11-13 September / Eylül 2014
TÜYAP Fair, Convention & Congress Center, İstanbul
7th International Ankiros Foundry Congress
7. Uluslararası Ankiros Döküm Kongresi

«EN 1563 Yeni Nesil Dökme Demirler»

«EN1563 - New Generation Ductile Iron»

Seyfi Değirmenci
Bülent Şirin
Bert Duit
(Componenta)

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

TURKİSH FOUNDRYMEN SOCİETY
SEPTEMBER 11-13.2014
İSTANBUL

AGENDA

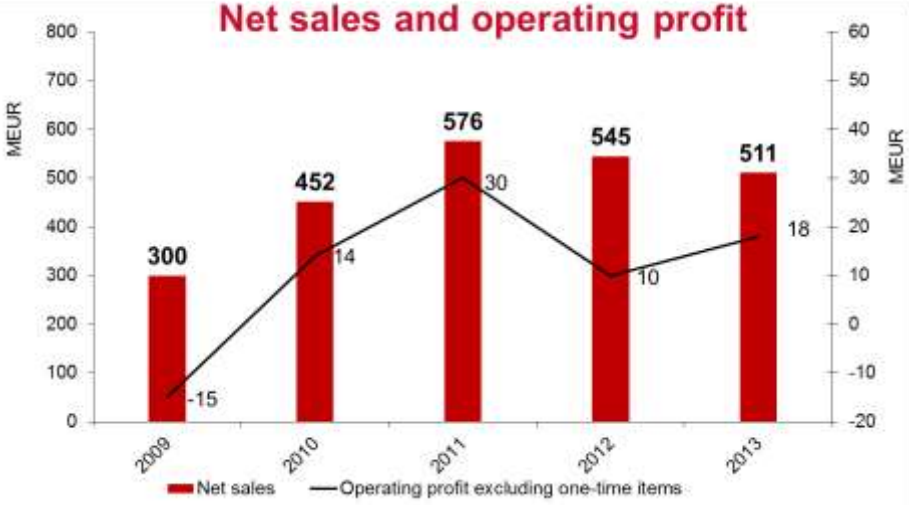
- Componenta Company overview
- SSF, Solution Strengthened Ferrite
- Mechanical properties
- Machinability
- Some examples of SSF designs
- Experiences
- Cost impact, how to act
- Summary

COMPONENTA
Casting Future Solutions

COMPANY OVERVİEW

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.



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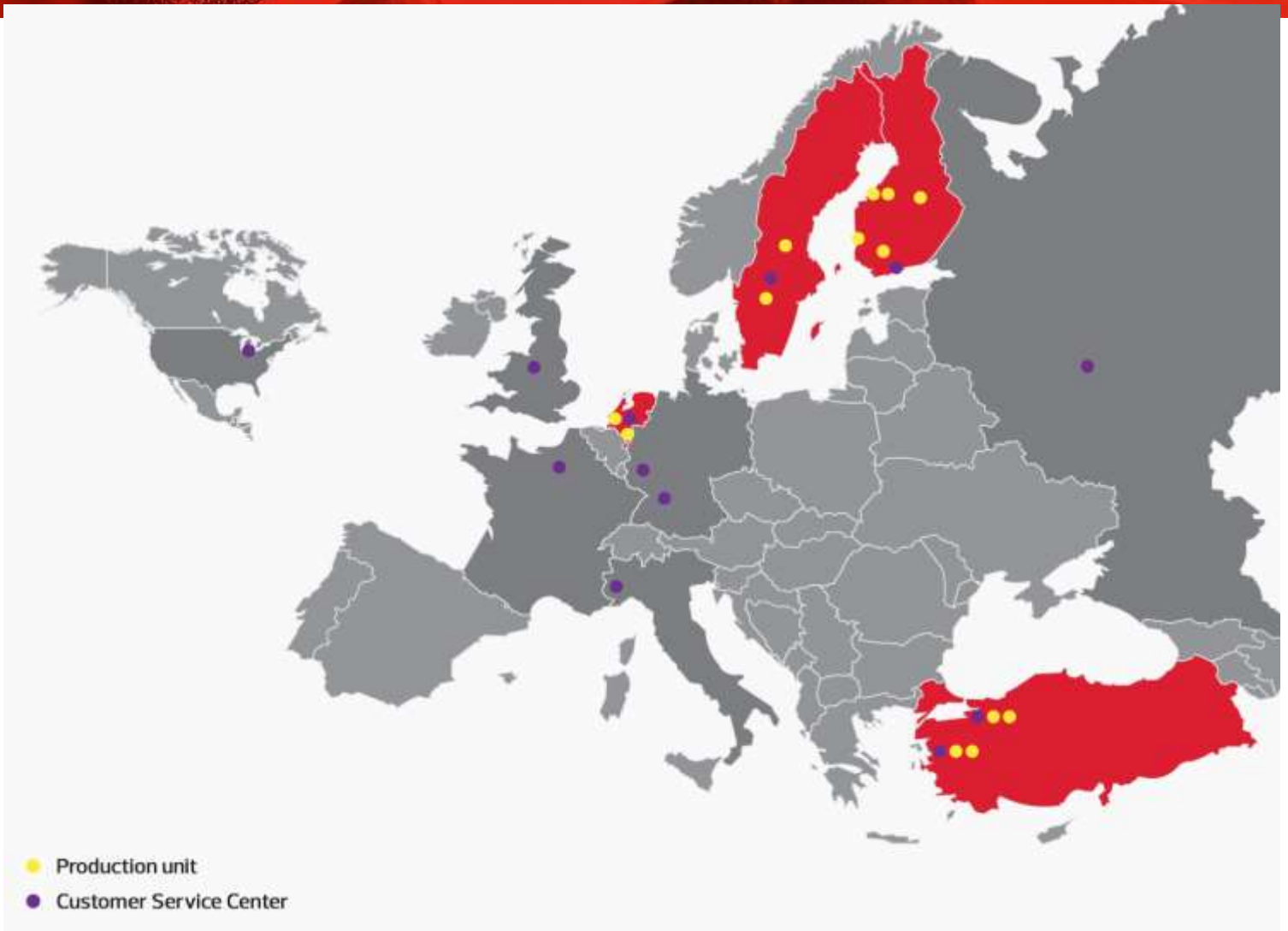
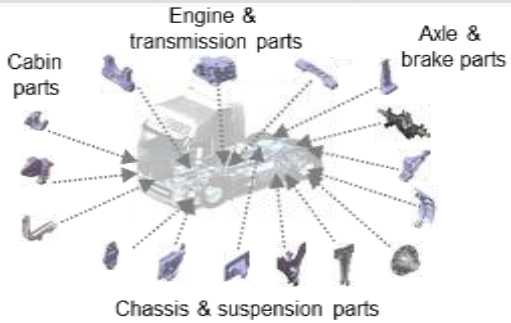
Ready to serve - strong local presence in key markets



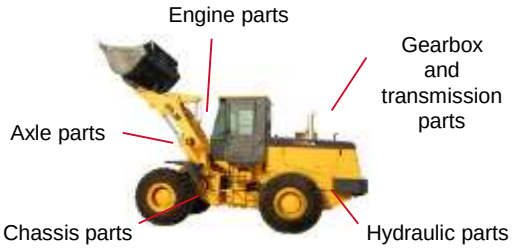
Strong market positioning in selected customer industries

Heavy trucks (31% of sales)



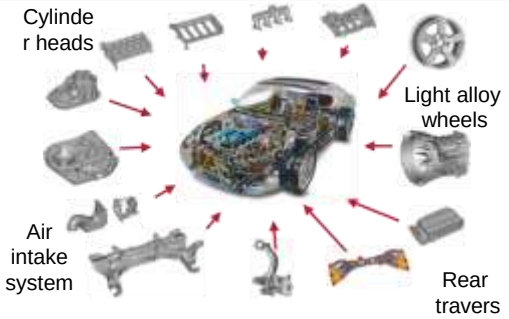
- Volvo Trucks a customer since 1960's
- Customized solutions through optimized component design and use of alternative materials to achieve vehicle weight goals

Construction and mining (19% of sales)



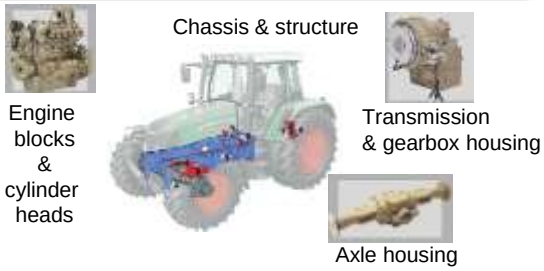
- Solutions for all major players using 3D CAD data and finite element analysis
- Components supplied to loaders, haulers, excavators and graders.

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.

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OUR BROAD CUSTOMER BASE
supports stability and innovation

DAIMLER

MAN

SCANIA

VOLVO

CATERPILLAR

JCB

VOLVO

Atlas Copco

BOMBARDIER
the evolution of mobility

KONE

WÄRTSILÄ

COMPONENTA
Casting Future Solutions

AGCO
Your Agriculture Company

CNH
INDUSTRIAL

JOHN DEERE

FIAT

Ford

RENAULT

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

OUR CAPABILITIES BY FOUNDRY

	TYPE OF THE LINE	BOX SIZE		TYPICAL MAXIMUM PRODUCT WEIGHT	CAPACITY		MINIMUM SERIAL/ YEARLY VOLUME	MATERIALS
		BOX SIZE (mm)	HEIGHT (mm)	(kg)	LINE (tons/year)	FOUNDRY (tons/year)	Moulds/serie or tons/year	
Iron foundries						**320,000**		
Finland						**68,000**		
Pori	Disa 2013	480 x 600	150 / 245	20	9000	18,000	50 moulds	GJL, GJS, SSF
	HWS	750 x 650	250 / 250	100	18,000		10 moulds	
Högfors	HWS	1,160 x 960	350 / 350	350		34,000	20 moulds	GJL, GJS, SSF, ADI
Suomivalimo	Furan handmoulding	MAX 2,600 x 3,600	MAX. 2,500	5,000		16,000	-	GJL, GJS, SSF, ADI
Netherlands						**92,000**		
Weert	HWS	1,250 x 850	400/400	350		36,000	15 moulds	GJL, GJS, SSF, ADI
Heerlen HWS	HWS	850 x 630	330/330	150		36,000	30 moulds	GJL, GJS, SSF, ADI
Heerlen Furan	Furan semi-automatic moulding	2,200 x 1,250	MAX. 1,600	3,500		20,000	20 tons	GJL, GJS, SSF, ADI
		2,500 x 1,750	MAX. 2,000					
		3,000 x 1,750	MAX. 1,600					
		3,300 x 2,000	MAX. 1,600					
Turkey						**160,000**		
Orhangazi	L1 +GF+	700 x 900	360/360	100	27.000	160,000	100 tons	GJL, GJS, GJV, SSF
	L2 HWS	1,250 x 900	400/400	300	32.000			
	L3 +GF+	700 x 900	360/360	100	32.000			
	L4 Disa 2013	650 x 535	200/370	20	9.000			
	L5 Disa 2120	850 x 650	260/400	55	16.000			
	L6 HWS	1,100 x 900	350/350	250	34.000			
	L7 HWS	1,960 x 1,260	400/400	500	36.000			

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)

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

APPLIED SOLUTION

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

SSF Solution Strengthened Ferrite

What is HiSi / SSF ?

- HiSi / SSF : **Hi**gh **Si**licon / **S**olution **S**trengthened **F**erritic 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.

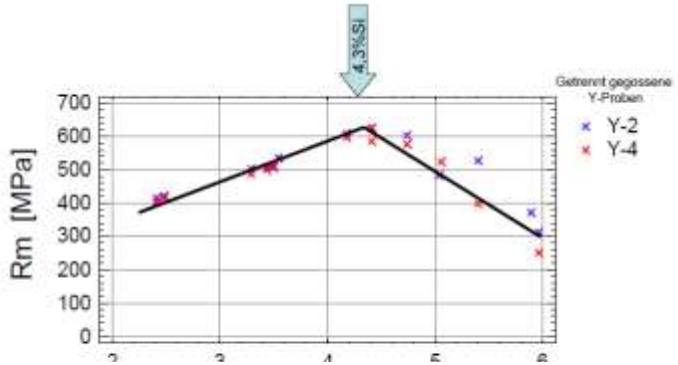
History

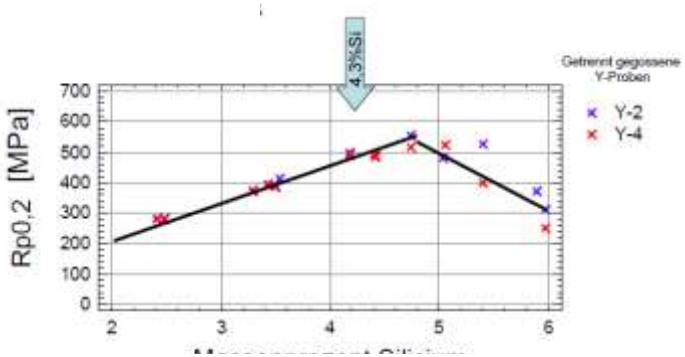
Developed in the early 90's by Volvo, Scania and Swedish Foundry institute

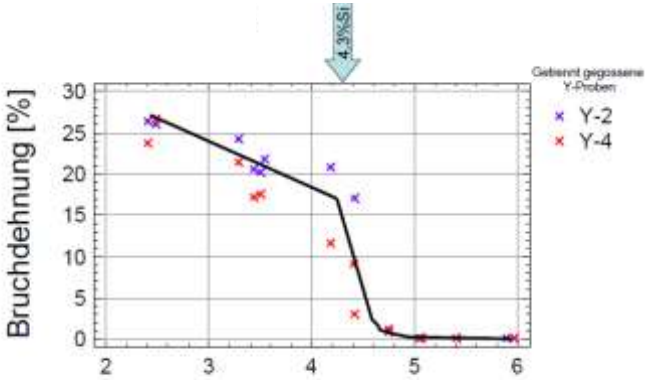
- 1998 - Swedish Standard, SS 140725 for grades 450-15 and 500-10
  - Lower values for elongation proposed to make it more acceptable for (German) Foundries
- 2004 - ISO 1083:2004, only grade 500-10 described
  - In Normative Annex A
- 2012 - EN 1563:2012, 3 normative grades mentioned:
  - GJS-450-18
  - GJS-500-14
  - GJS-600-10 : New grade introduced, mainly developed by Componenta (Joop Kikkert) as an alternative for forged steel or +GF+ Sibodur

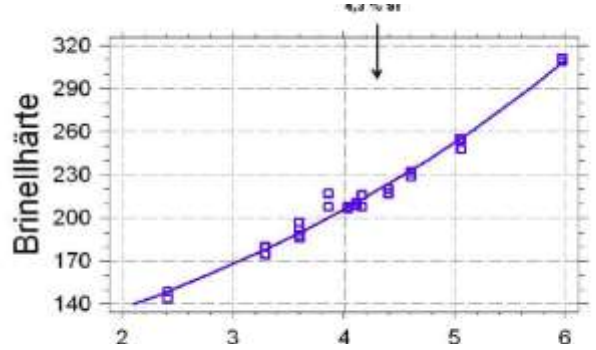
MECHANICAL PROPERTIES

Influence of Silicon on Mechanical properties









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Comparison of Mechanical Properties

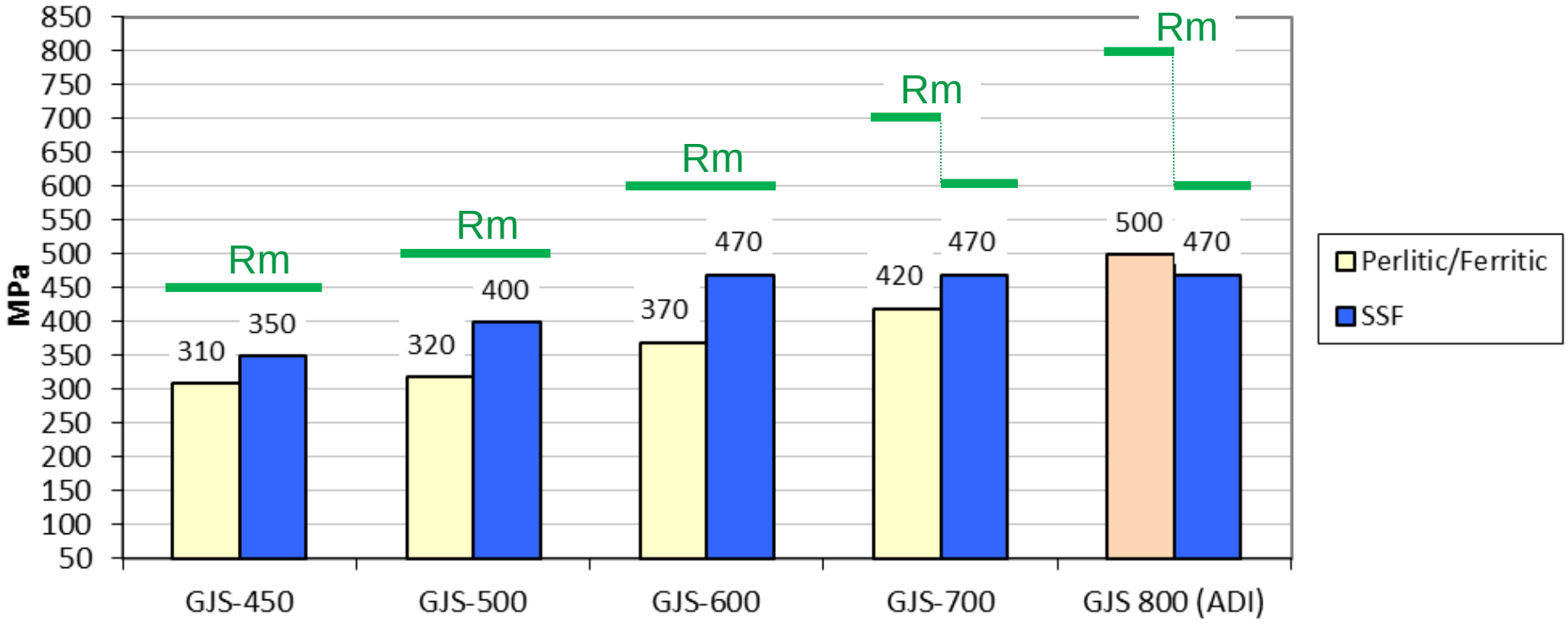
(blue row values for SSF, white normal ferritic-pearlitic grades, light pink ausferritic (ADI))

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

Similar CAT Spec	Material Designation	0.2% proof strength $R_{p0.2}$ Mpa min.	Tensile Strength R_m Mpa min.	Elongation A % min.	Brinell hardness range HBW	Modulus of Elasticity E kN/mm2	Un-notched Impact Energy (at RT) J min.	Fatigue limit (rotating bending) (dia. 10.6 mm) unnotched Mpa typical	Fatigue limit (rotating bending) (dia. 10.6 mm) notched Mpa typical
1E1477	EN-GJS-400-18-LT	240	400	18	130-175	169	120	195	122
1E0356	EN-GJS-450-10	310	450	10	160-210	169	80	210	128
1E4677A	EN-GJS-450-18	350	450	18	170-200	170	100	210	130
1E0596B	EN-GJS-500-7	320	500	7	170-230	169	70	224	134
1E4677B	EN-GJS-500-14	400	500	14	185-215	170	80	225	140
1E0596A	EN-GJS-600-3	370	600	3	190-270	174	40	248	149
1E4677C	EN-GJS-600-10	470	600	10	200-230	170	70	275	165
1E1122	EN-GJS-700-2	420	700	2	225-305	176	20	280	168
	EN-GJS-800-2	480	800	2	245-335	176	15	304	182
	EN-GJS-900-2	600	900	2	270-360	176	-	304	182
	EN-GJS-800-8	500	800	8	260-320	163…170	110	375	225
1E1495	EN-GJS-900-6	600	900	6	280-340		100	400	240

0,2% Proof Strength vs Tensile Strength

For equal tensile strength higher yield strength for SSF



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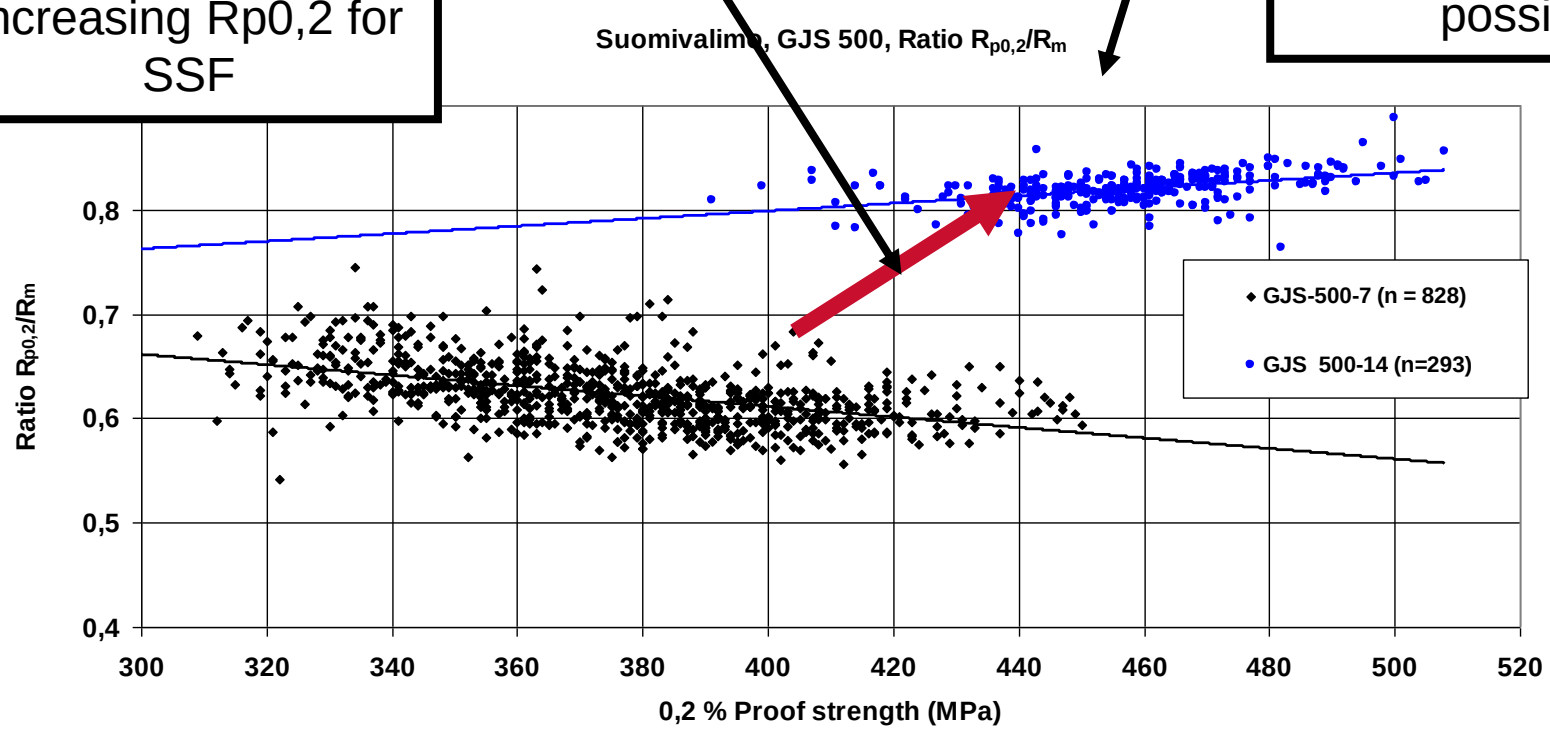
Ratio Rp0,2 / Rm for pearlitic and SSF cast iron

Ratio Rp0,2/Rm increases with increasing Rp0,2 for SSF

Design are based upon Rp0,2 instead of Rm, weight savings possible



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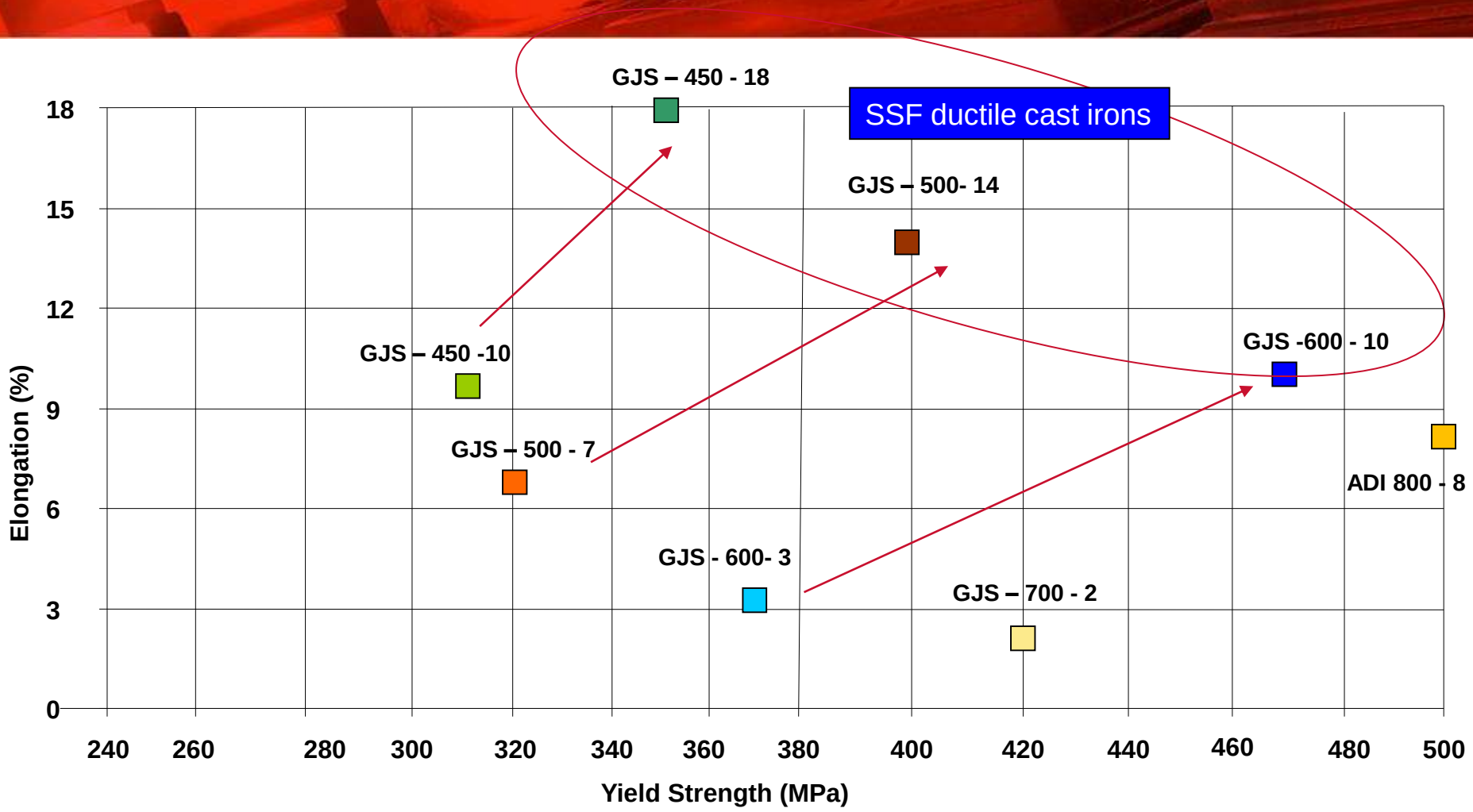
Elongation vs. Yield Strength

SFF Combination of high yield with high elongation



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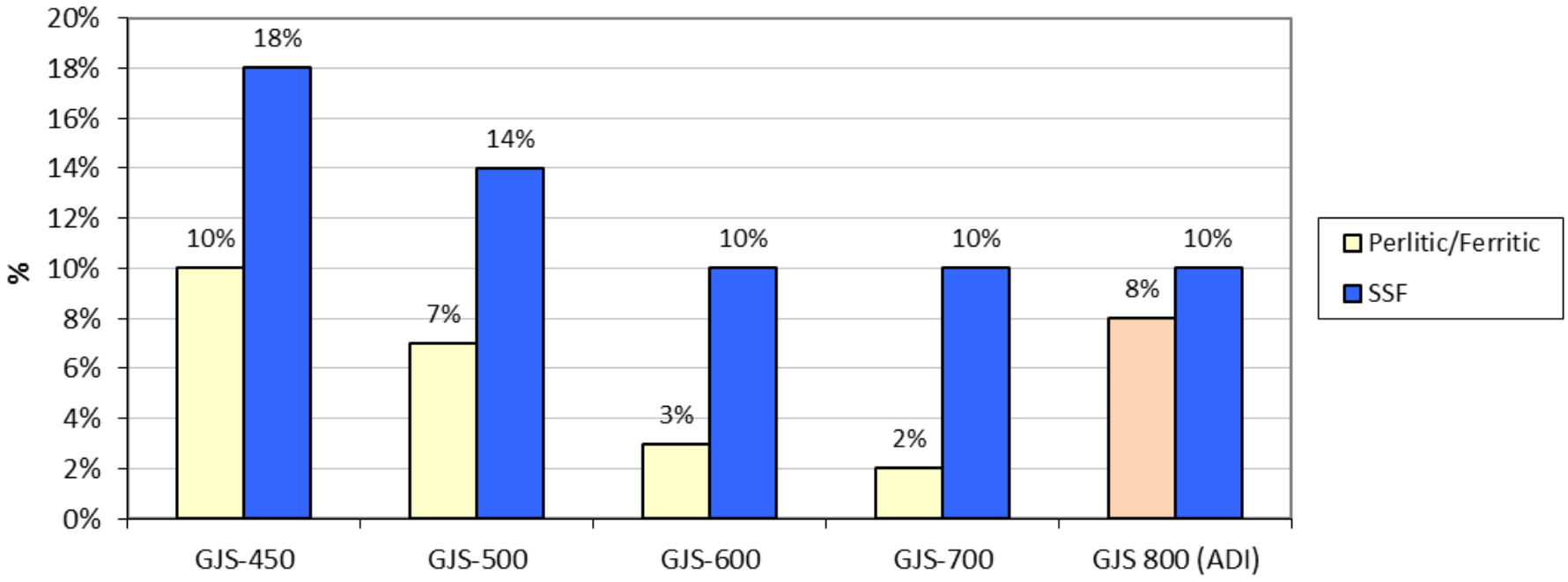
Elongation SSF vs Current Ductile Grades

SFF has up to 3 times higher elongation at equal strength levels



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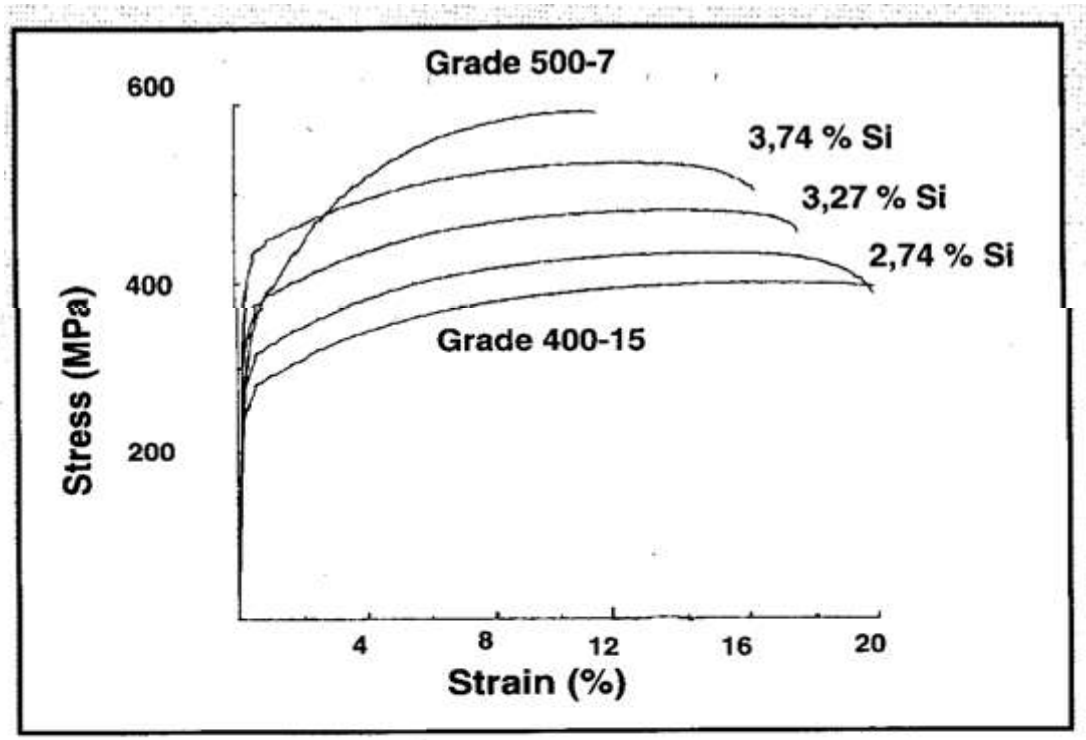
Tensile tests curves

Ferritic, SFF and ferritic/pearlitic grades



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

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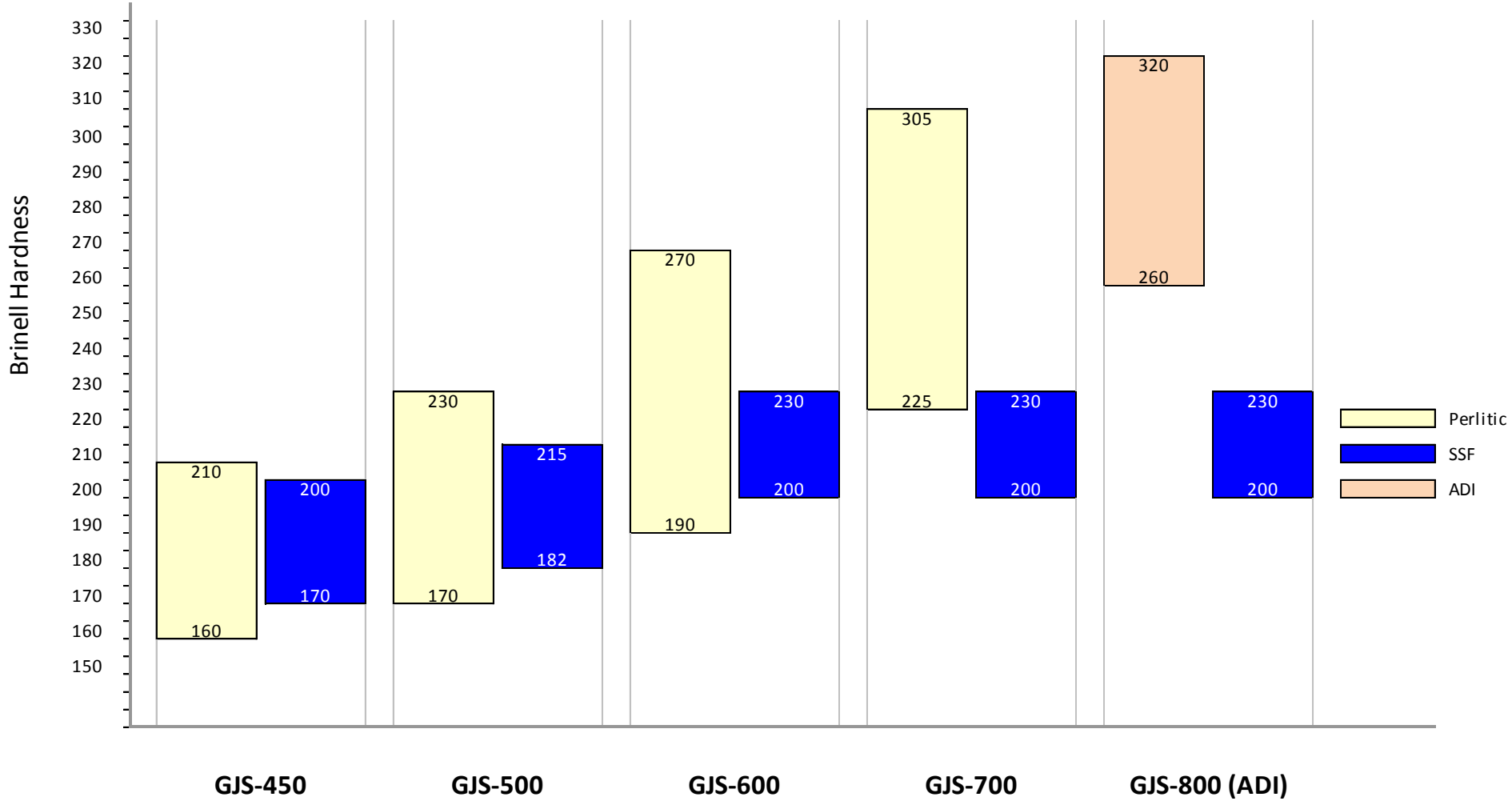
Brinell Hardness

SFF shows lower average hardness and less variation in hardness, piece to piece and within a piece



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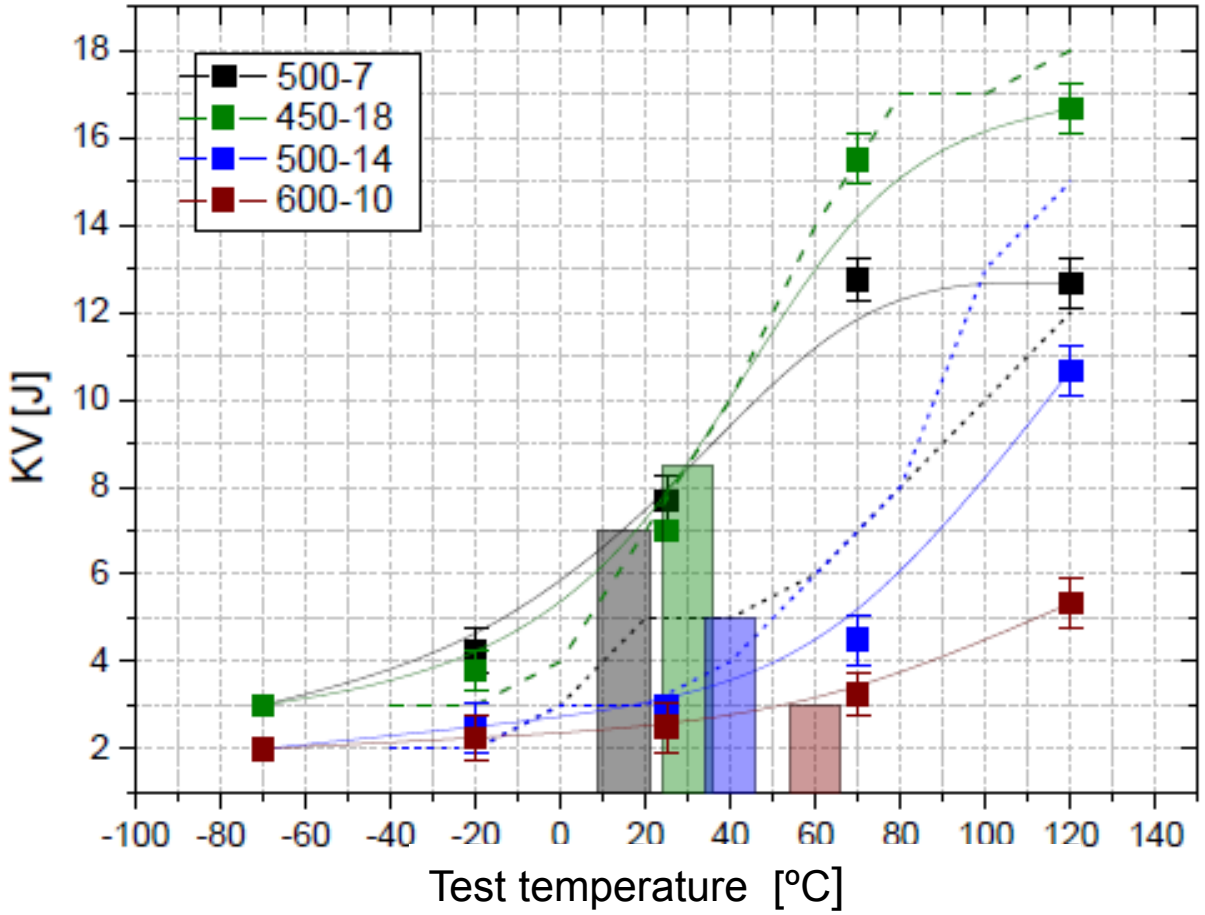
Comparison of Impact energy

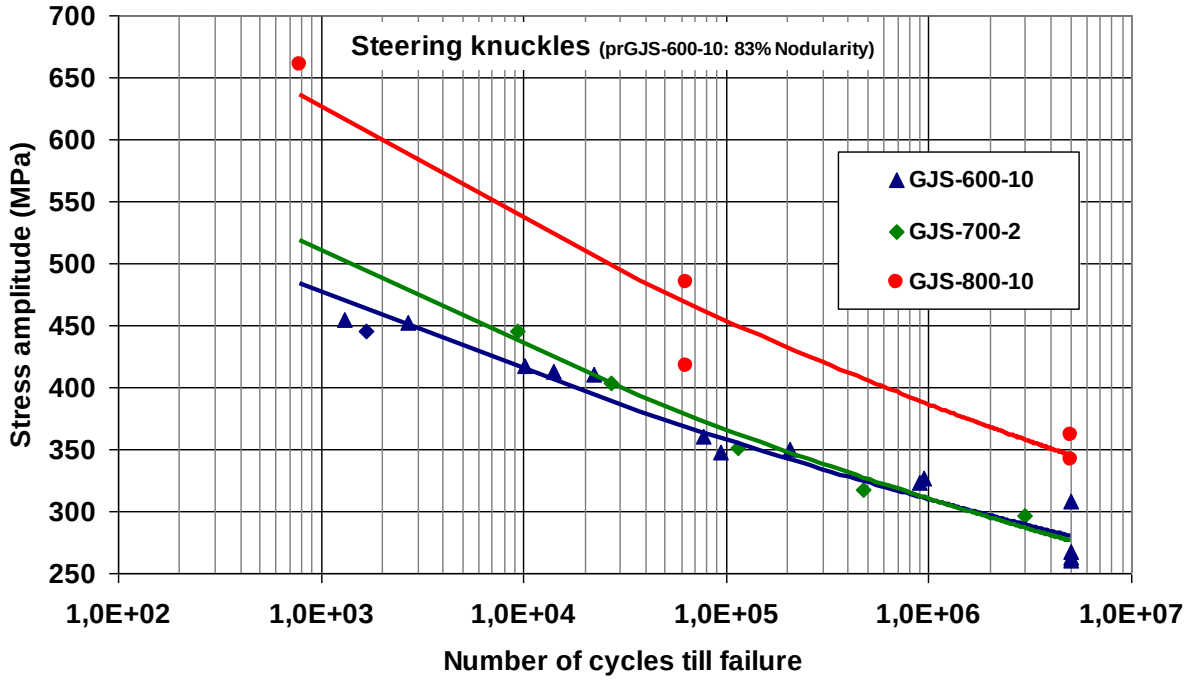


Charpy V-Impact test specimen

Source ÖGI Sirion projekt

Fatigue Strength

Rotating Bending, R= -1, Machined Surface



No difference in fatique limit for SSF compared to normal pearlitic cast iron, ADI has best fatique properties for machined specimens.

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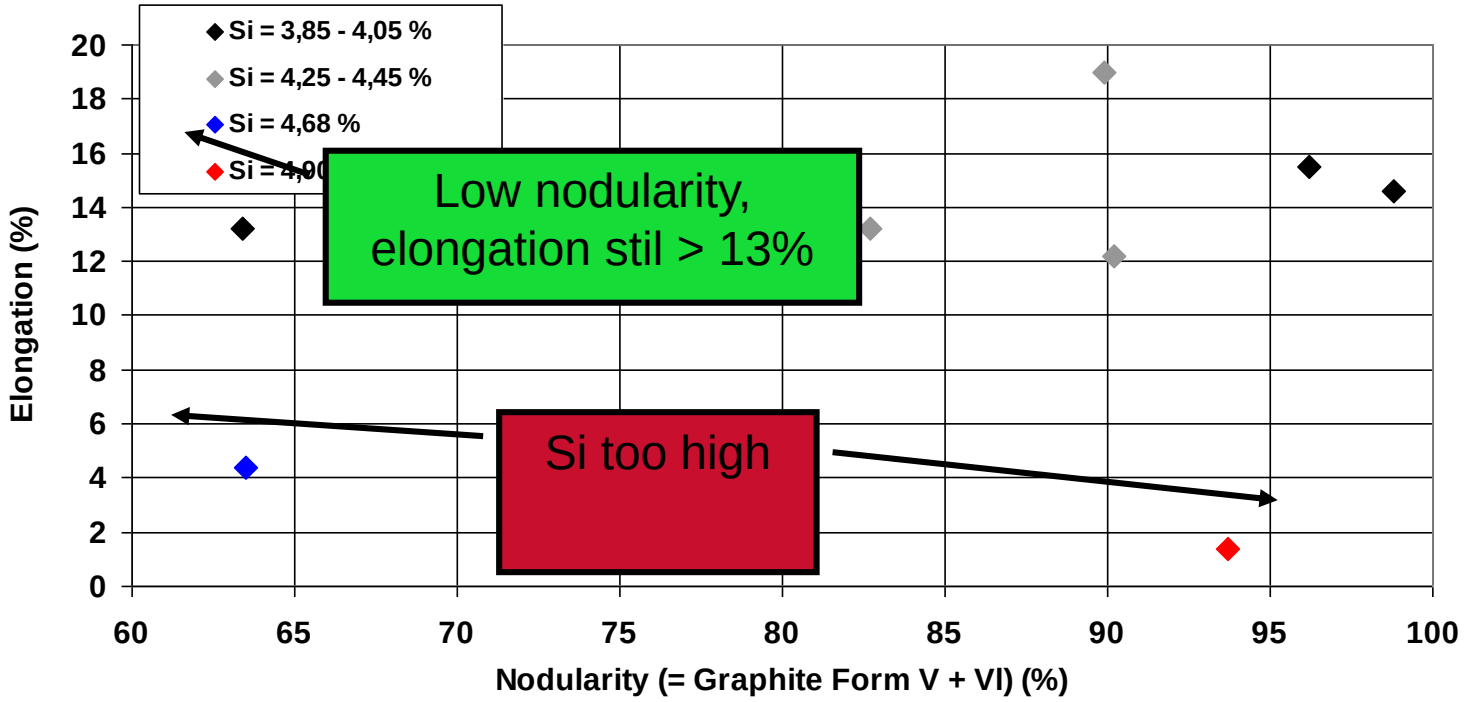
Influence of Nodularity on Elongation

Silicon % has higher influence as nodularity



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Mechanical properties

SSF vs EN 10293 Cast Steels

MATERIAL DESIGNATION	YIELD STRESS MPA	TENSILE STRENGTH	ELONGATION	HARDNESS	IMPACT ENERGY*
	$R_{p0,2}$ MPa min.	Rm MPa min.	A % min.	HBW	V-Notched at RT J
GJS 450-18	350	450	18	170 – 200	9
GE240 (+N)	240	450	17	MIN.~ 130	27
GJS 500-14	400	500	14	185 – 215	3
G20MN5 (+N)	300	480	20	MIN.~ 150	27
GJS 600-10	470	600	10	200 – 230	2 – 3
GE300 (+N)	300	600	15	MIN.~ 165	31
G42CRM04 (+QT)	600	800	12	-	31

* V-notched Charpy test samples, at room temperature. Source: EN 1563:2012 & EN 10293
N: Normalized, QT: Quenched & Tempered

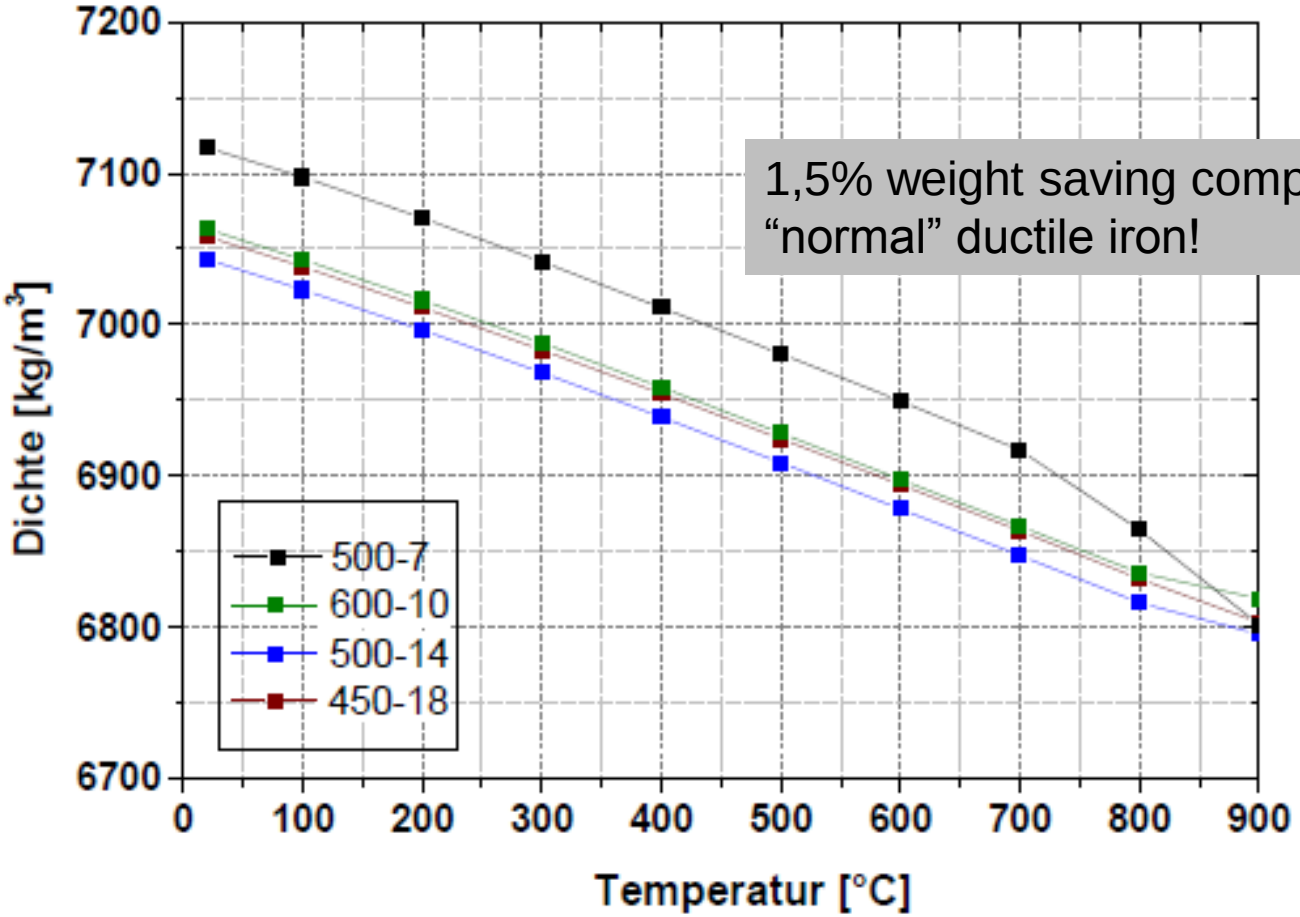
Average chemical analysis

SSF and Ferritic to Pearlitic Ductile Irons

MATERIAL DESIGNATION	C	Si	Mn	Cu
GJS 450-10	3.5 – 3.7	2.0 – 2.5	< 0.5	0.10 – 0.25
GJS 450-18	3.1 – 3.3	3.2	< 0.5	< 0.1
GJS 500-7	3.5 – 3.7	2.0 – 2.5	< 0.5	0.3 – 0.4
GJS 500-14	3.0 – 3.2	3.8	< 0.5	< 0.1
GJS 600-3	3.5 – 3.7	2.0 – 2.5	< 0.5	0.4 – 0.5
GJS 600-10	2.8 – 3.0	4.3	< 0.5	< 0.1
GJS 700-2	3.5 – 3.7	2.0 – 2.5	< 0.5	0.8 – 1.0

* 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

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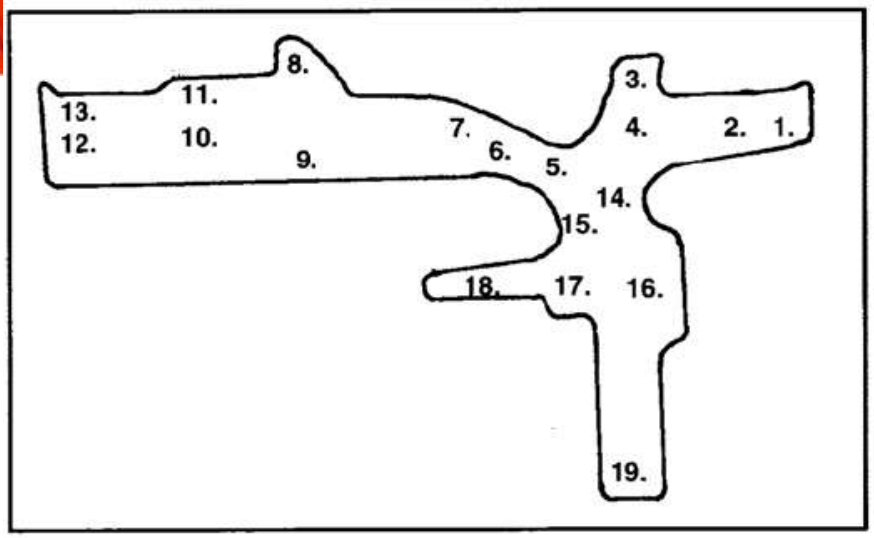
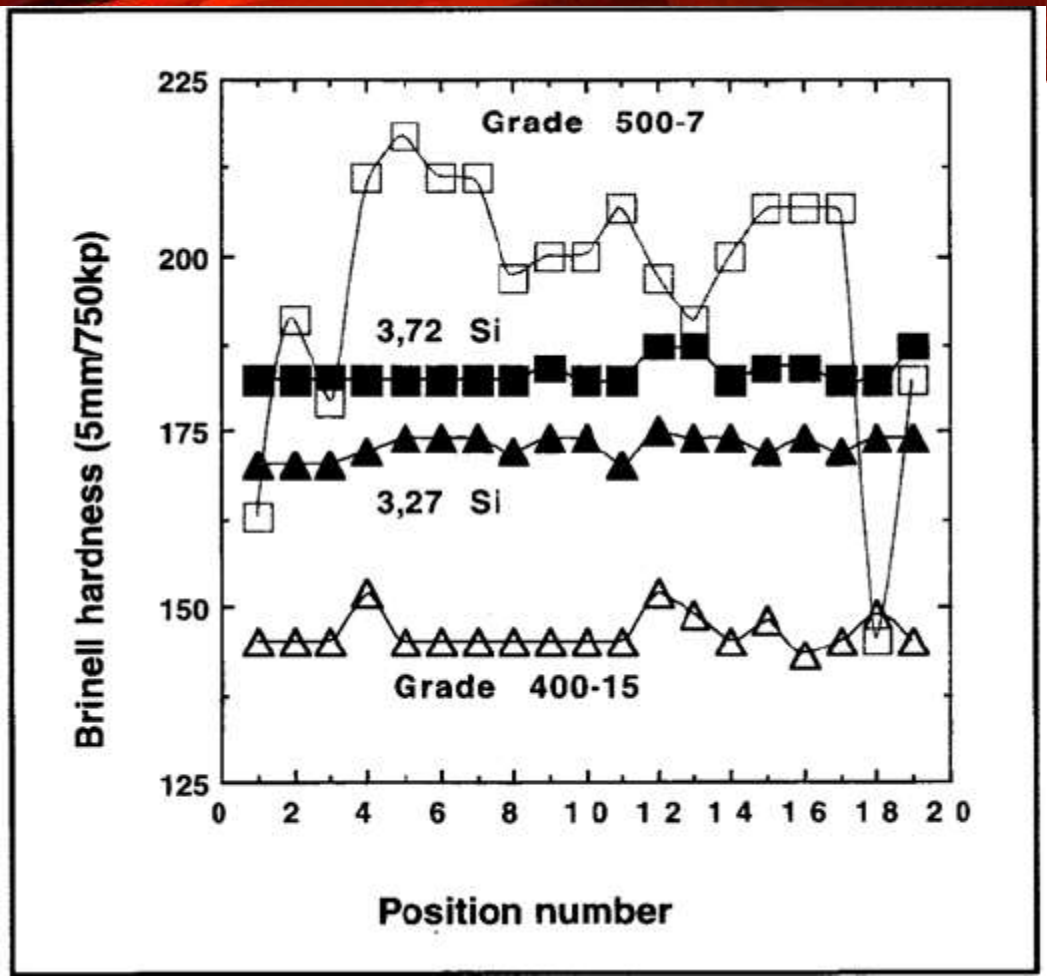
MACHİNABİLİTY

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.

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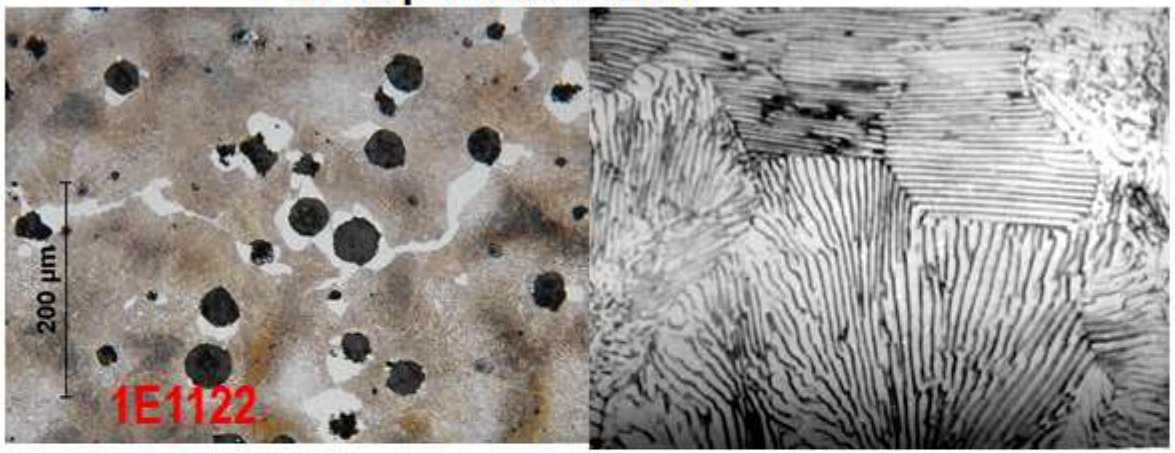
Difference in metal matrix

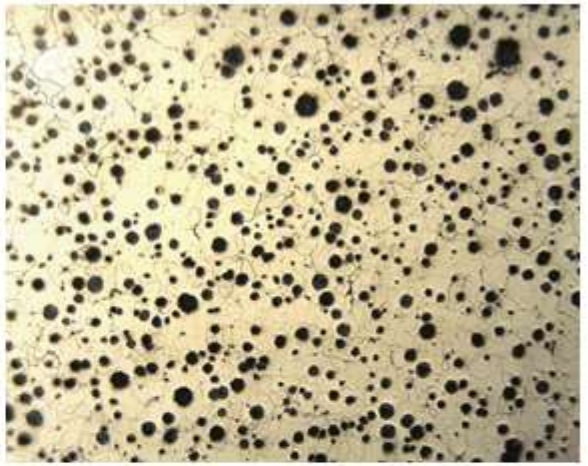
Ferrite/pearlite matrix



Pearlite is alpha ferrite + cementite (iron carbide)

Hard + relatively soft = Interrupted cuts

Ferrite matrix



Ferrite

Better machinability

- Hardness is lower and more consistent
- Pearlite/Ferrite acts as interrupted cut

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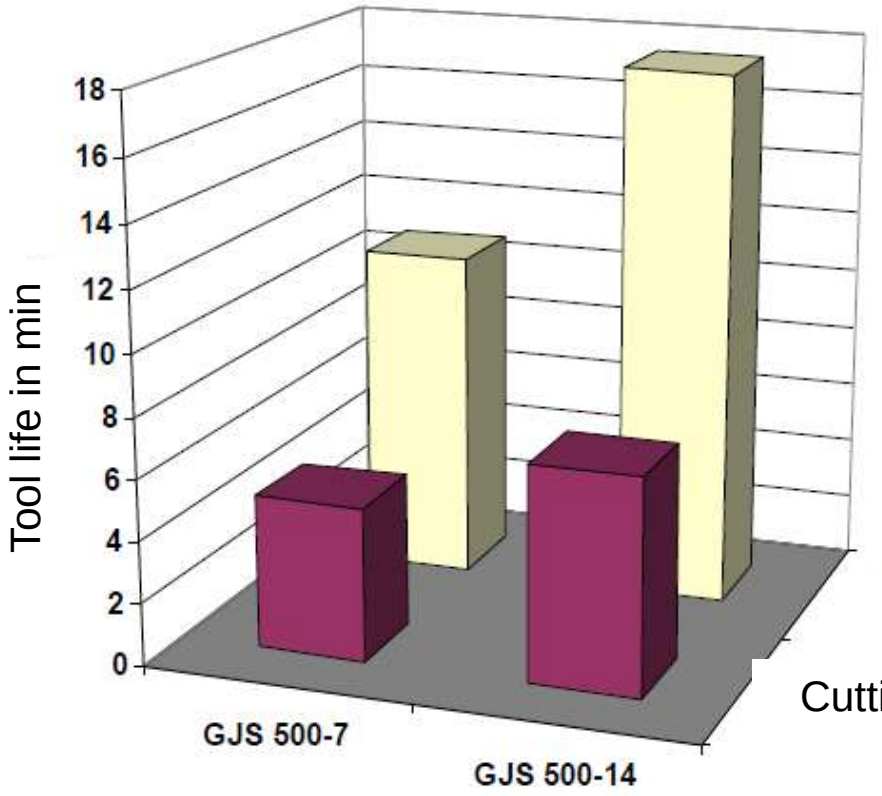
Tool Life

Tool life till 200 µm flange wear



Cutting speed 240m/min

Cutting speed 2320m/min

Source IfG Sirion projekt

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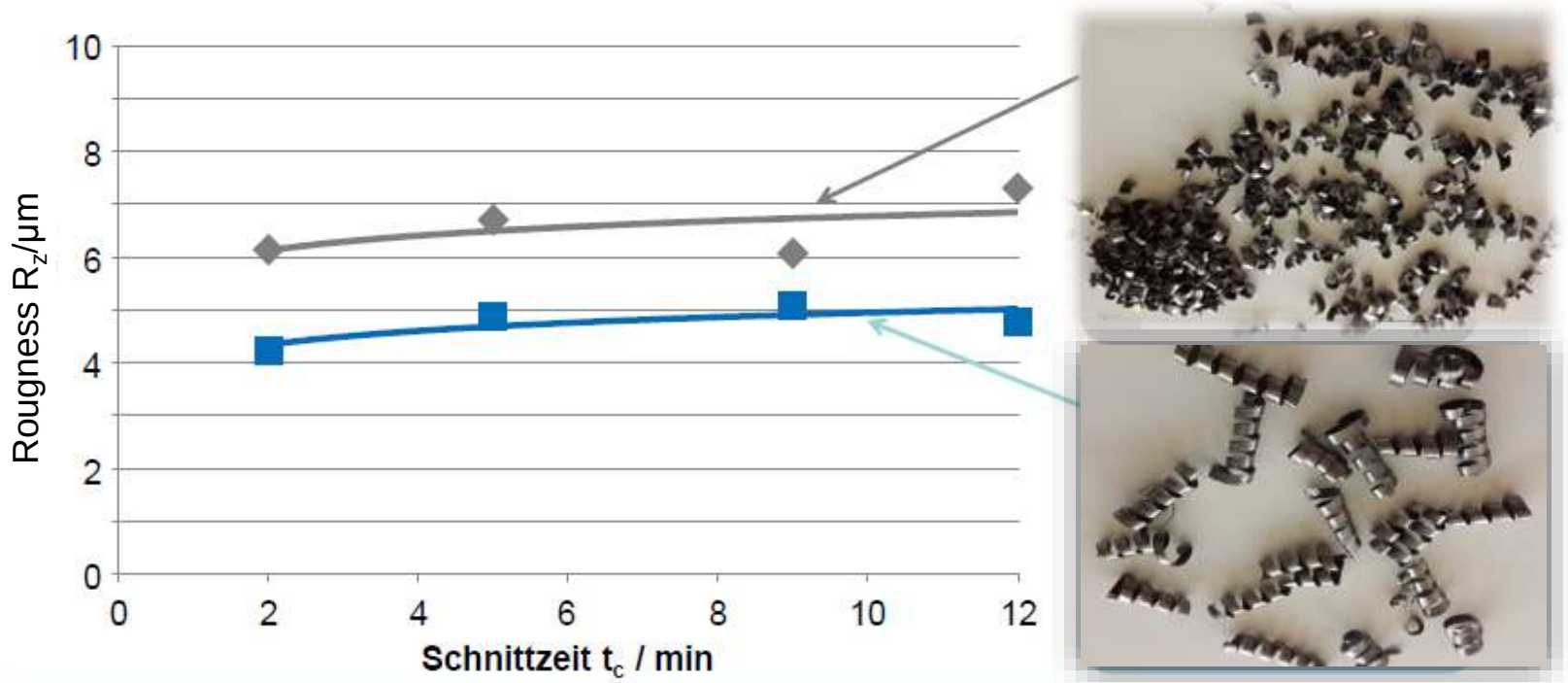
Surface roughness

Influence of metalic 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; κ_r = 95°; α_o = 6°; γ_{eff} = 4°; λ_s = -6°; HC-K05, Beschichtung: Ti(C,N)/Al_2O_3, CNMG 120408 FN

Source IfG Sirion projekt

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SOME EXAMPLES SSF DESİGNS

Agriculture: Rear Axle

Fabricated part converted into a casting, huge cost saving, increased loads possible

SSF grade: EN-GJS-600-10

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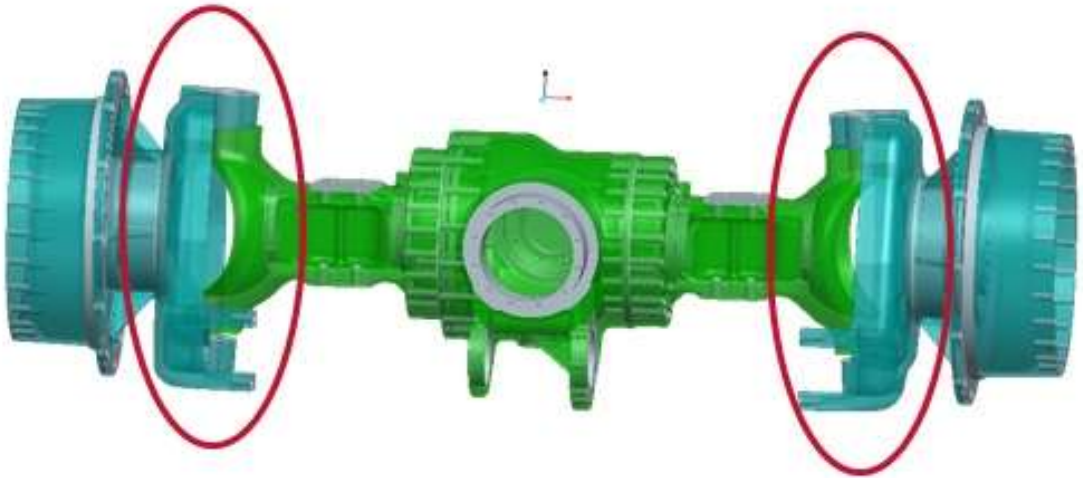
Agriculture: Steering knuckle



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 wallthickness
SSF Grade: EN-GJS-500-14

Agriculture: Support for exhaust pipe

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


EXPERIENCES

Experiences

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

Porosities in stub

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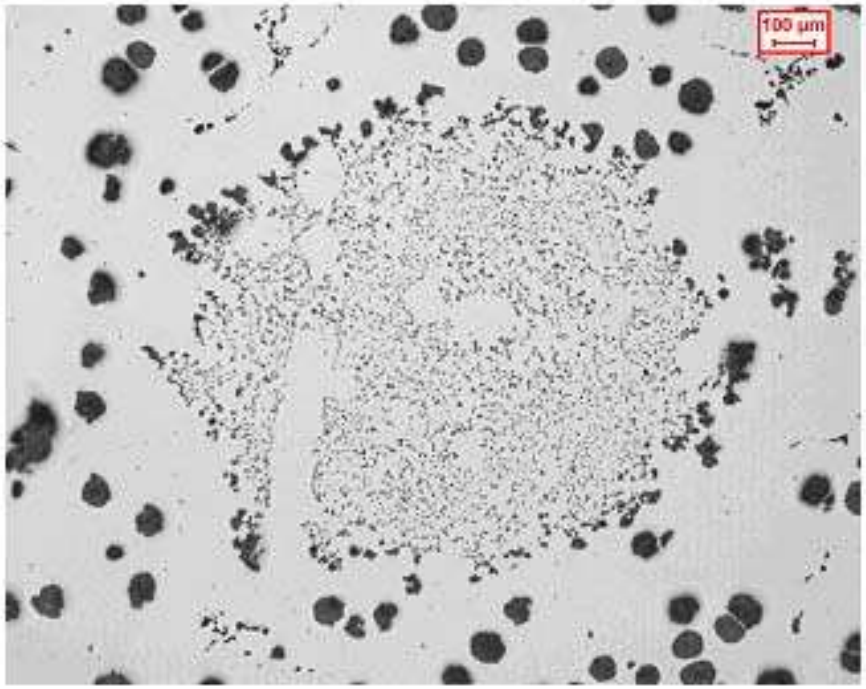
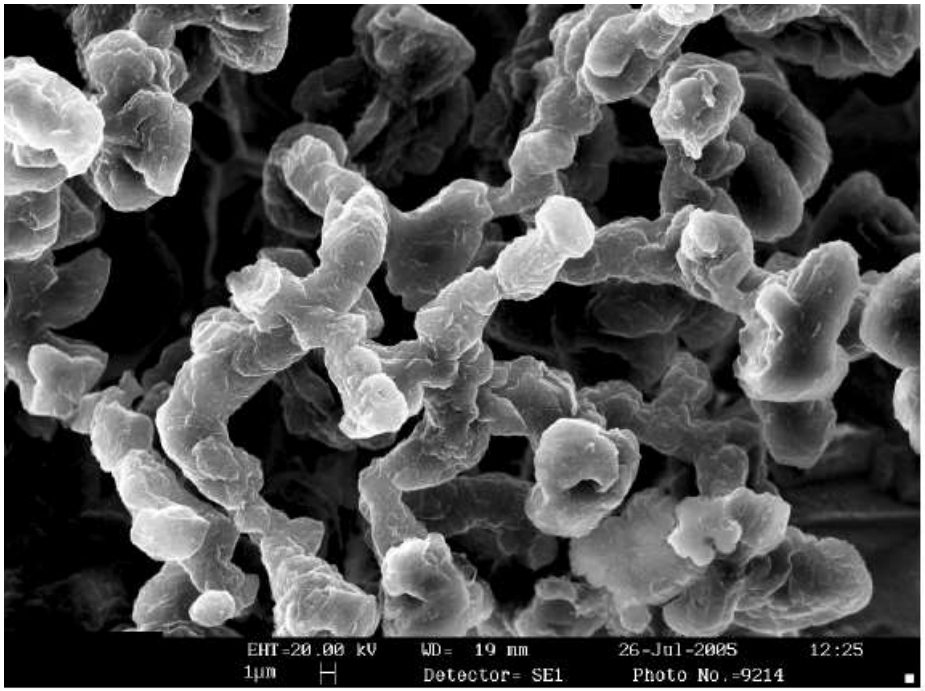
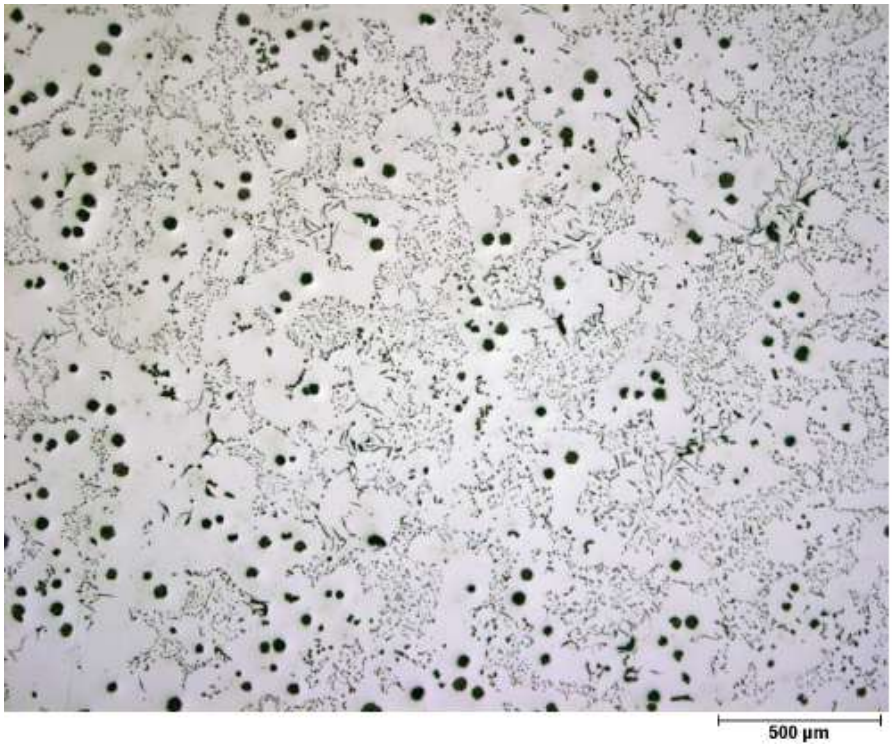
Chunky Graphite

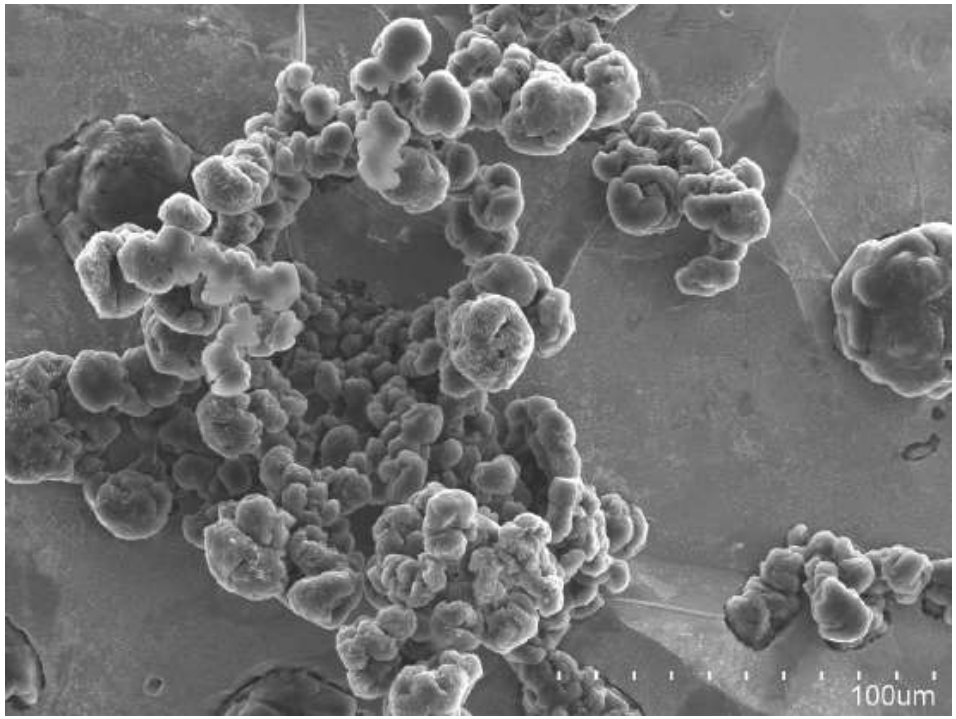




COMPONENTA
Casting Future Solutions

Deviation in graphite shape in SFF
chain of small nodules





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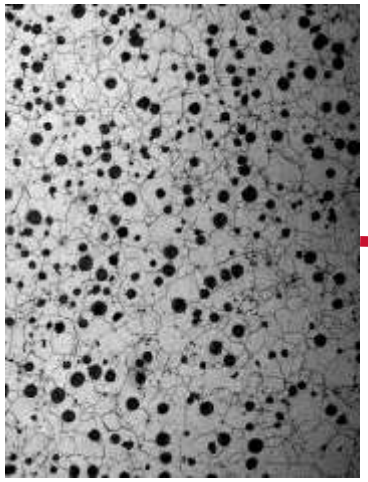
Casting Future Solutions

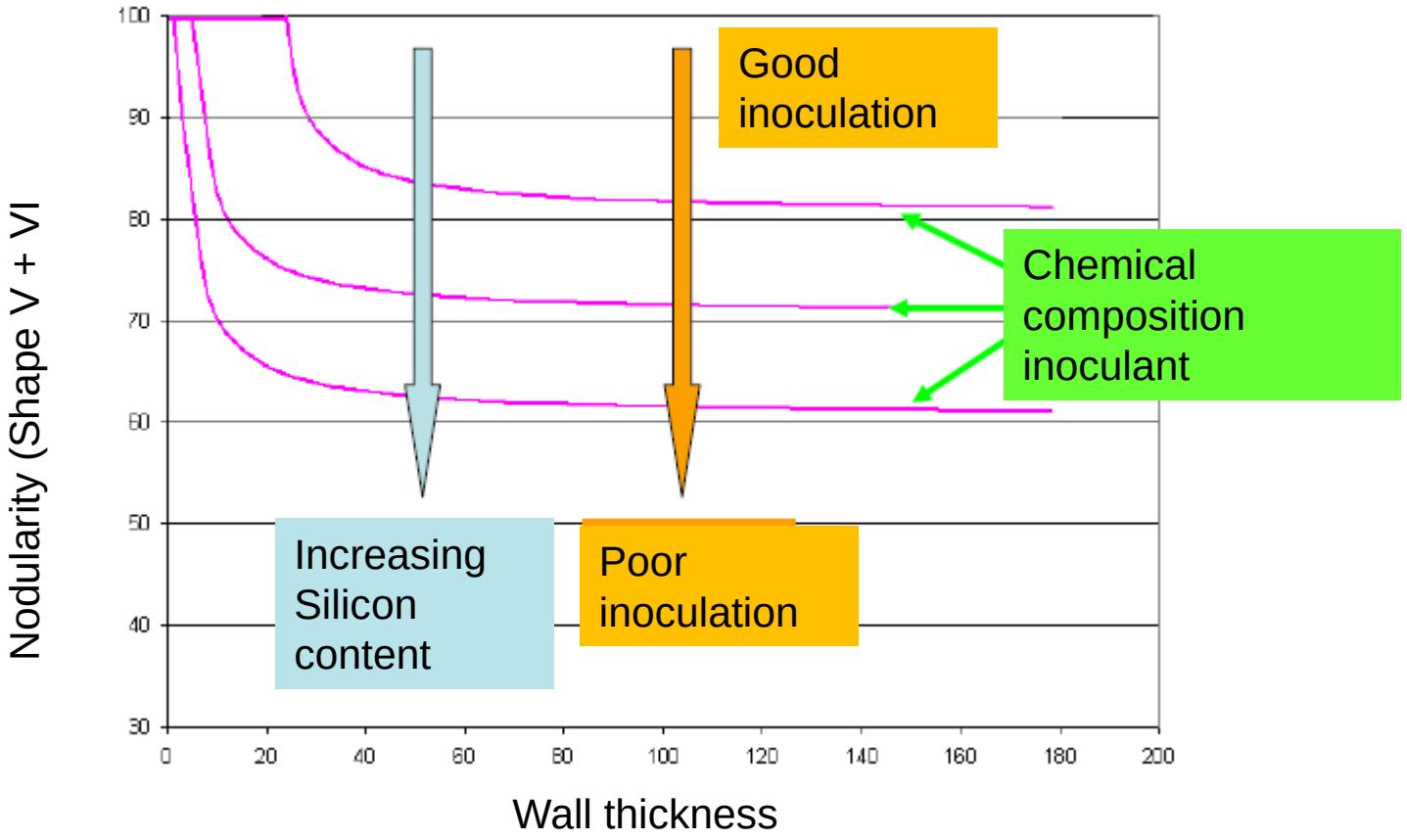
Chunky Graphite
Influenced by wall thickness

- Chunky graphite, partly due to too high Ce-con
- Measures :
  - Low Ce-containing FeSiMg
  - Addition of antimony
  - Reduced Si%

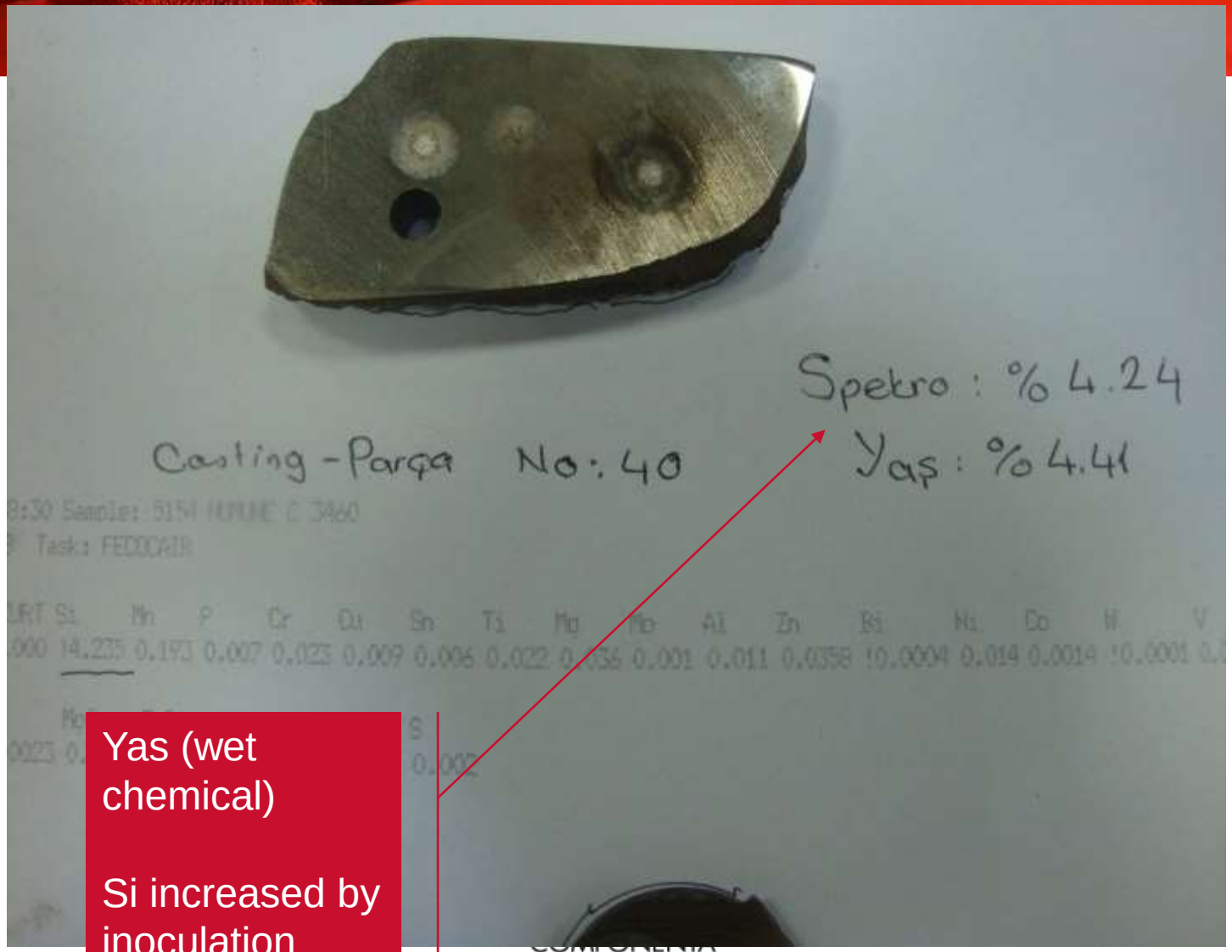


Breaking pont both parts

Influence of Inoculation on nodularity



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 !

COMPONENTA