamics (CFD) can be a crucial tool in the development of tailored burner design, as it provides insight into flow aerodynamics that may not otherwise be observed. This information can then be used to optimise burner design for improved fuel efficiency, product quality and production output.

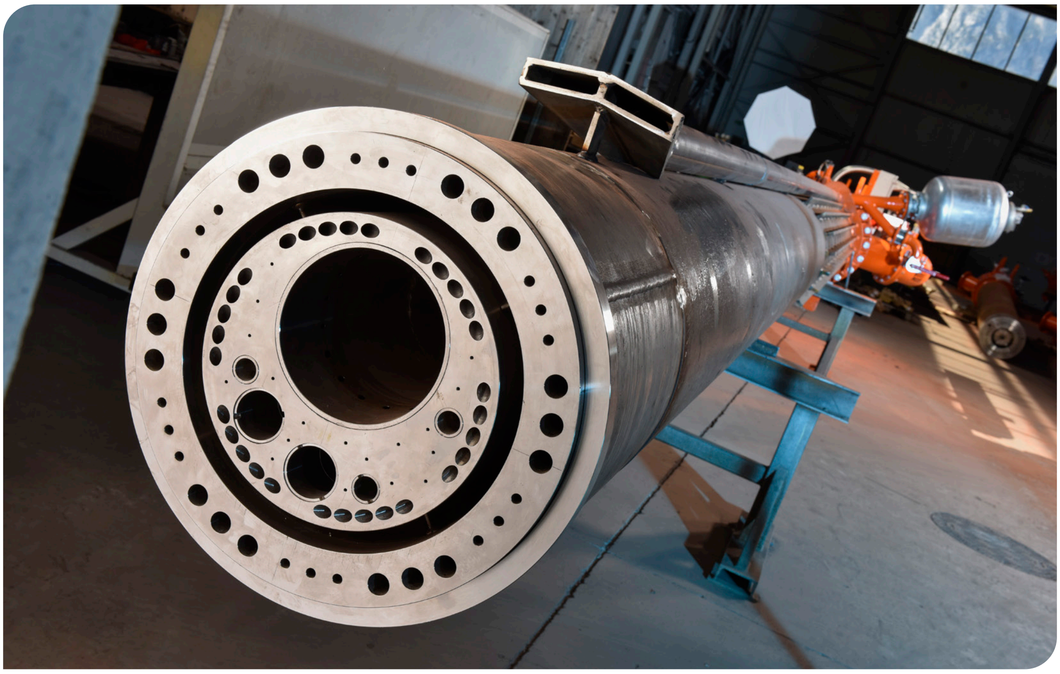
The case at Cemmac

Cemmac, a Slovakian cement producer, approached FCT Combustion with the aim to improve its AF firing rate. The plant operates a 5-stage in-line calciner kiln (L = 46m, Ø = 3.4m) that can produce 1200t/day of Portland clinker.

At the time of the study, coal and AF were fired in the kiln by a 30MW burner from another supplier based in Europe. Additionally, two calciner burners from that same supplier were used to fire coal in the calciner. Tyres were fed to the kiln inlet and RDF to the calciner at the twin tertiary air inlets.

The thermal substitution rate (TSR) of AF firing in the kiln was limited to 70% due to high CO levels, measured at the exit of the stage 4 cyclone (with stage 5 being at the bottom stage) in excess of 0.3% (3000ppm). Even when firing 100% coal, the firing rate was limited by CO, which in turn limited the degree of calcination and overall plant capacity. The loss on ignition of the stage 5 hot meal was high, at 8.4%.

Severe problems with build-up forming in the area above the kiln inlet chamber were also identified. To remove the build-up, the kiln was stopped for several hours roughly once every two weeks. The plant had also been experiencing low retention of sulphur in the clinker.



Right: FCT Turbu-Flex burner™.

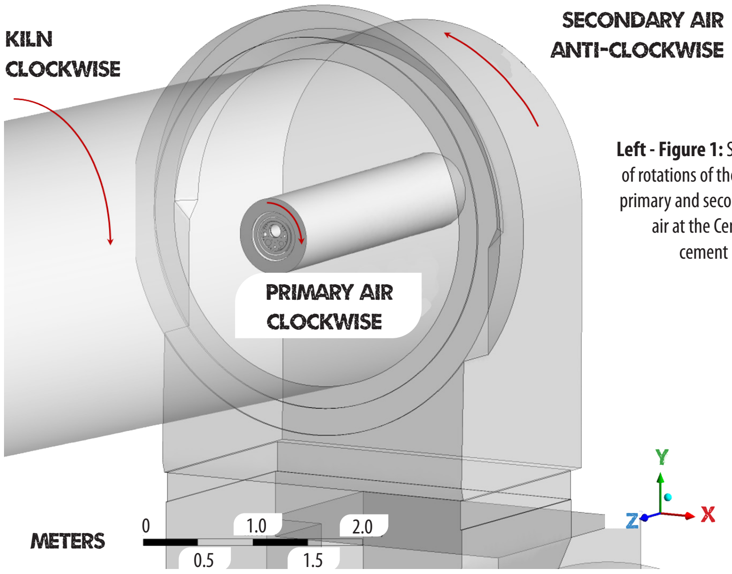
CFD study

FCT has an in-house team of CFD specialists, which undertook a comprehensive study into the combustion environment with the kiln operating with the burner used at the time. The CFD study found an inconsistency between the swirl direction of secondary air flow and burner swirl/kiln rotation due to the geometry and aerodynamics of the kiln hood and cooler (Figure 1). It is rare for the secondary air flow and burner swirl / kiln to rotate in opposite directions. In the case of the Cemmac plant, this mismatch was causing the fuel particles to follow an unusual flight path and hit the kiln wall and material bed before complete burnout. A localised reduction zone was then generated, leading to the excessive build-ups in the kiln due to the high sulphur volatility.

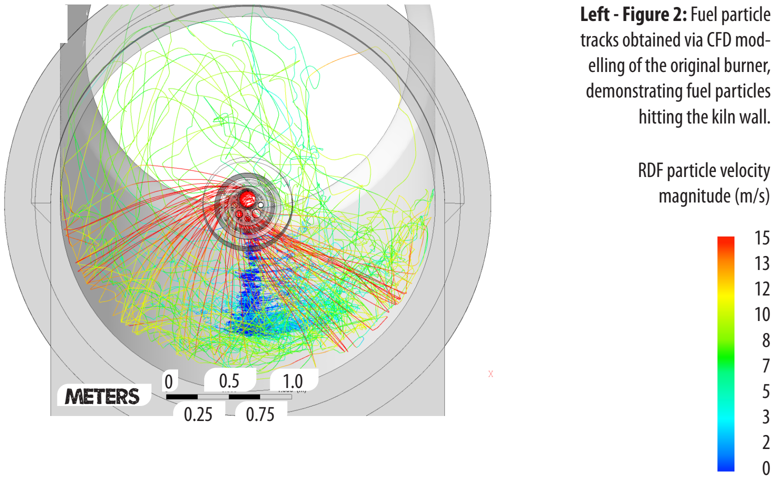
The first case modelled was the original burner with non-matching air flows between primary and secondary air flows. The RDF particle tracks predicted, as shown in Figure 2, reproduced the flight behaviour seen on site. This non-matching flow in the early stages of combustion led to the detrimental flight path of the fuel particles.

The original burner design was not well-suited to the existing kiln conditions due to being a relatively low momentum burner. This meant that it was unable to overcome the secondary air rotation and could not keep fuel in suspension long enough to burn optimally. Fuel was also being shot towards the wall.

As a point of comparison, FCT also modelled the performance of the Turbu-Flex™ burner in the same conditions, i.e, with burner swirl opposite to secondary air rotation (although in the same rotation of the kiln). The Turbu-Flex™ demonstrated better performance in these adverse conditions due to the burner's high momentum design, which was able to overcome the cross-current and keep the particles away from the kiln walls.

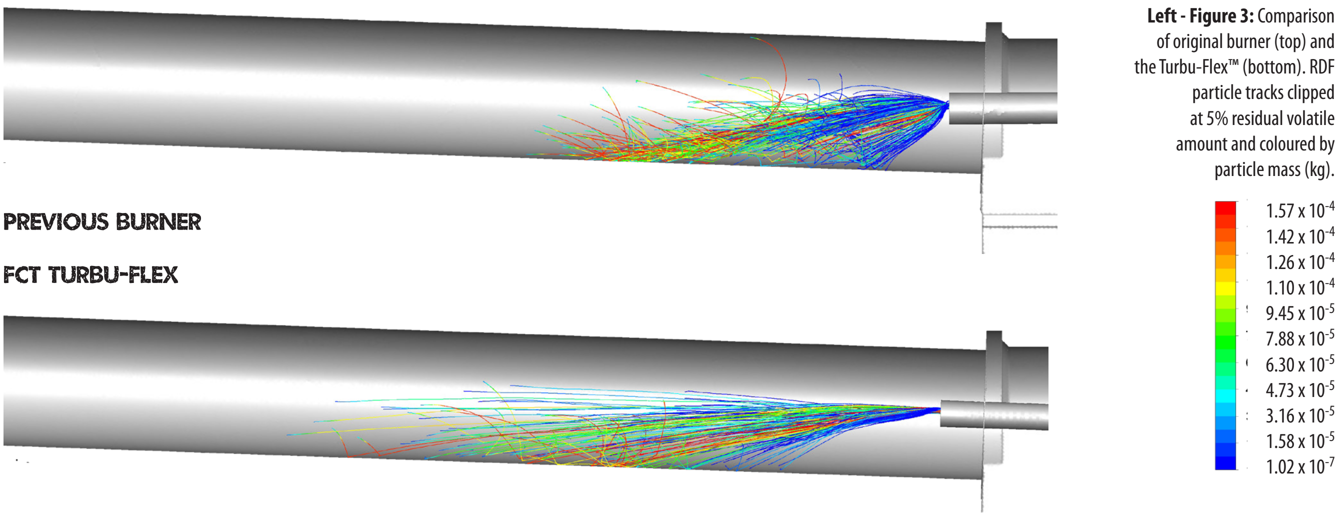


Left - Figure 1: Sketch of rotations of the kiln, primary and secondary air at the Cemmac cement plant.

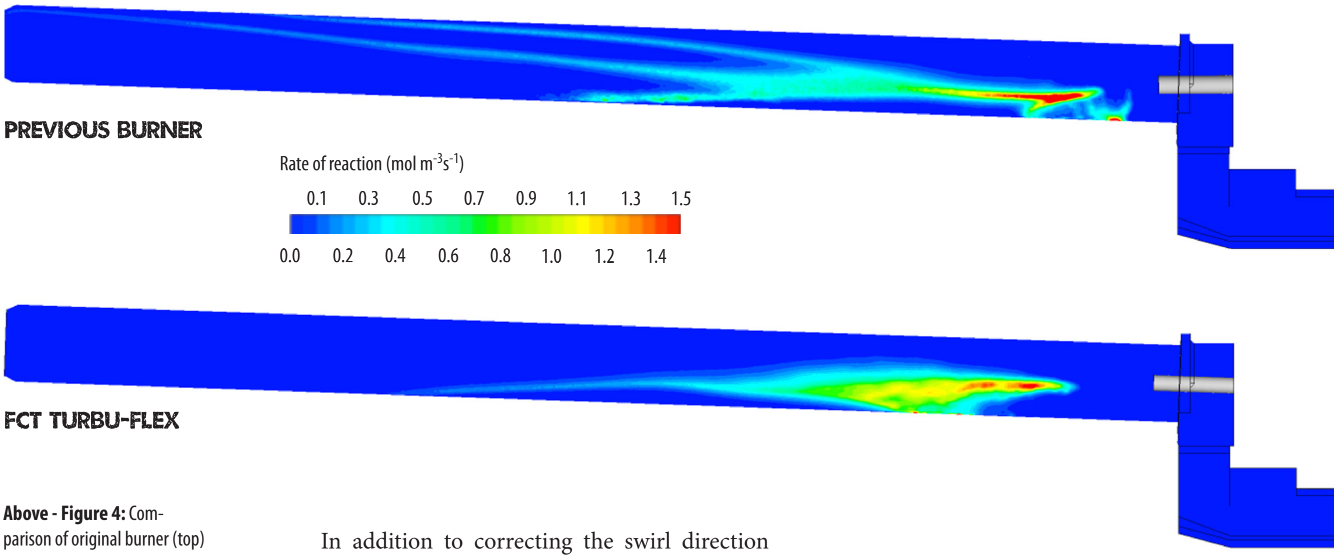


Left - Figure 2: Fuel particle tracks obtained via CFD modelling of the original burner, demonstrating fuel particles hitting the kiln wall.

An additional case was studied, matching the burner swirl and secondary air swirl rotation (opposite to kiln rotation). Figure 3 compares the particle tracks for the Turbu-Flex™ in this condition and for the original burner. RDF particles are suspended for greater distances and the in-flight combustion of the fuel particles is maximised.



Left - Figure 3: Comparison of original burner (top) and the Turbu-Flex™ (bottom). RDF particle tracks clipped at 5% residual volatile amount and coloured by particle mass (kg).



Above - Figure 4: Comparison of original burner (top) and Turbu-Flex™ (bottom). RDF volatile rate of reaction obtained on the kiln centre line plane.

In addition to correcting the swirl direction and RDF trajectories, FCT's Turbu-Flex™ burner also provided an increased rate of secondary air entrainment and heat release from the RDF. Figure 4 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.

Benefits of Turbu-Flex™

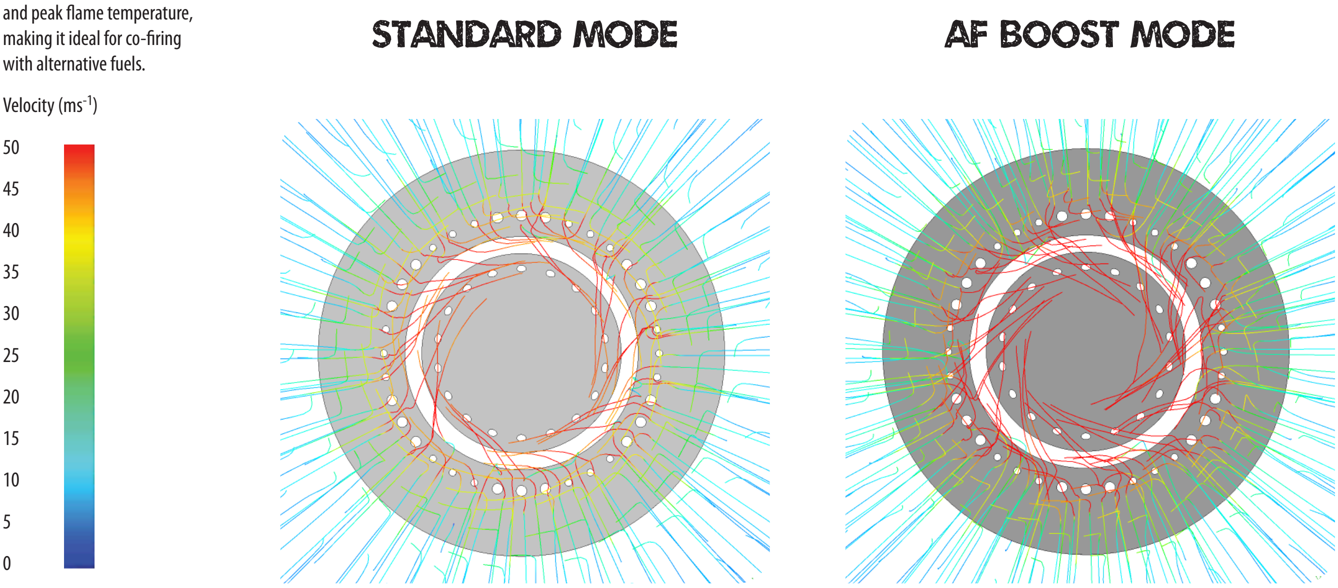
The CFD study formed part of a burner replacement programme at the Cemmac plant. The results of the simulations were used to optimise the performance of the new burner design. Based on the results of the CFD study, the original burner was replaced with the Turbu-Flex™ burner design, tailored for the plant's specific environment and set-up.

Designed with flexibility in mind, a key feature of the Turbu-Flex™ burner is that the primary air axial holes are in two groups, each with a separate air supply. As demonstrated in Figure 5, the turn of a single valve switches the burner to operating in AF Boost Mode, where the configuration changes from the standard configuration of many evenly distributed holes all at the same pressure, to a smaller number of holes at higher pressure that are grouped together.

Results

The performance of the Turbu-Flex™ burner was compared against the original burner over a six month period, measuring clinker production and clinker quality as two key performance indicators. The benefits of the new burner, as outlined in the results below, resulted in a return on investment of around 12 months when considering:

Right - Figure 5: The smaller number of holes grouped together can be seen to increase the secondary air entrainment into the core of the fuel stream and peak flame temperature, making it ideal for co-firing with alternative fuels.



- Increase in clinker production (considering larger cement sales volume as well as higher costs for CO_2);
- Reduction in kiln specific heat consumption;
- Reduction in CO emissions;
- Changes in NO_x emissions;
- Higher AF substitution rate.

Clinker production

The new Turbu-flex™ burner was found to operate with less CO content at the kiln inlet for the same exhaust fan settings, providing the potential to increase the kiln feed rate, and thus increasing the output of the kiln.

The kiln is now able to be operated at maximum production rate as allowed by the ID fan and the new burner has allowed the hourly output of the kiln to increase by 0.91t of clinker, a total of 6837t/yr during the whole year (Table 1). There was also a minor reduction in the specific heat consumption of the kiln.

Conclusion

In this case, the application of CFD provided crucial and otherwise hidden insights into the combustion environment. This knowledge positively contributed to a real-world burner optimisation solution that allowed Cemmac to increase AF substitution, while also solving the costly issue of kiln build-ups which was causing the plant frequent shutdowns.

The implementation of a specialist burner design, informed by these CFD results, enabled Cemmac to improve clinker quality and production while experiencing quick return on investment. The Turbu-Flex™ burner design, which does not include any moving parts, is easy to maintain and is expected to continue optimising the plant's production in the long term.

In terms of AF substitution increase, Cemmac can now exceed a firing rate of 80%. A higher AF substitution rate is possible but in this case was restricted because the current coal dosing system started to pulsate and become unstable with lower coal flows.

	Operating time (hr)	Total Clinker (t)	Rate (t/hr)
Original Burner (6 months in 2019)	3827	191,484	50.03
Turbu-Flex™ (6 months in 2020)	3939	200,650	50.94
Change (%)	+ 2.9%	+ 4.8%	+ 1.8%

Left - Table 1: Comparison of clinker production volumes with original burner and FCT Turbu-Flex burner over different six month periods.

Clinker quality

Clinker quality was determined by so-called 'off spec' rate, which is clinker with alite content less than 60% and free lime content higher than 3.5%. Results are detailed in Table 2.

Clinker produced using the new Turbu-Flex™ burner shows higher average content of alite than clinker produced with the original burner. However, the more important parameter is clinker off-spec rate, which is much lower with Turbu-Flex™ compared to the original burner. In 2020 Cemmac produced 11,468t less of off-spec clinker than with the original burner over a comparable period in 2019.

Left: Cemmac has been able to increase the quantity and quality of its cement, while reducing production costs and CO_2 emissions.

	Alite (%)	Off-spec Clinker (%)	Off-spec Clinker (t)
Original Burner (6 months in 2019)	64.52	12.8	24,510
Turbu-Flex™ (6 months in 2020)	66.46	6.5	13,042
Change (%)	+ 3.0	- 49.2	- 46.8

Left - Table 1: Comparison of clinker quality, as judged by proportion of off-spec clinker, with original burner and FCT Turbu-Flex™ burner over different six month periods.