Institut für Gießereitechnik, Düsseldorf

Cost effective heat treatment of 13Cr-4Ni martensitic stainless steel

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State of the art for the production of 13 Cr-Ni martensitic stainless steels

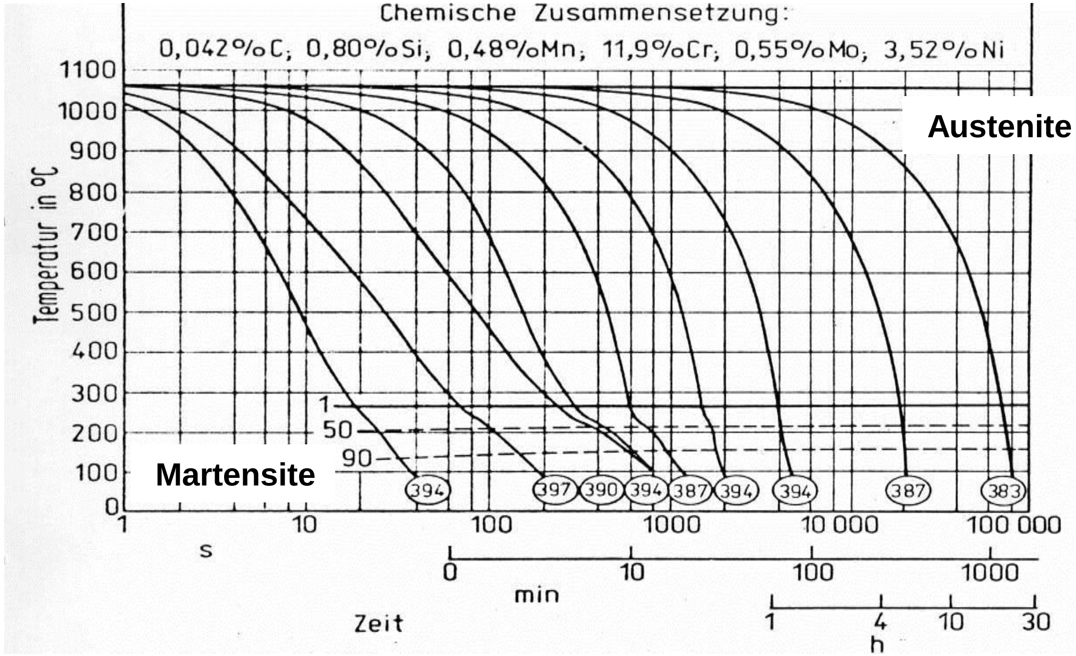
- **Development of this grade at the beginning of the 60th by +GF+**
- **Chromium alloyed steels with 12 – 17 % Cr are in the range between low alloyed heat treated steels and austenitic stainless steel.**
- **These alloys (e. g. 1.4317) exhibit a good corrosion resistance and strength and are well weldable.**
- **The melting takes place in induction furnaces (possible secondary metallurgy).**
- **Heat treatment with austenitization, quenching and tempering.**
- **Austenitization in air or under an inert protective gas.**
- **In the case of an air atmosphere a subsequent grinding is necessary.**

- **During the cooling down the microstructure of this steel is commonly trans-formed into martensite.**

- **The generation of pearlite starts due to the Ni content after a longer time.**

- **The time-temperature transformation diagramm shows the absent pearlite-area at medium cooling down times.**

- **In spite of this knowledge there is always the time and energy consuming austenitization step applicated.**



Maximium duration until room temperature: ≈ 25 h

Project target

- **Waiving of the austenitization as a traditional constituent of the hardening.**

- **Clarify if the absent dissolution of precipitations and homogenization of alloying elements (due to the absent austenitization) lead to lower mechanical properties.**

- **Determination of tolerable wall thicknesses and suitable chemical compositions to achive the demanded mechanical properties.**

Non-return valve 1.4317 (ACI Industriearmaturen GmbH)

Pump rotor disc 1.4317 (Innocast)

Approach to the project

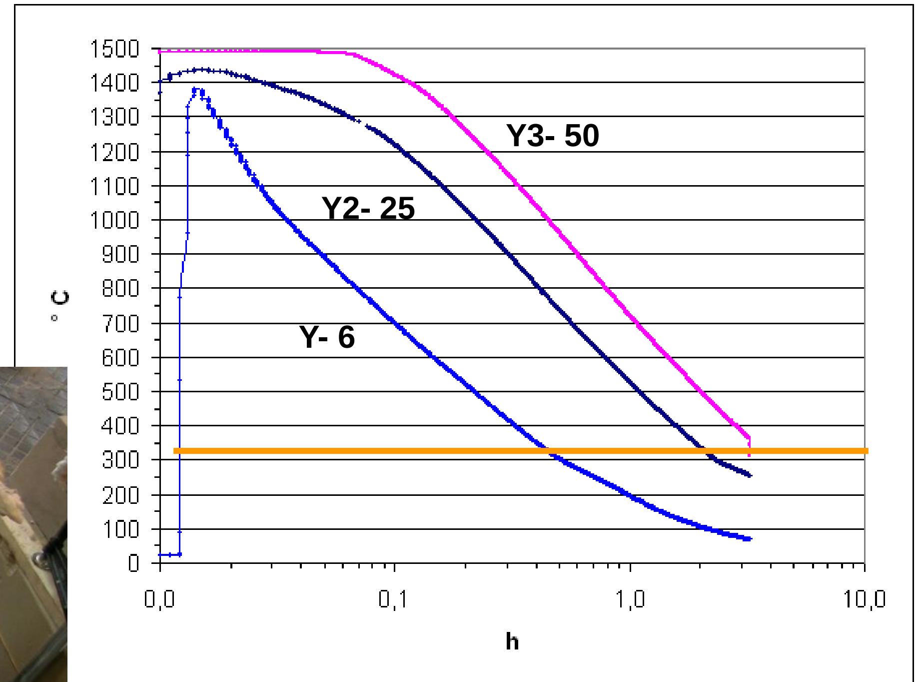
- **Melting of alloys with several chemical compositions inside the standard specification.**

- **Realization of different C, Si, Ni and Al contents.**

C	Si	Mn	P	S	Cr	Ni	Al	N	O
wt.%								ppm	
< 0,06	< 1	< 1	< 0,035	< 0,025	12-13,5	3,5-5			
0,11	0,57	0,26	0,015	0,006	11,9	4,72	0,009	158	213
0,07	0,33	0,30	0,015	0,005	12,0	3,72	0,009	207	224
0,04	0,59	0,24	0,014	0,007	12,0	3,95	0,050	136	205
0,04	0,25	0,18	0,010	0,008	12,8	4,20	0,029	126	272
0,05	0,68	0,66	0,013	0,007	11,9	4,65	0,006	n.b.	n.b.
0,03	0,27	0,25	0,009	0,009	12,0	4,45	0,023	n.b.	n.b.
0,04	0,34	0,23	0,010	0,005	11,7	4,39	0,006	182	342

- Casting of test pieces with different wall thicknesses (Y-shaped samples with 6, 25 and 50 mm).

- Recording of the different cooling curves inside the samples.



Maximium duration until room temperature: ≈ 10 h
Ms temperature: ≈ 4 h

- **Realization of the two different heat treatments**

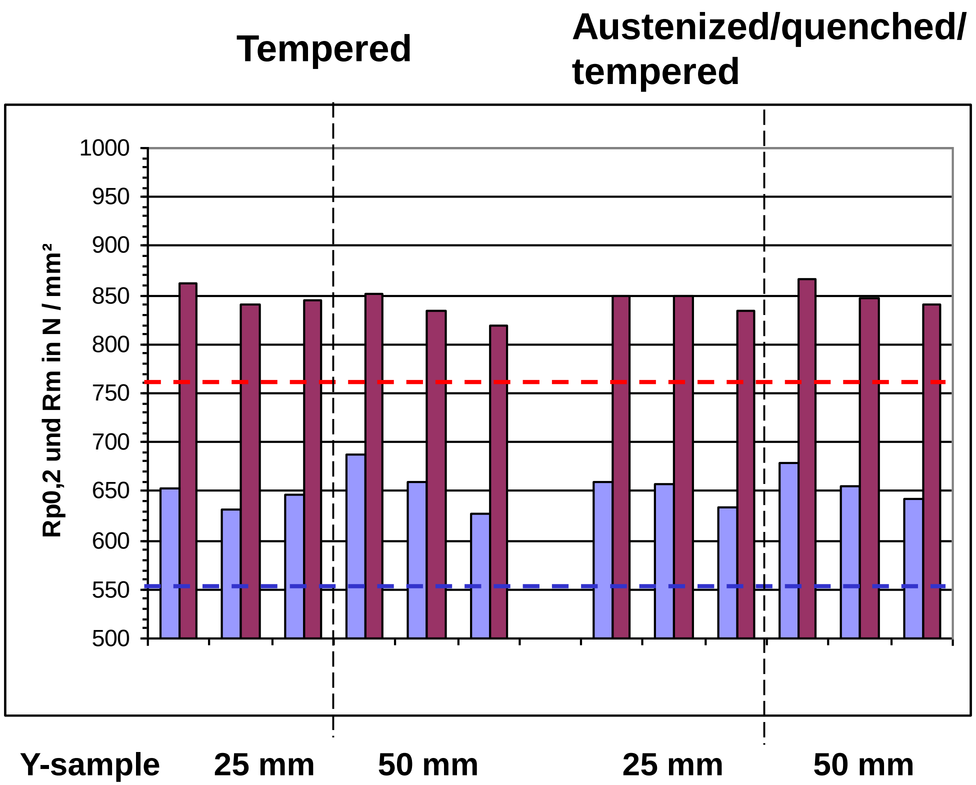
- **Examples of mechanical properties:**

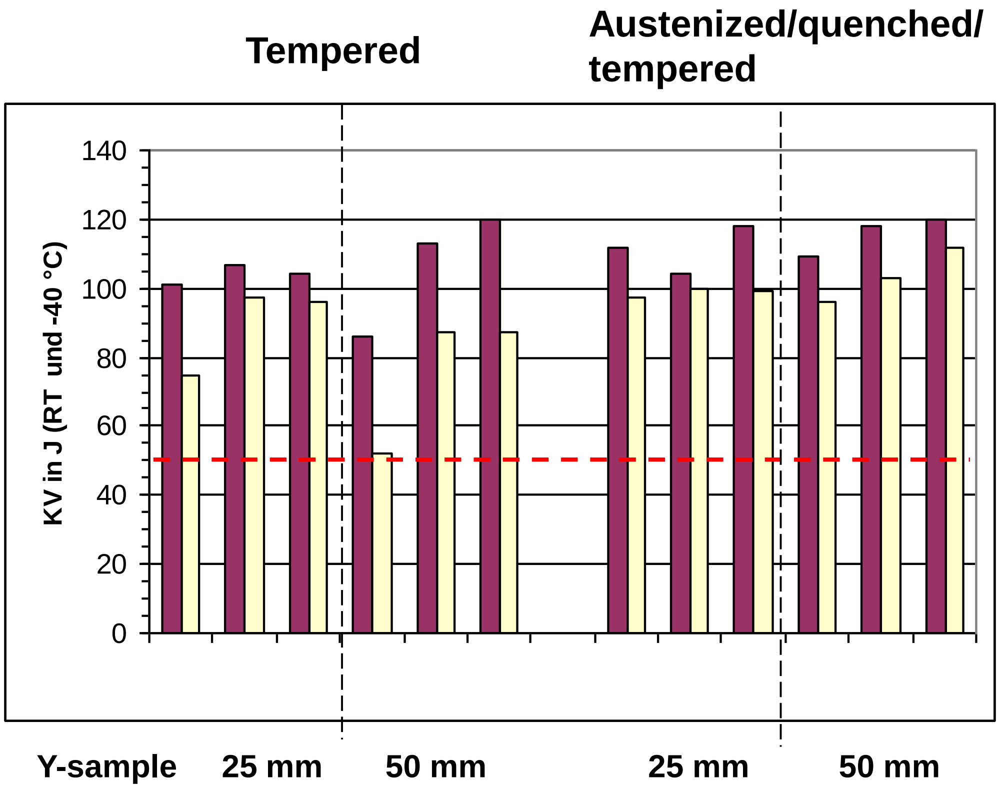
Y-samples	Heat treatment	Proof-strength	Tensile strength	Elonga-tion	Youngs-modulus	Impact strength	
		N/mm²	N/mm²	%	dN/mm²	RT [J]	-40°C [J]
25 mm	**Tempering**	628	829	15,4	204,2	103	88
	A/Q/T	616	825	16,3	204,9	113	104
50 mm	**Tempering**	623	835	14,5	200,4	100	80
	A/Q/T	604	824	16,8	203.5	115	108

DIN EN 10293 1.4317	**>550**	**760- 960**	**> 15**	**> 50**

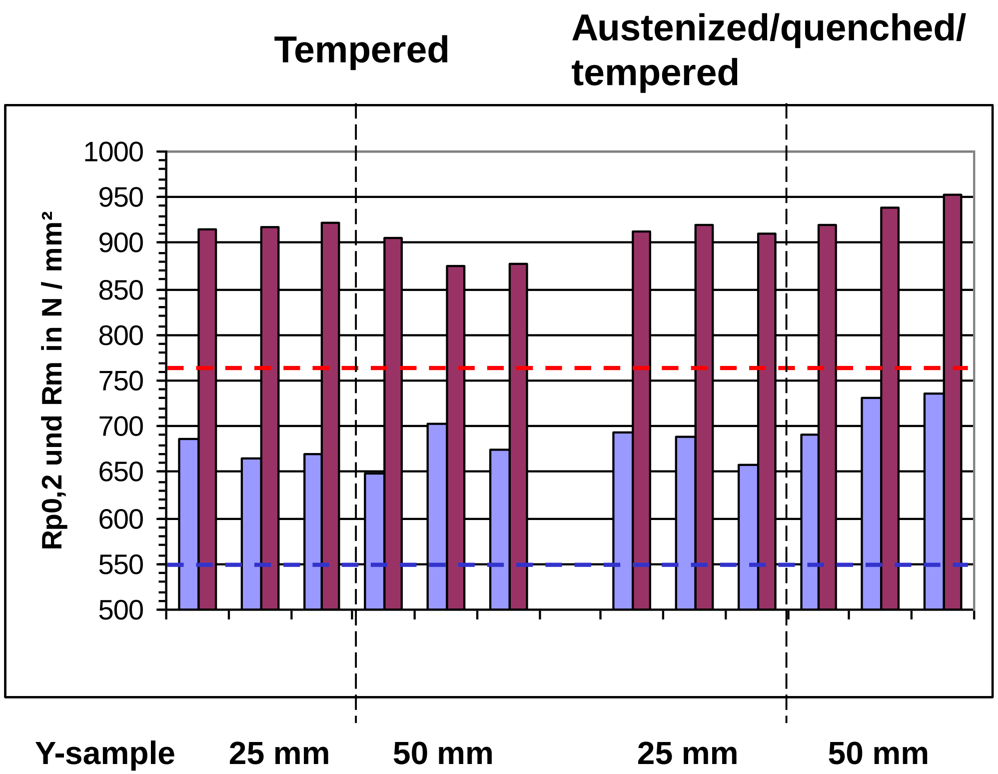
Results of the project

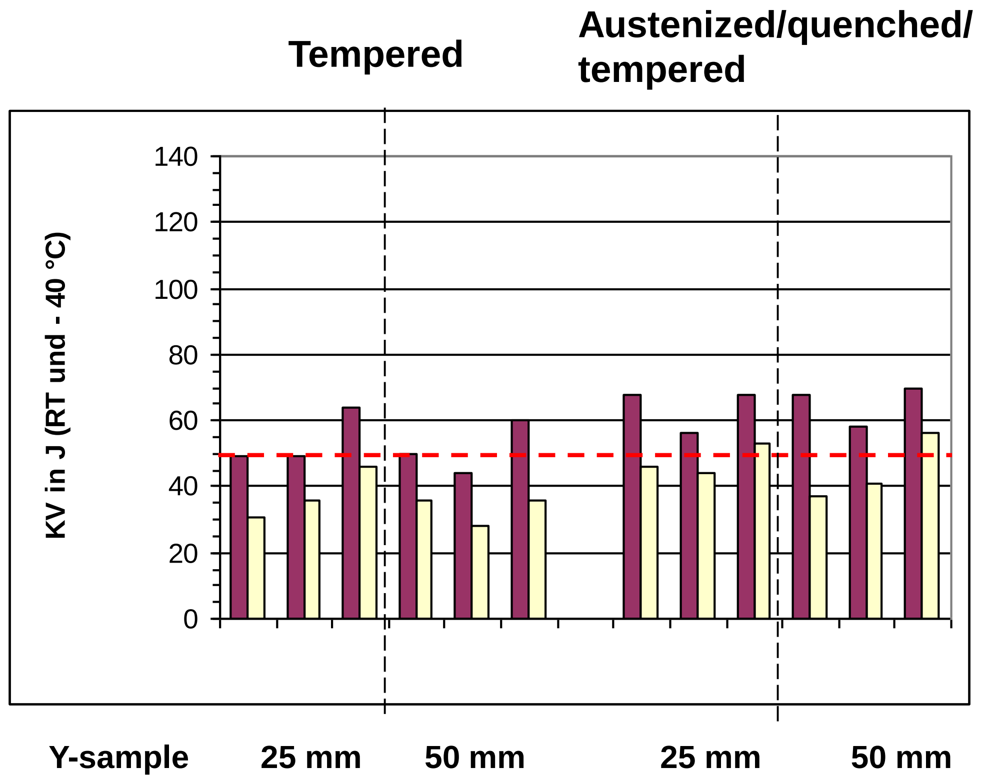
Mechanical properties of alloy: 0,07% C; 0,33% Si; 0,3% Mn; 12,0 % Cr; 3,7 % Ni





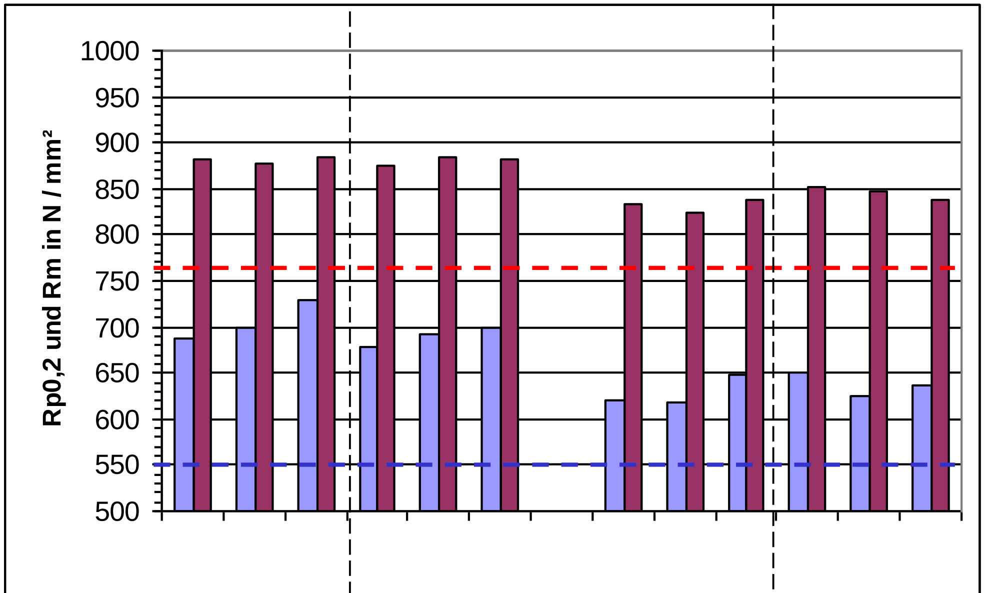
Mechanical properties of alloy: 0,11% C; 0,57% Si; 0,26% Mn; 11,9 % Cr; 4,7 % Ni

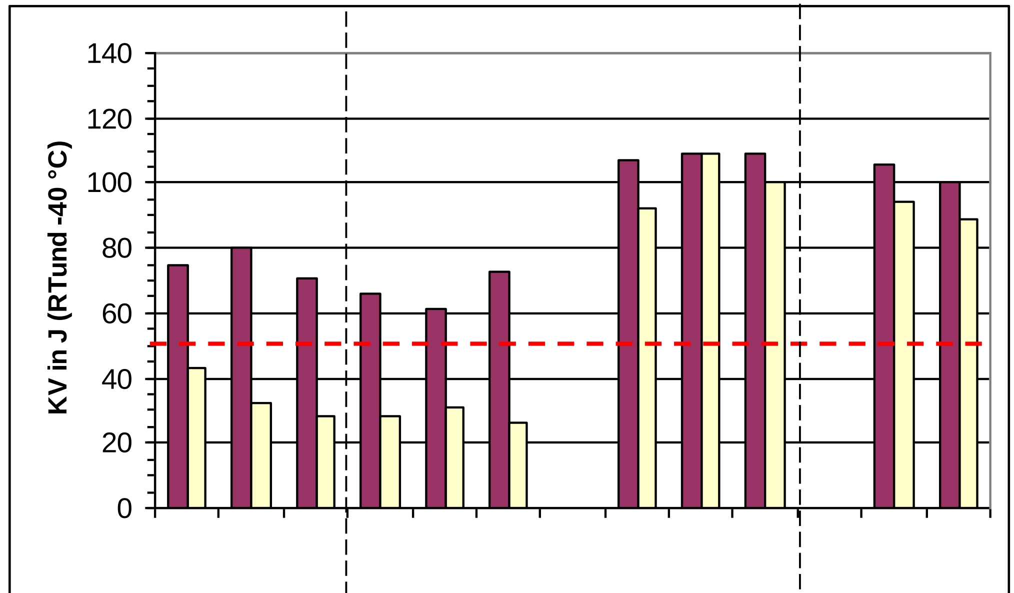




The higher carbon content leads to a lower ductility / impact strength!

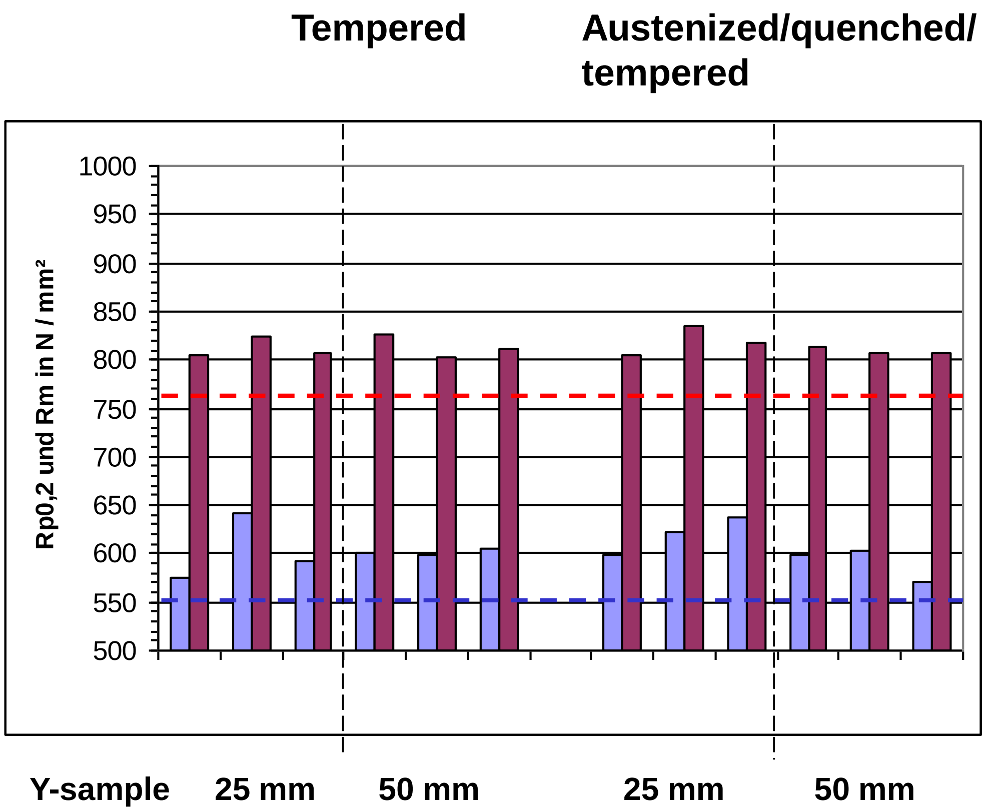
Mechanical properties of alloy: 0,05% C; 0,68% Si; 0,66% Mn; 11,9 % Cr; 4,65 % Ni

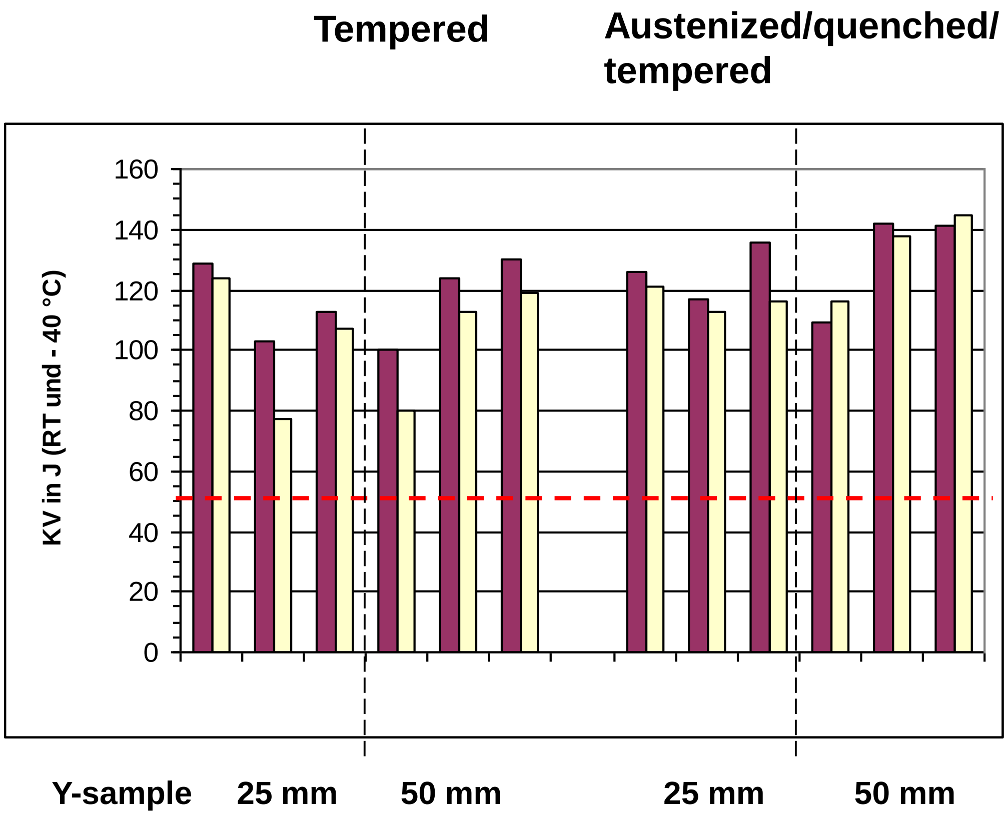




With a higher Si content the ductility is also lowered and the difference in the ductility between the two heat treatments is growing.

Mechanical properties of alloy: 0,04% C; 0,25% Si; 0,18% Mn; 12,8 % Cr; 4,20 % Ni





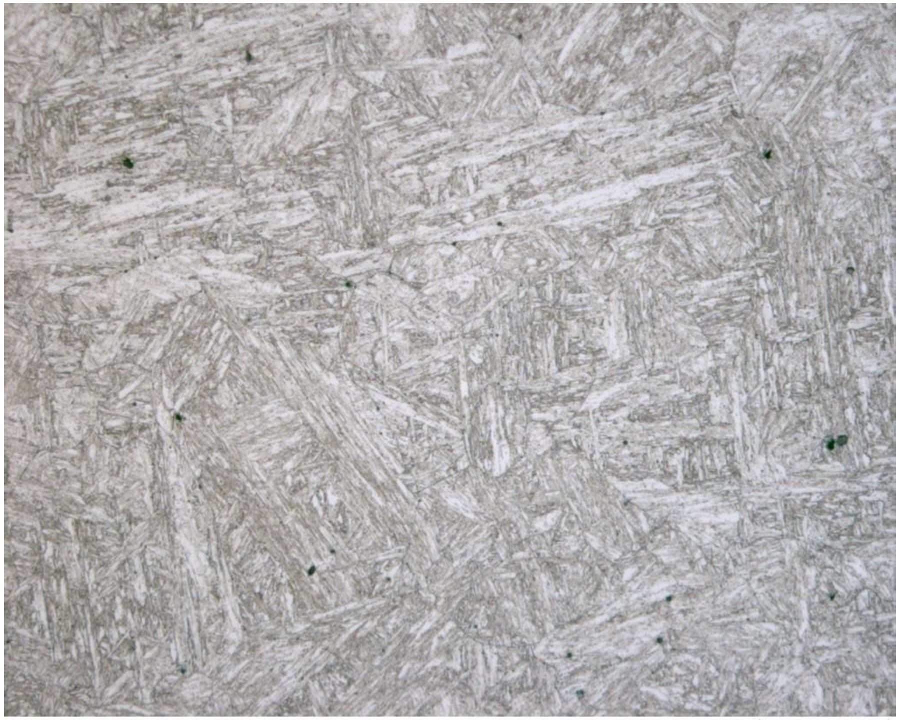
Due to the lower Si content the strength decreases a little and the impact strength rises (and the differences are smaller)!

Etched microstructure of alloy: 0,05% C; 0,68% Si; 0,66% Mn; 11,9 % Cr; 4,65 % Ni

Tempered

100 µm

Austenized/ quenched/ tempered

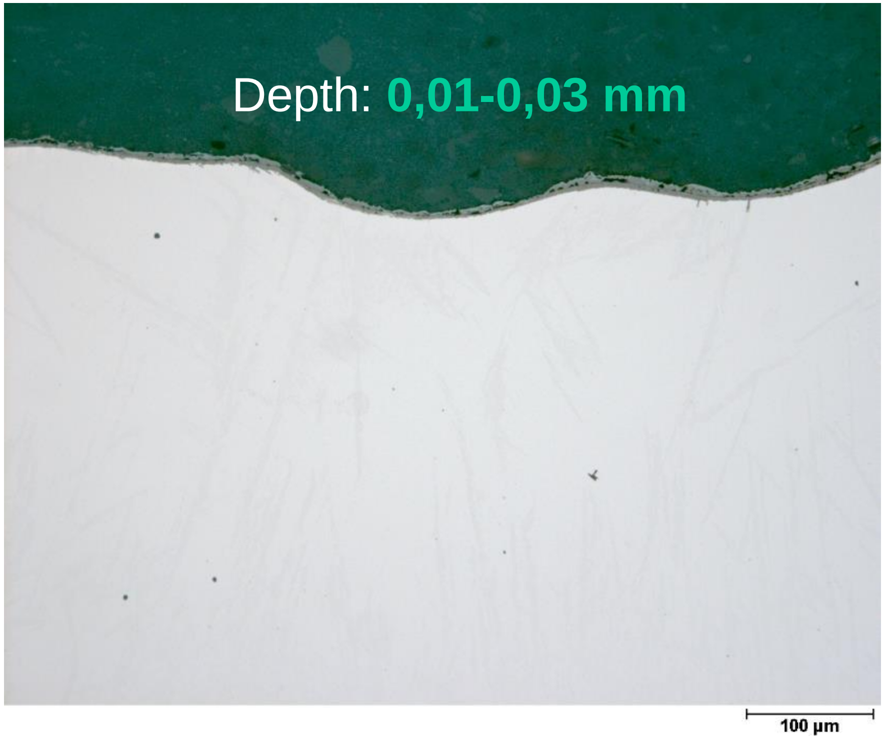


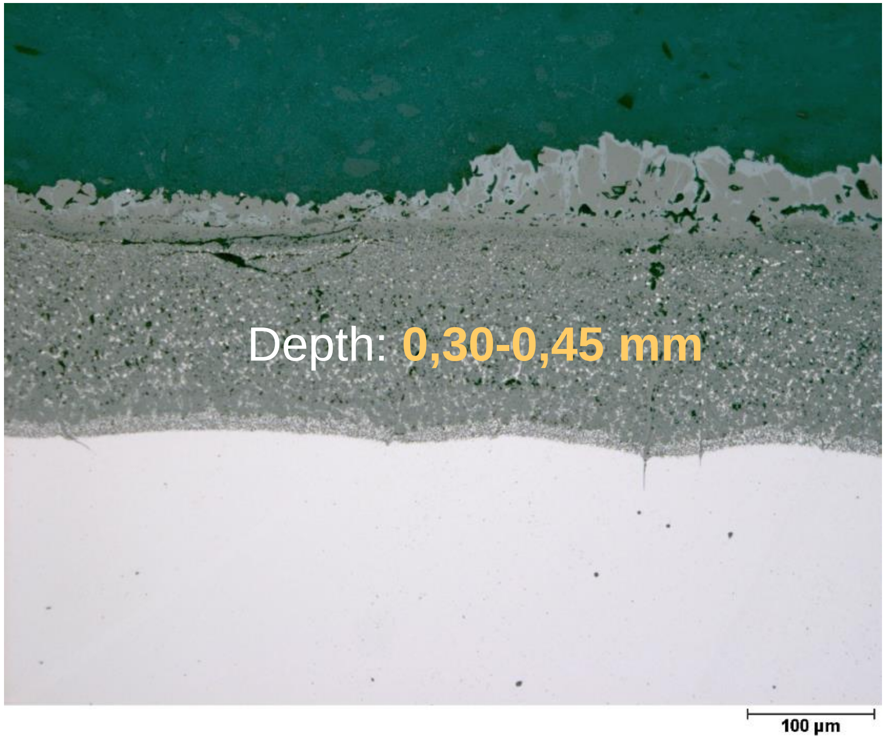
100 µm

Y2-sample 25 mm

Tempered martensite. No differences in the microstructures

Comparison of the scale layers at the different heat treated alloys

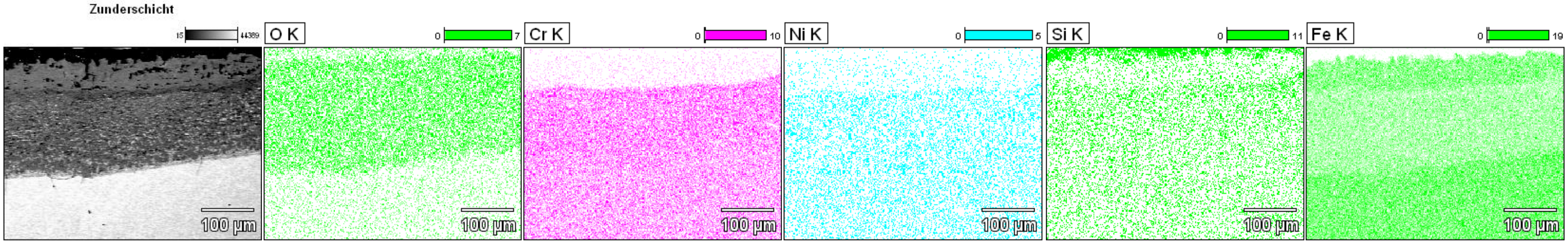




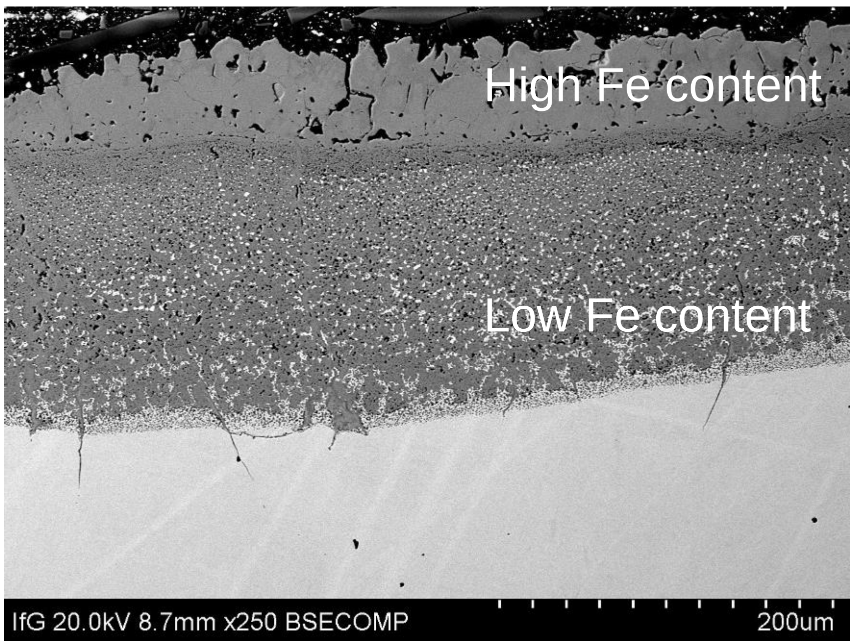
Heat treatment:

Tempered

Austenized/quenched/ tempered



distribution
Oxygen **Chromium** Nickel Silicon Iron



- **Un- and low alloyed steels generate a layer of FeO, Fe_3O_4 and Fe_2O_3.**

- **These layers are easy to remove by blast cleaning.**

- **The Cr alloyed steels generate a Cr enriched layer- which is not removable by blast cleaning.**

Consideration of cost effectiveness

	Cost distribution [%]	
	Complete heat treatment	Only tempering
Material (metal)	28,2	28,2
Material (mould sand, cores)	5,4	5,4
Labour mould and core making	13,9	13,9
Tempering	1,7	1,7
Austenitization/Quenching	2,4	-
Fettling (by hand, blasting)	10,5	5,3
Flame cutting	11,8	11,8
machining	15,9	15,9
Non-destructive testing	10,2	10,2
Total	100,0	92,3

Summarization

- **The mechanical properties of the 13Cr-4Ni martensitic stainless steel can be achieved without the conventional heat treatment.**

- **This observation is valid up to a wall thickness of about 50 mm currently.**

- **The mechanical properties demanded in the standard and which are realized only by tempering are best reachable by slightly lowered C and Si contents.**

- **The modified heat treatment lowers the scale thickness on the surface clearly.**

- **This leads to a significant cost saving of about 8 % and a shortening of delivery times.**

- **There are further investigations necessary regarding the enlargement of this procedure to higher wall thicknesses.**