Evaluating and predicting process behavior in a double shaft regenerative kiln

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Introduction
The process for lime manufacturing consists of the burning of calcium and/or magnesium carbonates at a temperature of between 900 and 1200°C, which is sufficiently high to liberate carbon dioxide, and to obtain the derived oxide (CaCO₃ → CaO + CO₂).

Values of CaCO₃’s dissociation temperature, are generally recognized and have been well authenticated by various studies, for calcite it’s 898°C for 760mmHg in a 100% CO₂ atmosphere. (fig.1).

Theoretical dissociation heat
I. Is slightly changing in function of ambient temperature and pressure;
II. Is consider to be 393 kcal/kg limestone at 898°C at equilibrium;
III. 393 kcal/kg Limestone is equal to 702 kcal/kg lime = 2.93 GJ/ t lime = 2.78 BTU/t lime.

In this purpose even if the “mainspring” is still the kiln in which the limestone is calcinated, an highly evaluation of raw material specific proprieties combined with fuel characteristic are crucial for obtaining high quality lime which is satisfactory for the current market.

A large variety of analytical techniques and kiln designs have been used over the years and around the world even if sales of lime kilns in recent years have been dominated by Double Shaft Regenerative Kiln mostly due to the lowest energy consumption and he environmental friendly process.

Cimprogetti Laboratory activity
Cimprogetti is the only Italian company, that constructed and put successfully in operation all of the major types of lime kilns, including Rotary Kilns, Single Shaft Kilns, Annular Shaft Kilns and Regenerative Kilns. We have the knowledge to recognize the relevant advantages and disadvantages of each type of these kilns combined with proprieties of selected raw material. In the last decades we have sold almost exclusively Twin Shaft Regenerative Kilns, because the lime market has considered this type of kiln competitive with others in terms of energy efficiency with the consequences to obtain high lime quality either with the lowest running cost or lowest emissions. The major improvement taking into account highly individualized nature of carbonates used, is to define a complete set of technical and scientific methods which can be useful to predict and evaluate the raw material sustainability in Regenerative kiln. (fig.2).

Recently, CIMPROGETTI’s technological laboratory started to record scientific data on all the stones sent from our client in combination with site trial experience thus various internal method have been performed too.

In order to obtain a lime product that is satisfactory for the market demand, it’s important to feed the kiln with pure carbonate rocks, i.e. high quality limestone or dolomite. (fig.3)
Among various parameters, the relevant limitation for regenerative kilns is the physical and mechanical behavior (stone cracking) of the stone during the calcination (Mechanical Degradation Test) and after the thermal shock (Drop Test).

It's possible to have available stones with good quality in terms of chemical and mineralogical compositions, but unsuitable in regenerative kilns, because the low mechanical degradation behavior during the calcination process (for instances marbles). For this reason, finalizing a tailor-made kiln design, Cimprogetti dedicates lots of preliminary characterization in laboratory of each material supplied by client, taking into account the actual limestone behavior and the selected fuel quality, to be able to guarantee a product according to the Customer request. (fig.4)

The new methodological approach

The new methodological approach is able to merge the process data collected during the operation with the "field of investigation" which have been developed in Cimprogetti technological department.

Preliminary lithological analysis is performed on rock sample as received, to evaluate important physical parameters, such as color, apparent density, porosity, and occasional superficial dust. Subsequently samples are washed, and cut with a diamond wire in the form of a prism with a standard dimension. Prisms of rock are polished using a glossy spray, and macroscopic description is performed. The same sample is used to obtain a thin section (30 microns of thickness), which is observed under a polarizing microscope. The so-called petrographic analysis permits to distinguish mud-supported, and grain-supported depositional or primary microfacies, characteristic of sedimentary carbonate rocks and the degrees of crystallization and the crystal size of diagenetic and metamorphic carbonate rocks. Moreover the image analysis is also possible to extrapolate numerical information for quantitative analysis. For example, it is possible to determine the micrite to sparite ratio, and the crystal size distribution.

In 2015 an important investment was made with the installation of a non-destructive examination (X-Ray fluorescence and X-Ray Diffraction) which makes unique the data analysis elaboration coming from Cimprogetti Technological Laboratory. Furthermore different technological tests are performed, the burning attitude which is evaluated with a standard burnability test, it is approximately equivalent to a thermo-gravimetric analysis, but is carried out on bulk rock samples, considering the ignition loss after a certain time at a certain temperature. The over-burning test at 1300°C, according to the internal method invented by Cimprogetti, permits to predict the sticking tendency of the lime at the maximum temperature of the kiln. This test is worldwide recognized by several lime producers as a standard for testing the lime agglomeration in Twin Shaft Regenerative (TSR) kilns.

Cimprogetti is making available the knowledge of his unique database as new Stone-AGE®

Quarry

Lower impurity also generally enhance lime properties, but combination of impurities derived from the stone and fuel are normally affecting the quality during the thermodynamics calcination with formation of different and unexpected phases. This is the reasons why it's important the deep knowledge of the deposit where the material is quarried.

Kiln Configuration

The thermal decomposition simulated in our lab leads the design and the kiln settings determination. The residence time of CaO in the kiln is critical during the calcination process. It was noticed that the residence time must be as short as possible for a "sensitive" stone. However, sufficient time must be allowed for heat to penetrate the particles of CaCO₃ and drive out the CO₂. Calcination occurs either with low temperature and high residence time, or high temperature and low residence time, depending on the stone type. The effect of excess air level has a sensitive impact, not only on thermal efficiency, but also on the flame shape and its dimension.

Fuel Selection

Fuel quality and stability and essentially fineness for solid fuels must evaluated during the design phase in order to enhance the lime quality and to better control the kiln behavior.

Technology

In conclusion the new methodological interdisciplinary approach is having the overall goal to extract information from a data set and transform it into an understandable structure for further predicting the final application of the industrial quicklime/hydrated lime.