Blast furnace slag granulation plant technology

A modern blast furnace can produce more than 1Mt/yr of slag. Slag granulation using water sprays is now an established technology. It not only simplifies blast furnace casting floor operations, but also provides an economic route for the production of a valuable raw material for a host of industries.

The blast furnace produces large amounts of liquid slag, which can be processed into valuable raw materials for the cement and other industries. For example, in cement production, granulated slag can replace up to 70% of the more costly Portland clinker. The slag volume depends on the quality of the raw materials used in the BF and may range from 200 to 500kg/THM. Typical production levels of a modern blast furnace are 8,000-12,000THM/day so the annual slag production could amount to more than 1Mt.

Efficient processing of blast furnace slag into a product suitable for further use is accomplished by a slag granulation plant. This paper summarises modern slag granulation plant technologies, which have been successfully demonstrated at industrial plants for more than 20 years.

SLAG GRANULATION PLANT

The main objective of the slag granulation plant is processing liquid blast furnace slag into valuable raw materials for the cement and construction industries. The value of the slag depends on its mineralogical, chemical, physical and mechanical properties, such as basicity, glass content, structure and moisture content. These technical properties are related to the blast furnace burden and process, the applied granulation technology and operating conditions, storage and dewatering time, etc, and Figure 1 illustrates its complexity.

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Fig 1 Complex dependency of slag technical properties

Fig 2 Schematic of a slag granulation plant
The slag granulation plant comprises a granulation section, a dewatering section and a storage section, as illustrated in Figure 2.

**Granulation section** Here, the liquid blast furnace slag is water quenched and solidified into small pieces, eliminating the need for heavy crushing equipment. The liquid slag flows by runners from the blast furnace to the granulation unit. From the runner, the liquid slag stream at around 1,500°C is poured into a high velocity water stream at the granulation spray head before ending up at around 50°C in the granulation tank. This rapid solidification followed by breaking up of the material into small pieces is controlled by the excess of water used. Due to the high temperature of the liquid slag, the water is partly evaporated and subsequently condensed in a condensing tower located above the granulation tank.

The production of slag during a blast furnace tapping normally ranges up to 10t/min. To cope with this variation, the water stream to the granulation unit can be controlled by an energy balance calculation to ensure efficient and economic performance. The control element is a valve, regulating part of the water flow to the granulation spray head.

The granulation spray head is the technological heart of the granulator and is where the water and slag are mixed intensively, ensuring fast and efficient granulation (see Figure 3). The spray head is designed to produce a specific flow pattern of water for optimum mixing and is located to direct high-pressure water jets into the free falling molten slag stream.

The main volume of water is directed by the jets to form a fast moving water trough in the bottom of the granulation chute. The purpose of this water layer, in addition to granulating the slag, is to protect the granulation runner and to carry away the granulated mix. Additionally, a number of jets are positioned on the sides of the slag stream to ensure all slag is granulated into small pieces as quickly as possible, to supply additional cooling, and also to propel the slag/water mix in the chute. The configuration of the water jets is such that the liquid slag will, under normal circumstances, not touch the bottom of the granulation chute.

The spray heads contain detachable nozzle plates with ceramic inserts and spray headers that can be replaced quickly during short maintenance intervals.

The water quantities for the spray head are approximately as follows:
- Lower bottom spray head 1,200m³/hr
- Upper bottom spray head 600m³/hr
- Side sprays 100m³/hr

Under normal circumstances, 1,800m³/hr is used for granulation, but at the last part of the BF cast, when the slag volumes might increase, an additional 900m³/hr can be added by activating additional spray heads and increasing the total flow to 2,400m³/hr.

The requirements of the spray head are:
- Simple and logical construction to reduce fabrication cost and simplify replacement
- Buildup of wear resistant materials, eg, the use of ceramic insets for the nozzles and guides
- Easy to inspect and easy to replace
- Easy access and easy to clean.

During this quenching process, water is evaporated and SOx compounds are released. These emissions can be eliminated by the application of a condensing tower that includes an assembly of water spray nozzles. These sprays ensure that emissions are dissolved in the water. They are then partly neutralised by the CaO in the slag. Views of the condensing tower system are shown in Figure 4.

The entire granulation tank is lined with wear resistant refractory as it is exposed to a highly turbulent and erosive mixture of water and slag sand. This mixture is transferred into the dewatering section.
Dewatering section

The granulation section adds water to the slag, which must be removed and recycled. Dewatering is required to lower the moisture content to ~15%. Additional dewatering to 12% can be achieved, if required, by stockpiling the granulated sand on a natural draining stockpile and letting it drain for another 24 hours prior to further transportation. Alternatively, silo dewatering down to 12% can be achieved in 12 hours or less. In that case, the dewatered slag can be discharged directly into a truck or on to a material handling system for further transportation.

Many dewatering systems have been used in the ironmaking industry. This paper will describe two of them: rotating dewatering wheel and static dewatering silos.

Two slag granulation plant arrangements are illustrated in Figure 5. Both systems are identical with regard to the granulation section and recycling of granulation water.

Rotating dewatering wheels

These wheels have been operating for more than 30 years in our industry. The main advantage of this system relates to the fact that it is compact and requires a lower investment compared to static dewatering silos. The rotating dewatering wheel is installed in a hopper, which is filled with the mixture of slag sand and water.
the produced slag is possible. High temperature resistant rubber is recommended for the belt material, as occasional high slag temperatures can occur.

Normally, the granulated slag can be stored in a vertical sand hopper with a clamshell lock-hopper discharge device. However, in mild climates without major frost problems, it can also be stored in simple stockpiles and reclaimed by front loaders or shovelled into trucks. The size of the stockpiles could be made sufficiently large, such that reclaiming can be done in day shifts only. Some measures must be taken at the conveyor discharge end, such as by rubber flaps, to prevent the discharged slag sand blowing away via wind or turbulence. The advantage of storing the granulated slag on the ground is that it naturally dewaters the slag pile over time. Since the slag has very strong chemically binding properties, there are hardly any contaminants in the drained water.

CONCLUSIONS

Efficient blast furnace slag granulation contributes to low cost hot metal.

Advantages of these systems can be summarised as:

- Simple plant configuration with few moving parts
- No heavy crushing equipment required
- Specially designed spray head produces uniform grain size (up to 3mm)
- Adjustable spray head produces slag sand of >98% glass content
- Condensation tower eliminates H₂S and SO₂ emissions
- Efficient cooling tower eliminates sand deposits and clogging
- High availability (>98%) and low maintenance due to the above.