Technology for granulating ferroalloys – the GRANSHOT® process.

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1 Introduction
The ferroalloy industry and in particular the ferronickel producers, has adopted the GRANSHOT metal granulation process, from UHT, to produce their end-product to be delivered to customers within the metallurgical industry, fig 1.

GRANSHOT is an industrial high capacity process, up to 250 tonnes/hour, that within 30 seconds produces ready-to-use granules that have a size and shape ideal for downstream metallurgical operations in EAF, AOD, foundries, etc. Ferroalloy producers appreciate GRANSHOT for the high production yield with a minimum of material loss. The high equipment availability of up to 98% and the ease-of-use also fits their operations and process operators well. Some of the installations include ANGLOAMERICAN Barro Alto, VALE Onca Puma, POSCO – SNNC, ERAMET Doniambo, BHP Billiton Cerro Matoso, SAMANCOR Ferrometals, and the upcoming XSTRATA Koniambo project. The GRANSHOT® process is marketed and sold by UHT – Uvån Hagfors Teknologi AB former known under the name of Uddeholm Technology AB.
2 Background

Within the steelmaking activity at Uddeholm in Sweden, a group of engineers pioneered, already in the early 1970s, what would come to be the GRANSHOT® metal granulation process. They needed to handle excess amounts of pig iron within the daily steel production. They set out to use rugged equipment and water as coolant, being readily available. The result was a process which showed to be a straightforward and cost effective solution as to produce metal granules with favorable shape and properties for re-use in downstream metallurgical processing.

![Image](image)

*Figure 2. The commonly used casting and crushing process for ferroalloys is time consuming, cause’s high levels of fines and with varying material properties.*

The news of the metal granulation technology was spread to the ferroalloy producers used to the common procedure of sand bed casting (fig 2) and crushing, having poor performance and being labor intensive. End-customers were also looking for a better product as to enter into their steel making process. Together they aimed at the following objectives:

- Increased productivity and avoiding tedious casting and crushing operations
- Minimize generation of fines and losses of the high cost ferroalloy product
- Create a homogenous and clean ferroalloy product to meet the demand for cleaner steels
- An alloy product easy to handle, transport and feed into metallurgical processes
- Define a repeatable, automated, secure and environmentally friendly process
- Minimize the implementation foot print as to retrofit existing ferroalloy plants

Typically, the casted ferroalloy would pick up impurities when casted. The casting also causes in-homogenous material analysis and sometimes there would be a mix of material analysis’s during the casting as well as during the crushing and packaging. This could require the supplier or trader to provide a sample analysis of the batch to be delivered, which is both cost and time consuming.
The high amount of fines included in the 0-10 mm crushed product, often with a dust-like material, is recycled back into the casting or melting process but the same fines are also produced during transport and handling. This grade is also being sold as a product to the steel plants, fig 3.

Figure 3. Dust-like fines from crushing operations, 0-10 mm, here FeCr, is sold and delivered in barrels to steel makers

These fines are a logistical problem and there is also an endless price discussion regarding fines by the producers, traders, distributors and purchasers. To the actual end-users the dust-like fines are more considered very difficult to utilize and enter into the steelmaking process, having a low yield factor as well being a health hazard to the staff.

Still today, ferroalloy producers, employ labor intensive production and handling of the ferroalloys, which has to be managed and supervised as to achieve a high product quality.
3 Ferroalloy granule properties

The size of the granulated product is typically within 4 to 25 mm with a spherical and deformed shape, fig. 1, without any dust-like content. This can however vary some depending on the composition of the metal. SLN reports a size range of 4-60 mm for their granulated FeNi material [ref 1] while Samancor reports typical 4-25 mm for their MCFeCr (IC3) material [ref 2].

The physical properties of granules make them ideal out of logistical and metallurgical aspects. Handling with front-loaders, magnets or conveyor belts work well as well as to enter the granules into the metallurgical process, either continuously or batch wise.

The high bulk density of the granulated product, typical 3500-4500 kg/m³, also ensures the granules to easily penetrate the slag layer during addition as well as allow for a rapid melting and dissolution in the hot metal bath.

The granulated product has a homogeneous composition identical to the metal fed into the granulator and without the variations in composition that is obtained when casting in sandpits.

4 GRANSHOT metal granulation process

The GRANSHOT technology set out to master some important aspects in solidification of liquid hot metal as to achieve an efficient and stable process.

- A steady and secure flow of hot liquid metal to be granulated
- High throughput capacity by good distribution and rapid cooling of the hot metal
- Effectively remove and transport the formed metal granules for dewatering
- Minimize any negative impact on the environment

The metal granulation process can be divided into some well defined steps, described below, fig. 4.

![Figure 4. Hot liquid metal is within 30 seconds transformed into metal granules (red track) with the help of process water (blue) as cooling and transport media.](image-url)
4.1 Hot metal handling
Liquid metal arrives to the granulation process by some different possible routes.

- Ladle in crane, metal is poured over lip
- Ladle in crane, metal is tapped from the bottom with sliding gates (fig 4)
- Ladle in ladle tilter, metal is poured over lip
- Direct tapping from furnace via runner to granulation unit (fig 10)

Each alternative have its different benefits and depends on the general logistics of the plant. Placing the ladle in a ladle tilter frees crane capacity and allows for smooth operation and tapping of hot metal to the tundish. Direct tapping to the GRANSHOT unit is ideal to cut costs for handling, maintenance of ladles as well as losses (skulls etc) and without any need for heavy crane capacity.

4.2 Granulation of metal
The hot metal leaves the tundish at a controlled flow rate and hits a refractory sprayhead, where the stream disintegrates into droplets, distributed evenly over the entire granulation tank surface, figure 5.

![Figure 5. Hot metal hits the refractory sprayhead, producing droplets, effectively spread out over the entire granulation tank surface.](image)

The droplets are immediately cooled when entering the water volume. The temperature of the granules is lowered as they sink to the bottom, exchanging heat with the counter–flowing cooling water. Effective cooling of the process water is achieved either with cooling towers or heat exchangers.

4.3 Dewatering
The ejector transfers the formed granules from the granulation tank to the dewatering unit. The transport of granules utilizes compressed air and water as to ensure high capacity and smooth operation. In the dewatering unit water is mechanically removed down to approximately 1%. The total process, from entering into the granulation unit and exiting the dewatering section, has so far only taken 30 seconds. For ferroalloys, the demand for a dry end-product requires to dry the material, typically using a rotary dryer.

The typical granule has a deformed spherical shape, ideal for conveyor transport, front loader handling or intermediate storage in silos. Cranes with magnets can also be used for magnetic metals.
4.4 Operation
The stand-alone granulation unit is completely automated, allowing one person to control the process while another person handles and supervise the hot metal handling. After preheating of tundish and nozzle for some 20–30 minutes the GRANSHOT unit is ready for use. The tundish is prepared and relined prior to use by maintenance staff or the process operators.

4.5 Installation
The GRANSHOT unit is designed to have a high granulation capacity, yet within a limited space as to facilitate an easy integration in new and existing plants, fig 6. It is also possible to locate the unit and direct the output of granules since the dewatering unit can be placed in a suitable location and direction just by redirecting the tube used for transporting the granules from the granulation tank. Pumps, water cooling and treatment systems are normally placed adjacent to the granulation unit. An installation would of course also incorporate control room, working and inspection platforms as well as stairways to access all parts of the installation.

Figure 6. A compact installation footprint is possible by the effective cooling of the hot metal.

The major media connections are water as for cooling and transport of granules. Industrial compressed air is employed in the transport of granules. The electrical power needed is for pumps, dewatering and control systems. For the preheating of nozzle and tundish, moderate volumes of LPG or natural gas are used.

A GRANSHOT unit for granulation of ferroalloy has a relatively small environmental impact. The process water is re-circulated in a closed piping system, with possibility to implement a heat exchange system. The risk of water pollution to the environment is therefore very low. Regarding air pollution the GRANSHOT process in itself has little impact, however pouring from the ladle should be carried out in such a way that dust emission from the heat is minimized. Normal existing plant ventilation and filter is sufficient as to handle these emissions.
5 GRANSHOT® in ferroalloy installations

The GRANSHOT process has evolved since the first installations in the 1970s. The huge number of installations, today well over 40, whereof 20 in ferroalloys, has resulted in a wealth of accumulated experience within UHT as to deliver economically viable, industrial and high capacity metal granulation processes. Ferroalloy producers find the GRANSHOT process attractive due to:

- High capacity granulation, fully adequate for the needs in ferroalloy production
- A minimum of metal loss, typically less than 0.5 % and no formation of dust
- Repeatable and industrial process due to rugged design and full automation
- Ease-of-use, equipment availability of up to 98% and a minimum of staff for operation
- Delivered as turnkey or as an engineering and key equipment project, including commissioning, start-up and process guarantees

The granulation capacity of GRANSHOT installations in a ferroalloy plant is related to the typical reduction furnace size which implies a granulation rate of some 2-3 tonnes/minute. Ferroalloy producers would also require having an integrated drying section as to achieve the correct maximum moisture content of the finished product.

5.1 Granulation of FeNi

Due to the ductile properties of the FeNi alloy, having problem to crush the material, causing massive amounts of fines, these ferroalloy producers were early to adopt the GRANSHOT process into their production, table 1. Some selected installations are also described below.

Table 1. There has been a rapid deployment of GRANSHOT FeNi granulation since 2000.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Country</th>
<th>Start-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>XSTRATA Koniambo</td>
<td>New Caledonia</td>
<td>2012 scheduled</td>
</tr>
<tr>
<td>AngloAmerican Barro Alto</td>
<td>Brazil</td>
<td>2011</td>
</tr>
<tr>
<td>VALE Onca Puma</td>
<td>Brazil</td>
<td>2011</td>
</tr>
<tr>
<td>POSCO SNNC</td>
<td>S. Korea</td>
<td>2008</td>
</tr>
<tr>
<td>AngloAmerican Minera Loma de Niquel</td>
<td>Venezuela</td>
<td>2003</td>
</tr>
<tr>
<td>SLN</td>
<td>New Caledonia</td>
<td>1977</td>
</tr>
</tbody>
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5.1.1 VALE Onca Puma

Started early in 2011, here the 120 tonnes/hour GRANSHOT unit was a complete equipment delivery from UHT, fig 7. In conjunction with the start-up VALE ordered from UHT to be present at site during one year for technical assistance.

Figure 7. FeNi granulation at VALE Onca Puma.
5.1.2 AngloAmerican Barro Alto
This plant was started up during spring 2011 and features a 120 tonnes/hour GRANSHOT unit. Hot metal arrives in a ladle which is placed in a tilter as to ensure a controlled flow of hot metal into the tundish that controls the pace of the granulation. As an alternative bottom tapping via a slide gate system can be used.

5.1.3 POSCO SNNC
This granulation unit was installed in 2008 and has a capacity of 120 tonnes/h, fig 8. The granulated FeNi is used within the POSCO group.

![Figure 8. Granulation of FeNi at POSO SNCC.](image)

5.1.4 BHP Billiton Cerro Matoso
UHT designed, delivered key equipment and commissioned the GRANSHOT equipment at Cerro Matoso. Other equipment was produced under license by a subcontracted company based on UHT designs.

5.2 Granulation of FeCr at SAMANCOR Ferrometals, South Africa
Ferrometals applied GRANSHOT already in 1985 as to be able to market, produce and deliver granulated FeCr, fig 9, including MC FeCr, the so-called IC3 product. The delivery was later updated in 2004. Ferrochrome comes in 35 tonnes ladles and is granulated at 2 tonnes/minute.

![Figure 9. Granulated FeCr.](image)
6 Trends & Outlook

From numerous metal granulation installations and being active around the world, UHT can see an increasing interest for granulated metals due to factors such as:

- Continued quest for further cleaner steels and better product qualities
- Automated and simplified handling as well feeding of alloying materials
- Cost control, both in ferroalloy production and in efficiency when use of alloying material

6.1 Cleaner steels

The need for increasingly better steel grade products and higher quality levels set the standards for what raw material to be used into the steel making processes; EAF, AOD, foundry processes etc. Such requested raw material parameters are homogenous composition, minimum of pollutants or oxides and rapid melting properties. As many ferroalloy grades, especially low carbon grades; LC FeNi, LC FeCr, are added at the very final stages of the production process requirements on cleanliness becomes even more important, since little time for removal of impurities are available. Remaining impurities in the material will be entrapped in the steel during casting causing risk of defects in the final product. Therefore the cleanliness levels of added materials should be as important for the steelmakers as those of chemical analysis and material size.

6.2 Automated and simple material handling

Any alloying material used into a metallurgical process should be suited for automated handling and feeding, that implies correct size and shape as to facilitate such processing.

6.3 Cost control

With rising material cost and fierce competition cost control is as vital as ever. It becomes important to further reduce any possible losses during production of ferroalloys but also ensuring that all of the ferroalloys really enter the metallurgical process. There is virtually no generation of dust and fines at any stage of the process or during transport and handling at customer which traditionally has implied a reduced price. Cutting production time is positive for the cash-flow, with material being ready for sales within some minutes. It has also been noted that granulated metal also saves costs when it comes to packaging and loading since the automated handling cuts the charging time dramatically. During these operations the granulated material generates close to no dust or fines, avoiding any further losses of costly ferroalloys, but also avoiding creating hazardous conditions.

As to cut costs and processing time, direct tapping of hot liquid metal from the furnace, fig. 10, is possible. This has been the modus operandi at BEFESA Scandust in Sweden, since 2003.

![Figure 10. Tapping directly from the furnace to the GRANSHOT unit saves on operational cost.](image)
There is also a demand for higher granulation capacity as reduction furnaces are gradually growing in capacity. This would not be any future problem since UHT has already installed a number of installations for granulation of pig iron where the capacity today has reached 240 tonnes/hour.

6.4 Creating further value for the ferroalloy industry

UHT is today focusing on applying the accumulated granulation experience and development work to continuously improve the technology as to control and optimize the granule size and to expand the application to other materials, for instance FeMn. In this work, UHT has invested in a pilot granulation unit, placed in the workshop. This unit allows UHT to conduct research, develop the process, and test different features and also to train customers. More importantly, the pilot unit is used for running customer defined tests. This allows to produce granulated material as to be verified and presented to selected end-customers. Such projects are held in close cooperation with customers, supervised by UHT metallurgist and followed by a thorough report and documentation.

7 UHT – solutions for the ferroalloy industry

UHT is a Swedish engineering company which focuses on 2 customer segments; granulation of metals with the GRANSHOT® technology and complete CLU converter refining solutions as to produce medium (MC) and low carbon (LC) ferroalloys or for stainless steel production.

The offer within CLU® converters includes all key-equipment; vessel, tilting, tuyeres, gas mixing station and process control system UTCAS®, etc. UHT has delivered such converter solutions to SAMANCOR Ferrometals and Thos Begbie as to produce MC FeCr and MC/LC FeMn, fig 11.

Figure 11. UHT delivers complete converter solutions as to produce MC and LC ferroalloy products.
This implies that UHT can provide a complete solution to ferroalloy producers as to achieve industrial and cost effective production of medium and low carbon ferroalloys. The conventional method to achieve these products is by the alumino- or silico-thermic process which is an exothermic chemical reaction, involving aluminum or silicon as the reducing agent at high temperature. The process involves mixing of hot metal from two furnaces and several vessels while decarburization of high carbon ferroalloys in a converter only involves one furnace.

Lower carbon ferroalloy products are often difficult to crush and a lot of fines are generated which makes the GRANSHOT granulation process highly suitable.

8 Conclusion
Granulation of metals, the GRANSHOT® process, as discussed here for ferroalloys, is today an economically viable and well proven industrial solution with well over 40 installations made by UHT. The following can be concluded when it comes to granulation of ferroalloys;

- Granulated ferroalloy products are favored in downstream utilization
- The GRANSHOT process fits the ferroalloy industry
- The market is asking for more granulated material

Figure 11. Granulated FeNi, ready for use with automated handling and feeding in any downstream metallurgical process.

9 References
Ref 1:

Ref 2: product sheet for MC FeCr IC3 material, September 2008