2008 TMS Annual Meeting & Exhibition
Characterization of Minerals, Metals and Materials

Effects of Microalloying on an Innovative Quenched and Tempered Plastic Mold Steel

Donato Firrao & al. – Politecnico di Torino
Maria Rosa Pinasco & al. – Università di Genova
Giuseppe Silva & al. – Politecnico di Milano, Polo Regionale di Lecco
Roberto Montanari & al. – Università degli studi di Roma Tor Vergata
Andrea Ghidini – Lucchini Sidermeccanica S.p.A.

Speaker: Gerosa Riccardo - Politecnico di Milano, Polo Regionale di Lecco

MAIN AIMS

- Two innovative steels for plastic molds were considered and many different investigations such as hardenability, tensile, impact, fracture toughness and rotating bending fatigue tests were performed; the prior austenitic grain growth was investigated too.

- Mereover some weldability tests were performed on one of the new steels and on the most common plastic molds steel, i.e. the ISO 1.2738.

MATERIALS (1)

- One of the most common and studied steels for plastic molds is the ISO 1.2738 and so in this work it will be considered as the reference steel. All the ISO 1.2738 data refer to a previous experimental investigation performed by the same authors.

C%	Cr%	Mn%	Ni%	Mo%	Si%	S%	P%
0.35 0.45	1.80 2.10	1.30 1.60	0.90 1.20	0.15 0.25	0.20 0.40	<0.03	<0.03

- New generation steels were proposed aiming to preserve the good mechanical properties of ISO 1.2738 increasing the fracture toughness and the weldability.

	C	Mn	Cr	Ni	Mo	Si	V	Nb	Zr	B
Steel A	0.2 0.3	1.3 1.6	1.2 1.5	0.9 1.2	0.4 0.7	0.1 0.4	0.10 0.14	0.01 0.03	0.02 0.04	0.001 0.002
Steel B	0.2 0.3	1.3 1.6	1.2 1.5	0.9 1.2	0.4 0.7	0.1 0.4	0.10 0.14	/ /	/ /	/ /

MATERIALS (2)

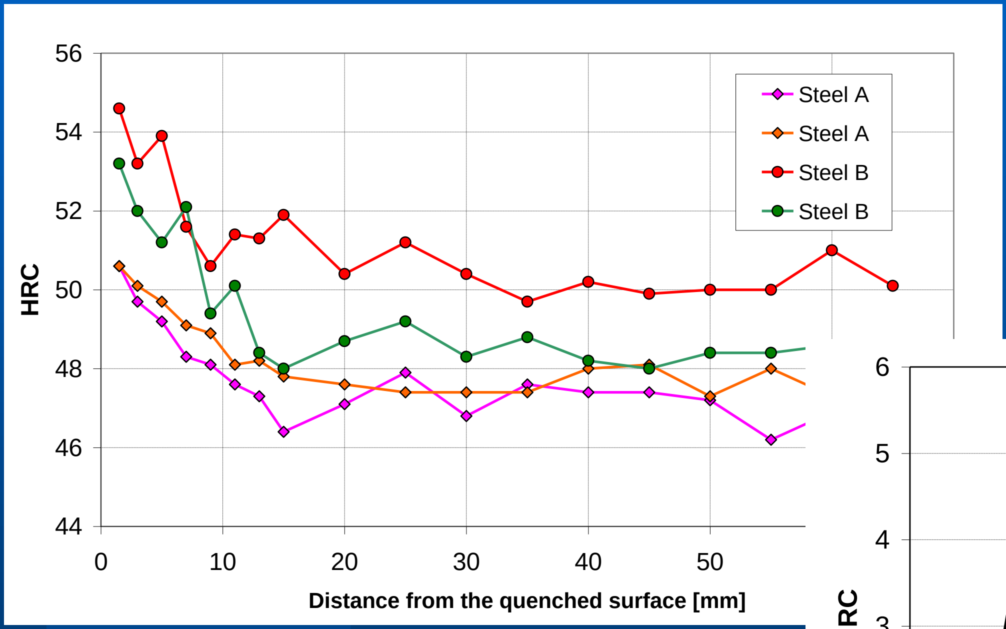
- ISO 1.2738 and Steel A were heavy sized blooms (about ***1.3m*** x ***1.2m*** x ***2.7m*** for the ISO 1.2738 and ***1.2m*** x ***1.0m*** x ***2.9m*** for the Steel A), while the Steel B had smaller dimensions (about ***350mm*** x ***300mm*** x ***1000mm***).

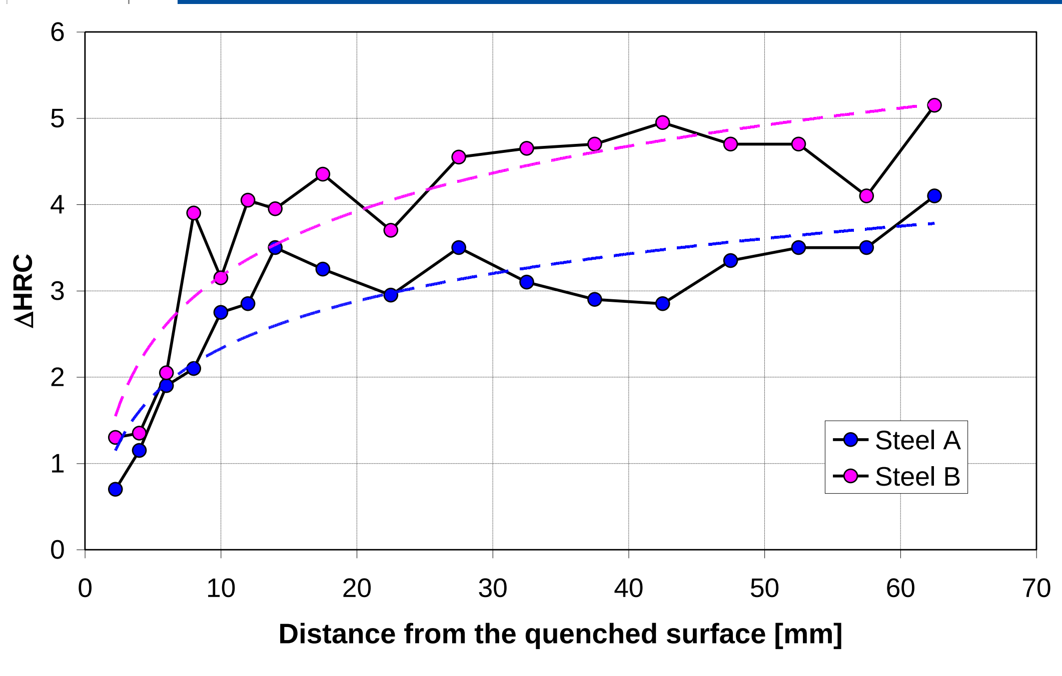
- The materials were delivered after the common industrial thermo-mechanical process: forging, dehydrogenation treatment, quench and tempering.

- All the materials were investigated at different depths from the surface to the core.

Hardenability - Jominy test

- Hardenability tests were carried out on Steels A and B in order to investigate the effect of microalloying elements.

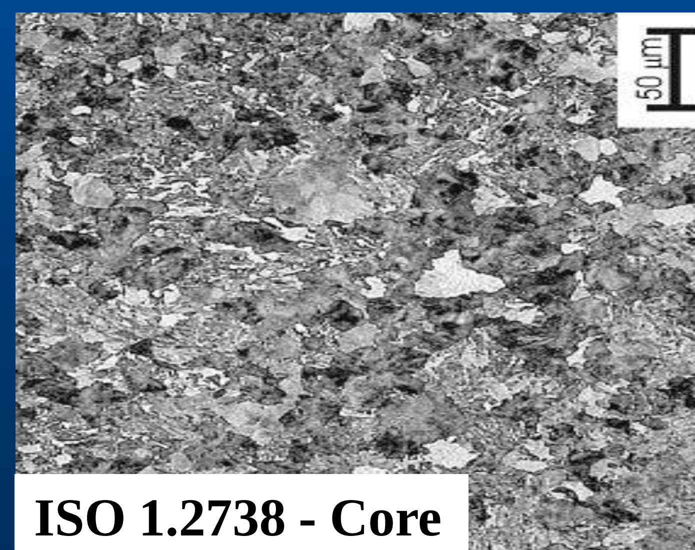




Microstructure

- The microstrucure was investigated for both Steels A and B and it was compared with the ISO 1.2738 one.
- In the superficial layers we found tempered martensite, while in the core bainitic structures were observed.
- In a previous investigation mixed microstructures of bainite and pearlite were found in ISO 1.2738.

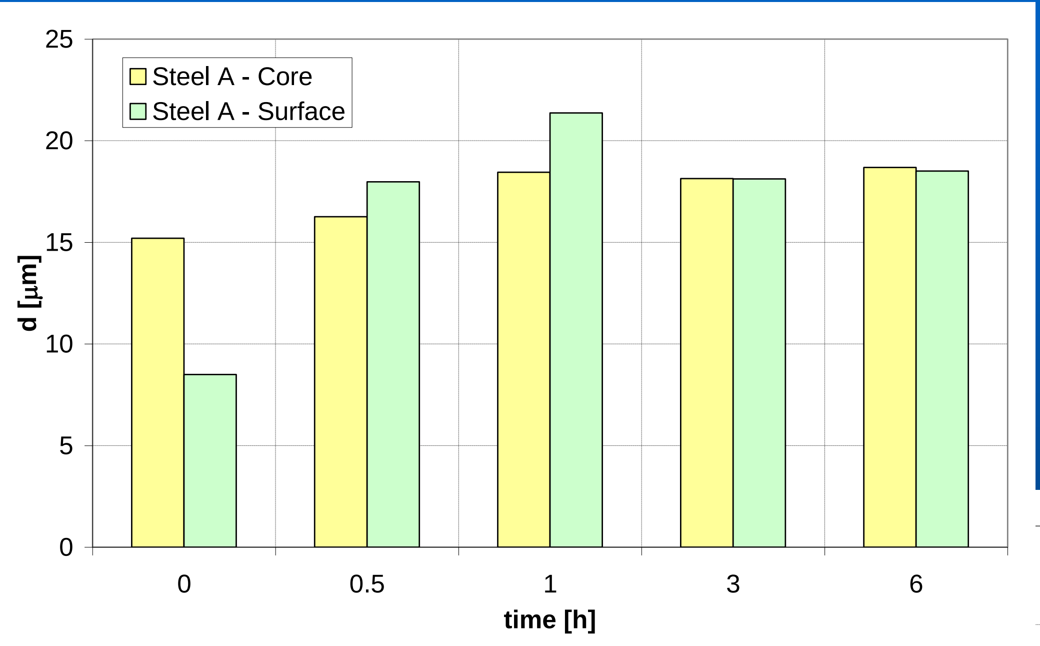
Steel A - Core



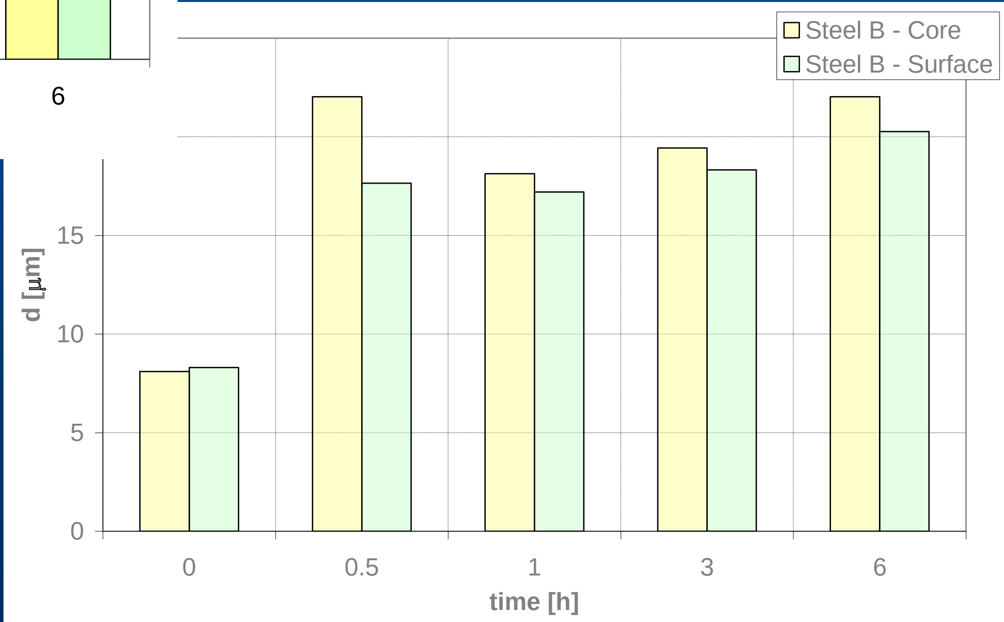
ISO 1.2738 - Core

Austenitic grain size

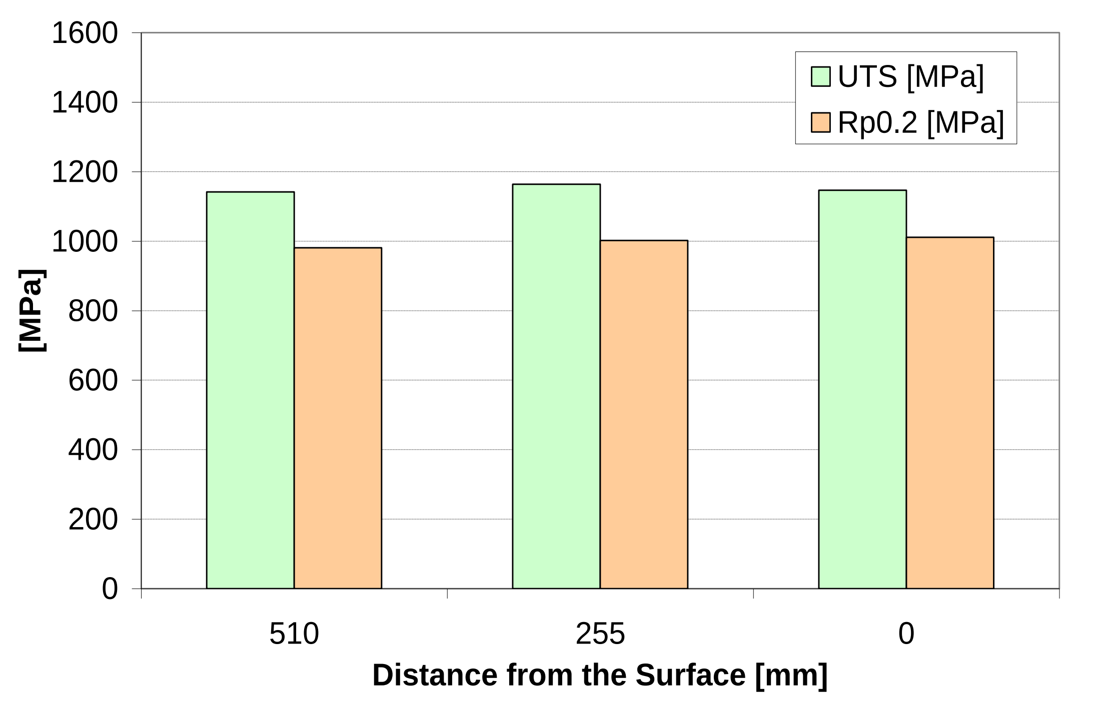
- The austenitic grain size and growth rate were investigated on Steels A and B. The austenitization temperature was T=890°C.



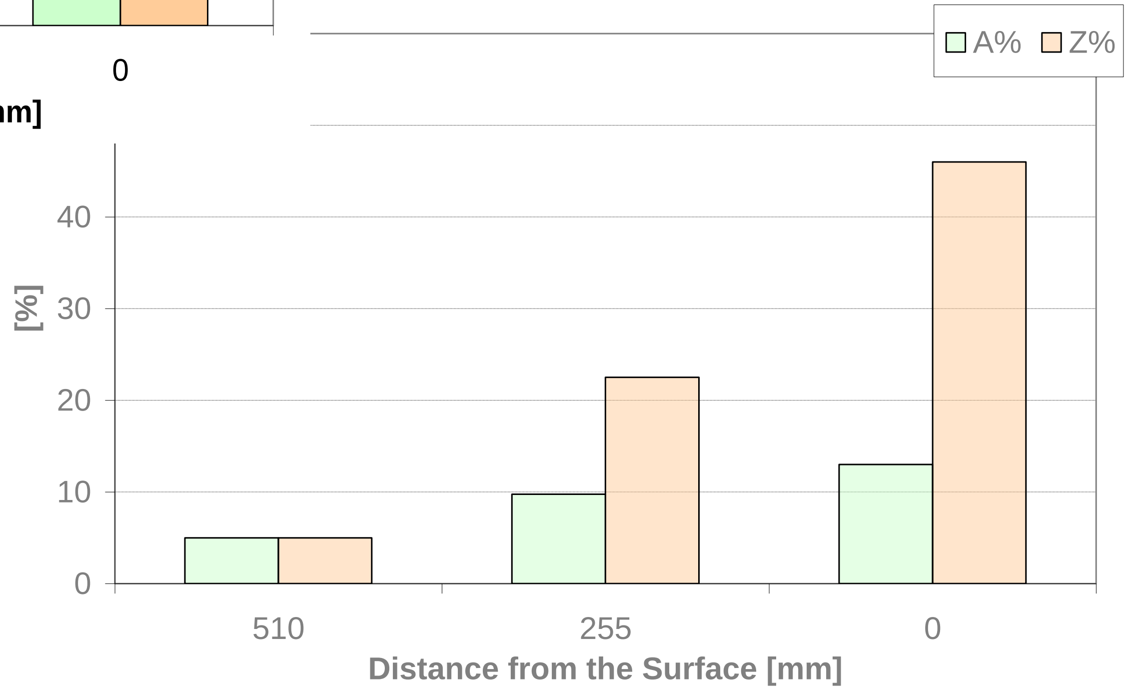
The soaking times were 0.5, 1, 3, 6 hours.



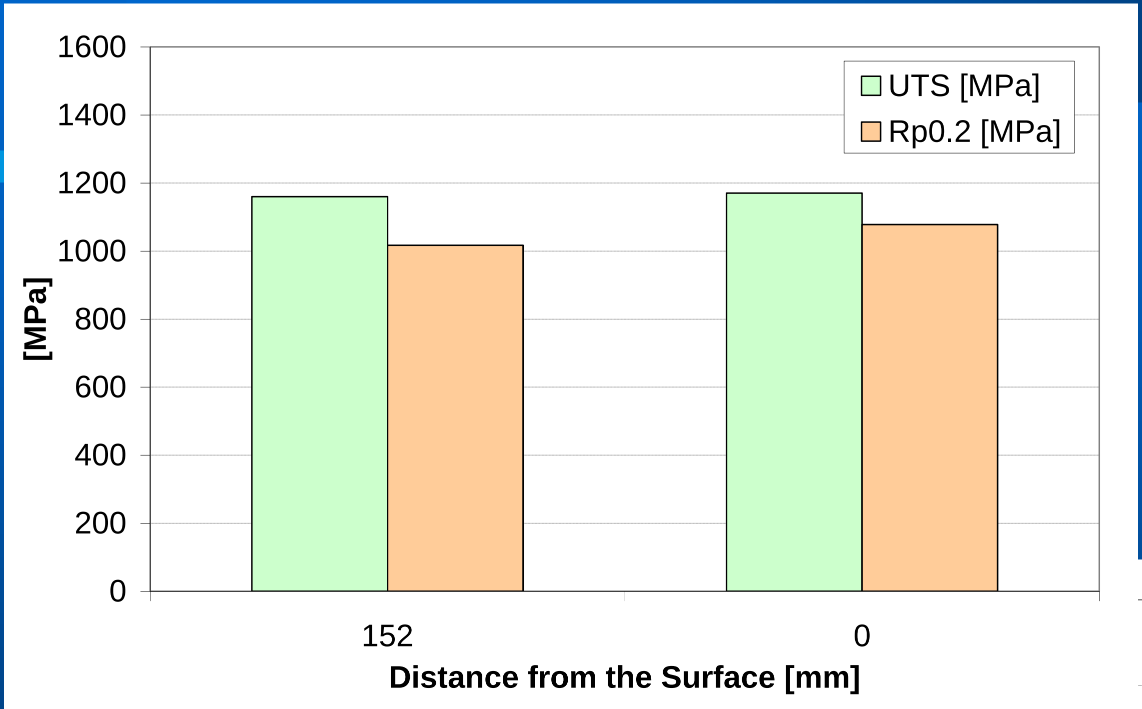
Tensile tests – Steel A

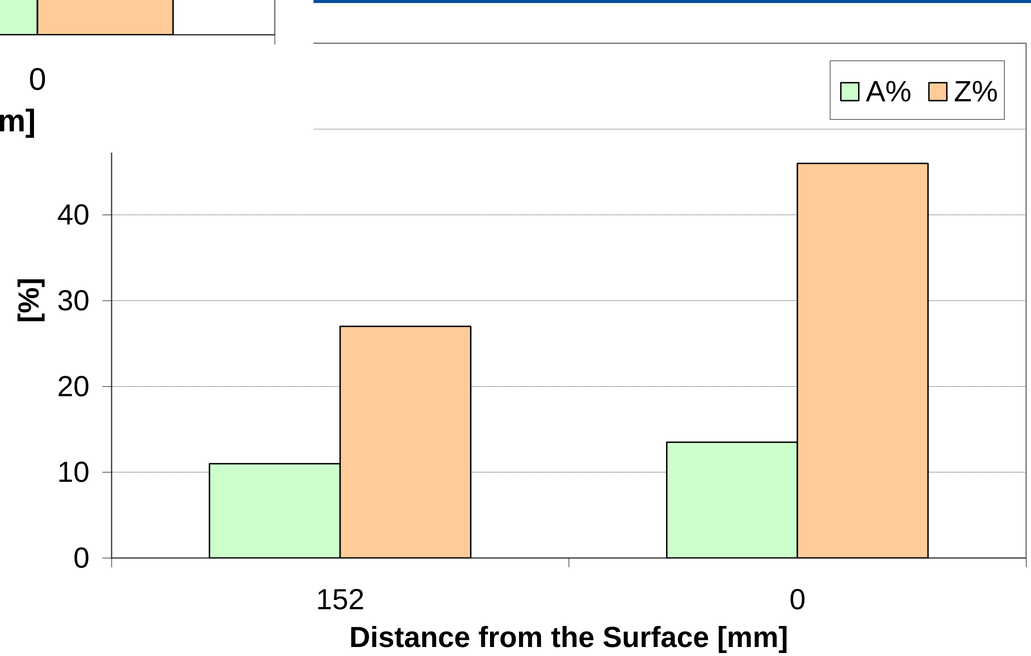


Previous investigations on ISO 1.2738 showed average values of ***1000 MPa*** for the UTS and ***800 MPa*** for the yield stress.

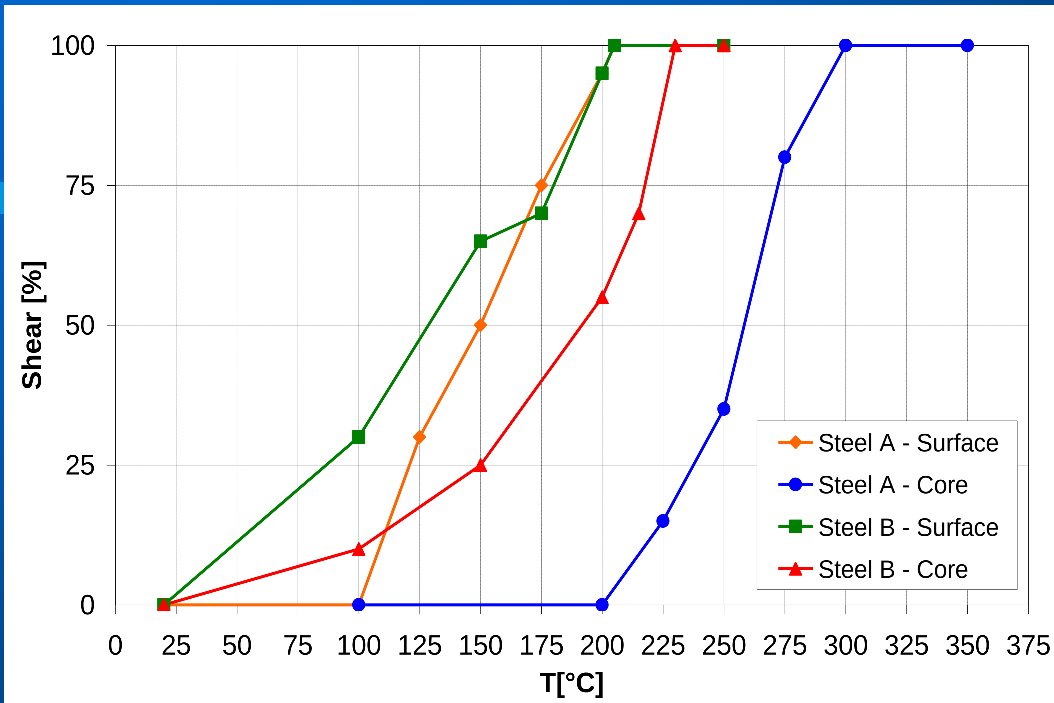


Tensile tests – Steel B



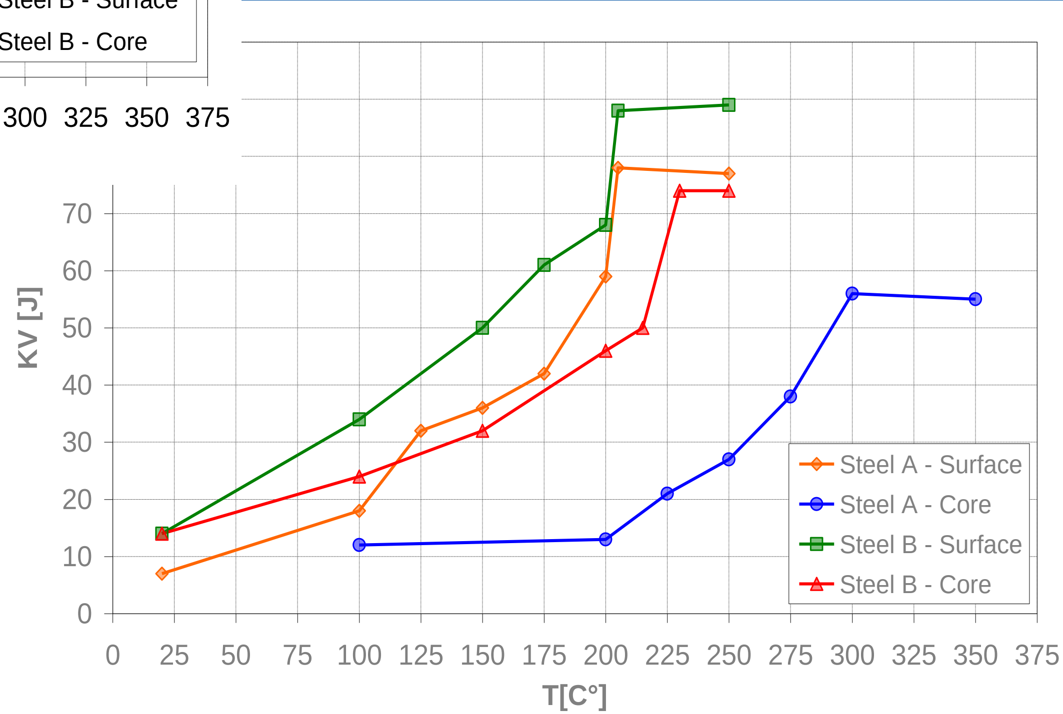


Impact Tests



Material	Position	FATT [°C]
Steel A	Surface	150
Steel A	Core	260
Steel B	Surface	130
Steel B	Core	190

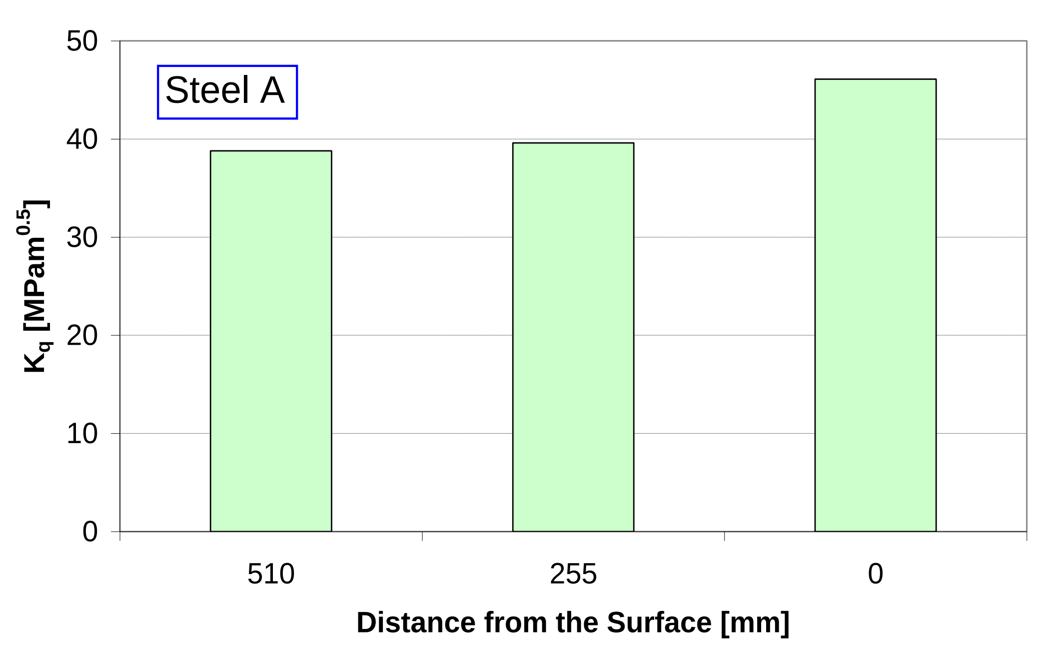
Previous investigations on ISO 1.2738 showed FATT included between 150°C and 270°C depending on sampling position.



Rotating Bending Fatigue

- The tests were carried out according to the Staircase Method.
- Steels A and B (both in surface position) were investigated finding a fatigue limit equal to ***627 MPa*** for ***Steel A*** and ***652 MPa*** for ***Steel B*** (both with 50% probability of failure)
- Previous investigations on ISO 1.2738 steel (in surface position) resulted in a much lower fatigue limit equal to ***550 MPa***.

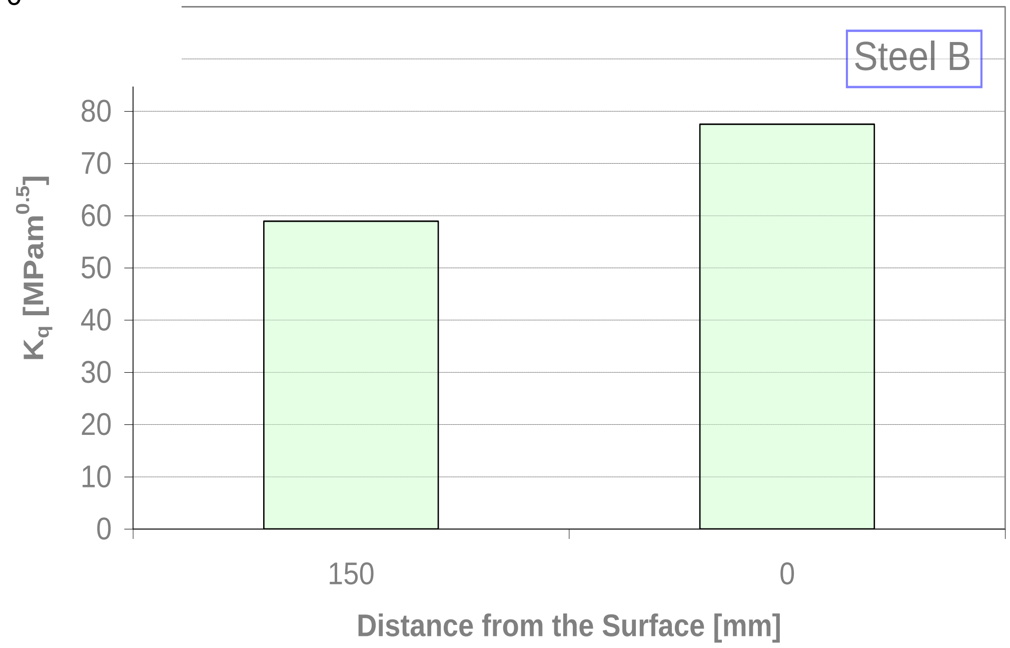
Fracture Toughness



Previous investigations on ISO 1.2738 showed Kq included between 35MPam$^{0.5}$ and 45MPam$^{0.5}$ depending on sampling position.

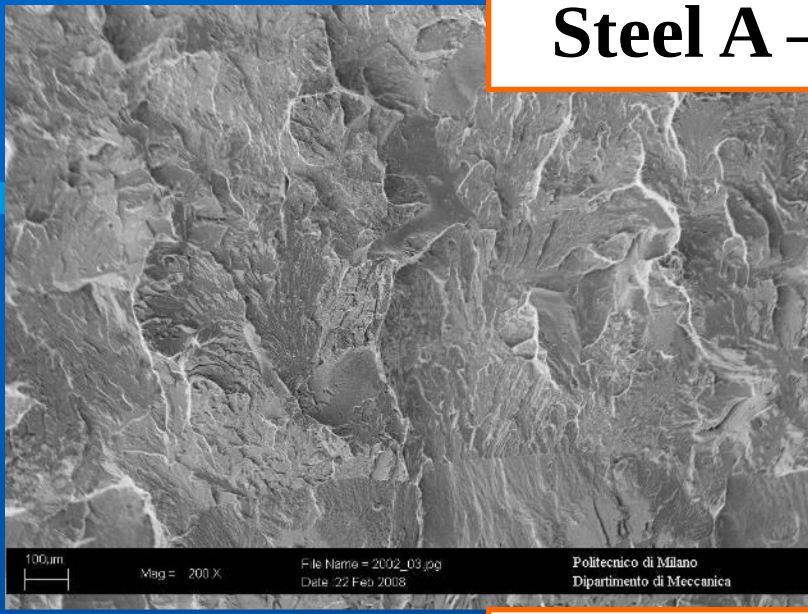
SENB3 samples were used B=35mm W=70mm L=160mm

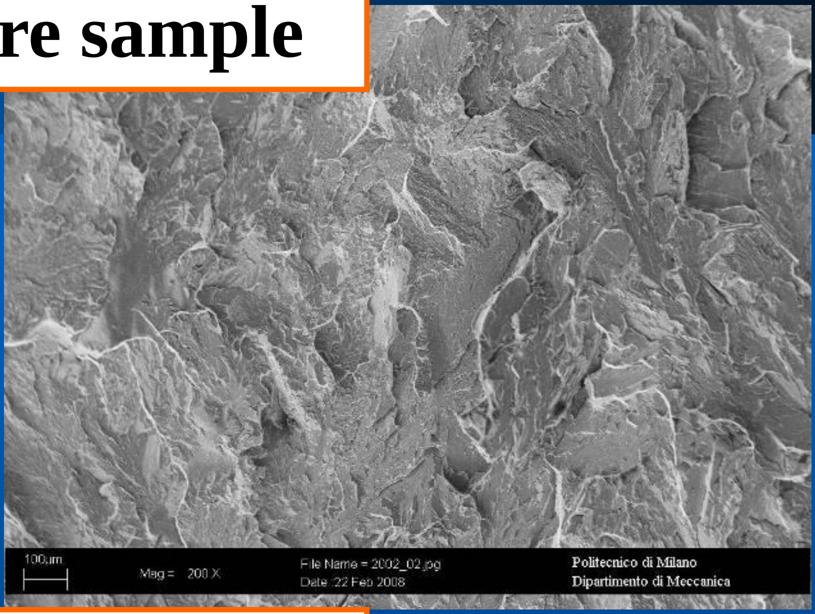
The tests were carried out according to ASTM E399-06.



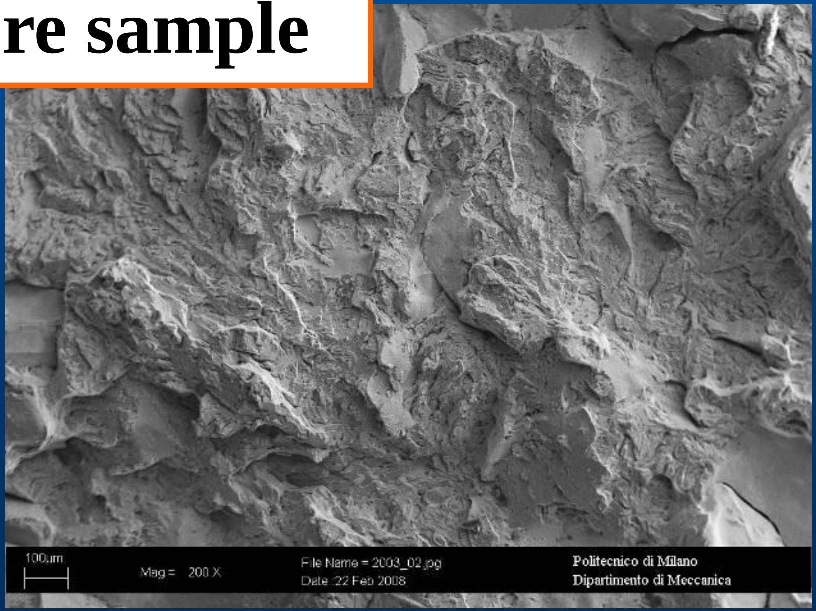
Fracture Toughness

Steel A – Core sample





Steel B – Core sample



Weldability Tests

• Weldability test were carried out on ISO 1.2738 and Steel A (both in core position) in order to compare the old material with the new one.

• The welding tests were performed on one half of the broken fracture toughness samples (35mm x 70mm x 150mm) by GTAW technique without welding metal.

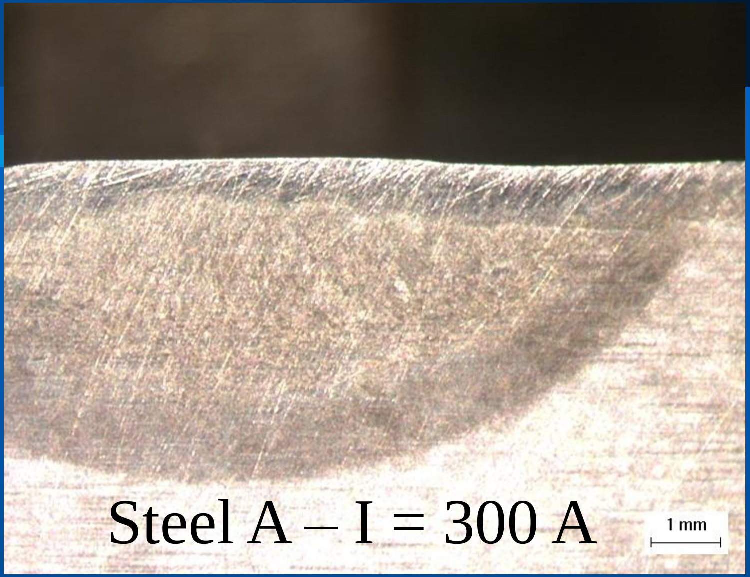
Material	I (A)	U (V)
Steel A		
Side 1	150	12.0
Side 2	200	12.7
Side 3	250	15.0
Side 4	300	15.5
ISO 1.2738		
Side 1	150	14.5
Side 2	200	14.0
Side 3	250	15.0
Side 4	300	17.0

• Four weldings were performed (one for each surface of the sample) varying the applied current.

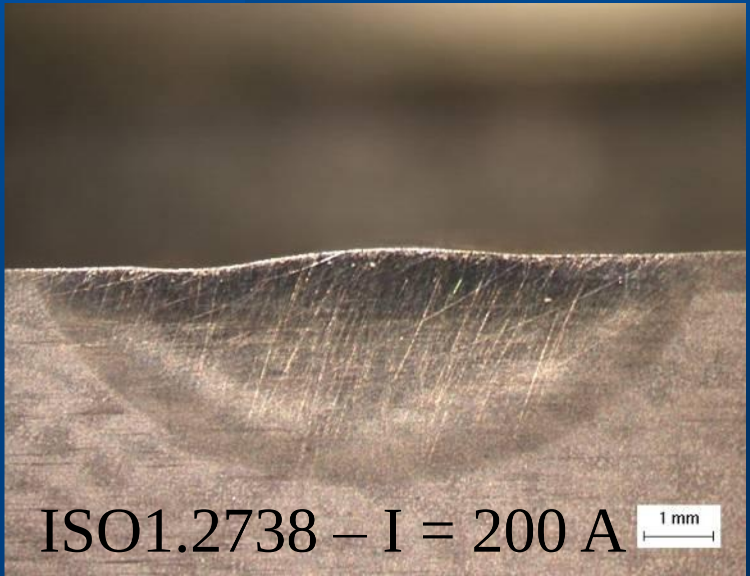
• HV 0.1 microhardness tests were carried out starting from the melted zone, through the HAZ (that is the most interesting region) till the parent metal.

Weldability Tests – Some pictures

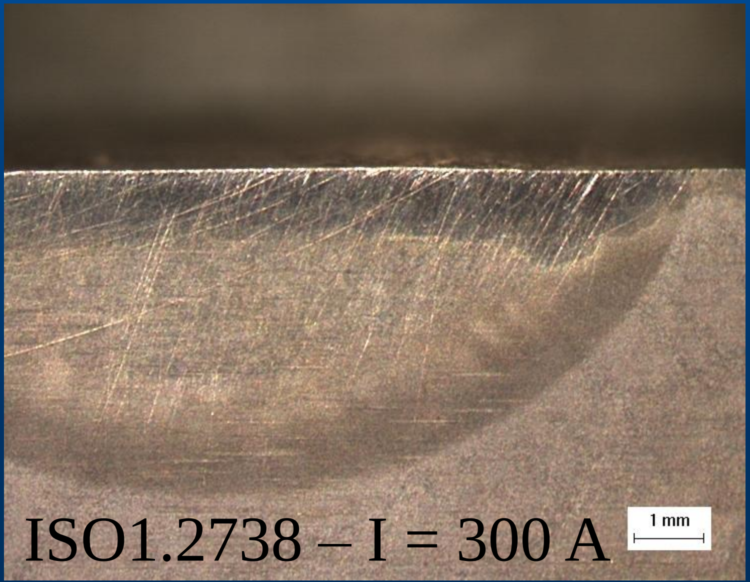
Steel A – I = 200 A



Steel A – I = 300 A

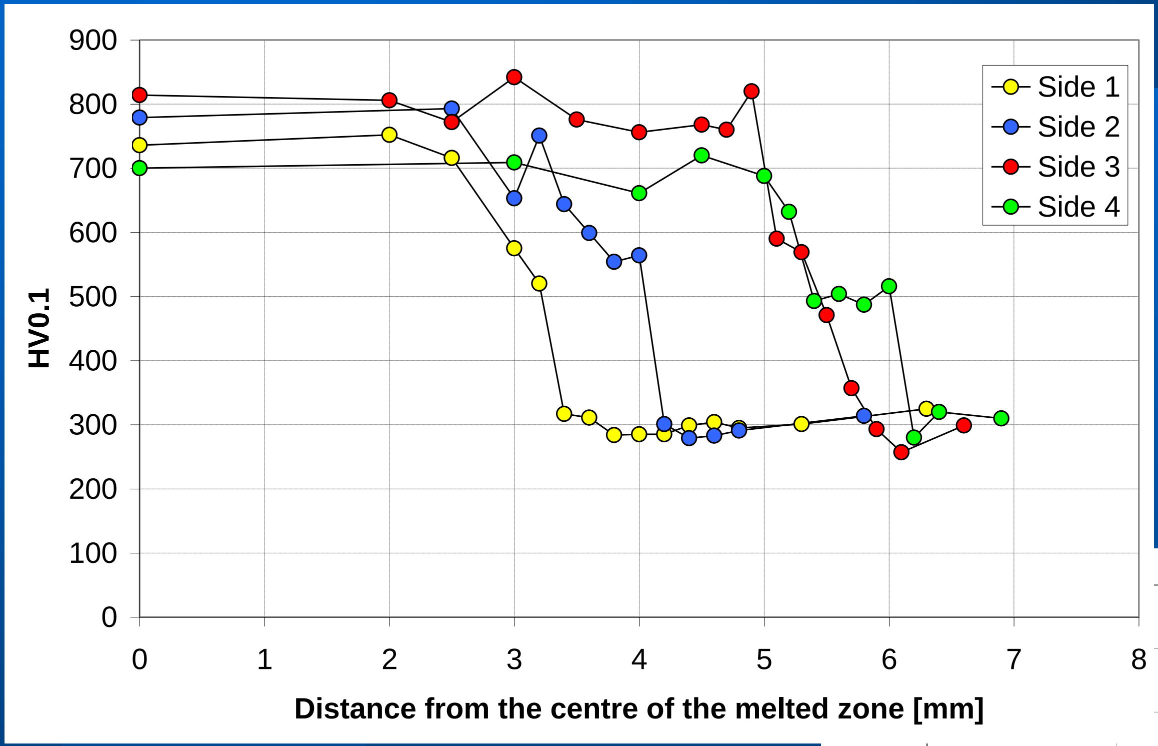


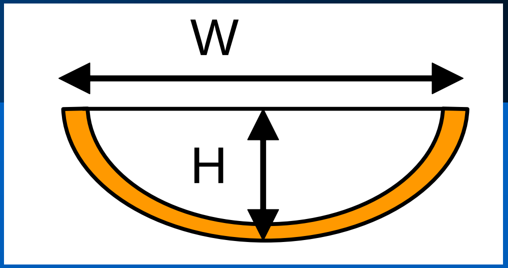
ISO1.2738 – I = 200 A



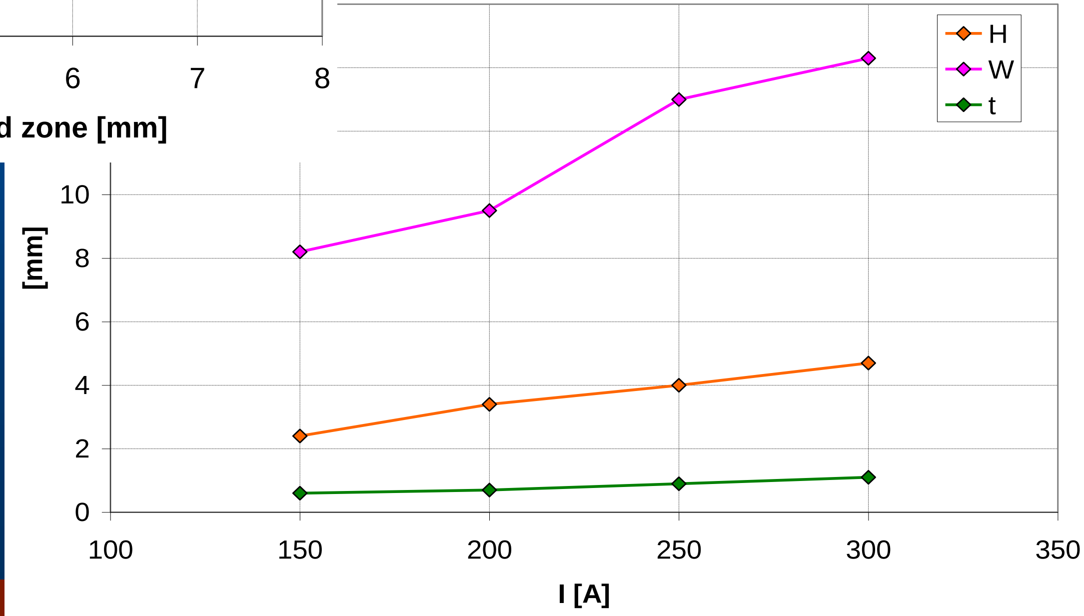
ISO1.2738 – I = 300 A

Weldability Tests – ISO 1.2738

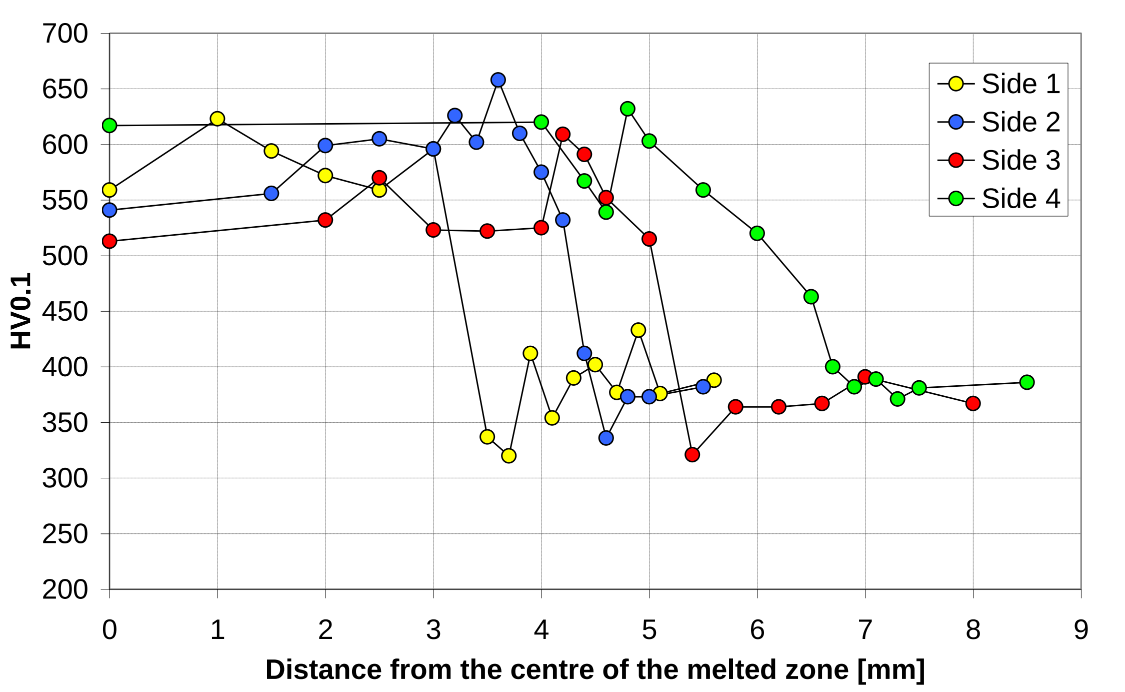


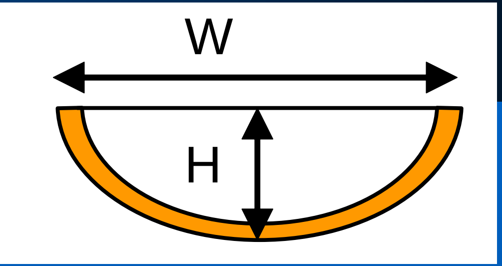


The HAZ thickness (*t*) were measured along the H direction.

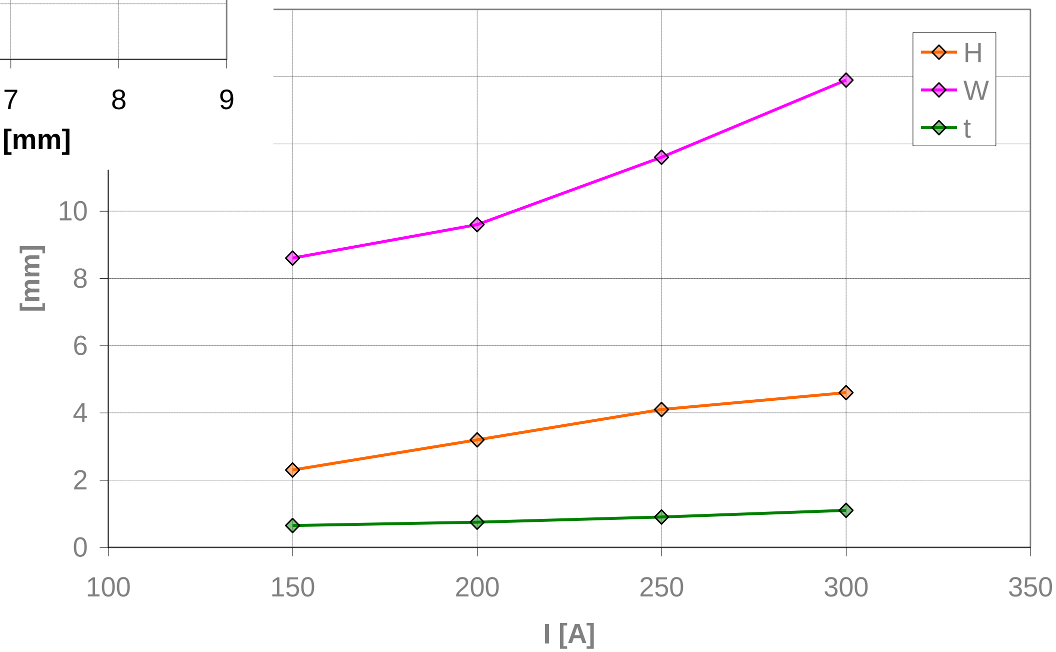


Weldability Tests – Steel A





The HAZ thickness (***t***) were measured along the H direction.



Concluding Remarks (1)

- Steels A and B hardenability is very close, even if the Steel A is slightly better.
- In both Steels A and B the microalloying elements (such as V, Nb, Zr) are very effective in controlling the prior austenitic grain growth.
- Steels A and B show very close tensile properties, generally higher than ISO 1.2738 ones.
- Steel B showed a better behaviour during the impact tests. The transition temperatures of both Steels A and B are comparable with the ISO 1.2738 ones.

Concluding Remarks (2)

- Steel B showed a slighly better rotating bending fatigue limit. Nevertheless both Steels A and B resulted in higher values respect to ISO 1.2738.
- Steel B showed a fracture toughness remarkably higher than Steel A, whose values are close to ISO 1.2738 ones. The thickness probably influence the heat treatment effectiveness and so the fracture toughness.
- The weldability tests confirm the better behaviour of the new steel (Steel A) respect to ISO 1.2738.