«EN1563 Yeni Nesil Dökme Demirler»
«EN 1563 - New Generation Ductile Irons»

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7. Oturum: Süreçler ve Kontrol
7th Session: Process and Control

Oturum Başkanı/Session Chairman: Mustafa Akyürek (Anadolu Döküm San. Tic. A.Ş.)
EN 1563 YENİ NESİL DÖKME DEMİRLER

Seyfi Değirmenci, Bülent Şirin, Bert Duit

TURKISH FOUNDRYMEN SOCIETY
SEPTEMBER 11-13.2014
İSTANBUL
AGENDA

- Componenta Company overview
- SSF, Solution Strengthened Ferrite
- Mechanical properties
- Machinability
- Some examples of SSF designs
- Experiences
- Cost impact, how to act
- Summary
COMPONENTA:
The second largest independent cast component supplier in Europe

- Componenta serves its customers by offering them casting solutions covering the whole value chain from engineering to finished components.
- The Group’s foundries and machine shops are located in Turkey, Finland, the Netherlands and Sweden. In addition, the Group has three forges in Sweden.
- Componenta’s customers are manufacturers of vehicles, machines and equipment in various industries: Global players such as Volvo, Caterpillar and Wärtsilä. Long-term customer relationships and strong credit ratings.
- Componenta’s shares are listed on the NASDAQ OMX Helsinki.
Ready to serve - strong local presence in key markets
Strong market positioning in selected customer industries

**Heavy trucks (31% of sales)**
- Volvo Trucks a customer since 1960’s
- Customized solutions through optimized component design and use of alternative materials to achieve vehicle weight goals

**Construction and mining (19% of sales)**
- Solutions for all major players using 3D CAD data and finite element analysis
- Components supplied to loaders, haulers, excavators and graders.

**Automotive (15% of sales)**
- Produces to leading OEM’s and has two own trademarks: DJ and MAXX
- Fine-tuned component features by advanced engineers: reduced weight, lower CO2 emissions, improved strength and fuel economy.

**Agricultural machinery (17% of sales)**
- Complex advanced engineering and co-design activities to meet technical challenges
- Cast components from iron to aluminium, rough or machines, possible surface treatment.

**Machine building (18% of sales)**
- Large segment with diverse sub-segments including: holding blades for windmills, railway equipment, compressor equipment industrial gears etc.
OUR BROAD CUSTOMER BASE supports stability and innovation

31%
Heavy Trucks

19%
Construction and Mining

18%
Machine Building

17%
Agricultural Machinery

15%
Automotive

31%
19%
18%
17%
15%

Heavy Trucks
Construction and Mining
Machine Building
Agricultural Machinery
Automotive

DAIMLER
CATERPILLAR
Atlas Copco
AGCO
Fiat
MAN
JCB
BOMBARDIER
John Deere
SCANIA
CNH
Ford
KONE
RENAULT
VOLVO
Wärtsilä
COMPONENTA

14.9.2014
WE WANT TO CONTINUE TO SERVE OUR CUSTOMERS for the next 100 years

OUR MISSION
Casting Future Solutions

OUR VISION
The preferred casting solution provider locally and globally

OUR STRATEGY
1. New Force efficiency projects
2. 100 million revenue growth
3. World-class product management
4. One Componenta

OUR VALUES
OPENNESS
HONESTY
RESPECT
# Our Capabilities by Foundry

<table>
<thead>
<tr>
<th>Foundry</th>
<th>Type of the Line</th>
<th>Box Size (mm)</th>
<th>Height (mm)</th>
<th>Typical Maximum Product Weight (kg)</th>
<th>Capacity</th>
<th>Minimum Serial/Yearly Volume (tons/year)</th>
<th>Moulds/Serie or Tons/Year</th>
<th>Materials</th>
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</thead>
<tbody>
<tr>
<td>Finland</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Iron foundries</td>
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<tr>
<td>Pori</td>
<td>Disa 2013</td>
<td>480 x 600</td>
<td>150 / 245</td>
<td>20</td>
<td>9000</td>
<td>18,000</td>
<td>50 moulds</td>
<td>GJL, GJS, SSF</td>
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<tr>
<td></td>
<td>HWS</td>
<td>750 x 650</td>
<td>250 / 250</td>
<td>100</td>
<td>18,000</td>
<td>18,000</td>
<td>10 moulds</td>
<td></td>
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<td>Högfors</td>
<td>HWS</td>
<td>1,160 x 960</td>
<td>350 / 350</td>
<td>350</td>
<td>34,000</td>
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<td>20 moulds</td>
<td>GJL, GJS, SSF, ADI</td>
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<tr>
<td>Suomivalimo</td>
<td>Furan handmoulding</td>
<td>700 x 900</td>
<td>MAX 2,600 x 3,600</td>
<td>MAX. 2,500</td>
<td>5,000</td>
<td>16,000</td>
<td>-</td>
<td>GJL, GJS, SSF, ADI</td>
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<tr>
<td>Netherlands</td>
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<td></td>
<td></td>
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<td>92,000</td>
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<tr>
<td>Weert</td>
<td>HWS</td>
<td>1,250 x 850</td>
<td>400/400</td>
<td>350</td>
<td>36,000</td>
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<td>15 moulds</td>
<td>GJL, GJS, SSF, ADI</td>
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<td>Heerlen HWS</td>
<td>HWS</td>
<td>850 x 630</td>
<td>330/330</td>
<td>150</td>
<td>36,000</td>
<td></td>
<td>30 moulds</td>
<td>GJL, GJS, SSF, ADI</td>
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<tr>
<td>Heerlen Furan</td>
<td>Furan semi-automatic moulding</td>
<td>2,200 x 1,250</td>
<td>MAX. 1,600</td>
<td>3,500</td>
<td>20,000</td>
<td>20 tons</td>
<td>GJL, GJS, SSF, ADI</td>
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<tr>
<td></td>
<td></td>
<td>2,500 x 1,750</td>
<td>MAX. 2,000</td>
<td>20,000</td>
<td>20 tons</td>
<td>GJL, GJS, SSF, ADI</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,000 x 1,750</td>
<td>MAX. 1,600</td>
<td>3,500</td>
<td>20,000</td>
<td>GJL, GJS, SSF, ADI</td>
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<tr>
<td></td>
<td></td>
<td>3,300 x 2,000</td>
<td>MAX. 1,600</td>
<td>3,500</td>
<td>20,000</td>
<td>GJL, GJS, SSF, ADI</td>
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<td>Turkey</td>
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<td></td>
<td></td>
<td></td>
<td>160,000</td>
<td></td>
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<tr>
<td>Orhangazi</td>
<td>L1 +GF+</td>
<td>700 x 900</td>
<td>360/360</td>
<td>100</td>
<td>27,000</td>
<td></td>
<td>100 tons</td>
<td>GJL, GJS, GJV, SSF</td>
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<tr>
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<td>L2 HWS</td>
<td>1,250 x 900</td>
<td>400/400</td>
<td>300</td>
<td>32,000</td>
<td></td>
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<tr>
<td></td>
<td>L3 +GF+</td>
<td>700 x 900</td>
<td>360/360</td>
<td>100</td>
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<tr>
<td></td>
<td>L4 Disa 2013</td>
<td>650 x 535</td>
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<td></td>
<td>L5 Disa 2120</td>
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<td>260/400</td>
<td>55</td>
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<td></td>
<td>L6 HWS</td>
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<td>250</td>
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<tr>
<td></td>
<td>L7 HWS</td>
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<td>36,000</td>
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</table>
Advanced properties of CERTIFIED SSF MATERIAL

- Superior yield strength – 13 to 27% improvement
- Even 3.3 times better elongation and improved fatigue properties
- Lighter structures of component enables higher loads with same wall thickness or thinner sections
- Excellent machinability in certain cases
- Less variation in mechanical properties
- Enhanced performance in elevated temperatures
- Possible to replace Steel fabricated parts, like forgings or welded constructions
35 % WEIGHT REDUCTION
- from welded steel construction to SSF casting

STARTING POINT
• Welded construction to be developed into a cast component
• Modular products for two Harvester Designs (Machine Building)

APPLIED SOLUTION
• Design release; made by customer in close cooperation with Componenta
• Desired material: 2nd generation SSF and one ADI part

END RESULT
• 4 functions in one product compared to welded construction
• 35% weight savings
• Machining savings
• Remarkable process phase savings
• Improved and even material properties
• Excellent end product for the customer
SSF Solution Strengthened Ferrite
What is HiSi / SSF?

HiSi / SSF: High Silicon / Solution Strengthened Ferritic spheroidal graphite cast iron.

- A high strength ductile cast iron quality alloyed with silicon (3.2 – 4.3 %, depending upon quality) instead of manganese and copper or tin.
- Alloying level of silicon is constant per SSF-grade, unlike normal ferritic-pearlitic grades, where alloying level of manganese and copper depends on casting size and geometry.
- Constant Si-level, independent of casting size and geometry, resulting in a fully ferritic matrix (max 5% pearlite) and homogeneous properties in all sections of the casting.
- Improved properties are caused by solid solution strengthening of the ferrite matrix by silicon.
History

Developed in the early 90’s by Volvo, Scania and Swedish Foundry institute

1998 - Swedish Standard, SS 140725 for grades 450-15 and 500-10
   - Lower values for elongation proposed to make it more acceptable for (German) Foundries

2004 - ISO 1083:2004, only grade 500-10 described
   - In Normative Annex A

2012 - EN 1563:2012, 3 normative grades mentioned:
   - GJS-450-18
   - GJS-500-14
   - GJS-600-10: New grade introduced, mainly developed by Componenta (Joop Kikkert) as an alternative for forged steel or +GF+ Sibodur
Influence of Silicon on Mechanical properties
## Comparison of Mechanical Properties

(blue row values for SSF, white normal ferritic-pearlitic grades, light pink ausferritic (ADI))

EN 1563:2012 and EN 1564:2012 - Mechanical properties measured on test pieces from cast samples (for relevant wall thickness t ≤ 30 mm)

<table>
<thead>
<tr>
<th>Similar CAT Spec</th>
<th>Material Designation</th>
<th>Rp0.2 Mpa min.</th>
<th>Rm Mpa min.</th>
<th>A % min.</th>
<th>HBW</th>
<th>E kN/mm²</th>
<th>(at RT) J min.</th>
<th>Un-notched Impact Energy</th>
<th>Fatigue limit (rotating bending) (dia. 10.6 mm)</th>
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<tbody>
<tr>
<td>1E1477</td>
<td>EN-GJS-400-18-LT</td>
<td>240</td>
<td>400</td>
<td>18</td>
<td>130-175</td>
<td>169</td>
<td>120</td>
<td>195</td>
<td>122</td>
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<td>1E0356</td>
<td>EN-GJS-450-10</td>
<td>310</td>
<td>450</td>
<td>10</td>
<td>160-210</td>
<td>169</td>
<td>80</td>
<td>210</td>
<td>128</td>
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<td>1E4677A</td>
<td>EN-GJS-450-18</td>
<td>350</td>
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<td>170-200</td>
<td>170</td>
<td>100</td>
<td>210</td>
<td>130</td>
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<td>1E0596B</td>
<td>EN-GJS-500-7</td>
<td>320</td>
<td>500</td>
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<td>1E4677B</td>
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<td>400</td>
<td>500</td>
<td>14</td>
<td>185-215</td>
<td>170</td>
<td>80</td>
<td>225</td>
<td>140</td>
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<td>1E0596A</td>
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<td>600</td>
<td>3</td>
<td>190-270</td>
<td>174</td>
<td>40</td>
<td>248</td>
<td>149</td>
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<td>470</td>
<td>600</td>
<td>10</td>
<td>200-230</td>
<td>170</td>
<td>70</td>
<td>275</td>
<td>165</td>
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<td>700</td>
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<td>225-305</td>
<td>176</td>
<td>20</td>
<td>280</td>
<td>168</td>
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<tr>
<td></td>
<td>EN-GJS-800-2</td>
<td>480</td>
<td>800</td>
<td>2</td>
<td>245-335</td>
<td>176</td>
<td>15</td>
<td>304</td>
<td>182</td>
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<td>EN-GJS-900-2</td>
<td>600</td>
<td>900</td>
<td>2</td>
<td>270-360</td>
<td>176</td>
<td>-</td>
<td>304</td>
<td>182</td>
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<td>EN-GJS-800-8</td>
<td>500</td>
<td>800</td>
<td>8</td>
<td>260-320</td>
<td>163...170</td>
<td>110</td>
<td>375</td>
<td>225</td>
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<td>1E1495</td>
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<td>900</td>
<td>6</td>
<td>280-340</td>
<td>100</td>
<td>400</td>
<td>240</td>
<td></td>
</tr>
</tbody>
</table>
0,2% Proof Strength vs Tensile Strength

For equal tensile strength higher yield strength for SSF
Ratio $R_{p0,2}/R_m$ for pearlitic and SSF cast iron

- Ratio $R_{p0,2}/R_m$ increases with increasing $R_{p0,2}$ for SSF.

- Design are based upon $R_{p0,2}$ instead of $R_m$, weight savings possible.

Graph showing the relationship between $0.2 \%$ Proof strength (MPa) and $R_{p0,2}/R_m$ for GJS-500-7 (n = 828) and GJS 500-14 (n = 293).
Elongation vs. Yield Strength
SFF Combination of high yield with high elongation

<table>
<thead>
<tr>
<th>Yield Strength (MPa)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GJS – 450 - 10</td>
<td>10</td>
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<tr>
<td>GJS – 500 - 7</td>
<td>7</td>
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<tr>
<td>GJS – 600 - 3</td>
<td>3</td>
</tr>
<tr>
<td>GJS – 700 - 2</td>
<td>2</td>
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<tr>
<td>SSF ductile cast irons</td>
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</tr>
<tr>
<td>GJS – 500- 14</td>
<td>14</td>
</tr>
<tr>
<td>GJS – 600 - 10</td>
<td>10</td>
</tr>
<tr>
<td>ADI 800 - 8</td>
<td>8</td>
</tr>
</tbody>
</table>
Elongation SSF vs Current Ductile Grades

SFF has up to 3 times higher elongation at equal strength levels
Tensile tests curves
Ferritic, SFF and ferritic/pearlitic grades

From: Björkegren and Hamberg, Ductile iron with better machinability compared to conventional grades
Brinell Hardness

SFF shows lower average hardness and less variation in hardness, piece to piece and within a piece.
Comparison of Impact energy

Charpy V-Impact test specimen

Source ÖGI  Sirion projekt
Fatigue Strength
Rotating Bending, R= -1, Machined Surface

No difference in fatigue limit for SSF compared to normal pearlitic cast iron, ADI has best fatigue properties for machined specimens.
Influence of Nodularity on Elongation

Silicon % has higher influence as nodularity

- Si = 3.85 - 4.05 %
- Si = 4.25 - 4.45 %
- Si = 4.68 %
- Si = 4.90 %

- Low nodularity, elongation still > 13%
- Si too high
# Mechanical properties
## SSF vs EN 10293 Cast Steels

<table>
<thead>
<tr>
<th>MATERIAL DESIGNATION</th>
<th>YIELD STRESS MPA</th>
<th>TENSILE STRENGTH</th>
<th>ELONGATION</th>
<th>HARDNESS</th>
<th>IMPACT ENERGY*</th>
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<tr>
<td></td>
<td>Rp0.2 MPa min.</td>
<td>Rm MPa min.</td>
<td>A % min.</td>
<td>HBW</td>
<td>V-Notched at RT J</td>
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<td>GJS 450-18</td>
<td>350</td>
<td>450</td>
<td>18</td>
<td></td>
<td>9</td>
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<td>GE240 (+N)</td>
<td>240</td>
<td>450</td>
<td>17</td>
<td>MIN.~ 130</td>
<td>27</td>
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<tr>
<td>GJS 500-14</td>
<td>400</td>
<td>500</td>
<td>14</td>
<td>185 – 215</td>
<td>3</td>
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<tr>
<td>G20MN5 (+N)</td>
<td>300</td>
<td>480</td>
<td>20</td>
<td>MIN.~ 150</td>
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<td>GJS 600-10</td>
<td>470</td>
<td>600</td>
<td>10</td>
<td>200 – 230</td>
<td>2 – 3</td>
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<tr>
<td>GE300 (+N)</td>
<td>300</td>
<td>600</td>
<td>15</td>
<td>MIN.~ 165</td>
<td>31</td>
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<td>G42CRM04 (+QT)</td>
<td>600</td>
<td>800</td>
<td>12</td>
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<td>31</td>
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</table>

*V-notched Charpy test samples, at room temperature. Source: EN 1563:2012 & EN 10293  
N: Normalized, QT: Quenched & Tempered
Average chemical analysis
SSF and Ferritic to Pearlitic Ductile Irons

<table>
<thead>
<tr>
<th>MATERIAL DESIGNATION</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cu</th>
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</thead>
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<td>GJS 450-10</td>
<td>3.5 – 3.7</td>
<td>2.0 – 2.5</td>
<td>&lt; 0.5</td>
<td>0.10 – 0.25</td>
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<td>3.1 – 3.3</td>
<td>3.2</td>
<td>&lt; 0.5</td>
<td>&lt; 0.1</td>
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<td>GJS 500-7</td>
<td>3.5 – 3.7</td>
<td>2.0 – 2.5</td>
<td>&lt; 0.5</td>
<td>0.3 – 0.4</td>
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<td>GJS 500-14</td>
<td>3.0 – 3.2</td>
<td>3.8</td>
<td>&lt; 0.5</td>
<td>&lt; 0.1</td>
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<tr>
<td>GJS 600-3</td>
<td>3.5 – 3.7</td>
<td>2.0 – 2.5</td>
<td>&lt; 0.5</td>
<td>0.4 – 0.5</td>
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<tr>
<td>GJS 600-10</td>
<td>2.8 – 3.0</td>
<td>4.3</td>
<td>&lt; 0.5</td>
<td>&lt; 0.1</td>
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<tr>
<td>GJS 700-2</td>
<td>3.5 – 3.7</td>
<td>2.0 – 2.5</td>
<td>&lt; 0.5</td>
<td>0.8 – 1.0</td>
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</tbody>
</table>

* These chemical analyses are only guidelines. The final analysis is tailored according to customers needs.
Specific density

1.5% weight saving compared to “normal” ductile iron!

Source ÖGI Sirion projekt
MACHINABILITY
Variation of Hardness in section of Wheel Hubs

Reduced variation and lower average hardness results in 10-20% lower machining costs

From: Björkegren and Hamberg, Ductile iron with better machinability compared to conventional grades Foudryman, December 1998, page 386-391.
Difference in metal matrix

Ferrite/pearlite matrix

Ferrite matrix

Pearlite is alpha ferrite + cementite (iron carbide)

Hard + relatively soft = Interrupted cuts

Ferrite

Better machinability
- Hardness is lower and more consistent
- Pearlite/Ferrite acts as interrupted cut
Tool Life

Tool life till 200 µm flange wear

Cutting speed 240m/min
Cutting speed 2320m/min

Source IfG Sirion projekt
Surface roughness
Influence of metallic matrix on surface roughness and shape of chips

Außenlängsdrehen (Standzeitkriterien: VB = 200 µm): \( v_c = 320 \) m/min; \( f = 0,15 \) mm; \( a_p = 0,5 \) mm; Emulsion; \( \kappa_f = 95^\circ; \alpha_o = 6^\circ; \gamma_{eff} = 4^\circ; \lambda_s = -6^\circ; \) HC-K05, Beschichtung: Ti(C,N)/Al₂O₃, CNMG 120408 FN

Source IfG Sirion projekt
SOME EXAMPLES
SSF DESIGNS
Agriculture: Rear Axle

Fabricated part converted into a casting, huge cost saving, increased loads possible
SSF grade: EN-GJS-600-10
Agriculture: Steering knuckle

Redesigned; reduced weight and increased load, replaces steel forging
SSF Grade: EN-GJS-600-10
Highway Bus: Air Spring Member

Redesigned; weight saving, 8 mm wall thickness
SSF Grade: EN-GJS-500-14
Agriculture: Support for exhaust pipe

Weight saving, combining functions
SSF Grade: EN-GJS-500-14
Experiences

- “Imperfections”/“Discontinuities” ;
  - Ductile Iron ➔ slag, porosities, nodularity

- Spectrometer

- Nodularity sample
Porosities in stub
Chunky Graphite
Deviation in graphite shape in SFF chain of small nodules
Chunky graphite, partly due to too high Ce-content.

Measures:
- Low Ce-containing FeSiMg
- Addition of antimony
- Reduced Si%
Influence of Inoculation on nodularity

- Good inoculation
- Chemical composition inoculant
- Increasing Silicon content
- Poor inoculation

Nodularity (Shape V + VI) vs. Wall thickness
Comparison Spectro with Wet chemical Analysis

Yas (wet chemical)

Si increased by inoculation
COST IMPACT AND HOW TO ACT
How to get the most out of SSF

- Do not copy current design 100% into the new design
  - Except for test purposes to compare the SFF with current grades
- Start more or less from scratch
  - Use the better mechanical properties like
    - higher 0.2% proof strength values
    - higher elongation rates
- Think “Out of the Box”
- Work together with the supplier to optimize the casting design as early as possible
SUMMARY
Advantages of HiSi / SSF

- Higher yield strength – 13 to 27% improvement
- Better elongation – up to 3.3 times
  - Higher yield and better elongation can lead to a reduction of weight of the components
- Uniform metallic matrix (fully ferritic vs ferritic to pearlitic)
  - More uniform hardness distribution and mechanical properties
    - Better machinability
    - Comparable or better fatigue properties
- Not so sensitive to low nodularity, because of the solution strengthening effect
  - 20 % of non-spheroidal graphite is accepted in EN1563
Advantages of HiSi / SSF

- Less sensitive to carbide formation in thin walled sections
  - Possibility to design thinner sections
- Improved weldability
- When converting from steel, a weight saving of at least to 9% due to density reduction
  - (from 7.8 kg/dm^3 to 7.05 kg/dm^3)
- Resulting in:
  - Up to 10% - 20% weight saving possible in design
  - Up to 10% - 25% lower machining costs
Downside

• No surface hardening possible

• More sensitive for chunky graphite formation (> 60 mm wall thickness)

• Base chemical composition different from other qualities of cast iron

Ferritic-to-Pearlitic matrices are **only** justified when hardness (as-cast / surface hardened) is more important than all other properties: yield strength, ductility, fatigue strength, machinability, dimensional accuracy, etc.
Casting Future SOLUTIONS

Thank you !