Pig Iron Granulation at Iscor Saldanha Steel

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INTRODUCTION

The Iscor Saldanha Steel has successfully installed a Granshot™ metal granulator to accommodate excess iron production from the Corex. This paper discusses the iron granulation method compared to traditional alternatives such as sand bed pooling. In the comparison, the operational costs are reviewed and usefulness of the product formed is discussed. Finally, the impact of the Granshot™ metal granulator on the existing iron making and steelmaking operations are presented.

BACKGROUND

Iscor Saldanha Works

Located next to Saldanha Bay, Figure 1, the Iscor Saldanha Steel works receives most of its raw materials by rail. The lump iron ore for the Corex and Midrex is brought from the iron ore mines at Sishen, off loaded at the iron ore export terminal at the port from where the steelplant is fed by transporting it on a 5 kilometres long conveyor belt.

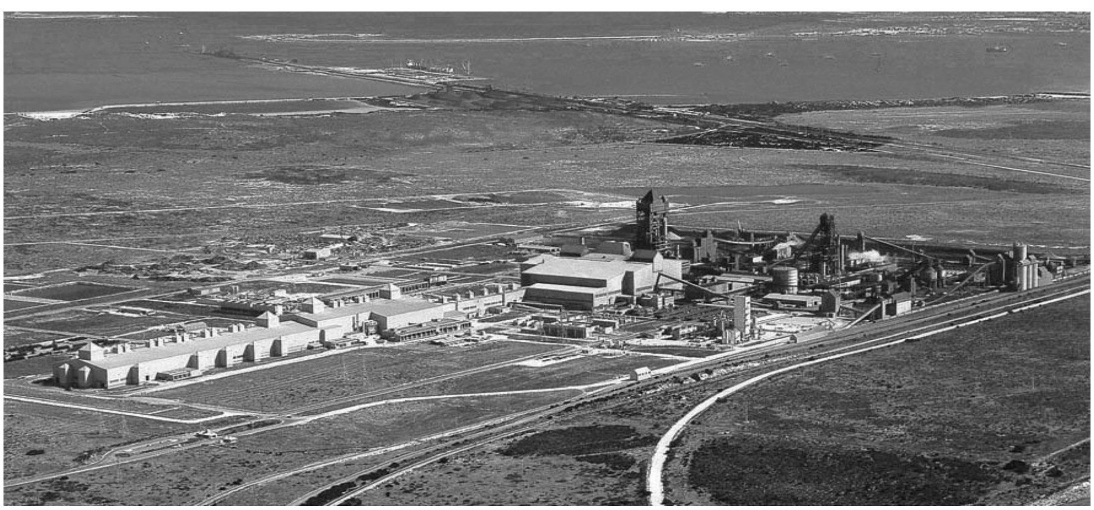

Figure 1 Overview of Saldanha works

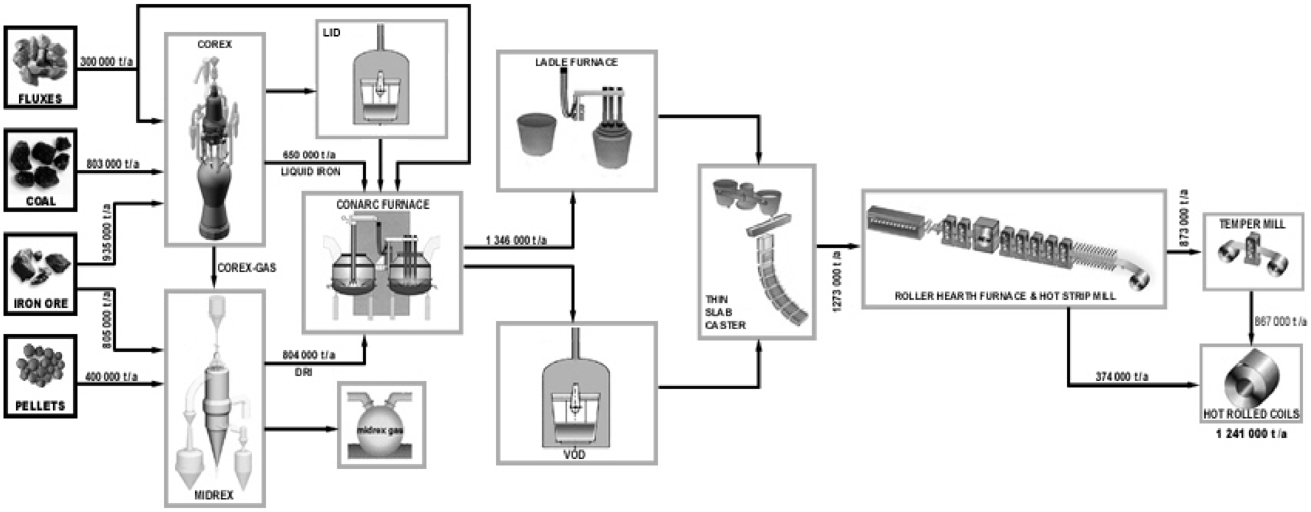

Figure 2 The Saldanha Steel production routes

In the plant, primary iron making operations consists of a Corex which produces liquid iron, and as a by-product from the melter–gasifier, reducing gas. This gas is then used as a reducing agent in the Midrex direct reduction plant producing direct reduced iron (DRI), Figure 2.

The liquid hot metal and solid direct reduced iron is charged into the meltshop's Conarc vessels, a combined converter and electric arc furnace unit. This twin-shell unit mimics the geometry of a BOF vessel and is specially adopted to cope with the large gas volumes formed when using a carbon-rich feed. This is achieved by running the Conarc in two alternating modes - oxygen blowing mode and electric arcing mode

After primary operations a twin ladle furnace station and one vacuum oxygen decarburization unit refines the liquid steel before it is forwarded to a single strand thin slab caster. The 75 – 90mm produced slabs are hot rolled to a 20-30 mm thickness and coiled in a coil box. After further hot rolling and processing the final product of hot-rolled coils 1-8.5 mm is ready.

The production chain at Iscor Saldanha works is very short, with approximately 16 hrs between Corex and Midrex raw material charging to the finished hot-rolled coils, and the possibilities for intermediate buffering of metal are few. Consequently, there is a pronounced focus on the production throughput and virtually no intermediate buffers exist.

Metal Granulation

Metal granulation in water is a well-established method for rapid solidification of liquid metal into a medium sized product form. One of the most common methods, Granshot™, is widely spread among ferro-alloy producers with more than 35 installations world-wide. The granulation method directly produces a ready-to-sell product while alternative methods for ferro-alloys solidification, such as bed casting, needs further processing like crushing and screening which is cost intensive, lowers the metallic yield, and produces lower quality product.

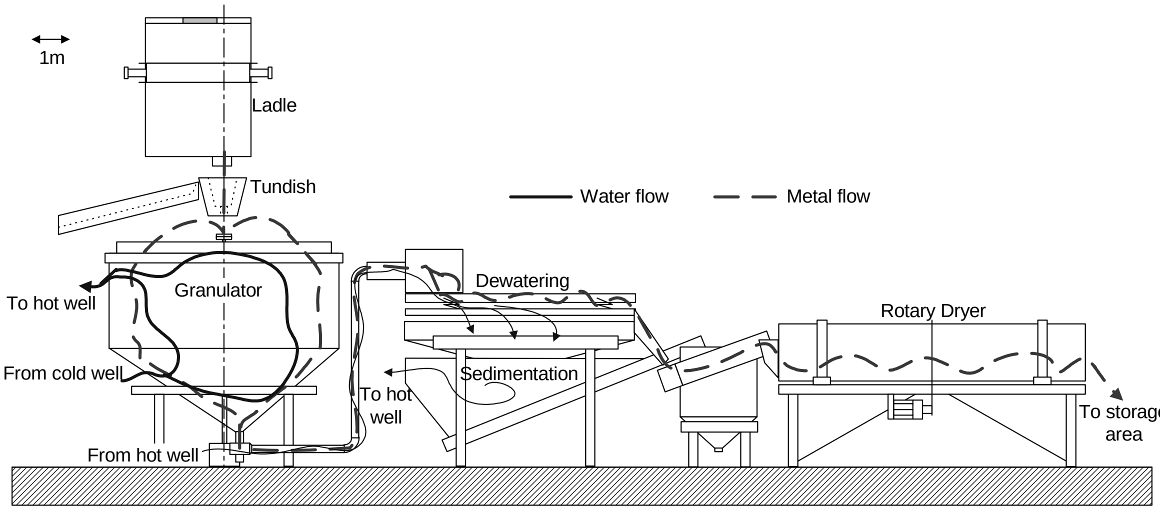

Figure 3 Typical Granshot™ set-up

Table I: Some physical and chemical properties of different iron bearing feedstock[2-4]

		DRI/HBI	No 1 Bundles	GPI™
Chemical composition [wt-%]	%C	1.5	-	4.6
	%Si	0	-	1.2
	%FeO	6	Combined oxygen ~ 1.1%	0
	$\%SiO_2$	1.5		0
	$\%Al_2O_3$	0.8		0
	%CaO	1.2		0
	%MgO	0.3		0
	%Fe	88.7	> 96%	94.2
Residuals [wt-%]	%(Cu+Ni+Mo+Sn)	0.05	0.16*	0.05
Bulk density [ton/m^3]		1.6 – 2.7	~ 1.1	~ 4.5
Energy consumption** [kWh/ton Fe]	$CaO/SiO_2 = 1.5$	439	378***	268

* Also includes the elements Pb, Sn, Mo, Zn, W, As, Sb, Co, Ni and Zr.

** Theoretical value based on the assumption that all latent chemical energy (oxidation of C and Si) is utilized and that formed SiO_2 is balanced by CaO-addition.

*** Calculation based on the assumption 100% Fe.

Although the ferro-alloy industry has mainly adopted the Granshot™ metal granulation technique today, it was originally designed in the early 1970ties with the purpose of granulating liquid iron from a blast furnace at the Hagfors works (Sweden) of the company Uddeholm AB.[1] This idea has now once again been brought forward to solve the complex logistics in integrated iron- and steelmaking.

When the liquid metal arrives to the granulation plant the metal is poured into a tundish, Figure 3. The tundish weighing system automatically controls the pouring rate in order to maintain a constant ferrostatic head, i.e. constant flow rate through the tundish nozzle outlet. As the metal stream leaves the tundish and strikes the refractory target positioned beneath the nozzle, the liquid metal is distributed evenly over the cooling water body. The metal cools down/solidifies partly in-flight before penetrating the water surface. At impact into the water the granules will be deformed slightly but are prevented from splitting up, thus avoiding fines generation.

As the granules sink through the water volume the metal heat content is transferred to the cooling water, allowing the granules to reach a temperature below 100°C. In the next step the granules are discharged from the granulation tank and dewatered on a vibrating screen. Finally, the product material – granulated pig iron (GPI™) - is transported to an intermediate storage area by a conveyor belt.

Granulated Pig Iron (GPI™)

The GPI™ material shows valuable physical and chemical properties, Table I. It combines the high metal content of prime scrap with the low residuals contents of virgin iron sources. From a practical point of view, the high bulk density and physical shape is suitable for efficient material handling, Figure 4.

Figure 4 Granulated Pig Iron (GPI™) produced at Saldanha Steel

THE ISCOR SALDANHA GRANULATION PLANT

Why Iron Granulation?
There are three main reasons for this which can be found in the Saldanha Steel focus on throughput and the geographical location of the Saldanha works:

- In the endeavour to maximise throughput, every ton of liquid iron tapped from the Corex should be utilized in the meltshop for steel production, without any waste of metal feed. Nevertheless, production disturbances do occur from time to time, and surplus liquid hot metal may then be available. By diverting this iron to a granulation plant for solidification, the metal can be accommodated until it re-enters the main production flow as a solid metallic feedstock going into the meltshop Conarc unit.
- Granulated iron can be introduced into the Conarc furnace via the existing conveyor system without having to slew the furnace roof open. This impacts immensely on the furnace tap to tap time.
- Saldanha works is located on the perimeter of the Saldanha Bay, next to the sensitive eco-system of the Langebaan Estuary Park. In addition to this, the works premises rests on a major aquifer. This means strict governmental restrictions on water and air pollution which simply ruled out any of the traditional methods for excess pig iron handling, e.g. sand bed pooling.

When is Iron Granulated?
There are a number of typical scenarios when the Corex hot metal is diverted to the granulation plant:

- *Out of specification liquid iron.* This may occur immediately after long shutdowns at the Corex (during initial taps) or during periods with Corex process instability. Conditions may vary from the metal being to cold for the Conarc to accept or to high sulphurous or phosphorous levels. The effects of out of specification chemical compositions can be diluted in the product or even in the final application thereof.
- *The Corex casthouse maintenance.* The casthouse at the Saldanha Corex have two sides for tapping. The tapping channel, which can contain up to 40 tons of liquid iron, sometimes needs to be drained for maintenance. The hot metal is then tapped into a ladle, deslagged and transported to the granulation plant.
- *Corex oversupply.* At times Saldanha Steel may experience an oversupply of liquid iron from the Corex, which will usually mean that the Conarc production rate is slowed down due to casting tempo restrictions. This inevitably results in an accumulation of liquid iron between the Corex and the Conarc that will be granulated.
- *Downstream stoppage.* The same conditions as described above will apply when an unexpected downstream stoppage from the meltshop occurs. Since all production units run in series, and no buffer zones exist between them, the granulator is started up and the supply from the Corex is accommodated.
- *Maintenance shutdowns.* Saldanha Steel has planned maintenance shutdowns for the entire plant every 14 – 16 days. This however excludes the Corex. On these days the total liquid iron produced for the 12 to 16 hours is granulated successfully, without the Corex having to reduce their production rate.

In the Saldanha plant operations approximately 4.5% of the total amount of liquid iron produced at the Corex plant is granulated. The benefits of pig iron granulation in integrated steelmaking have been discussed in depth earlier.[5]

Plant Design and Function
The iron granulation plant at Saldanha works was designed to accommodate the surplus liquid Corex iron. This should be possible to perform at short notice and at the same pace as liquid iron is produced at the Corex. Furthermore, the product formed should be ready-to-use when leaving the granulation unit without any additional processing required.

Table II: Saldanha Steel Granshot™ iron granulation plant specifications

Plant design capacity:	~ 2000 t/day
Granulation rate:	2 t/min (nominal) 2,5 t/min (shorter periods)
Heat size:	85 metric tons (average) 75 – 105 metric tons (span)
Heat input (metal):	~ 40 MW @ 2 t/min
Control mode during normal operation:	Fully automatic
Water cooling capacity:	50 MW (1200 m^3/h)
Cooling equipment:	4 modular evaporative cooling towers
Water treatment:	In-line hydro cyclones for particle separation Bleed and make-up water No chemical additives to water

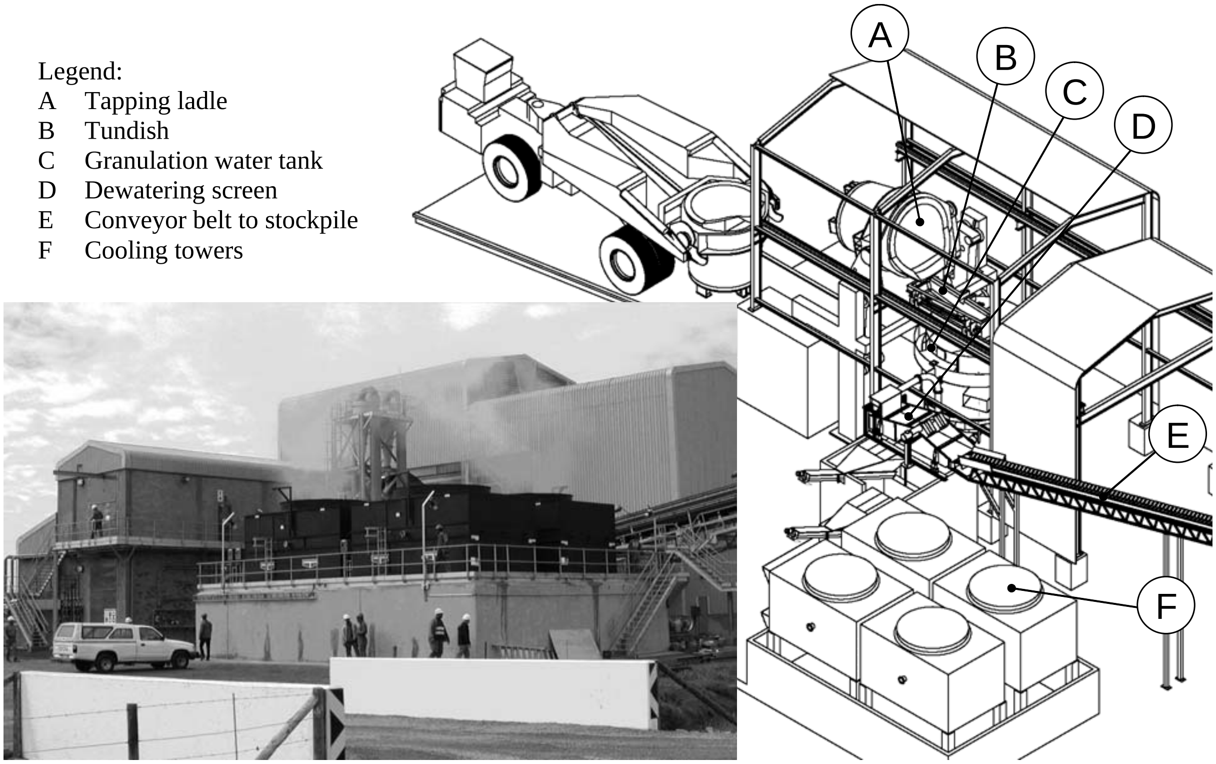

Figure 5 The Saldanha Steel granulation plant

The iron granulation plant at Saldanha works, Figure 5, is situated on a separate location within reach by the Kress carrier ladle transporters carrying the liquid iron from the Corex plant. On arrival the ladle is docked into a ladle tilter and after the initial manual tilting, the operator releases control to the granulation process control system. From there and onwards, the granulation is performed fully automatically until ladle change. The Saldanha granulation plant specifications are summarized in Table II.

Operational Experiences

The granulation plant was commissioned and taken over by Iscor Saldanha Steel in November 2002. Up until today (June 2004) approximately 88.8 ktons of hot metal has passed through the granulation plant for further use in the Conarc vessel. The operational experiences have shown that the plant design is fulfilling its task and, if more iron would be available, could handle a considerable larger amount of metal on the average monthly granulation capacity, Table III.

The granulation plant has proved to be a low cost operation. After several months of operational experience it is now concluded that the pay-off time will be shorter than previously predicted. In particular, the running costs have shown to be lower than expected now indicating a figure less than 2.5 € per ton granulated in conversion cost (capital costs excluded). Also the GPI™ value-in-use has proven to be higher than initially estimated when used in the Saldanha works steel plant operations. Granulation operational data at Saldanha works are summarized in Table IV.

THE COST DRIVERS

There are several cost drivers for implementing an iron granulation unit into an integrated steelmaking production flow. In traditional integrated steelmaking (BF-BOF) considerable savings[5] are identified mainly due to effects of an increase in the BF operation stability. In addition, a high value-in-use product is produced as a premium. The advantage of an efficient handling of excess iron is clear to most iron and steel plant operators. The operational and capital costs of granulation, however, need to be reviewed and compared to alternative solutions.

Table III: Saldanha Steel Granshot™ production figures (tons/month).

Sep-02	Oct-02	Nov-02	Dec-02	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03
2292	3880	1925	2998	2482	3820	3668	3284	5100	2461	3743
Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04
3722	2359	5882	4250	2649	2809	2546	4003	2914	15240	6836

Table IV: Saldanha Steel Granshot iron granulation plant operational data.

Typical production cases:	
Iron oversupply from COREX®:	One ladle of 75–105 t of hot metal
Steelmaking maintenance stop 12-16 hrs:	Granulation of all COREX® iron (250-300 t tap of hot metal every 2.5 hrs)
Granulation start-up time requirements:	< 5 min (no preheating required) ~ 30 min (preheating required)
Granulation time requirements:	~ 45 min (granulation) ~ 15 min (ladle change)
Typical production:	4000 t/month (average)
Metal yield:	~99.2 %
Personnel required for operation	
No of additional personnel recruited:	None
Granulator operator	1 (Normally stationed at the ConArc)
Media and Consumables	
LGP or Corex Gases:	Tundish preheating burners.
Electrical power supply:	Main consumers are water pumps, cooling towers, material handling system and hydraulic unit. Approximately 650 kW used during granulation.
Pressurized air:	Approximately 10 Nm^3/min required.
Refractory consumption	
No of heats in sequence with one tundish:	6 (Limited by ladle handling)
Tundish maintenance when not in use:	Addition of ramming material & releasing agent.
Tundish relining frequency:	Once per year.
Refractory sprayhead consumption:	1 pcs per granulation sequence.

Savings in Iron and Steel Production

The iron making

After the iron granulation plant was commissioned the Corex iron making plant has gained one major advantage – stability. Today the Corex keep on producing at a steady pace independent of down-stream operational status. The results of an increased Corex stability are:

- Less variation in hot metal chemistry, especially with respect to silicon levels.
- Less variation in hot metal temperature.
- Lower energy consumption.

The decrease in hot metal chemistry and temperature variations has strong implications on the steel plant operations, thus avoiding problems such as excess BOF slag formation, prolonged treatment time and excess FeSi-addition.

The steelmaking

As described previously, the Conarc process combines the electric arc furnace and converter operations into one twin-shell unit. Liquid hot metal, and direct reduced iron or scrap are charged in the furnace holding a liquid heel. The 30-tonnes liquid heel holds a highly oxidized slag on top, which needs to be reduced prior to charging.

This was previously done by an aluminium addition, a method relatively costly, but has now been substituted by the addition of GPI™. The added GPI™'s carbon and silicon content reduces the slag and at the same time additional iron feedstock is charged into the furnace. The combined effect of the GPI™-addition saves 250 kg Al and simultaneously replaces 4 tons of DRI per heat.

The GPI™ may also be added as part of the main feedstock and is then fed continuously at a rate of 0.5 tons/min into the furnace. The GPI™ added is then partly substituting the Midrex DRI. This enhances the furnace performance due the higher metallic content and lower amount of unreduced material/gangue in the GPI™ (compared to DRI), Table I. The relatively high carbon content of GPI™, around 4.5%, enhances foaming slag during the Conarc arcing phase. This is indicated by a distinct decrease in noise level shortly after the feeding of GPI™ has started.

The high carbon content is also used as a mean to compensate for DRI of poor quality. Bleeding (20 tons/hr) GPI™ into the DRI feed enhances the furnace performance and compensates for the bad effects of the poor quality DRI. On scrap heats up to 20 tons of GPI™ is fed into the furnace which at times constitute up to 10% of the scrap mix.

Granulation versus Pooling

Most integrated steelmaking plants today uses a sand bed pooling solution as the main alternative when excess iron needs to be accommodated. At a glance, one would believe that this is a less costly alternative compared to granulation. When taking in the total picture, however, the result may be quite the opposite. Below follows a comparative discussion between pooling and granulation.

Operations

In granulation a ready-to-use product is produced without any post-treatment operations, such as drying, required. From the granulation plant the granules are transported by conveyor belts directly to a storage area. Iron pooling produces large, thick sheets of solid iron which, after a long period of cooling, needs to be processed into pieces with a size manageable by excavators and trucks. After transportation to a nearby area additional crushing and screening operations are performed. When the desired size fraction is reached the material is stored on stockpile.

The granulation process takes place within an enclosed building without external influence on the operations. Pooling, on the other hand, is carried out outside and is dependent on weather conditions. In wet conditions (rain) the operator is forced to reduce the pooling rate or steam explosions may occur.

Product

Granulated iron is very close to 100% metallic while iron originating from a pooling facility contains slag and sand (from the bed) to around 1% of the weight. When the pooled iron is used as steelmaking feedstock an increase in slag volumes and dust generation may be expected, i.e. reduced productivity (tonnes per hour) and increased consumption figures. The granulated material has a shape typically between 5 and 40 mm and is suitable for continuous feeding into down stream operations. Crushed pooled iron is usually added using a scrap basket, with additional handling cost, lower yield and a much higher energy consumption.

Space requirements

The footprint of a granulation unit consists of two major parts; the granulation plant main building and a stockpile area. The total area of these is considerably smaller than that of a sand pooling facility, usually holding approximately 10 casting beds to cope with the extended solidification and cooling times. Furthermore, space is required for the crushing and screening operations as well as the material storage.

Transportation of liquid metal and product

Due to the space requirements the pooling area is usually located at a distance from the other facilities. This means additional wear on the transportation system, increased fuel consumption and extended allocation of transport units and personnel.

Environmental impact

A granulation plant mainly generates steam from the cooling system and some minor amount of sludge separated from the cooling water circuit. There is virtually no fumes or dust generated during the operation. The iron pooling operation is usually considered to be an environmental problem due to red fumes and dust originating the different processing steps. There is also a difference in the environmental impact when using the product, mainly related to the percentage of non-metallic content.

Equipment maintenance

The major difference in maintenance costs between pooling and granulation is due to the difference in post-treatment. Solidified pig iron is a hard material, which is abrasive on any equipment used to break and crush the metal. Machinery used for post-treatment of solid iron will need extensive maintenance.

Running costs

A cost estimate carried out at Saldanha Steel showed that the running costs (capital costs excluded) for the total granulation process is considerably lower (a factor 5-10) than the operational costs for the actual pooling operations alone. This includes the initial breaking up of the solid sheets of pooled iron but excludes the transportation of material as well as the crushing and screening operations.

CONCLUSIONS

The Iscor Saldanha Steel has successfully installed a Granshot™ granulator to accommodate excess iron production from the Corex plant. The granulation of iron has proven to be the most cost effective method compared to traditional alternatives such as sand bed pooling. The operational cost of the granulator is considerable lower compared to pooling and the prime metal product shows excellent performance as a raw material feed into the steelmaking operations.

Benefits have been seen on the Corex operation due to an increase in stability. Also the Conarc steelmaking operation has been enhanced by the use of a metallic feedstock with high levels of Si and C and without any content of gangue or unreduced oxides.

The return on investment has been higher than initially estimated.

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