World’s First High-capacity Granshot® Iron Granulation in Operation at SSAB Oxelösund

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ABSTRACT

A Granshot® metal granulation system has been incorporated as a standard method for excess hot metal handling at SSAB Oxelösund AB, Sweden. The Granshot® plant fulfills the design requirements to decouple the ironmaking and steelmaking, and accommodates the complete BF’s output. Except for shorter operation periods due to temporarily excess of hot metal, prolonged steel plant maintenance shut-down of 17 days has proven the Granshot® process to be viable for continuous high capacity operation. This paper discusses the principal layout of the Granshot® plant, operational experience, and the usability of a Granshot® granulation plant and the product in steelmaking operations.

INTRODUCTION

The Granshot® granulation system is a process for converting liquid metal into granules by rapid solidification in water. The simplicity of casting directly from liquid metal to ready-to-use bulk material, without any intermediate crushing and sieving step, has made the method the most cost-effective alternative. In addition, the produced granules have a rounded, dense shape, and contain a minimum of fines and oxides/slal. The Granshot® granulation system is the world’s leading method for ferro-alloy granulation.
Granshot®, which was originally used in the early 1970s for iron granulation at the Hagfors plant, Sweden, by the company Uddeholmsbolaget, now shows a revival for its original purpose – iron granulation. The process fulfils an important need in most ferrous plants:

- Production of merchant iron (EAF feedstock) from stand-alone blast furnaces (BF).
- Handling of excess hot metal from the ironmaking plant in integrated steelmaking plants.

Again, it is the simplicity of the method, in combination with a high capacity that meets a standard BF throughput, which makes the method suitable to the ironmaker.\(^1\,3\).

SSAB Oxelösund is the third integrated steelmaker in recent years which have commissioned a Granshot® granulation system. The installed system is the first high capacity Granshot® designed in order to fully pace the BF output.

In the year 2006 SSAB Oxelösund, Sweden, awarded Uvån Hagfors Teknologi AB (UHT; formerly known as Uddeholm Technology AB) the contract for process know-how and key components. UHT is the owner of the Granshot® process developed in-house and with more than 40 reference production units supplied worldwide.

**BACKGROUND**

**The problem - pacing of liquid iron feed**

Pacing of the blast furnace (BF) throughput with the steelmaking operations is an unsolved dilemma of the integrated steelmaking plant:

- The BF should preferably operate continuous at a steady pace with predefined tapping intervals and a minimum of shutdowns.
- The steelmaking operations are by definition batch operations of relative complex nature, which requires planned or unplanned shutdowns on an irregular basis.

Today, minor disturbances or offsets in the pacing between ironmaking and steelmaking are normally handled by buffering of hot metal in the torpedo car fleet. Typically, the torpedo cars hold a few hours of BF-production, which is sufficient to handle the normal shifts in liquid iron supply and demand.

If the hot metal buffer exceeds the torpedo car fleet capacity, the BF will either be put on idle or the hot metal is diverted to an emergency casting system. Emergency casting of hot metal is usually performed directly from the torpedo car into a sand-pit or similar (also known as “beaching”). This method produces a poor product, requires considerable post-casting efforts, and has considerable environmental drawbacks.

**The solution – produce iron feedstock in an additional production system**

A Granshot® granulation plant accommodates most liquid metals at a high production rate and converts it to a prime granulated metallic product – suitable for bulk handling.

A Granshot® plant decouples the pacing of the ironmaking and steelmaking facilities and is logistically positioned in between the two plants. Excess hot metal from the BF is diverted to the Granshot® which produces granulated iron (GPI®) whenever required. This eliminates BF shutdown due to steel plant interference and the produced GPI® is suitable as internal feedstock as coolant in the BOF, or for external sales to be used as a prime virgin feedstock in EAF’s.

**THE SSAB OXELÖSUND CASE**

At the SSAB Oxelösund integrated steelplant in Oxelösund, Sweden, the Granshot® granulation plant was added as part of the production system for mainly four reasons:

1. It would be advantages to operate the BF’s at a higher production rate. This target production rate was close to the steel plant maximum pace and frequent periods of excess iron were foreseen.
2. A more steady BF operation was desired. Historically, about 50% of the BF’s production stops was due to steel plant interference.
3. Swedish authorities declined hot metal sand pit casting on a regular basis due to environmental reasons.
4. SSAB has an annual steel plant shut down period for 15-20 days. During this period the BF’s have previously been shut down which has been unbenefficial for the BF’s production economy and hot metal quality.
With a Granshot® granulation unit available the steel plant and BF operations are becoming much more independent and the hot metal production can be produced without downstream constraints. This solution shows considerable advantages:

- The BF production unit can be optimized from the internal production economy.
- The BF shut downs due to downstream reasons are diminished.
- Disturbances in hot metal quality (temperature and chemistry) due to BF shut downs are minimised.
- The long annual BF shutdown with considerable thermal stress on refractories is removed.
- The steel plant production programme can be optimised based on steelmaking and casting operations without constraints in metal throughput.

The SSAB Oxelösund Granshot® granulation plant was also designed in order to be suitable for liquid steel granulation. This option opens for internal production of prime cooling feedstock to be used in the internal steelmaking operations and for sales to external customers.

**THE SSAB GRANSHOT® PLANT**

**Plant key figures**
- Design granulation rate: 4 tonnes/min
- Nominal granulation rate: 3 tonnes/min
- Ladle batch size: 200 tonnes
- Power input: 80 MW
- Water-cooling capacity: 80 MW
- Process water system volume: 300 m³

Plant footprint: 13 x 15 m  
Water handling footprint: 10 x 20 m

**Plant location**
The Granshot® granulation plant is located in the steel plant casting bay. This location offers most operational flexibility since both hot metal and steel may be fed into the granulator.

The location also shows some drawbacks due to necessity to keep some steel plant facilities, such as cranes and the hot metal pouring pit equipment, operational during shut down periods.

**Plant equipment**
The Granshot® plant at SSAB, Figure 1, consists of the following basic components:

![Figure 1. Schematic overview of the Granshot® granulation plant at SSAB.](image-url)
A twin ladle turret, similar to designs used in continuous casting systems, handles the ladles during the granulation operation. The turret in combination with a tundish enables a smooth sequence granulation without operational shutdown in between ladles.

SSAB uses standard steel plant ladles, which are equipped with sliding gate arrangement for bottom pouring. A few selected ladles are designated for hot metal handling.

Also the tundishes used in the granulation are standard continuous casting tundishes with only minor modifications. This have several advantages from operational and maintenance point-of-view. The tundish is equipped with a stopper rod system enabling the granulation to be stopped within seconds if problem occurs.

The stopper rod is used for start and stop only. Granulation rate is controlled by metal head control via load cells on the tundish in combination with selection of outlet nozzle diameter.

A ceramic sprayhead is used to distribute the tapping stream of liquid metal evenly over the water surface. The sprayhead is a critical component, which must withstand thermal shocks and long-term impact of a tapping stream. A typical metal umbrella during granulation is seen in Figure 2.

The granulation tank holds the water volume necessary to accommodate the liquid metal film and formed droplets distributed from the sprayhead by the impact momentum of the tapping stream.

The tank has an upper spherical part and a lower conical part, which concentrates the granules to the tank centre in the lower end.

The solidified metallic granules exits in the granulation tank lower end and are transported out of the tank onto a dewatering screen by means of an air-water ejector system. After most water has been removed in the dewatering system, conveyor belts transports the GPI® product to the off-loading point where it is stored in a stockpile.

The water handling and cooling system is carefully balanced in order to ensure that the large amount of heat added by the liquid metal will be removed. From a closed circuit process water system the coolant is pumped into the granulation tank lower section. As the cooling water passes upwards through the granulation tank, the temperature increases. At the tank top end, the cooling water exits via an overflow and returns to the water handling system. The return hot process water passes through heat exchangers where the heat is released to a sea water system connected to the Baltic Sea. Figure 3 shows the SSAB Granshot plant in operation.

![Figure 2. Granshot® granulation - typical metal umbrella formation.](image-url)
RESULTS – OPERATIONAL EXPERIENCES

The Granshot® granulation plant at SSAB Oxelösund has now been in operation for almost 2 years and one major steel plant shutdown period has passed. During a period for 17 days the steel plant operations were aborted for the purpose of major maintenance activities. During this period one of two BF’s were in operation generating 2000 tonnes of hot metal/day. 100% of this output was scheduled for granulation.

Throughput
The granulation rate during the steel plant shut down period was typically 3 tonnes/min and this was kept for a sequence of 2-3 batches, which was the suitable pace to match the BF output.

Maximum granulation rate experienced so far is 4.2 tonnes/min and the longest sequence granulated is 7 heats (1290 tons). The sequence length may increase should the BF output increase.

Product usage
GPI® produced from the Granshot® granulation is used extensively internally as BOF scrap addition and shows qualities such as easy handling, high metallic yield, and rapid melting/dissolution.

Due to the extended steel plant shutdown period the amount of GPI® produced exceeds internal needs. Consequently, GPI® has been shipped to the SSAB plant (formerly IPSCO) in Mobile, Alabama, USA, as well as to other minimills around the world, to be used as iron feedstock in the EAF.

DISCUSSION

The Granshot® in integrated steelmaking
It is the firm belief of the authors that Granshot® granulation is a supreme tool for solving the logistic mismatch between hot metal production and steelmaking. It allows the production system to have one more degree of freedom, which allows a more cost effective and environmental-friendly production.

Since the Granshot® at SSAB Oxelösund has been commissioned the number of granulations sequences performed are around 450 (approximately 145 000 tonnes of pig iron in February 2009). All of them would have caused the BF to shutdown if the Granshot® was not available due to the new firmer restrictions on sand pit casting.
The product - GPI®

GPI® shows several superior properties if compared to the product of sand pit casting. The granule shape is superior for raw material handling with conveyor belt, magnet, front-end loader, bin systems, and scrap skip. The compactness of the granules and relative small shape allows pre-loaded raw materials to obtain a high bulk density; see Figures 4 and 5.

![GPI® product at off-loading point from conveyor belt.](image1)

![Granshot® - typical granules.](image2)

The GPI® has a chemical composition identical to the hot metal fed into the granulator. No oxidation or slag entrapment is detected which is confirmed by the high metallic content.

The GPI® can be considered to be used in a number of metallurgical operations, some of which are listed in Table I.
**Alternative methods**  
Granshot® granulation is the only viable method that matches the throughput of a typical BF on a continuous basis.

Sand pit casting is a high capacity method but eventually the sand pits are full. At this stage the hot metal layers needs to cool off and the tedious work of breaking up the metal starts. Sand pit casting also generates considerable amounts of fumes and the product is difficult to handle.

The pig casting machine is an alternative with a considerable lower capacity than the Granshot®. The pig casters are usually built in twin lines when higher capacities are foreseen, but even then the capacity is strongly limited due to the solidification time of the liquid iron in the moulds. The pig caster also requires more mechanical maintenance as a consequence of the complex design. The pig caster product – the pig - has identical properties to the granule except for the larger size, which excludes handling in bin systems.

**Future challenges**  
The Granshot® granulation plant has met design expectations at SSAB Oxelösund. It is the author’s belief that the full potential of the process is still to be developed as plants with capacities of even higher flows are expected.

Also granulation of steel is a future area of interest. At SSAB Oxelösund steel granulation will be performed during periods of BOF excess capacity (caster maintenance), which is expected to be a welcomed product for the stainless steel producers.

### Table I. The use of GPI® in different steelmaking operations.

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<thead>
<tr>
<th>GPI® use-case</th>
<th>Suitability</th>
<th>Comment</th>
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<tbody>
<tr>
<td>Blast Furnace</td>
<td>Suitable</td>
<td>• Recycling of GPI® into the BF burden to boost and/or promote iron throughput. This is a special case to be considered when production situation at hand requires, e.g. shortage of iron due to one ironmaking unit on hold for relining.</td>
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| Electric Arc Furnace | Very suitable | • Virgin feedstock low in residuals.  
• Suitable to load in scrap bucket, high density valuable for efficient charging.  
• Possible to feed continuous through fifth hole. Charging with power on, lowering of tap-to-tap.  
• High carbon content, promotes slag foaming.  
• High metallic content and small size reduces risk for electrode breakage. |
| Basic Oxygen Furnace | Very suitable | • Excellent cooling scrap – neutral composition.  
• Suitable to load in scrap skip (high density and efficient magnet loading).  
• Possible to feed continuous for temperature control during blow.  
• Small size ensures rapid melting and dissolution – no late carbon boils. |
| Ladle Furnace      | Limited use  | • Suitable for exact recarburization. Limited primarily by chemical composition (Phosphorous and Sulphur). |
| Continuous Casting | Very limited use | • Used as starter head cooling scrap. |
CONCLUSIONS

The Granshot® granulation plant at SSAB Oxelösund has proven to be a suitable production plant for accommodation of excess hot metal from the BF. The system meets the demand of flexibility and rapid start up in order to function as a back-up facility. The Granshot® has also proven its capacity and reliability in order to match the production of a single BF for a steel plant shut down period of 17 days. The produced GPI® proves as an excellent ferrous feedstock for internal use in the BOF and for shipping over seas to EAF operators.

REFERENCES

