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INTECO special melting technologies GmbH

Steelmaking and Remelting Technologies - your key to high value market segments
INTECO at a glance

General Information
INTECO special melting technologies GmbH has been founded in 1973 as a wholly private company with the objective to provide supply and services to the metals and related industries Worldwide with over 300 employees.

Equipment & Process Technology for Melting, Casting and Solidification of carbon, quality steels and superalloys

Productportfolio and Customers

<table>
<thead>
<tr>
<th>Services</th>
<th>Special Metallurgy</th>
<th>Steelmaking Metallurgy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Investment Studies</td>
<td>Electroslag Remelting</td>
<td>Electric Arc Furnaces</td>
</tr>
<tr>
<td>Engineering</td>
<td>Vacuum Arc Remelting</td>
<td>Ladle Furnaces</td>
</tr>
<tr>
<td>Projektmanagement</td>
<td>Vacuum Induction Melting and Pouring</td>
<td>VD / VOD Plants</td>
</tr>
<tr>
<td>Trainings</td>
<td></td>
<td>Ingot Casting</td>
</tr>
<tr>
<td>Consulting</td>
<td></td>
<td>Continuous Casting</td>
</tr>
</tbody>
</table>

Customers: Steelmaking Industry
Product Portfolio

- Electric Arc Furnace
- VD/VOD
- Ingot Casting
- VSD
- RH
- Ladle Furnace
- VAD
- Continuous Casting
- ESR
- VAR
- VIM
INTECO Landscape
Change strategies

- Focus on Customer
- Focus on Speed
- Focus on Innovations
- Focus on Service
- Focus on Quality
- Focus on Volume
- Focus on .................

Differentiate or Die
Long Products - Saarstahl

Cast blooms

Semifinished products

Steel bars

Steel wire

Source: http://www.saarstahl.de/
Main Operation Features

- Low energy consumption
- Low electrode consumption
- Heating rate up to 5° C/min
- CC-Electrode arms
- ISEC electrode controller
- Easy access and maintenance
Main Operation Features

- Short treatment time
- Minimum temperature losses
- Extremely favourable decarburisation and degassing results
- Deoxidation
- Chemical heating
- Efficient alloying/fine trimming with high accuracy
New Secondary Metallurgical Plant for Saarstahl
Billets and Semifinished Products - DEW

Continuous Casting Billets Siegen

Semifinished Products from the rolling mill Witten

Continuous Casting Billets Witten
New Secondary Metallurgical Plant for DEW Witten

90 – 130 ton Ladle Furnace equipped with:
- Syncronized cover lifting system
- Material handling system
- T&S lance Equipment

110 / 130 ton VOD/VD-Plant equipped with:
- Oxygen blowing lance
- Material handling system
- Steam ejector vacuum pump
New Secondary Metallurgical Plant for DEW Witten

90 – 130 ton Ladle Furnace
Main Operation Features
- Temperature adjustment
- Desulphurization
- Fine tuning of analysis

110 / 130 ton VOD/VD-Plant
Main Operation Features
- Degassing
- Decarburization
- Desulphurization
- Temperature adjustment
- Fine tuning of analysis
Change of Production Route (Asia)

Electric Arc Furnace (50 t)  
Ladle Furnace  
AOD  
CCM (sq. 150 mm; 280 x 325 mm)

- Stainless Steels (304, 430)
- Start Carbon content up to 1.8 %
- Final Carbon content > 0.025 %
- High production quantities within similar steel groups (campaign operation)
- Low flexibility for specialities (single heats)
- Long preparation time for restart of casting for single heats/low sequence rates
- No crack sensitive steels (e.g. hot work tool steels)
New Production Route – VD/VOD

- Electric Arc Furnace
- Ladle Furnace
- AOD
- CCM

+ VD/VOD

- ULC steel grades (C < 0.025 %)
- Ultra low sulphur steels (S < 0.003 %)
- Low gas contents (N, H)
- Vacuum degassing is required for large ingot production
- Adjustment of hydrogen content for ESR steels
- Higher flexibility – wider product range
New Production Route - IC

- Electric Arc Furnace (50 t)
- Ladle Furnace
- AOD
- CCM (sq. 150 mm; 280 x 325 mm)

+ Ingot Casting

- Production of crack sensitive steel grades
- High flexibility on formats and batch sizes
- Ingots up to 100 tons with INTECO’s multi ladle casting
- Round electrodes for ESR
- New products and markets
New Production Route - VSD

- Electric Arc Furnace (50 t)
- Ladle Furnace
- AOD Furnace
- CCM (sq. 150 mm; 280 x 325 mm)

- Production of ingots > 100 tons
- Very low gas contents (esp. Hydrogen)
- Increasing demand for very large forgings for turbines, reactor vessels, ...
New Production Route - Triplex

- Electric Arc Furnace (50 t)
- Ladle Furnace
- BOF
- AOD
- VD/VOD
- Ingot Casting
- CCM (sq. 150 mm; 280 x 325 mm)
Economic Aspects

- Single heats or low batch sizes can be produced more economically with VD/VOD and ingot casting

- Products with higher market value (large size components, tool steels, ...)

- Door opener for high alloyed ESR grades

- Production of virtual all steel grades (including non-continuous castable alloys)
Role of VHD Furnace for the Production of Long Products

Main Operation Features

- Combination of LF & VD process
- No increase of gas content during heating,
- No reoxidation
- Improved steel cleanliness
- Low carbon pick up
- Buffer between melting & casting unit
- Homogenisation of composition & temperature
- Final deoxidation
- Desulphurization
- Temperature adjustment
- Fine trimming of composition
Some Impressions ...
... some impressions
Carbon Pick Up vs. Pressure

- Virtually no carbon pick up at reduced pressure
- Very well suited process for steel grades with very low carbon specification
Casting - Facts

Share of CC in world steel production

© Stahlinstitut VdEh

Ingot Casting Production in Germany

© Stahlinstitut VdEh
Change Trends towards larger Bloom Formats

- Trend towards continuous casting of blooms > 600 mm diameter
- Better yield and internal quality compared to ingot casting

Applications:
- Bearing cases
- Train wheels
- ...
Change Trends towards Larger Bloom Formats

2-Strand Jumbo Bloom Caster:
Larger products (e.g. bearing cases) are possible

Challenges:

- Very high holding and straightening forces!
- Impact on solidification

Our Approach:

- Investigative design and engineering study coupled with thermo mechanical simulations
Typical products – Ingot casting
Typical products – Ingot Casting
Ball bearing steels

Rings

Steel Bars

Tubes

Pictures: http://www.ovako.com
General Trends in Ingot Casting

- As for most production processes
  - Reduction of costs
  - Increase in productivity
  - Improvement of workplace safety

- Mechanization and (semi-)automation especially for ingots with high number of items
  - Advanced Teeming Systems

- Increasing demand for very large ingots
  - Multi-Ladle Casting
  - Vacuum Ingot Casting
Advanced Teeming System ATS – Typical layout

- Bottom plate preparation plant
- Teeming stations
- Stripping
- Mould storage
- Mould cleaning
Typical components

Brick laying machine

Bottom plate and mould preparation

Transfer car

Casting car

Mobile stripper

Mould washing unit
Heavy Forging Ingots-
Large Size Components
Turbine & Generator Rotors
Main Operation Features

- Shroud Manipulator
- Steel Stream Protection (Argon Purging)
- (Hydraulic) Weighing System for Casting Rate Control
MULTI LADLE CASTING

Basic Idea
- Casting multiple ladles (usually two) to one large ingot under atmospheric conditions
- Bottom Pouring

Benefits
- „Doubling“ EAF heat size
- Relatively low investment

Required Equipment
- Casting Car with some specialities
- Casting Crane (with sufficient clearance)
Multi Ladle Casting - Process

First Ladle is placed into the casting car

Second Ladle is placed on top

Slide gates are opened, start casting

Casting
Role of the VSD Process for the Production of Heavy Forging Ingots

- Mainly for degassing during ingot casting (VIC)
- For heavy ingots, mainly energy section (reactors vessels, turbine discs, ...)
- Ultra low hydrogen content is achievable
  - Eliminate or reduce flaking problems
- Advantages if casted ingots heavier than ladle capacity
  - Casting of multiple ladles to one ingot is possible
VIC at SeahBe Steel (Korea)

• Production of ingots > 500 tons (from 5 ladles)
  ✓ Entering new markets for large sized forgings
  ✓ Reduced heat treatment times due to ultra low hydrogen content
- Ingot Size up to 510 tons
- 7 Vacuum Vessels
  - Vessel 1 – 4: 160 – 510 tons
  - Vessel 5 – 7: 60 – 160 tons
- 2 Vacuum Covers
- 1 Vacuum Pump
- VSD Cover and Switching Device are moved by crane
- Parameter:
  - Casting Ladle direct on vessel cover
  - Pressure: ≤ 1 mbar
  - Casting speed: 2 – 6 (8) t/min
SeAH Besteel Corporation, Korea
SeAH Besteel – First Heat
March, 16th 2009
INTECO’s Level 2 System

Control, supervision and administration of the steelmaking process by an integrated production management system

Components

- Master Data Management
- Order Management
- Process Scheduling, Control and Supervision
- Heat Tracking
  - Metallurgical Process Models
  - Ladle (Temperature) Tracking
  - Reporting
Change Trends towards higher Process Control and Supervision

Levels of Process Control

- LEVEL 4
  - Plant-wide MES (e.g. SAP)
- LEVEL 3
  - INTECO Level 2 System
- LEVEL 2
  - ELECTRIC ARC FURNACE
  - SECONDARY METALLURGY
  - CONTINUOUS / INGOT CASTING
- LEVEL 1
- PLANT LEVEL
Added Values for our Customers

- comprehensive administration of the steelmaking process
- Integrated dynamic, metallurgical process models control the steelmaking based on scientific findings:
  - Reduced error rate (e.g., target analyses not achieved)
  - Continuous, reproducible production
  - Cost reduction by optimal use of materials
- Optimal production scheduling by mathematical models (reduced waiting times at each plant)
- Extensive reporting, a requirement for special steels
## Reasons for the Application of Remelting Processes - General

<table>
<thead>
<tr>
<th>Quality</th>
<th>Cost Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>No achievement of the required material properties with conventional methods (e.g. ingot casting)</td>
<td>high costs and efforts related to the conventional methods</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology</th>
<th>Market and Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulties and Limitations related to conventional methods</td>
<td>Technical regulations by material specification, Achievement of a competitive advantage, Enforcement of competitors</td>
</tr>
</tbody>
</table>

Change Trends towards near net shaped billets – The ESRR process

- **Big sized electrode** (electrode sizes of bigger cross sections as compared to the billet cross section)
  - Lower production cost for electrodes
  - Higher yield
  - Fewer electrode changes

- **Increased melt rate** as compared to standard ESR (2-5 times higher)
  - Increase annual capacity
  - Make the process more economical

- **Highest productivity** in case of continuous operation
  - Reducing down times
  - Increase overall productivity

Economic production of high quality near net shaped remelted billets
Change Trends towards near net shaped billets – The ESRR process

Max. billet length 9.3m
Change Trends towards near net shaped billets – The ESRR process

Surface appearance of a nickel-base alloy billet produced in ESRR operation
Change Trends towards near net shaped billets – The ESRR process

Macrostructure of ESRR austenitic stainless steel A304L (meltrate 600 kg/hour)
Sound and more homogeneous material; example on type 1.4568 material

Improved cleanliness; no macro inclusion; example on 1.4542 type material

Rolling direction

C-scan display made by a 50 Mhz focused ultrasonic probe. One shoot every 25 µ in X and Y.

40 x 72 mm/ 5 mm depth

Initial material

remelted material

Ferriere, D.: UGITECH Contribution, INTECOSymposium 2008, Shanghai
Change trends towards large sized ESR ingots

Main Market:

- **Power Generation** - Conventional, Nuclear & Renewable Energy such as Gas and Steam Turbines, Mono-Block rotors, Generator Shafts, Wind Turbines, Pressure vessels, Discs, Blades, Tubes for Boilers, etc.
- Petrochemical Industry, Oil & Gas
- Bearings, Transmissions
- Aerospace
- Mechanical Engineering
- Construction, Mining
- Etc.

**Note:** ESR-Remelting Capacities for ingots >1600mm dia. in 2012 are approx. 4-5 times higher compared to 2008
Worldwide energy demand

- World energy consumption will be driven up by 50% in next 25 years
- 2035: Increase of total energy demand 84% in non-OECD and 14% in OECD countries
Benefits of the ESR process for the production of heavy forging ingots

**WHY REMELTING? – Influence of Remelting**

**Cleanliness Level**
- Reduced content of non-metallic inclusions
- Lower size of remaining inclusions
- Close control of chemical analysis from bottom to top

**Ingot Structure**
- Slow directional solidification
- Minimization of segregations
- Minimization of pores

**Forging Operation**
- Higher Yield
- Lower forging ratio
- Cylindrical Ingot with uniform diameter
- Less Forging Steps
- Smooth Surface in general allows direct hot working

Higher ductility, less anisotropy

Improved mechanical properties
Ø2600mm ESR ingot remelted on Nov. 18th 2011
2600mm dia. ESR ingot, 249 t SA508 Gr3
145 ton Combined Plant, Japan
1900mm dia. ESR ingot, 112t
23CrNiMoV8
1900mm dia. ESR ingot, 95 ton
COST FB2
### Selected Chemical Analysis of large-sized ESR ingots (145 ton)

#### Chemical Analysis (low alloyed steel)

<table>
<thead>
<tr>
<th>position</th>
<th>Si</th>
<th>Al</th>
<th>Cr</th>
<th>N [ppm]</th>
<th>O [ppm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>electrode</td>
<td>0.09</td>
<td>0.003</td>
<td>2.12</td>
<td>49</td>
<td>21</td>
</tr>
<tr>
<td>Top</td>
<td>0.08</td>
<td>0.004-0.005</td>
<td>2.13</td>
<td>57</td>
<td>21</td>
</tr>
<tr>
<td>Mid</td>
<td>0.06-0.07</td>
<td>0.004-0.005</td>
<td>2.11-2.16</td>
<td>64</td>
<td>24</td>
</tr>
<tr>
<td>Bottom</td>
<td>0.04-0.06</td>
<td>0.005</td>
<td>2.10-2.11</td>
<td>85</td>
<td>29</td>
</tr>
</tbody>
</table>

#### Chemical Analysis (10% Cr steel)

<table>
<thead>
<tr>
<th>position</th>
<th>Si</th>
<th>Al</th>
<th>Cr</th>
<th>Nb</th>
<th>N [ppm]</th>
<th>O [ppm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>electrode</td>
<td>0.09</td>
<td>0.006</td>
<td>10.24</td>
<td>0.050</td>
<td>235</td>
<td>27</td>
</tr>
<tr>
<td>Top</td>
<td>0.08-0.09</td>
<td>0.005</td>
<td>10.23-10.26</td>
<td>0.051-0.052</td>
<td>233</td>
<td>23</td>
</tr>
<tr>
<td>Mid</td>
<td>0.08</td>
<td>0.005</td>
<td>10.21-10.27</td>
<td>0.050-0.051</td>
<td>241</td>
<td>22</td>
</tr>
<tr>
<td>Bottom</td>
<td>0.07</td>
<td>0.005</td>
<td>10.15-10.22</td>
<td>0.043-0.046</td>
<td>210</td>
<td>23</td>
</tr>
</tbody>
</table>
... the byproduct?!?

- High costs for slag disposal
- Restricted area for deposition
- Metallics are lost in the slag
Slag recycling

Recoverable scrap

Recycled construction material
Benefits of slag recycling

- Lower slag volumes for disposal
- Lower costs for disposal
- Revenues for recovered scrap and ferro alloys
- Revenues for recycled construction material (if slag composition is suitable)
Have an eye... on our technology

Thank you for your attention