Blast furnace hearth management and cast house practice in the new age of raw materials

With ever increasing demand for iron ore, a trend already apparent is for a deterioration in ore quality, resulting in greater quantities of slag, affecting burden descent and liquid flow through the hearth. These circumstances will provide a catalyst for lining wear management with bosh, stack and hearth linings coming under additional stress. Trough and runner designs may also need to change

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In recent years, much of the pressure on profitability in the global steel industry has been exerted by raw material prices. The cost component of raw materials per tonne of finished product has risen to such levels that steel producers have little opportunity to improve their profitability by relevant percentages. Obviously, during the crisis years, the raw materials debate has been dominated by price levels as well as imbalances in demand and supply. New mining projects are well under way and, even though many of these may be hampered by financial or other problems, these will eliminate the imbalances in demand and supply in the longer term and are expected to relieve the industry of some of the burdens of the recent price levels.

Another trend, however, is for raw materials to degrade in quality, introducing pressure on operations that is not expected to fade when new projects start supplying. In addition to the financial challenges imposed by the dynamics in raw material supply, steel producers will continue to experience operational challenges for years to come. Current trends demonstrate that lower quality raw materials will hit everyone in the near future. One of the first areas of the integrated steel plant to be affected is obviously the blast furnace. In order for operations to remain as stable as possible and demand to continue to be met, operators as well as plant managers may find some very attractive options to prepare for the challenges of the new age of raw materials.

TRENDS

With the increasing demand, particularly from China, new projects and developments in existing supply have demonstrated that trends will be related mainly to impurity and the type of feedstock that will be available.

As shown in recent publications [1], Chinese iron ore production has demonstrated exceptional growth over the past 10 years to meet the equally exceptional growth in demand. Ferrous content of the iron ore supply, however, has declined over the same period by approximately 50%. Given China's dominant position, this trend is to be taken seriously. Moreover, low ferrous contents have been common in other high growth areas for quite a number of years. Since past mining projects focused mainly on developing richer deposits, miners are now confronted with projects supplying lower grade ores. Not only does the upgrading of lower quality ores add CAPEX to a project and hence an additional price component to every tonne of shipped ore, it may not be cost-effective in terms of yield loss to maintain the same end values of purity as before, so the decline is slowed rather than eliminated.

Another side-effect of the necessity to upgrade lower quality ores is that the process generates ferrous units with granulometry that only allows for agglomeration to pellets instead of sinter. This adds to a number of other trends in raw material supply affecting the available mix of the ferrous feedstock. It is expected that lump ore fitting the current quality and size specification will run out in the next decade. The quantity of sinter fines from these sources are expected to increase, compensating in part for the current sinter sources that are degrading in size toward the pellet fines size range.

With sinter feed currently being the preferred material for many operators and lump ore being financially more attractive, a shift towards a larger pellet component in the furnace's feedstock calls for a change in operational thinking as well as equipment to accommodate it. Alternatives such as persevering with existing burdening strategies as long as possible will come at the price of further increased pressure on profitability.

CONSEQUENCES

Obviously, moving away from what is currently perceived as an optimum burden calls for adaptation of daily routines as

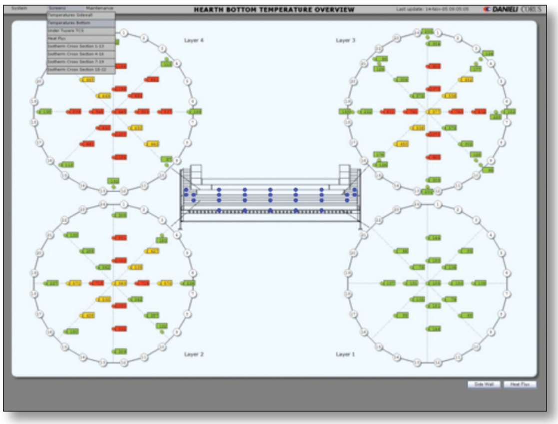

Fig 1 **Overview visualisation showing the temperature and alarm status for the hearth pad**

Fig 2 **Overview of temperature display with alarm status for sidewall**

well as potential modifications of equipment. Primarily, the process will be affected in the following ways:

- **Slag volume** Lower grade iron ores bring about more impurities, and already slag volumes below 200kg/tHM as achieved at some state-of-the-art plants are a thing of the past. Best in class slag rates are now back above 200kg/tHM and are likely to rise to 300kg/tHM and beyond
- **Heat load** Since the upgrading of lower grade ores and the sliding granulometry of available fines will produce a substantial pellet feed, many plant operators will find that economics dictate a shift towards a higher pellet content, which can introduce higher heat loads inside their blast furnaces
- **Coke rate and productivity** Increasing slag volumes will require a higher fuel input into the furnace, and where injection rates are already running at maximum, this will require a higher coke rate. These effects will result in a lower maximum productivity of the furnace
- **Process stability** During the changes to higher slag rate and increasing pellet percentage it is reasonable to expect that it will take some time to optimise the process again to the new operating characteristics. During this transition process stability is likely to suffer.

In practice, scenarios for the production process will vary widely. Consequences in terms of slag composition and therefore hot metal quality require debate in their own right and will not be discussed here. A small number of other scenarios are listed below, but also here, a change in raw materials may affect the process in many other areas:

- Higher slag volumes will influence the gas flow
- With higher slag volumes, liquid flow through the hearth will be more challenging, leading to increases in fluctuating liquid levels in the hearth. In the extreme case, burden descent will be affected.
- The increased incidents of compromised gas flow due to raw material changes are likely to appear as increased hanging with more frequent and severe slips. This will provide a catalyst for greater lining wear, with bosh, stack and hearth linings coming under more stress
- Higher slag rates may be difficult to accommodate by the existing trough and runner system, especially since in many cases, production has been ramped up substantially above the cast house initial design values

To accommodate these (and many other) scenarios, the following improvements are expected to be required:

- Hearth management for optimum drainage and minimum wear to counter the higher slag volumes
- Adapting process and burdening strategies for optimum stability and minimised heat loads on the furnace wall
- Assessment of existing furnace linings and design of new linings for the ability to operate on a wider variety of raw material qualities at higher heat loads without negatively affecting campaign lengths
- Assessment and de-bottlenecking of existing cast house layouts and design of new cast house layouts for the revised liquid flows

COUNTERMEASURES

Many of the unfavourable consequences of future lower grade raw materials will be accommodated by the expertise and creativity of the blast furnace operators. There are, however, some practical solutions to support them in their endeavours to regain optimum control of the process and achieve maximum campaign lengths for the trough and runner systems as well as the furnace hearth and lining. In addition, some measures beyond operation can be taken to this same end.

HEARTH MONITORING SYSTEM

Since the successful management and control of hearth refractory temperatures is key to managing campaign life, ▷

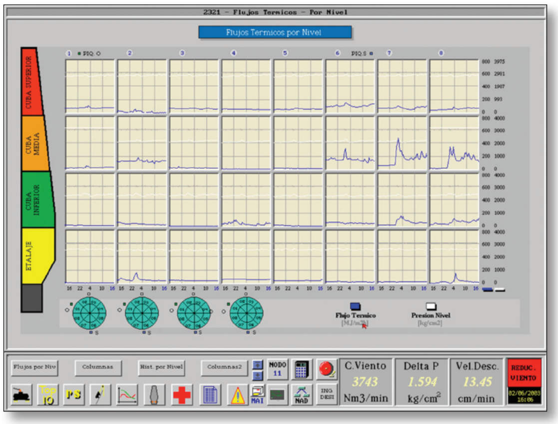

Fig 3 **Example of temperature spikes on the lining**

this becomes especially relevant when lower quality raw materials intensify the events that introduce thermal attack. Management and control begins with reliable measurement, and so increasingly extensive thermocouple grids are used in the tapholes and hearths to give an indication of what the refractory temperatures are. Of substantial benefit to these thermocouple installations is the understanding of how the hearth temperatures respond to operational conditions, and when the temperatures in the hearth are such that the lifetime of the refractory is in threat. This can be done with the correct tools.

Danieli Corus has developed a Hearth Monitoring System for monitoring temperature-related process values. The impact this can have on campaign life is defined by the access and insight the operator gains from viewing the system. In systems where the thermocouple data is only available as trends, or even as data figures, the time required making sense of this data in a practical sense is not always available to the control room operator. By taking the data and presenting it in an immediately understandable format, instantly updated and shown relative to its location in the hearth, the operator can immediately relate this information to what else is going on in the blast furnace.

The hearth of a blast furnace tends not to wear on a time-dependent basis, and is far more likely to be event-dependent, where incidents which may only last a few days can cause damage that reduce the refractory thickness by more than has been removed in, eg, the last two or three years. In these cases, it is the timely reaction to these events that is important for protecting the hearth refractory in real time, and not the post-event analysis. The analysis after the event will only give the amount of refractory lost, and actions that may help avoid the same amount of refractory being lost again under similar circumstances.

By bringing the hearth temperatures, the heat flux, isotherms and Relative Scab Index into the control room, the operator has the opportunity to see for himself how these are related to the way the blast furnace is operating. The reaction time to incidents is therefore reduced and, rather than explaining why refractory was lost, it may be possible to avoid it being lost in the first place. This possibility is the key to bringing the operator in the driving seat for understanding and ultimately controlling the situations that can lead to loss of refractory, and so preserving the condition of the hearth throughout the campaign. Two examples are shown in *Figures 1* and *2*.

LINING DESIGN AND MAINTENANCE

Some burden compositions and some operational practices (such as low productivity operation) introduce very little thermal and chemical attack. When raw material qualities are deteriorating in general and specific burden mixes cease to be available, low heat load operation will have to be discontinued in many cases. Only very few lining designs have proven capable of achieving long campaigns in spite of high to extremely high heat loads (regardless of whether these are caused by high productivity operations or swings in raw material qualities). *Figure 3* illustrates temperature spikes on the lining typical of that found in cases of process irregularities due to obstructed gas flow.

In greenfield situations or in cases where a furnace is renovated substantially, allowing for fundamental design decisions, it is essential to design the lining for high heat load capability as well as resistance against abrasion. A high conductivity lining, such as the Hoogovens dense plate cooled concept, is designed to support the formation of a stable process skull for protection against thermal, chemical and mechanical attack **[2]**. Additional experiences, as well as how an optimum lining design contributes to process stability and a lower cost per tonne, are illustrated in references 3 and 4.

Where operators of furnaces that are in mid-campaign experience a sudden or even gradual decline in raw material quality parameters, it is recommended to assess the furnace lining and revise its maintenance strategy and plan. The current state of the furnace may be assessed by taking core drilling samples supported by temperature profile readings. Once the current state is known, with the risks and consequences evaluated, and the operating level determined within a bandwidth imposed by degrading and/or fluctuating raw material qualities, future scenario planning is then possible.

Scenarios are numerous and should first be narrowed down based on revising the lining design for maximum accommodation of thermal, chemical and mechanical attack to maximise future maintenance intervals as well as security. Then, criteria with respect to risk, costs and planning, should be set for assessing alternatives. Forecasts for future demand and prices should be estimated, and from that, the necessary investment to meet these demands ▷

can be identified. It is in this latter part that the many possibilities may be discussed. Depending on the current plant configuration it may be appropriate to discuss reline plans over a number of years for a succession of furnaces. Alternatively, the challenge may be to maintain output while planning and even beginning a rebuild project.

By addressing these points in a systematic way, all repair scenarios from 'emergency patch repairs' to 'full scale relines' can be reviewed on their business aspects. An independent auditor can help in making realistic risk assessments.

OPERATIONAL IMPROVEMENTS

Any operational improvements will be entirely dependent on the nature of the changes that were made to the burdening characteristics. Any shift toward greater pellet use to replace lump ore may well improve the gas flow through the furnace, dependent, of course, on the quality of the material being introduced, and the quality of the material being phased out. In any event, a modification to the burden distribution pattern is likely to be required, in order to correct for the differing rolling characteristics.

Where the change in burden components means a change in the slag forming constituents then the volume as well as the characteristics of the slag must be considered. An increase in alumina in the slag can, for example, be compensated by an increase in quartzite to dilute the slag again, but this will add to the volume of slag to be removed. Any change to the slag volume or viscosity will influence the ease with which it flows to and out of the taphole, and so appropriate measures must be available to the operator to maximise the slag flow out of the taphole to avoid fluctuating liquid levels in the hearth.

TROUGH SYSTEM DE-BOTTLENECKING

A blast furnace plant may be built for over 60 years of production. Repair intervals may be anywhere between 10 years for hearth repairs or 30 years for revamp projects with substantial scope. Given the impact, a fundamental re-design of the cast house and its trough and runner system is not typically part of projects that are executed at intervals shorter than 30 years. Today, a blast furnace may produce two to four times as much hot metal as what it was initially designed for. The cast house is the most labour-intensive area of the plant and the impact of dramatic increases in production are felt here in particular. Production levels that are substantially above initial design values drive the trough and runner systems to their limits.

The equally dramatic increases in slag rates that may be expected when operating on lower grade raw materials add to this phenomenon. Operating the trough and runner systems at their limits is difficult in its own right, the requirement to drain an additional 50-100% of extra slag volume adds urgency to the need to de-bottleneck.

De-bottlenecking an infrastructure intended for the drainage of 5,000t of hot metal and 1,250t of slag per day for the ability to drain 11,000t and 3,500t per day, respectively, is a practical job that calls for practical experience as well as sufficient expertise of both cast house operation and refractories construction. Cast house layouts come as varied as blast furnace designs and each has individual characteristics that allow for improvement.

Health and safety play a more important role here than anywhere given the labour-intensive nature of the cast house.

CONCLUSIONS

It is impossible to know what the future will hold, but studying trends and predicting likely outcomes can be a useful place to start. The dominance of blast furnaces as the major ironmaking route is not threatened at the moment, with the emergence of mini-mills and alternative ironmaking methods having found their niche and are co-existing.

The recent demand, fuelled by China, and the economic crises have largely hidden the third significant trend over the last 10 years, and that is the declining availability of premium iron ore reserves. The overall quantity is not under threat, and many new projects are in the pipeline, but the overall quality and the granulometry of the product from each mine is on the decline, and this is not likely to be reversed.

It is therefore of paramount importance that the BF manager starts looking where he can prepare for the potential decline in raw material quality that is to come, and make solid changes. This can mean greater stockhouse flexibility, improved furnace lining durability, greater monitoring capability or indeed reviewing rebuild or greenfield plans with a view to the likely situation in 15 to 20 years rather than that of today. **MS**

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