Maximising existing potential

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As the costs of a capacity upgrade are significantly less than those of constructing a greenfield plant, it is often better to harness the potential of an existing facility when looking to enhance capacity. Energy and other production costs must be taken into consideration and therefore cement producers can often benefit from specialist guidance when increasing the capacity of existing equipment.

Holtec Consulting explains how conducting a comprehensive plant technical audit can be an effective tool for optimising operations as well as upgrading existing equipment

Upgrading the capacity of an existing cement kiln increases clinker production and can also improve energy efficiency. While the extent of the benefits offered by such an upgrade depends on specific operational conditions and energy consumption, in Holtec Consulting's experience, the retrofitting or upgrading of the pyroprocessing section can yield minimum thermal savings of 15-20kcal/kg clinker and electrical savings of 3-5kWh/t of cement. In addition, the cost of an upgrade project is typically around 60-70 per cent less than that of a greenfield construction.

Methodology

For each kiln upgrade project, Holtec carries out a three-step process:

1. a comprehensive study of the kiln section, including an assessment of existing equipment and operating practices
2. the recommendation of improvement measures, accompanied by a feasibility study covering technical concepts and financial calculations
3. implementation of the technical concept.

To carry out a comprehensive assessment of the pyroprocessing section a specialist team visits the plant to view the scope for upgrade. The team will carry out process measurements as well as collect and evaluate further data to establish the potential capacity of the kiln section. It will also assess the preheater, precalciner and cooler, including relevant fans.

Potential kiln capacity assessment

Specific volumetric loading and specific thermal loading are the main criteria in assessing and dimensioning the kiln. These in turn depend on the burnability of the raw mix, which is a function of the chemical and mineralogical composition, the fineness and homogeneity of the raw mix. Key indicators in the chemical and mineralogical composition are the lime saturation factor (LSF), the silica modulus (SM), the share of quartz coarser than 45µm and the share of calcite coarser than 125µm. A raw mix which is very homogenous and easy to burn enables a higher kiln volumetric loading. Table 1 shows the parameters that enable a kiln evaluation in case of a normally-burnable raw mix.

For example, in a kiln of ϕ5.5m x 86m, operating at 7000tpd and with an effective kiln volume of 1729m³, a sustainable specific volumetric loading of 5.5tpd/m³ would result in a maximum achievable clinker production of 9500tpd ($1729m^3 \times 5.5tpd/m^3 = 9509.5tpd$ clinker). The basis and evaluation of this typical kiln tube is summarised in Table 2. From this data, it becomes clear that the kiln speed needs to be increased to 5rpm to achieve 9500tpd clinker output with a 12 per cent filling. To meet this requirement, the following options are available:

Table 1: parameters for kiln evaluation (normal mix burnability)

Kiln parameter	*Value*
Volumetric loading – sustainable (tpd/m³)	5.5
Thermal loading (Gcal/h/m²)	5.0
Degree of filling (%)	12-14

- increasing the kiln speed by changing the reduction ratio through modifying the gear box internals and replacing the existing motor with a suitable high-capacity motor
- replacing the existing kiln drive system with a new, suitably-designed system.

However, the mechanical stability of the kiln system needs to be established to enable capacity to be raised to 9500tpd.

Table 2: kiln parameters and evaluation for a typical kiln

Kiln parameter	*Value*
Capacity (tpd)	9500
Diameter (m)	5.50
Length (m)	86
Speed (rpm)	5.0
Slope (%)	4
Specific heat consumption (kcal/kg clinker)	700
Fuel firing in kiln (%)	33
Brick thickness (m)	0.22
Kiln evaluation	
Kiln L/D	16
Effective volume (m^3)	1729
Effective cross-sectional area (m^2)	20.11
Circumferential speed (cm/s)	144.0
Filling (%)	11.73
Specific volume loading (tpd/m^3)	5.49
Specific thermal loading (Gcal/h/m^2)	4.55
Retention time (min)	16

Preheater, precalciner and cooler assessment

In addition to assessing the potential of the kiln, the plant's preheater, precalciner and cooler systems are evaluated.

Preheater

The number of preheater stages and strings depends on several factors, including plant capacity and moisture content in raw materials. Modern preheaters are designed for low-pressure drops which must provide good separation efficiency, particularly in the top and bottom stages. Cyclone inlet velocities are designed in the range of 12-15m/s.

Preheater performance is assessed through process measurements of temperature, pressure and oxygen profiles. In addition, gas velocities in riser ducts are calculated at current production levels. Acceptable norms for preheater assessment are given in Table 3.

The pressure profile of each preheater stage and the gas velocities inside the riser ducts for the upgrade capacity are then worked out. If these pressures exceed acceptable norms, changes to the existing preheater will need to be carried out.

These could include:

- replacement of the existing top cyclone with low pressure drop, high-efficiency cyclones
- addition of a parallel third cyclone to the top twin cyclones of the preheater
- addition of an extra stage
- conduction of computational fluid dynamics (CFD) study for a cyclone that offers a high pressure drop of more than 120mmWC
- replacement of existing downcomer duct with suitable bigger duct
- enlargement of cyclone inlets and riser ducts
- replacement of existing dispersion boxes with the latest technology and suitably-designed versions
- lowering the height of the dispersion box by up to 0.5m from the immediate bottom cyclone roof
- replacement of existing meal flaps with new ones
- halting false air in preheater.

A structural audit needs to be carried out to establish the stability of these modifications in the existing structure.

Precalciner

The precalciner allows calcination to take place before the meal enters the kiln as up to 60-70 per cent of total fuel is introduced into a stationary reactor.

Combustion performance in the precalciner is influenced by various parameters, including the following key factors:

- gas retention time needs to be sufficient to enable complete combustion in the precalciner, ie, 6-8s depending on fuel reactivity.
- temperature – as raw meal is heated, calcination does not suddenly occur at a well-defined temperature. This process starts at 600-700˚C and completes at 900-1000˚C, following the S-curve (see Figure 1). The exact shape and position of this curve may vary between raw meal types.
- good mixing of fuel with available oxygen – optimum fuel dispersion into the gas flow is essential.
- The flow of the air-gas mixture has to be favourable for combustion.

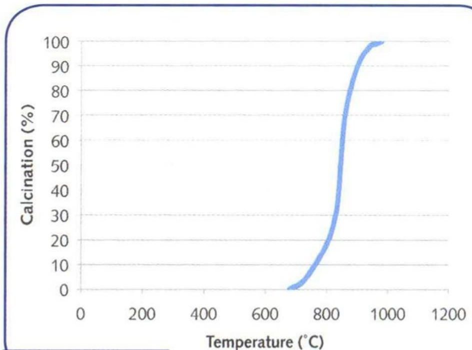

Figure 1: S-curve

- The meal distribution in the combustion zone has to be optimum.

Precalciners offer the following key benefits:

- more stable kiln operation due to improved kiln control via two separate fuel feed and control points
- more stable kiln operation due to controlled meal conditions at the kiln inlet
- reduced thermal load in the burning zone
- higher kiln availability
- longer life of the burning zone refractory
- lower NO_x emissions.

Table 3: acceptable preheater assessment norms

Normally recommended draught at preheater exit (mmWG)	<90
Gas velocities in cyclone inlets, riser and downcomer ducts (m/s)	12-15
Gas residence time in precalciner – with use of waste fuels (s)	>6
Tertiary air take-off velocity (m/s)	<5-6
Tertiary air duct gas velocity (m/s)	>25

To assess the precalciner, gas retention time in the precalciner is estimated and compared with a 6-8s standard. If the gas residence time is less than the standard value, the following changes are often recommended:

- extension of the precalciner length
- installation of a new, suitably-designed precalciner
- replacement of existing SLC-type calciner by an ILC calciner
- replacement of existing precalciner burners with new ones.

Clinker cooler and cooler fans

The clinker (grate) cooler is a cross-current heat exchanger which cools the hot clinker from 1400˚C to less than 100˚C and recovers heat from the clinker.

The specific loading of the latest-generation grate coolers meets the accepted norm of 45tpd/m^2 while the required specific air is about 1.8-2.0Nm^3/kg clinker.

Clinker cooler assessment estimates the grate cooler loading and specific cooling air requirement at the upgraded production level and compares it with the accepted norm. If loading on the cooler is higher than this standard, the grate area needs to be increased accordingly until loading falls below 45tpd/m^2.

When upgrading a cooler, the following changes are often recommended:

- Increase the grate area by adding a module to the existing cooler or extending its length. In case of the latter, extra cooler fans may have to be included.
- Install static grate plates for the first 7-8 rows of old-generation coolers. This improves the secondary and tertiary air temperatures and heat recuperation efficiency.
- Replace existing grate plates with new-generation, high-efficiency grate plates.

In addition, an assessment of the mechanical stability of the existing grate cooler needs to be carried out to establish its suitability for cooling the target clinker capacity.

Preheater fan

Process measurements will help to establish the specific gas volume (Nm^3/kg clinker) at the preheater exit. The same specific gas volume will serve as the basis for estimating the gas volume at the target production level. All other parameters, such as oxygen content, return dust and preheater fan efficiency must be kept constant.

The specific gas volume at the preheater exit may vary from 1.4-1.6Nm^3/kg, depending on the fuel composition and excess/false quantities in the system. For example, a specific gas volume (operating) at the preheater exit of 1.5Nm^3/kg clinker at a production level of 7000tpd clinker will lead to an expected gas volume of 593,750Nm^3/h (1.5Nm^3/kg clinker x 9500tpd clinker x 1000/24) when the production capacity is upgraded to 9500tpd clinker.

The expected static pressure at target production can be calculated using the following formula:

$P2/P1 = (Production\ 2/Production1)^2$.

If the expected gas volume and pressure are less than the design specifications of the existing preheater fan, they will be adequate to meet the new requirements. If not, tipping of the existing preheater fan could improve the capacity by 5-8 per cent. An alternative is to replace the existing fan with a new, suitably-design high-efficiency fan.

Cooler ESP fan

Process measurements are used to establish the specific gas volume (Nm^3/kg clinker) at the cooler exhaust, which is then used as a basis to estimate the cooler exhaust gas volume at the targeted production level. For example, a specific gas volume (operating) at the cooler exhaust of 1.1Nm^3/kg clinker at a production level of 7000tpd clinker will lead to an expected gas volume of 435,416Nm^3/h (1.1Nm^3/kg clinker x 9500tpd clinker x 1000/24) when the production capacity is upgraded to 9500tpd clinker.

Again, the expected static pressure at target production can be calculated using the following formula:

$P2/P1 = (Production\ 2/Production1)^2$.

Similar to the case of preheater fan, if the expected gas volume and pressure are less than the design specifications of the existing cooler ESP fan, they will be adequate to meet the new requirements. If not, tipping of the existing cooler vent fan could improve the capacity. An alternative is to replace the existing fan with a new, suitably-designed high-efficiency fan.

Conclusion

Upgrading the production capacity of an existing cement plant will help to reduce output costs. The use of available equipment to its full potential, together with supplementary technology can significantly increase the capacity of a cement works. In addition, optimisation of the plant's operation and the installation of energy-efficient components can further improve energy conservation and enhance overall plant capacity.

Using available equipment to its full potential together with supplementary technology can significantly increase a plant's capacity