Analyse to excel

The complex nature of lime calcination and the various factors that impact on the quality of the final product gives rise to a vast quantity of data. Raw material quality is at the start of this process and the detailed analysis of such materials plays a key role not only in the final product quality but also in terms of kiln performance.

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Industrial lime production needs high-grade limestone and/or pure dolomite resources in widely- and long-term available mineral deposits. Preliminary geological surveys in the field allow the producer to identify deposits with suitable qualities and volumes. The exploitation of such a resource requires the preliminary modelling of quarry fronts, the calculation of extractable volumes and the evaluation of handling large tonnages of material in compliance with legally-prescribed security levels. Mining activity includes different industrial, sometimes highly-mechanised operations, from blasting to crushing, sorting, handling and storing raw material volumes for feeding stockpiles and finally, the kiln. Monitoring raw materials in the laboratory represents the first step to ensure final product quality (see Figure 1).

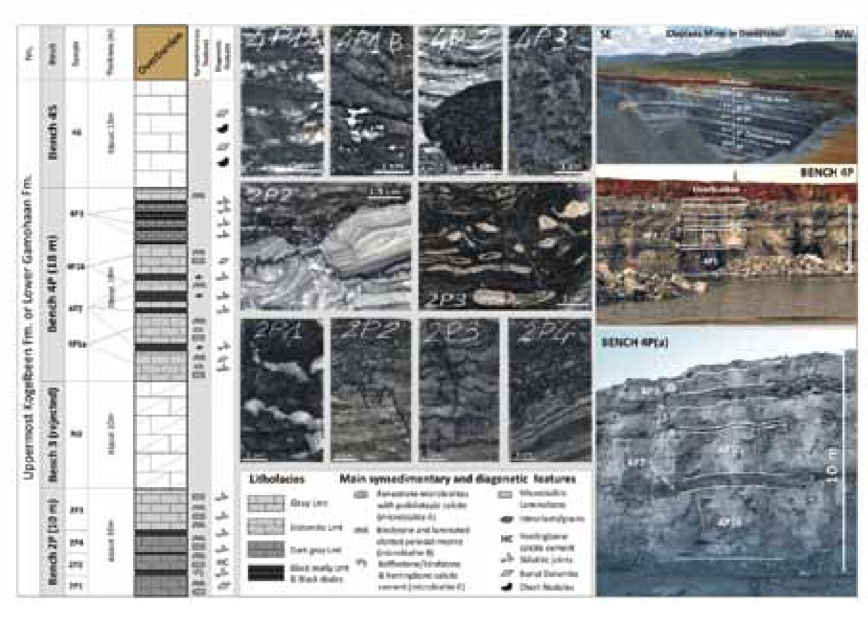


Figure 1: example of stratigraphic log of one mine. The mine is split into four different benches (2P, 3P, 4P and 4S) with each bench representing different rock types, ie lithofaces that show characteristic petrographic features

Cimprogetti's customers send carbonate rock samples to evaluate their suitability for the production of quicklime in their industrial kilns. Cimprogretti has analysed and stored more than 2000 samples from all over the world. New geological and mining expertise recently enhanced the company's laboratory and supports the client with a complete "stone evaluation" prior to kiln design.

Internal procedures for the characterisation of raw materials and burnt products – mostly invented by Cimprogetti and in some cases, validated by important global lime producers – are performed to evaluate the impact of the composition and microstructure of different carbonate rocks on the quality, and the performance of the quicklime/hydrated lime products in different industrial applications.

Cimprogetti's innovative approach includes a preliminary lithological analysis on the sample as received, followed by petrographic analysis according to modern geological classifications. Samples are cut in the form of prismatic chunks, and subsequently transformed into 30µm-thin sections to be viewed under polarised light microscopy (PLM). Image analysis is also carried out using digital software packages for extrapolating quantitative information. This kind of study allows the company to collect detailed information about the rock's microstructure and grain composition (see Figure 2).

Recently, thanks to the integration of modern X-ray instruments for chemical and mineralogical analyses, Cimprogetti is able to perform a more in-depth and accurate characterisation of raw materials and final products. In particular, it can predict and solve different issues related to the design of a new kiln or hydration plant.

For applications ranging from basic research to quality control, two powerful benchtop Rigaku devices were installed:

1. Supermini200, a sequential wavelength dispersive X-ray fluorescence spectrometer (XRF-WDS) for chemical analysis from oxygen (O) through uranium (U) of almost any material
2. MiniFlex600, an X-ray diffractometer (XRD) for mineralogical analysis of any material. This XRD can perform qualitative and quantitative analysis of polycrystalline materials.

Quantitative phase analysis (QPA) by Rietveld method on X-ray powder diffraction (XRD) data, combined with the XRF-WDS and the optical microscopy (PLM), allows to efficiently characterise and control different geological materials, including limestones, dolomites, marbles, clay minerals, burnt lime and hydrated lime products.

Geological material analysis and the related material science expertise, are the relevant identification card of Cimprogetti's technological laboratory. This scientific information from the laboratory is the main reference for Cimprogetti's

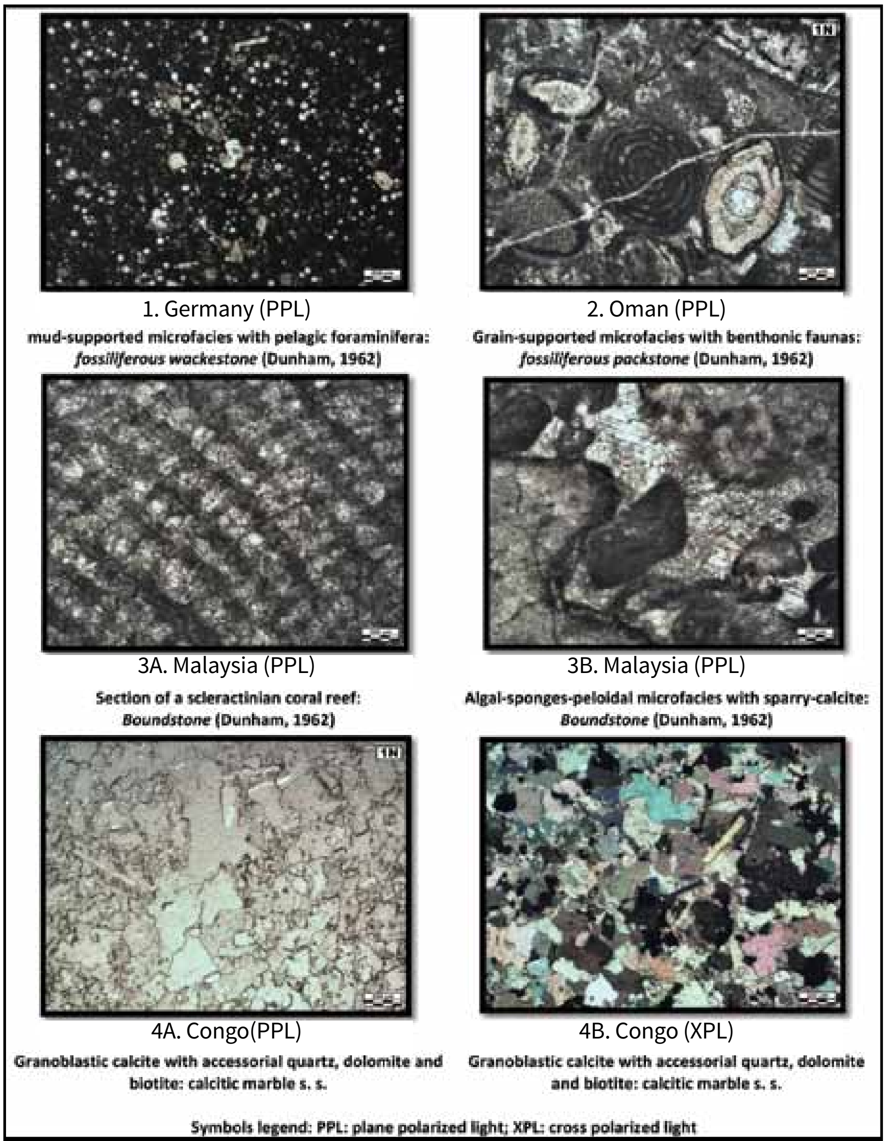


Figure 2: preliminary lithographical analysis allows the collection of information about the rock's microstructure and granular composition

commissioning engineer and for the client to achieve an enhanced kiln performance.

A consistent scientific background can be really useful in cases where technical assistance is required in terms of monitoring the process (eg during kiln start-up or fine tuning) and predicting rock behaviour in the preheating, combustion, and cooling zones of the kiln.

Following the market trend, which has seen a switch from old technologies to shaft kilns, the company has focussed on lump formation, stickiness, cracking and dust formation during calcination at the top kiln temperature range. These issues are related to the specific characteristics of carbonate rock, including its composition (ie geochemical and mineralogical impurities) and microstructure (grain type, texture, crystal size and porosity).

In collaboration with the University of Ferrara and the University of Milano-Bicocca, Cimprogetti is currently carrying out wide-ranging research on different carbonate rocks supplied by clients across the world. The project uses a selection of samples with the most negative technical parameters – ie low reactivity, low burnability, high stickiness, high dust load – to better understand the negative effects on lime production. This enables the research team to find technical solutions to enhance their suitability in terms of shaft kiln use.

Ongoing analyses of physical, chemical, mineralogical and petrographic composition, combined with burning behaviour as well as technical

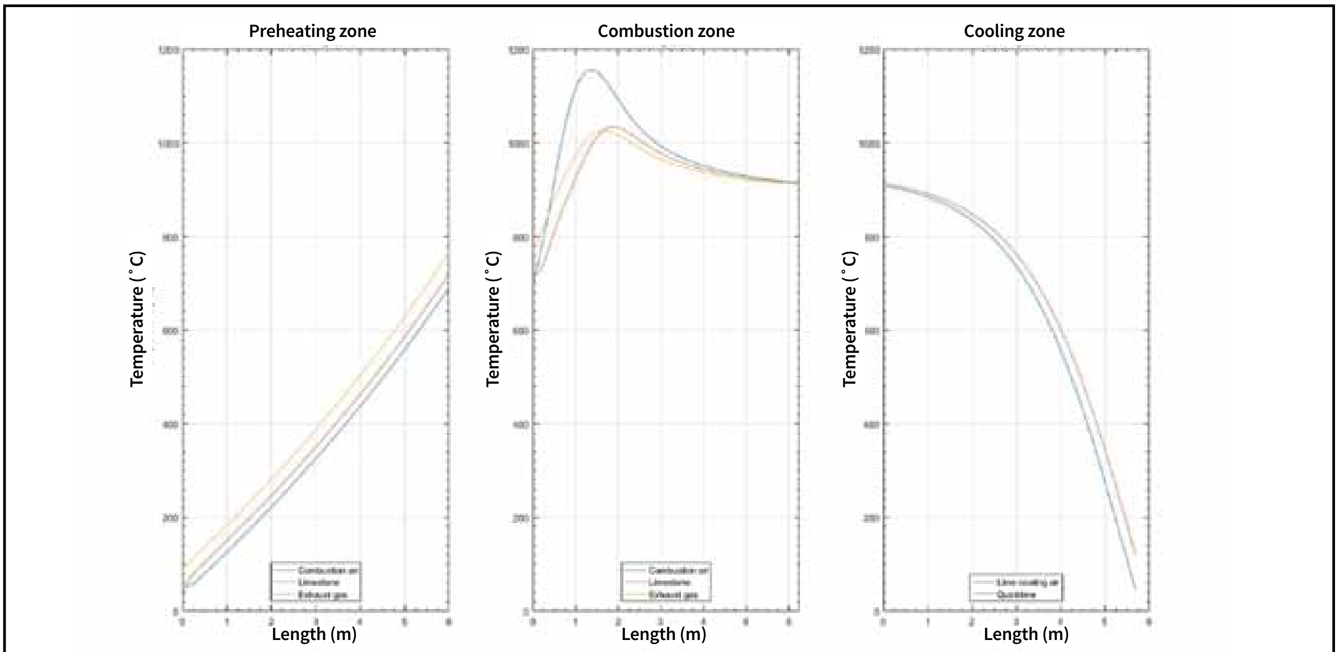
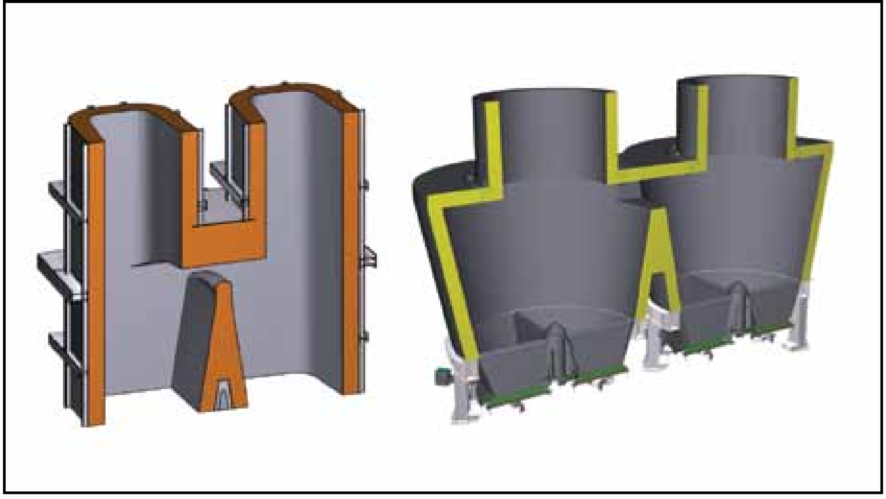


Figure 3: Cimprogretti's analytical database serves as the basis for calculating the thermodynamic behaviour of the limestone in the kiln

Figure 4: parallel flow regenerative kilns can be divided in two key groups: direct cross-over kilns (left) and radial cross-over kilns (right)



characterisation of burnt and/or hydrated products, will clarify different tendencies and possible critical issues. In particular, the analysis of the insoluble residue (which is generally constituted of clay, opaque minerals and organic matter) can be a key factor in understanding the burning behaviour and the sticking tendency at high temperature. The analysis of the crystal size distribution represents the key factor in understanding and preventing the cracking tendency during the calcination process in the shaft kiln.

The final goal of this collaborative research activity is to design a shaft kiln that takes into account the impacts of raw materials and fuels.

Cimprogetti's analytical database is used by the process engineers to calculate the thermodynamic behaviour of the limestone into the kiln, adopting modern mathematical tools combined with other fundamental information, such as the fuel type, rock size and process conditions (see Figure 3). As a rule, the kiln capacity and rock feed size are not the governing criteria for the kiln's choice. The client who requested Cimprogetti to evaluate the feasibility of using a different quality of limestone combined with a selection of fuel, is willing to obtain a product appropriate to the market and in the end, accurately predict the final quality. Therefore, Cimprogetti's approach is to select the shaft kiln technology to be adopted based on limestone quality, fuel selection and client request in terms of market requirements: a single shaft kiln with a capacity of 100-200tpd or a parallel flow regenerative (PFR) kiln with capacities up to 700tpd and with two main types (see also Figure 4):

1. direct crossover, featuring a single channel placed between the shaft
2. radial crossover, featuring circular channels around the shafts, which are connected in the central part.

PFR kilns have the lowest energy requirements – 50 per cent less than rotary kilns with preheaters.

Cimprogetti's latest mathematical model, developed with Mathlab, is able to select the best kiln for the client's market demand. Key questions are:

- How much is the consumption?
- What is the forecast maximum capacity?
- What is the expected final product quality?
- What environmental impact can be expected?
- What is the expected safety factor?
- What is the forecast maintenance cost?
- How many members of staff will be required?

The intelligent use of these process data can improve asset utilisation, logistics and maintenance, contributing to overall excellence.

For example, in the design of the new 700tpd Vanguard® lime kiln, Cimprogetti performed a standard set of analyses to predict the behaviour of the limestone fed into the system and as a result, enable the design to be optimised to avoid segregation and to ensure a uniform limestone loading into the kiln.

The most relevant limitations for regenerative kilns is the physical-mechanical behaviour of the rock during the calcination process and after the thermal shock. It is quite common for available rocks with good quality in terms of chemical and mineralogical composition

"In today's lime industry it is no longer sufficient to optimise existing equipment and outdated technology."

to be unsuitable for the regenerative kiln due to their low mechanical behaviour in the calcination process. For this reason, when finalising a tailor-made kiln design, Cimprogetti focusses on either laboratory experiments, mathematical modelling and process simulation. One example is RockyDem, a specific software which simulates the granular flow behaviour of differently-shaped and sized particles. It can be usefully applied to the case of a limestone kiln feed. This kind of simulation allows an understanding of how the limestone reaches the top of the kiln. This enabled Cimprogetti to improve the design of the kiln loading system with a uniform rock distribution.

The new scientific approach developed in collaboration allowed the design department to enhance the engineering with the 3D geometry of the kiln charging system and inform the client about the preferable rock size to be used.

Finally, Cimprogretti's software engineers design an automation system that corresponds with all activities carried out during limestone analysis, fuel suitability and process calculation.

Conclusion

The lime industry is currently in a state of flux. Investments in modern kiln technology focus less on large production volumes but aim to enhance quality in a more cost-efficient way and with reduced environmental impact. To nurture such innovation in the lime industry always demands a certain degree of openness as innovation goes hand in hand with tradition and culture. Digitalisation and automatisation can provide levers.

In today's lime industry, it is no longer sufficient to optimise existing equipment and outdated technology. Companies need solutions that enable the correlation of a multitude of 'data' from different specialities such as geology, mineralogy, crystal chemistry, physics, mathematics, mechanical and valuable experience and insights in an unique environment and share these with professionals of different disciplines. ■