Beneficiation of Iron Ore with alljig® and gaustec®

a case study of a 1500 t/h iron ore beneficiation plant

Dipl.-Ing. Andreas Horn
Abstract

Mineral processing is characterized by a constant adaptation to changing raw materials and market conditions. It is the link between the mined raw material and a marketable product. As a lot of high grade reserves are exploited, a steady deterioration of raw material quality can be observed. At the same time, the customers’ requirements for product purity and consistent quality increase.

Over the last years beneficiation techniques for iron ore have become more important in order to achieve a maximized utilization of ore resources and to produce competitive products according to international standards.

allmineral has been engaged in hematite iron ore beneficiation with its gravity separators since the mid nineties. The delivery of jigs started for the upgrading of iron ore for its utilization in a Direct Reduction Plant in Australia. Since then, various other installations with jigs for lump and fines as well as upstream separators for fines are in operation in Brazil, Australia, India and South Africa. Low grade run of mine and/or dump ores are being processed with alljig®, allflux®- and gaustec®-separators as the core equipment.

This paper describes the project of a 1500 t/h beneficiation plant for haematitic iron ore in India. The data presented show the entire project from flowsheet development to plant engineering and construction. It focuses on the specific advantages of jig application on iron ore upgrading due to the possible high gravity cuts and the easy and low cost operation. The gaustec®-wet high intensity magnetic separators offer high capacity in combination with unsurpassed process flexibility.
Innovative Technology for Upgrading of Ores

- Iron ore mining and beneficiation in India in the past and today
- Jigging technology | alljig®
- alljig® - underbed pulsed | alljig® - side pulsed
- WHIMS technology | gaustec®
- alljigs® | gaustecs® around the world | examples
- JSPL | The biggest integrated iron ore beneficiation plant in India
  - Pilot tests with minijig® and minimag®
  - Flowsheet development
  - Plant layout and general arrangement
  - Impressions from the construction site
Iron ore mining in India has been widely characterized in the past by methods developed for high grade deposits and relatively small mine outputs, i.e. selective mining of the high grade material and simultaneous dumping of low grades and fines.

This scenario has been changing dramatically in recent time for a number of reasons and demands new approaches:

- Ratio of high grade/low grade in the deposits is coming down.
- The specific value of % Fe in saleable product increased significantly over the last years.
- Fines, frequently disregarded as waste, are becoming a valuable product considering the upcoming sintering and pelletization capacities in India.
- Modern beneficiation processes allow for effective and low cost upgrading of lump, fines and ultrafines.

In September 2008 allmineral received the order for the plant engineering and the supply of the key machinery for the largest integrated iron ore beneficiation plant in India with a capacity of 1,500 tph. The plant is based on alljig® sidepulsed jigs and gaustec® wet high intensity magnetic separators as core equipment.
## Iron ore mining and beneficiation

### In the past
- Mining of high grade deposits
- Selective mining of high grade areas and dumping of low grade ores
- A lot of small capacity mines and few high capacity mines

### Today
- Ratio of high grade/low grade in the deposits is coming down.
- The specific value of % Fe in saleable product increased significantly over the last years.
- Fines, frequently disregarded as waste, are becoming a valuable product considering the upcoming sintering and pelletization capacities.
- Modern beneficiation processes allow for effective and low cost upgrading of lump, fines and ultrafines.
Separation of minerals in jigging machines is based on the fact that particles will stratify in pulsating water. The upward and downward currents fluidise and compact the grains into relatively homogenous layers. Low density pieces stratify on the surface, while specifically heavy grains settle to the lower level of the bed.

alljig® jigging machines are air-pulsed, because the pulsation of the water can be generated practically wear-free and so the stroke-motion *(frequency, amplitude and shape)* can be adjusted within a wide range, easily during operation.

After stratification the discharge of heavy product is done by an automatic, PLC- controlled discharge system. The discharge is the second criteria essential for excellent jig performance. In this regard a precise detection of the stratified density horizons and a continuous discharge of high grade product are needed, with a product discharge rate depending on feed characteristics, but guaranteeing a constant product quality independent of feed characteristics.

alljig®-jigs are in operation for the cleaning of different raw and recycling materials. The only prerequisite is a difference in the particle density. More than 400 alljigs® have been delivered to date – worldwide. They are in use for various applications ranging from iron ore to coal, sand and gravel, as well as the recovery of metal from slag. Because of the low operating costs compared to heavy media plants and the possibility of higher separation densities (> 4.0 g/cm³) jigs are considered as state of the art equipment for iron ore beneficiation.
alljig® - applications | more than 400 units worldwide

for:

- coal
- iron ore
- sand | gravel
- rubble
- contaminated soils
- metal-slag
- non ferrous minerals
- diamonds
- salt and others

alljig® for beneficiation of lump iron ore
Depending on the arrangement of the air chambers, side- and underbed-pulsed jigs are available. allmineral supplies both types, which are compared on the next page. In terms of process efficiency, there is no difference between the two types of jigs since the same stratification is achieved with the same water movement.

The side-pulsed Baum-type allmineral jig is limited to a jig bed width of 3 m. The largest underbed-pulsed jig supplied by allmineral is operated at a coal mine, it is 5 m wide. The largest allmineral underbed-pulsed jigs in iron ore are 4 m wide and are in operation in the world’s biggest jig plant at Sishen mine in South Africa.

The main differences concern the different position of the air chamber and type of air control. The disk valves used for the air control in the underbed-pulsed jigs need control air instead of the electrically driven rotary piston of the side-pulsed jigs. The maintenance costs for disk valves tend to be higher and even low wear leads to change in the control timing and therefore to a possible reduction in jig performance. The control system of an underbed-pulsed jig is complex and requires suitably qualified personnel to operate it. In contrast, the Baum jig with side-pulsed action is simple to maintain and operate.

The jigs are widely used in iron ore beneficiation to reduce the amount of silica and alumina. While in South Africa, Australia and Brazil the silica content is in the focus, in India the challenge is more on the reduction of the alumina content. While the jigging technology has been in use for more than ten years in Australia, Brazil, and South Africa, the Indian iron ore producers have discovered the value of this technology and are in the process of installing and commissioning.
Comparison of underbed and side-pulsed alljig® machines—Schematic
The separation of particles in Wet High Intensity Magnetic Separators (WHIMS) is based on the fact that minerals have different magnetic susceptibilities. Particles with high magnetic susceptibilities are attracted by the magnetic forces in a magnetic field while particles with low magnetic susceptibilities can pass through the magnetic field.

The gaustec® wet high intensity magnetic separator (WHIMS) has been designed and improved by skilled engineers based on their practical experience of more than 20 years.

Several features introduced to the standard equipment led to the best possible operational flexibility and easy maintenance.

A wide range of sizes starting from the smallest unit for research and process design applications with a rated feed capacity of 0.3 t/h, to the biggest equipment of its kind ever constructed, the GX-3600 with a rated feed capacity of 800 t/h.

The WHIMS are widely used in iron ore beneficiation worldwide to reduce the amount of silica and alumina in fines. The gaustec® WHIMS as a Brazilian technology has been successfully gained market leadership in Brazil and is now headed for worldwide market leadership with more than 60 units sold in the last 5 years, comprising to date of 45 in Brazil and 17 in India.
gaustec® WHIMS | more than 50 units worldwide

gaustec® Schematic
**gaustec® | Major Improvements**

**gaustec®**
Wet High Intensity Magnetic Separator

- Separates ores and other paramagnetic and feebly magnetic minerals with a particle size up to 3 mm
- Matrix is made of grooved plates
- Vertical and unhindered flow through the matrix
- The high gradient magnetic field is independently adjustable for each rotor
- Rougher and cleaner/scavenger process step possible in one single machine
- Rotor speed is adjustable from 3 to 7 rpm
- Throughput rates of 6-480 t/h per machine @ 2.5 mm gap and 50 % solids in the feed

Major improvements compared to traditional WHIMS led to:

- Higher separation efficiency
- Higher flexibility
- Higher capacity in a single unit
- Magnetic field is independently adjustable for each rotor
- Cleaner- / Scavenger operation in a single *gaustec®* WHIMS possible
- Increased matrix area at constant rotor diameters
- Width of magnetic poles is adjustable
- Reduced energy consumption
- Higher operation reliability
- Easier access for maintenance by increased distance between the rotors
gaustec® - 3600 | feed capacity 3 x 200 tph
gaustec® - GX 3600 | feed capacity 360 - 800 tph

gaustec® - GX 3600 | The biggest WHIMS in the world!
gaustec® - 3600 | workshop test | at Hari Machines Ltd., Rajgangpur | India
Key facts

- allmineral received the order for the plant engineering and the supply of machinery in September 2008.

- The plant is based on alljig® sidepulsed jigs and gaustec® WHIMS as core equipment.

- The equipment is manufactured in India with all key components supplied from allmineral Germany.

- Indian fabrication partner is Hari Machines Ltd., Rajgangpur.

- allmineral in Germany did the entire basic engineering.

- allmineral Asia Ltd. did the entire detail engineering with support from several engineering agencies in Kolkata.

- JSPL is responsible for the purchase of equipment like screens, mills, thickeners, etc..

- JSPL is responsible for the construction and erection.

- Commissioning started in December 2010.
Stratification jig tests have been made with -5 +1 mm and -16 +5 mm samples with the minjig® in allmineral’s pilot test facilities in Germany in order to evaluate the suitability of the jigging process.

The lump ore -16 +5 mm is well liberated. The following page shows pictures from the top and bottom layer samples generated in the minjig®.

Another extensive campaign with jig and WHIMS tests including crushing and grinding of jig rejects and WHIMS rejects was performed by the IMMT in Bhubaneswar, India. The results from all testwork where the basis for the flowsheet development.
Selected lump ore samples from minijig® test

<table>
<thead>
<tr>
<th></th>
<th>Fe %</th>
<th>Al₂O₃ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>61.70</td>
<td>4.13</td>
</tr>
<tr>
<td>Top Layer</td>
<td>52.88</td>
<td>8.12</td>
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<tr>
<td>Bottom Layer</td>
<td>67.15</td>
<td>1.86</td>
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</table>
Selected fine ore samples from minijig® test

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<td>4,79</td>
</tr>
<tr>
<td>Top Layer</td>
<td>54,24</td>
<td>8,11</td>
</tr>
<tr>
<td>Bottom Layer</td>
<td>65,70</td>
<td>2,58</td>
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**Flowsheet development**

The flowsheet was developed based on the following ROM data:

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<th>A</th>
<th></th>
<th></th>
<th>B</th>
<th></th>
<th></th>
<th>C</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>m %</td>
<td>Fe%</td>
<td>Al₂O₃%</td>
<td>m %</td>
<td>Fe%</td>
<td>Al₂O₃%</td>
<td>m %</td>
<td>Fe%</td>
<td>Al₂O₃%</td>
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<tr>
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<td>3,2</td>
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<td>100,0</td>
<td>61,6</td>
<td>3,8</td>
<td>100,0</td>
<td>60,4</td>
<td>3,6</td>
</tr>
<tr>
<td>&lt; 0,063</td>
<td>25,7</td>
<td>55,8</td>
<td>7,2</td>
<td>5,1</td>
<td>58,5</td>
<td>4,8</td>
<td>58,5</td>
<td>3,8</td>
<td></td>
</tr>
<tr>
<td>0,063 - 0,25</td>
<td>25,7</td>
<td>55,8</td>
<td>7,2</td>
<td>5,1</td>
<td>58,5</td>
<td>4,8</td>
<td>58,5</td>
<td>3,8</td>
<td></td>
</tr>
<tr>
<td>0,25 - 0,5</td>
<td>4,9</td>
<td>61,3</td>
<td></td>
<td>2,1</td>
<td>58,5</td>
<td></td>
<td>6,1</td>
<td></td>
<td></td>
</tr>
<tr>
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<tr>
<td>5 - 18</td>
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<td>2,8</td>
<td>30,0</td>
<td>61,7</td>
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<td>&gt; 18</td>
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<td>65,9</td>
<td>1,5</td>
<td>12,6</td>
<td>66,0</td>
<td>1,6</td>
<td>21,7</td>
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<td>1,9</td>
</tr>
<tr>
<td>0,063 - 0,25</td>
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<td>4,8</td>
<td>58,5</td>
<td>3,8</td>
<td></td>
</tr>
<tr>
<td>0,25 - 0,5</td>
<td>4,9</td>
<td>61,3</td>
<td></td>
<td>2,1</td>
<td>58,5</td>
<td></td>
<td>6,1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0,5 - 1</td>
<td>9,4</td>
<td>63,4</td>
<td>1,9</td>
<td>4,9</td>
<td>61,3</td>
<td></td>
<td>3,7</td>
<td>60,5</td>
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</tr>
<tr>
<td>1 - 5</td>
<td>20,6</td>
<td>63,7</td>
<td>1,9</td>
<td>20,5</td>
<td>61,5</td>
<td>3,4</td>
<td>15,0</td>
<td>61,0</td>
<td>3,2</td>
</tr>
<tr>
<td>5 - 18</td>
<td>26,8</td>
<td>64,5</td>
<td>2,0</td>
<td>36,6</td>
<td>64,4</td>
<td>2,8</td>
<td>30,0</td>
<td>61,7</td>
<td>3,1</td>
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<tr>
<td>&gt; 18</td>
<td>17,5</td>
<td>65,9</td>
<td>1,5</td>
<td>12,6</td>
<td>66,0</td>
<td>1,6</td>
<td>21,7</td>
<td>63,5</td>
<td>1,9</td>
</tr>
</tbody>
</table>

The flowsheet was developed based on the following ROM data:
The development of the flowsheet for this plant was made in order to achieve the following targets:

<table>
<thead>
<tr>
<th></th>
<th>Fe %</th>
<th>Al₂O₃ %</th>
<th>Yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>61,70</td>
<td>3,40</td>
<td></td>
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<tr>
<td>Concentrate</td>
<td>&gt; 64</td>
<td>&lt; 2,00</td>
<td>&gt; 85</td>
</tr>
<tr>
<td>Rejects</td>
<td>≈ 47</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mass flow calculations had to be made for three different particle size distributions: coarse feed, average feed and fine feed.
Simplified Flowsheet
Key technology for the beneficiation process

**alljig®** G-2200 x 3000 sidepulsed jigs | lump ore -30 +5 mm *(DRI product)*
**alljig®** F-2500 x 3000 sidepulsed jigs | fine ore -5 +1 mm *(Sinterfeed)*
**alljig®** F-2500 x 3000 sidepulsed jigs | crushed lump rejects -5 +1 mm *(Sinterfeed)*

**gaustec®** G-3600 WHIMS | fine ore -1 +0,1 mm *(Sinterfeed)*
**gaustec®** G-3600 WHIMS | crushed fines jig rejects -1 +0,1 mm *(Sinterfeed)*
**gaustec®** G-3600 WHIMS | ultrafine ore -0,1 mm *(Pelletfeed)*
**gaustec®** G-3600 WHIMS | ground fine ore WHIMS rejects -0,1 mm *(Pelletfeed)*

Key technology for the Layout and Plant General Arrangement

- Incorporation of existing scrubbers
- Use of existing product conveyors
- New plant site in a small valley
- Use of existing tailings thickener as a process water tank
Development of Layout and Plant General Arrangement
Development of Layout and Plant General Arrangement

Sectional drawing of the Main Building
Development of Layout and Plant General Arrangement

View of the Main Building
Development of Layout and Plant General Arrangement

View of a single alljig® module consisting of two alljig® G-2200 x 3000 and one alljig® F-2500 x 3000
Development of Layout and Plant General Arrangement

View of the WHIMS area 3 x gaustec® - 3600 for -1 +0.1 mm and 1 x gaustec® - 3600 for -0.1 +0.02 mm
Impressions from the construction site

Construction site in October 2009

View to existing washing plant
Impressions from the construction site

Construction site in December 2009 with four gaustec® - 3600 on foundations
Impressions from the construction site

**Erection of concentrate and classifying thickener**

**March 2010, installation of the first alljigs®**
Impressions from the construction site

Main building in March 2010, all alljigs® installed, steel structure erection ongoing
Impressions from the construction site

Construction site in December 2010 with the gaustecs® and alljigs®
Conclusion

The increased demand for iron ore concentrates in the last years as well as the mining of low grade deposits leads to a growing demand for separation technology for lump ores, sinter feed and pellet feed. Because of the low operating costs compared to heavy media plants and the possibility of higher separation densities (> 4.0 g/cm³) alljigs® are considered as state of the art equipment for the beneficiation of lump ore and sinter fines.

The gaustec® wet high intensity magnetic separators (WHIMS) are frequently used for a particle size < 1 mm. The individual adjustment of the magnetic field strength for both rotors of the gaustec® allows for processing of different particle size fractions with optimized settings in a single machine.
Beneficiation of Iron Ore

Main features introduced to the gaustec® WHIMS that improve their performance beyond the known limits of Magnetic Separator Technology:

allmineral
Aufbereitungstechnik GmbH & Co. KG
Baumstraße 45
47198 Duisburg | Germany
T _+49 (0) 20 66 . 99 17 - 0
F _+49 (0) 20 66 . 99 17 - 17
head@allmineral.com
www.allmineral.com

allmineral Llc.
Suite 1 - F, 1360 Union Hill Road
Alpharetta, Georgia 30004 | USA
T _+1 . 770 . 410 02 20
F _+1 . 770 . 410 08 07
allmineral@aol.com
www.allmineral.com

allmineral Sp.zo.o.
Ul. Powstańców Śl. 5
53332 Wrocław | Poland
T _+48 (0) 71 . 783 70 11
F _+48 (0) 71 . 780 44 18
biuropl@allmineral.com
www.allmineral.com

allmineral (Pty.) Ltd.
P.O. Box 73171
Fairland 2030, Johannesburg | South Africa
T _+27 (0) 11 . 478 53 80 18
F _+27 (0) 11 . 478 53 88
allmin@global.co.za
www.allmineral.com

allmineral Asia Pvt. Ltd.
Eco Space Business Park, 6th Floor, Block-B
Premises No.II F/11, Action Area-II
Rajarhat, New Town, Kolkata 700 156 | India
T _+91 . 33 . 40 17 . 41 00 to 41 09
F _+91 . 33 . 40 17 . 41 10
office@allmineral.asia
www.allmineral.com