THE MOVE TO NATURAL GAS

Roger Hassold, Renata Favalli, Yvonne Yu, and Jordan Parham, FCT Combustion Pty Ltd, discuss the conversion of a calciner from oil to natural gas firing using CFD modelling.

Introduction

Natural gas can be an attractive fuel, as there is no need to stockpile, store, blend, grind, or preheat, it has a high heating value, low carbon emissions, and, in some regions, a low price. However, operationally its use can cause challenges, due to its high ignition temperature, high flue gas volume, and low heat transfer when compared with liquid and solid fuels.

At a cement plant in the Middle East, the kiln and calciner were typically run using 80% natural gas, supplemented by 20% heavy fuel oil. However, as heavy fuel oil is significantly more expensive than natural gas, the plant wanted to eliminate heavy fuel oil firing. When this was attempted by installing gas burners in the same location in the calciner as its HFO burners, the plant experienced significantly detrimental effects, including high temperatures and CO emissions at the preheater exit, as well as a reduction in feed rate to 200 tph.

The plant could have continued their trial-and-error approach, using different burner designs, and suffered high fuel costs and low production. Instead, FCT Combustion

Table 1. **Boundary conditions used in CFD modelling.**			
Boundary	**Mass flow rate**	**Temperature**	**Composition**
Tertiary air inlet	26.17 kg/sec.	850°C	Air
Kiln inlet	16.8 kg/sec.	1050°C	17.25% H_2O; 12.48% CO_2 0.401% O_2; 0.2% CO
Natural gas inlet	1.497 kg/sec.	15°C	86.85% CH_4; 7.97% C_2H_6; 4.67% N_2; 0.5% CO_2; 0.01% O_2
Primary air for gas burner	2 kg/sec.	13°C	Air
Heavy fuel oil inlet	0.3856 kg/sec.	100°C	$C_{19}H_{30}$
Primary air for oil burner	0.0753 kg/sec.	12°C	Air
Meal inlet	54.83 kg/sec.	780°C	54.85% $CaCO_3$; 26.47% SiO; 8.71% CaO

Figure 1. Four stage inline calciner.

was engaged to study the calciner, determine what was limiting the substitution of natural gas, and deliver a cost-effective solution. This article discusses how FCT Combustion used CFD modelling of the calciner and installed new burners that enabled the calciner to operate on 100% natural gas, saving €500 000 – €600 000 per year, while increasing kiln feed rate by 15% and reducing specific fuel consumption by 4%.

Modelling the calciner

When changing a calciner from firing heavy fuel oil to natural it is not just a matter of installing new burners in the same location as the existing ones. There are many factors that need to be considered and understood including the following:

- The inherent differences between the fuels and how they disperse, mix, and burn.
- The aerodynamics of the calciner vessel.
- The location of the meal entry point(s).
- The resultant heat transfer to the meal and the degree of calcination.

In order to investigate the above factors, FCT Combustion built a computational model of the calciner in ANSYS Fluent. Table 1 summarises the boundary conditions used in the model. Total firing rate is 85 MW.

Simulating the existing operation

To understand the performance of the existing calciner, three operating conditions were modelled:

1. 100% heavy fuel oil (100%HFO).
2. 20% heavy fuel oil and 80% natural gas (20%HFO:80%NG).
3. 100% natural gas (100%NG).

In its original configuration, the calciner performance was characterised as the following:

- 100%HFO: fuel burns out well without high levels of CO.
- 20%HFO:80%NG: some CO is generated limiting further increase in natural gas firing.
- 100%NG: not possible due to high CO levels.

Figure 2 shows the aerodynamics and the temperature in the calciner vessel for these scenarios. In all cases the dominance of the tertiary air is evident, generating flow recirculation in the calciner. However, the flow fields are quite different, and recirculation regions change sides as natural gas is introduced into

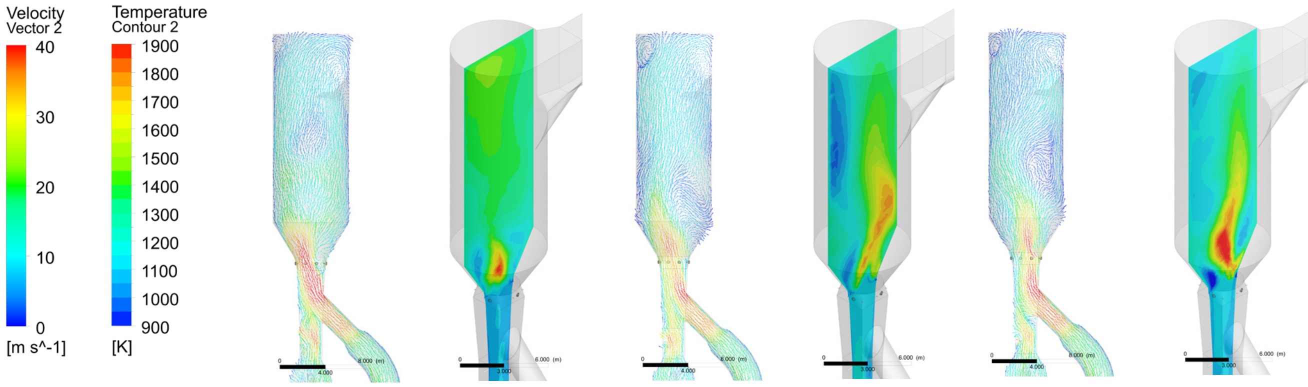

Figure 2. Aerodynamics and temperature for 100%HFO(left), 20%HFO:80%NG (middle), and 100%NG for existing burners (right).

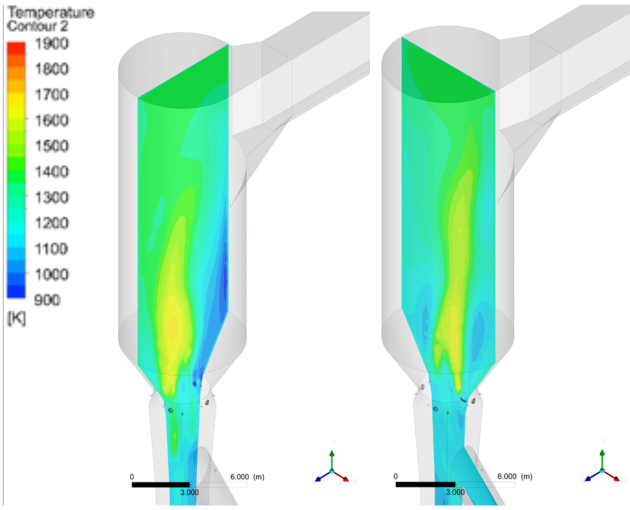

Figure 3. Temperature field in the calciner after the addition of the new FCT burners in the TAD.

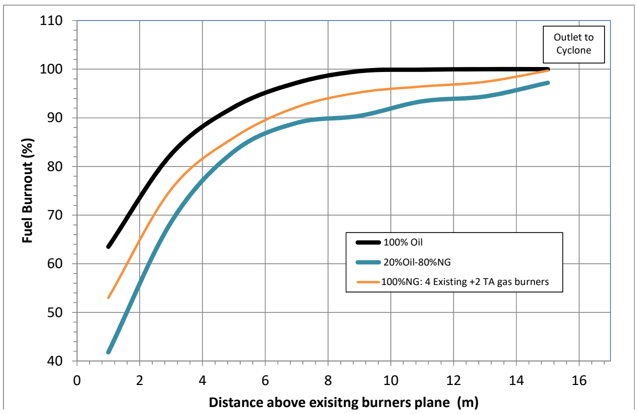

Figure 4. Fuel burnout comparison of the existing burners with the addition of the FCT burners in the TAD.

the system. These changes in flow pattern, associated with the higher ignition temperature and lower heat transfer of natural gas, influence the flame position and the upward extent of the high-temperature region, creating stratification and impacting calcination.

Modelling of the calcination showed that for 100%HFO firing the calcination is complete at approximately half the height of calciner vessel, while in the cases where gas is co-fired or used as the only fuel, part of meal particles reached the top of the vessel with its full content of $CaCO_3$, i.e. completely uncalcined.

When the fuel burnout was assessed, for 100%HFO, the burnout is 100% complete by 9 m above the burners. However, when firing 20%HFO:80%NG, the fuel burnout is not complete at the calciner exit and combustion continues on into the bottom stage cyclone, raising the calciner and preheater exit temperatures. When firing 100%NG, at least 6% of the fuel leaves the main calciner vessel unburnt. Although fuel oxidation continues in the outlet duct, approximately 1.8% of the fuel enters the cyclone unburnt, causing the high CO emissions.

Finding a solution with CFD

The computational predictions of the existing calciner and burners were consistent with the actual calciner performance issues seen on the plant. In particular they showed that there is a difference in the velocity and temperature fields between the various firing configurations, which also affects the calcination pattern.

In order to find a solution for the 100%NG case, FCT Combustion considered a wide range of new burner designs and locations for the calciner. The best solution identified was to install two new FCT burners in the exit of the tertiary air duct (TAD) to preheat the tertiary air and enhance the rate of reaction of the natural gas injected at the main burners. In this configuration, 87% of the total firing rate is provided by the existing four burners, while the two new FCT burners, in the TAD, provide the remaining 13% of the heat output. In this way the temperature of tertiary air is raised to accelerate the reaction rate of natural gas to be comparable with HFO rate, so that calcination reaction is activated with sufficient heat and completed within the average residence time of the meal particles. The effect of new burners in the TAD on the calciner temperature field is shown in Figure 3.

The impact of new burners in the TAD on calcination was predicted to be comparable to the 100% oil case, without uncalcined particles reaching the top of the equipment.

The effect of different burner configurations on the fuel burn-out, as a percentage of total fuel consumption, is compared at various distances above the existing burners in Figure 4. The burnout performance on 100%NG with the new TAD burners is better than the existing 20%HFO80%NG, approaching that of the 100%HFO case.

Results from real-life implementation

The CFD study predicted that adding two small gas burners in the TAD would produce a significant increase in performance. This was a practical and cost-effective solution that did not require altering the design/layout of the existing gas burners.

Figure 5. Installation of the FCT burners in the TAD.

Hence, two new burners from FCT Combustion were purchased. These burners were designed to fire about 10% of the total gas supply to the calciner. They were installed in opposing positions in the TAD (Figure 5).

During the commissioning period, the kiln was initially operating on the original burners firing 100%NG, achieving a feed rate of only 200 tph. Within seconds of turning on the additional FCT burners, the preheater exit temperature dropped 16°C, even though there was anincrease in the total calciner firing rate, demonstrating that the new burners had improved the calciner performance by increasing the degree of calcination and absorbing more heat from fuel combustion.

In the days following the installation of the new FCT burners, the kiln feed rate was increased by 15%, to 230 tph, while maintaining the preheater exit temperature at the level previously attained at 200 tph, (Figure 6). In addition, the specific fuel consumption dropped 4% and clinker quality was maintained.

Conclusion

Using CFD, FCT Combustion has successfully improved the operations of a cement kiln calciner by decreasing its fuel costs and increasing its production. The computational model built by FCT enabled unique insight into the aerodynamics, combustion, and calcination process in the calciner in the existing operation, allowing the development of a cost-effective solution that delivered substantial benefits when implemented in real life.

The CFD model demonstrated that the key difference from firing different fuels in the calciner was the velocity and temperature fields between the various firing configurations, which affected the calcination pattern. A solution was identified: installing new FCT burners in the TAD, in order to accelerate combustion of NG and produce an even

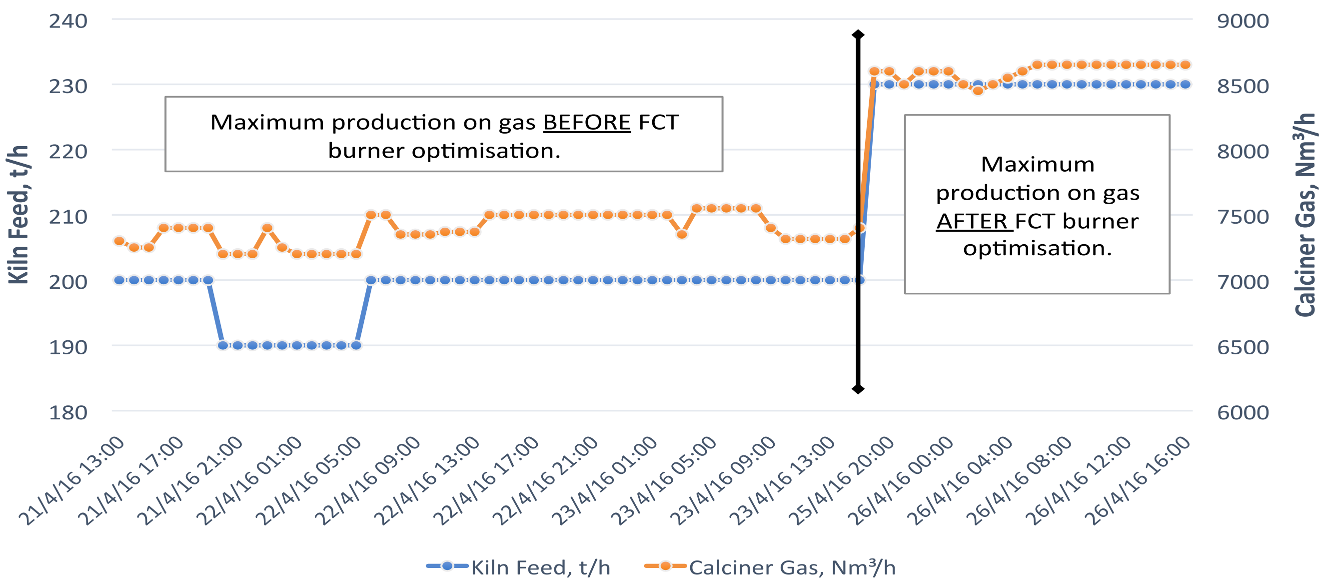

Figure 6. Calciner gas firing rate and kiln feed rate before and after FCT burner optimisation.

heat distribution in the calciner vessel. Only 10% of total gas supply was redirected to these new burners, which were simple to install. This illustrates that in a calciner, the burner location is often more important than the design of the burners themselves.

When the new FCT burners were installed in the TAD, the calciner was successfully able to operate on 100%NG. By eliminating the use of heavy fuel oil, it is estimated savings of €500 000 – €600 000 per year were realised. Furthermore, the kiln feed rate was increased 15%, while maintaining the preheater exit temperature, the specific fuel consumption dropped 4%, and the clinker quality.

About the authors

Roger Hassold is the General Manager of FCT Combustion. He has been at the company since 2014. A graduate in chemical engineering and holding a advanced management programme certificate, he is an experienced Combustion Engineer, designing, installing, and commissioning advanced burner systems for industrial clients and solving complex pyroprocessing problems with the use of CFD modelling. Hassold is also an experienced Production Manager, Technical Manager and Process Engineer in the cement and lime industry and has worked with a large range of kiln technologies and product types.

Yvonne Yu has been a CFD Modelling Engineer at FCT Combustion since 2015. She graduated in mechanical engineering and international economy and trade, holding two master degrees from the University of Adelaide in mechanical and aerospace engineering. Yu has worked with renewable fuels and is an experienced CFD Modelling Engineer, developing CFD projects for kiln and calciner burners in the cement, lime, and iron ore pellet industries, as well as for ceremonial flame applications and R&D projects.

Renata Favalli has been a CFD Modeller at FCT since 2017 but has been developing CFD projects for pyroprocessing industries, as well as for the environmental control sector, since 2007. In 2004, Favalli held an Academic Visitor position at Imperial College, London, shortly after her PhD graduation at IPEN – Research Institute on Energy and Nuclear Power, a Brazilian autarchy associated to the University of Sao Paulo.

Jordan Parham has been CEO of FCT Combustion since 2017 but has worked for the company since 2002. Parham is a graduate in mechanical engineering and has a PhD in combustion and fluid dynamics with extensive experience as a Combustion Engineer, designing and installing advanced burner systems for industrial clients, including R&D of the GyroTherm burner technology, which FCT Combustion has an exclusive license to market worldwide.