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A system for the energy effective concentrate feed into furnaces

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This paper sets out to clearly identify all elements that make up an effective furnace feed system. These are outlined and the more common types of technology are listed. These technologies all play an important role in the final delivery of all feed materials to the furnace.

Introduction

The feed of concentrates and other additives into furnaces is becoming a more sophisticated field of engineering compared to the historical, and in many instances current, systems that have been and are used today.

The need for the improvement of furnace feeding systems is brought on by two major driving forces. The first of these is the more sophisticated furnace designs that are being built. These strive to smelt more material for the same footprint that the original smelters use and also to get a higher yield of smelted ore per kWh of energy used.

In essence this means significantly higher energy densities and better energy efficiencies.

The role that the feeding of concentrates and other additives plays is vital to the metering and the distribution of material, and has to be better controlled to absorb the increased energy being introduced in the furnace. Failure to do this can lead to unstable operation of the furnace, unbalanced energy distribution, and over-heating, amongst other operational difficulties, rendering the furnace unusable.

The second driving force is the cost of power.

The paper that I presented two years ago¹ argued that the original introduction of injection systems as a means to feed furnaces was initiated by the global oil crisis in the late 1970s. The world is now in another global energy crisis. This is seen in Southern Africa as the rapid increase in the price of electricity, the recent Eskom price increases ratified by NERSA validate this point, which in turn affects the bottom line of all the electrical-powered smelters and will be placing an industry-wide emphasis on improving throughput in the same furnaces as well as dramatically improving energy utilization.

The furnace feeding technologies which Clyde Materials Handling Africa (Pty) Ltd (CMHA) are able to offer to the furnace designers and operators will allow them to exploit the full benefit of new furnace designs and technologies. This will allow the industry to improve the energy utilization as well as increase the energy density of the designs-leading to the smelting industry remaining competitive in regard to global production price indices.

There is an important final aspect of these systems which needs to be added to the overall picture and that is the environmental soundness of the systems offered and specifically the containment of dust emissions into the atmosphere.

This paper outlines the technologies, areas in which these technologies have been used, and strategies for the application of these technologies in future applications.

Overview of furnace feeding systems

Furnace feeding technologies are often thought of as the final feed system from the furnace feed bin into the furnace. In reality, the furnace feed system comprises a number of subsystems which, when designed, selected, and sized correctly, ensure that a suitable feed of material can be introduced into the furnace. This allows the benefits of different feeding strategies to be exploited allowing increases of energy density into furnaces and improvements in the energy utilization.

In the event that any aspect of the sub-systems do not perform correctly, then the overall effect on the furnace is to introduce an aberration that will lead to reduction in production capacity and increase in energy needed.

The sub-systems that make up the entire chain of a furnace feeding system are:

- Drying
- Bulk storage
- Conveying systems
- Furnace storage
- Screening
- Additive addition
- Off-gas dust return and metering
- Metering
- Furnace distribution.

There are those in the industry who could argue that the first six items above are not part of the furnace feed system *per se*. This author's argument is that changes in the drying process can result in variation to the feed material that, in turn, can significantly affect the process in item 9, furnace distribution. This, in turn, can lead to drastic furnace failure and significant production downtime.

Hence all of the above systems need to be in place to ensure that the final feeding step can be correctly performed.

Of the steps identified above, CMHA are directly involved in all of them. Step 1 is the only one that CMHA is indirectly involved in, yet are still able to include this into any overall system that is offered.

A brief overview of the technologies used in the listed sub-systems is as follows:

Drying

- Rotary dryers including steam tube types
- Tunnel or conveyor belt dryers
- Spray dryers
- Fluidized bed
- Flash dryers.

Bulk Storage

- Bulk bags
- Steel silos
- Slip cast cement silos
- Screw feeder outlets
- Gate valves
- Belt feeders
- Vibrating feeders
- The Clyde Dome valve.

Conveying

- Belt conveyors
- Pipe conveyors
- Scraper conveyors
- Lean phase conveyors
- Dense phase conveyors.

Furnace Storage

- Ground-based storage systems
- Small hopper elevated systems
- Large hopper elevated systems.

Screening

- No screens
- Simple static screens
- Rotating trommel screens (active)
- Vibrating screens (active)
- Double static screens
- Double active screens.

Off-gas dust return and metering

- Scraper conveying systems
- Lean phase conveying
- High temperature Dense Phase Clyde Roto Feed system.

Additive addition

- Vibrating feeders
- Metering screws
- Rotary valves
- Double flap valves
- Standard valves
- Table feeders
- Clyde Roto Feed system
- Clyde Roto Screw system.

Metering systems

- Screw feeders
- Vibrating feeder
- Clyde Roto feeder
- Belt metering
- All systems using associated load cells.

Furnace Distribution

- Scraper conveyors
- Vibrating pipes

- Gravimetric chutes
- Screw feeders
- Air slides
- Dense phase pneumatic systems.

The above list is by no means exhaustive, but certainly covers more than 90% of the sub-systems expected to be found in smelting industries feeding fine dried concentrates along with other additives fed into smelting furnaces.

Furnace feeding system assessment

Drying

The first two systems listed above were originally used extensively in the smelting industry. These have been superseded by the final three. Currently, the most common newly-installed systems are the flash dryer and fluidized bed dryer. Spray dryers are still used but they require that significantly higher moisture is evaporated compared to fluid bed and flash dryers. This means operating energy costs are higher, equipment sizes larger. In an environment of cheap energy costs, these were seen as acceptable although in South Africa this is changing rapidly.

Improvement in pressure filter technology has seen mechanical dewatering become more rugged and more cost-effective at producing consistent filter cakes suited to fluid bed systems and flash dryers.

The major requirement for a drying system in performing a suitable role in an overall furnace feeding system is to produce a consistent final product to be fed into the furnace feeding system.

A definition of consistency that is most applicable to dryers would be:

- Consistently accurate final moisture content
- Consistent particle size distribution of dried product
- Stable production rates
- Integrated tramp removal systems
- Energy utilization or efficiency.

In the experience of the author, the system which exhibits the best performance related to the above parameters is the flash drying system. The spray drying system surpasses the flash dryer with regard to tramp removal as the atomization device (spray nozzles or rotating atomization disc) prevents the passage of tramp into the system. The spray drying is, however, more subject to process failure from variations in the feed materials whereas the flash dryer is able to withstand significant variations in feed material with a consistent output material. The flash dryer is ultimately more energy-effective as the feed material is in the range of 10–20% moisture, whereas the spray dryer requires a minimum of 30% moisture. The spray dryer is more efficient as the inlet temperatures on operation are in the range of 900–1 000°C whereas the flash dryer is generally limited to a maximum of 700°C. The author has, however, witnessed a flash dryer that ran successfully with an inlet temperature of 1 000°C for a period of three days. It is not known how long this could have continued for without serious damage to the system.

Fluidized-bed systems are subject to producing a range of material that can include large particle size ranges which are not always controllable. This will lead to downstream furnace feed difficulties, which can affect the reaction dynamics of the furnace and could lead to significant furnace damage in extreme cases.

Bulk silos

The major focus areas for bulk silos are:

- Flow of product into the silo
- Silo off air filtration
- Silo design for mass flow
- Silo base aeration
- Product outflow control.

It is important to ensure that when dried concentrate is transported into a storage silo that material is introduced in a manner that promotes distribution across as large a cross section of the silo as possible. A system which is not promoting distribution should then strive to focus the direction of the introduced material to the centre of the silo or the centripetal centre of the section of the silo which that inlet point covers in a distributed inlet system.

Silo air filtration systems historically have been bin-mounted filter systems. These systems use reverse pulse cleaning with the material falling straight back into the silo. Factors that need to be taken into consideration with these systems are the dust loading and the related particle size distribution of the dust that is expected to be collected in these filters.

There has been a trend to move towards integrated ground-based reverse pulse filters. In various scenarios these are valid but are significantly more expensive than bin-mounted filters and require an additional conveying system to re-elevate the captured fines to the storage silo. In many installations these have been installed as a consequence of maintenance issues and not due to process issues. In the event that the capital expenditure is warranted, then the use of a ground-based system is not bad. However if there is a maintenance issue regarding bin filters, the ground-based system can equally fail due to the same reasons. The solution is a management issue and not a technical issue.

It is vital that a professional silo design is done by a fully qualified and experienced silo design consultant. Silo failures and specifically silo hold-ups can be disastrous. Many short-cuts in silo design and selection are made, and more often than not these fail.

It is not always practical for extra large silo systems to have conical-based outlet formats to single or multiple outlet points. In the event that a silo has a shallow sloped or flat bottom, aeration systems are required. Aeration systems become some of the least accessible systems in any furnace feeding system. The emphasis should be on a system that is rugged and has low maintenance features.

Product outflow control

The outflow control of concentrate is vitally important. Most often, the outflow control system will be determined by where the concentrate will be going to as opposed to where it has come from.

The majority of concentrates flowing from bulk storage silos which form part of furnace feeding systems are being delivered into pneumatic conveying systems, of which the majority these days are Dense Phase systems. This would mean that the concentrate is flowing directly into a Dense Phase pressure vessel or alternatively a buffer hopper that is located between the silo and the Dense Phase vessel.

For this type of system, the requirement for outflow control is a simply a flow/no flow requirement. To perform this, the correct valve system is needed. The Clyde Dome Valve has exhibited excellent characteristics to perform in

this application. It offers the ability to supports large loads from the pressure exerted by a silo full of concentrate (up to 3 000 tons), operation for long periods of time without the need for maintenance. Fully-sealed capability and the ability to close through a flooded chute of concentrate add to the benefits of this system.

Most importantly, the system is similar to a full-bore ball valve and allows filling rates of up to 8 tons in 30 seconds. This equates to fill rates in the range of 900–1 000 t/h. Other systems that are able to achieve this level of fill rate with the integrity of operation and low maintenance characteristics are not available at the more cost-effective price, space utilization, and simplicity of operation.

Conveying

The technology for the conveying of concentrates from storage silos to the furnace feed bins has in the majority of modern installations been Dense Phase conveying systems. The advantage that these systems have over other mechanical systems mentioned above is the ability of a Dense Phase conveying systems to route around line-of-sight obstructions between storage silos and the furnace feed bins that will be used.

Another problem that has occurred with mechanical systems is dealing with the flowability of hot or warm concentrates that have flow characteristics that are extremely fluid. Mechanical systems have often failed from an inability to convey the material at all.

There is a possibility that Lean Phase conveying systems are used but generally these systems do not meet the performance parameters that Dense Phase systems are able to achieve. A problem in the industry with suppliers of Dense Phase systems who are not fully qualified to supply such systems is that they are then operated as Lean Phase systems and serve to spoil the industry for the application of well-designed Dense Phase systems.

Special applications of the Dense Phase technology are used when certain furnace feed material needs to be conveyed. These materials include highly abrasive materials, materials with large particle size distributions (generally d_{50} of greater than 500 microns) and materials that exhibit 'strange' characteristics.

An example of a strange material is one that, with a fine particle size distribution, exhibits rapid de-aeration characteristic and also has a high bulk density. These materials tend not to be easy to convey and although initially appear to convey successfully, the system can fail after a number of conveying cycles.

These systems then require additional techniques to allow the Dense Phase system to perform adequately. This makes the Dense Phase system even more technical and sophisticated and this means that the companies supplying these systems must have the capability to test and assess the success of the system. As mentioned earlier, with silos which are not correctly designed, a Dense Phase system which does not work correctly due to incorrect design and/or selection can lead to a serious disaster as has been seen with numerous applications around furnaces when dealing with various materials such as slag, crushed matte, and reverts.

Dense Phase conveying systems that are correctly designed and applied are able to provide many years of trouble-free minimum maintenance operation.

Furnace storage systems

Furnace storage systems are an extremely vital aspect of the

holistic understanding of effective furnace feed systems. It is at this point in an overall furnace feed supply system that the transition from batch-based systems is made to continuous feeding.

The consistent flow of material from these storage systems ensures that any further rate control device and subsequent distribution system can work correctly. If this system is erratic, has random flow characteristics, or any other operational flaws in regard to the flow of material from the system, these will be reflected as operational aberrations in the performance of the furnace. Furnace performance problems derived from this piece of equipment will be difficult to correct by a process control system or by the intervention of an alert and intelligent operator. Corrections to these problems will result ultimately in reduction in furnace performance and, in extreme cases, without attentive operators or a furnace control system that is able to compensate could result in drastic furnace failures.

A further important aspect of these furnace storage systems is location. Historical systems positioned the furnace storage systems above the furnace located and supported in the furnace structural system.

As a consequence of the location of these storage units they tended to be small, as the loads associated with the storage had to be supported by the structure, and it is reasonably well-accepted that supporting large loads at height within structural steel buildings increases the cost of the building significantly.

Small storage units result in other problems, accentuated if pneumatic conveying is used to convey material to the storage units. The first problem relates to material (or metal) accounting. When material is being fed into and out of the storage unit at the same time it becomes difficult to keep account of the nett in- or out-flow with any accuracy. As the units are small this occurs frequently and hence the level of inaccuracy becomes more pronounced when trying to account for the actual amount fed into the furnace.

In situations where the value of the concentrate smelted warrants this, these storage units have been made as large as possible, to compensate for this problem and to remove the effect it has on the accuracy, which in relation to the value is extremely important to retain accuracy.

An alternative, but not often used, system is to have ground-based furnace storage silos. These can then be of any size and could be as large as the main storage silos. There are systems that feed from these storage units directly to the furnace distribution system in an accurate and controlled manner. These feed systems are essentially injection systems or derivatives of injection systems. The correct application of these systems can in many instances lead to significant installation savings as well as improved feed control into the furnace.

Screening

Screening of dry concentrates is an often-ignored aspect of furnace feeding systems. The effect of tramp in the form of metallic scrap through to discarded personal protection equipment such as gloves, hardhats and gas masks causes significant problems with the consistent feed of concentrate into furnaces. This is further pronounced when there is a requirement (and most modern systems fall into this category) for good energy efficiency as well as an ever-increasing demand to increase production through existing plants which increases the power intensity required to be used in a furnace.

When furnaces are operating at the extreme edge of the operating envelope to achieve the higher throughputs, any random input or uncontrolled aspect could result in the system losing control, specifically a situation where the power input is too high-leading to severe and sometimes catastrophic furnace failures.

Inconsistent feed into the furnace and inconsistent distribution of that feed represents such a random or uncontrolled input. This is also an input that is directly related to the power input.

The majority of feed problems can be related to the levels of tramp that reach the final furnace feed systems. These types of problems include:

- Complete blockage leading to no flow at all
- Partial blockage leading to restricted flow
- Blockage leading to incorrectly diverted flow
- Blockage leading to random uncontrolled flow
- Blockages which can cause massive overflow.

The use of a screening system will ensure that the above problems can be completely eliminated, resulting in a better ability to balance the flow of concentrate and the distribution of concentrate far more precisely. This has been seen to improve furnace production capacity.

Additive addition

In many furnace feed applications there is a requirement to add additional components to the concentrate. These include lime, silica, other ores, reverts, and other additives which can act as catalysts or reaction enhancers.

The manner in which these are introduced in the main flow of concentrate is important. In most instances, these will need to be added into the furnace in specific ratios relating to the concentrate itself. In large modern furnaces, an important aspect of this is to get good distribution of an additive whose overall feed rate is a small percentage of the main concentrate.

If the system is not configured correctly, then the feed of the additive is likely to be fed to only one section of the furnace. This could mean that the residence time for suitable distribution in the furnace is longer to ensure adequate distribution and hence this can begin to have an effect on the production through the furnace.

There are systems available which are able to blend a small flow of additives into a large flow of concentrate accurately with ratio-controlled flow. The system is able to maintain the ratio over a varying range of total solids flow prior to final distribution. The Clyde Roto Feeder injection systems do this. There is the additional benefit that numerous additives can be introduced into the main concentrate flow concurrently and all of these are able to be introduced at differing ratios to the main concentrate flow, resulting in a well-blended mixture which is introduced directly into the furnace and hence the changes in ratios and the effect of the additives could be noticed in the furnace almost immediately. Furthermore, there is no opportunity for any separation of the additives from the main phase.

An important aspect of additive addition is to ensure that materials (such as tramp) are not introduced to the furnace feed which then cause flow problems.

Metering systems

Metering systems are used in most furnace feed systems. This is the most important aspect of the system, as this is the final control of the mass flow rate of material into the furnace.

The metering systems are used on all components being fed into the furnace. An important consideration is the particle size distribution of the feed being dispensed and choosing the metering system accordingly. This will also be affected by the quantity of feed being fed and the turndown ratio required.

A common element of all feed systems regardless of the technology is that they will all perform as best as the technology can if the material that they are fed is consistent and tramp-free. It is this point on the metering of feeds into furnaces that is most important. To achieve this all upfront systems discussed above play roles in ensuring consistent tramp-free materials are delivered to the furnace feed metering system.

Distribution systems

When large furnaces are being fed with material, multiple feed points are used. The distribution system which directs material from the metering systems to the furnace feed points must be able to achieve a number of processes as outlined below:

- Accurate feed representation of the metering system at the furnace feed point
- Minimal material hold-up in the distribution system
- No leakage of material into unselected feed points
- Long operating campaigns between maintenance requirements
- Densified material fed into the furnace.

Conclusions

This paper has set out to clearly identify all elements that make up an effective furnace feed system. These have been outlined and the more common types of technology have been listed.

These technologies all play an important role in the final delivery of all feed materials to the furnace.

The important aspect of the technologies used is that, when correctly applied, these will result in a controlled consistent feed into the furnace. This will allow for better utilization of the energy used in the furnace and will also allow for increased production through the furnace.

Inconsistencies in the feed system can result in significant furnace operational problems and, in certain instances, failure.

The feed of material into furnaces is often not fully assessed and analysed. More modern furnaces, recent installations, and planned new installations do have improved systems. However, many of these still have some basic problems that can lead to furnace operation problems.

References

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Mr Kirsch has over 22 years of extensive experience in process design, control strategy, commissioning, training, long-term support, sales and marketing, which he applied to this demanding role. In Sub Saharan Africa alone, he has excelled in designing, selling, installing and commissioning projects for blue chip companies such as Sappi, Nestle, Anglo Platinum, Colgate, BHP Billiton and Impala Platinum, ensuring all planning and design methods meet the highest international standards.

In 1982 he graduated with a BSc in Mechanical Engineering, [BSc Eng (Mech)] from the University of the Witwatersrand. It was also at Witwatersrand that he studied towards an MSc in Mechanical Engineering in 1986. The field of study was the application of Nuclear Physical techniques to the field of mechanical wear. Areas researched included Nitrogen ion implantation as a means to reduce wear rates in steels and the irradiation of steels to form Cobalt 56 to measure wear rates remotely.

Mr Kirsch joined Clyde Bergemann Africa in 2001 as a member of the Management team and since then he has seen the Company grow from strength to strength. In his role as an Executive Director, he is heavily focussed on Business Development using his vast expertise in new technology and sales.

