INSTITUTO DE PESQUISAS TECNOLÓGICAS

COMUNICAÇÃO TÉCNICA

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Investigating the influence of trace tantalum on the microstructure and mechanical properties of niobium microalloyed steels

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INSTITUTO DE PESQUISAS TECNOLÓGICAS

INVESTIGATING THE INFLUENCE OF TRACE TANTALUM ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF NIOBIUM MICROALLOYED STEELS

Thermec 2025 – Tours, France

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TABOCA

where we are

São Paulo Campus

103500 m²
built area

Interior

Franca
Lab for Footwear and Individual Protection Products

S. José dos Campos
Lab for Lightweight Structures

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SÃO PAULO
GOVERNO DO ESTADO

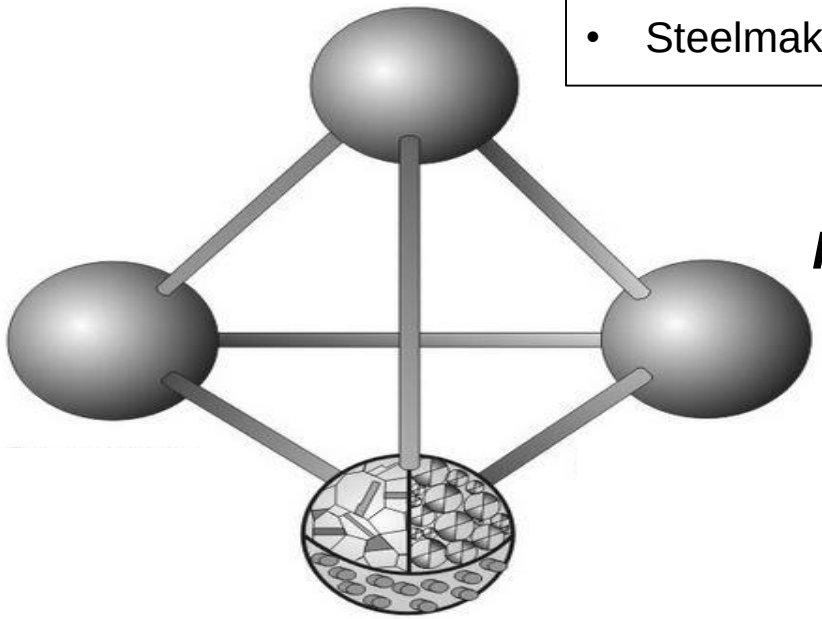
LABORATORY OF METALLURGICAL PROCESSES - PORTFOLIO

- Pyrometallurgy and Electrometallurgy
- Solidification and Casting
- Mechanical Working
- AM and Powder Metallurgy
- Minning and Industrial Waste Processing
- Physical and computational modeling

Processes

- Rolling mill rolls
- Grinding media
- Automotive components
- Semi finished products (strip,rod)
- Biomass pellets
- Steelmaking Slag → Cement

Product



Properties

- Tribology (EPUSP)
- Mechanical properties
- Magnetic properties (EPUSP)

- Fe-C-X system
  - X = Si ⇒ cast iron
  - X = Cr, Ni ⇒ stainless steel
  - X = Cr, V, Mo, W, Mn ⇒ wear resistant
  - X = microalloying Nb,V,Mo ⇒ low alloy steels
- Special metals: SG silicon, Nd and Nd-Fe-B, Ti-Nb alloys

Microstructure

CONTEXT

- **Mining company founded in 1969, operating in tin mining and metallurgy, as well as industrial minerals.**
- **FeNb and FeNbTa**
- Request made by the Marketing/Sales team at TABOCA
- Presence of Ta in FeNb
- Difficulty in marketing FeNb with Ta content
- Removal of Ta from FeNb involves high costs ($)

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OBJECTIVES

- Investigate the possible synergistic effect obtained between niobium and tantalum when added to steels intended for mechanical construction.
- Mechanical tests: tensile and impact
- The project evaluated microalloyed steels for mechanical construction that are produced through the thermomechanical rolling process, which aims to achieve a final microstructure with the smallest possible grain size.
- Selected chemical compositions:

	C	Si	Mn	Cr	Ni	Mo	Ti	Al	V	B	Nb
LG960QT	≤ 0,18	≤ 0,5	≤ 1,5	≤ 0,8	≤ 1,2	≤ 0,7	≤ 0,03	≥ 0,015	≤ 0,08	≤ 0,003	≤ 0,07
NM450	≤ 0,35	≤ 0,7	≤ 1,7	≤ 1,1	-	≤ 0,55	≤ 0,05	≥ 0,01	-	-	≤ 0,03

ANALYSIS OF FeNb

- Chemical analysis of raw material (FeNb)
  - ICP OES
  - ICP MS

Matéria Prima	Nb (wt%)	Fe (wt%)	Ta (ppm)	Al (wt%)	Ti (wt%)	Mn (wt%)	P (wt%)	Cr (wt%)	Ni (wt%)	Mo (wt%)	V (wt%)
Fe w/Ta	60,38	27,67	1,46	0,08	0,030	0,85	0,19	0,03	0,0042	0,07	0,017
Fe w/o Ta	61,90	29,22	0,09	0,08	0,318	0,75	0,16	0,04	0,0199	0,008	0,012

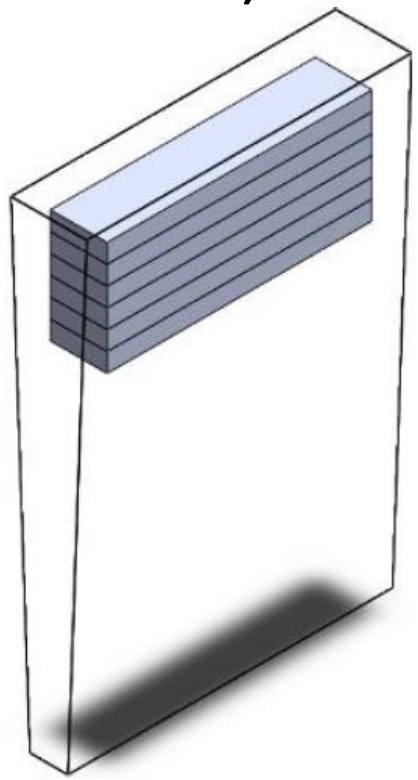
HOW MUCH TANTALUM ARE WE INCORPORATING?

- Usually, in steels for mechanical construction, about 300 to 700 ppm of Nb is added.
- For this Nb addition, using raw material with Ta, we are incorporating amounts that can vary between 5 and 14 ppm.

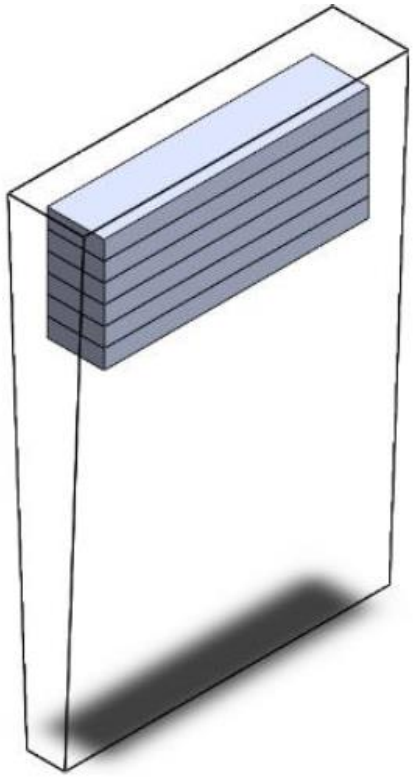
Tantalum content		
LG960QT	**wt %**	**ppm**
No Ta FeNb	0,000193	1,93
With Ta	0,00142	14,16
NM450	**Wt %**	**ppm**
No Ta FeNb	0,00007	0,74
With Ta	0,00054	5,4

SPECIMEN PRODUCTION

- **The chemical compositions for the study were determined.**
- For each chemical composition (microalloyed with Nb), two ingots were produced using raw material with Ta and w/o Ta (total: 4 heats).
- Plates were machined and then subjected to rolling.
- The rolling parameters were defined jointly with client based on experience from previous work.



INGOT PRODUCTION



ALLOY LG960QT

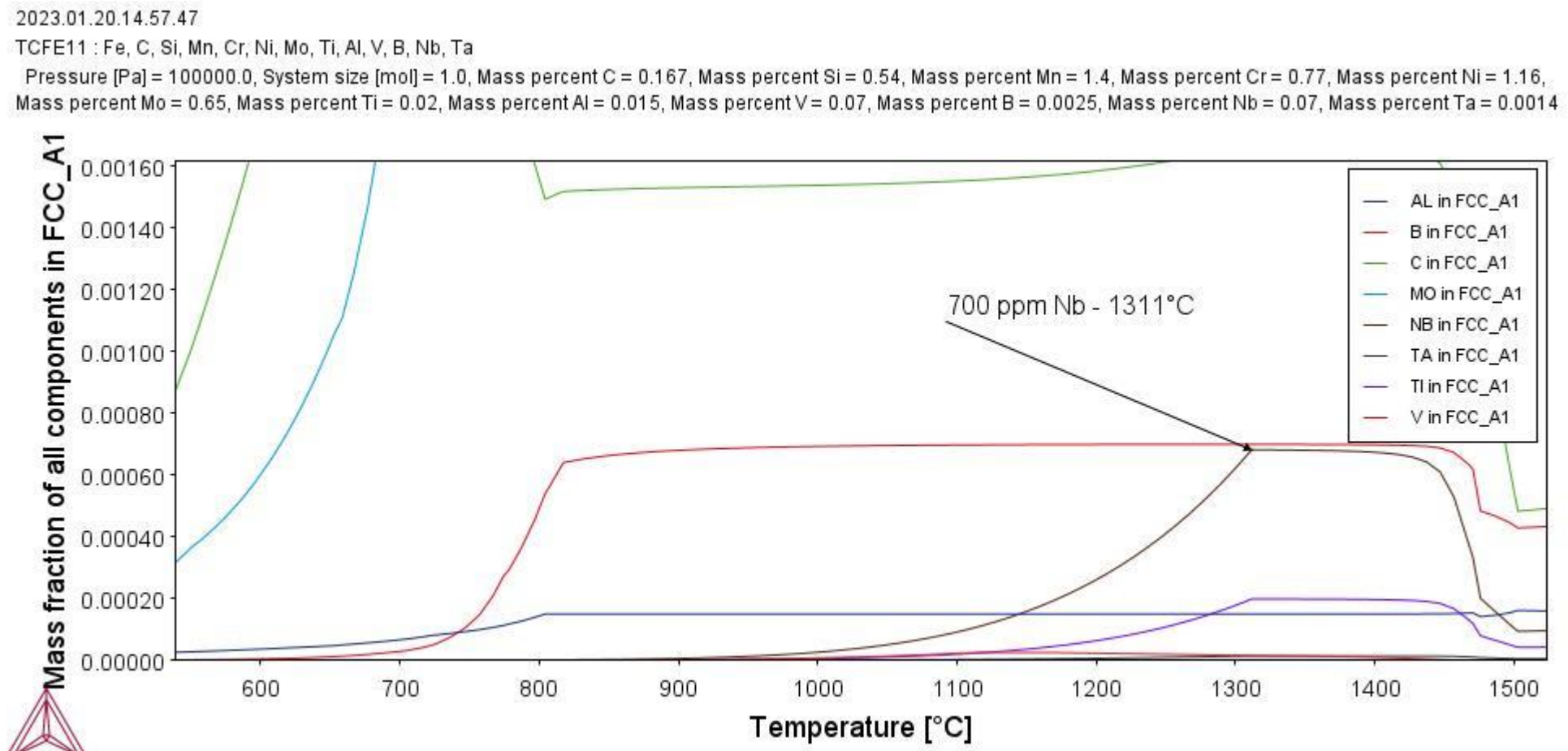
	C (wt%)	Si (wt%)	Mn (wt%)	Cr (wt%)	Ni (wt%)	Mo (wt%)	Ti (wt%)	Al (wt%)	V (wt%)	B (wt%)	Nb (wt%)	Ta (ppm)
LG960QT	≤ 0,18	≤ 0,5	≤ 1,5	≤ 0,8	≤ 1,2	≤ 0,7	≤ 0,03	≥ 0,015	≤ 0,08	≤ 0,003	≤ 0,07	-
LG960QT (no Ta)	0,164	0,543	1,404	0,772	1,178	0,667	0,02	0,015	0,069	0,0030	0,072	2,24
LG960QT (with Ta)	0,169	0,535	1,409	0,766	1,15	0,635	0,021	0,016	0,069	0,0024	0,068	14,15

LIGA NM450

	C (wt%)	Si (wt%)	Mn (wt%)	Cr (wt%)	Mo (wt%)	Ti (wt%)	Al (wt%)	Nb (wt%)	Ta (ppm)
NM450	≤ 0,35	≤ 0,7	≤ 1,7	≤ 1,1	≤ 0,55	≤ 0,05	≥ 0,01	≤ 0,03	-
NM450 (no Ta)	0,361	0,792	1,647	1,084	0,473	0,051	0,021	0,027	1,07
NM450 (with Ta)	0,365	0,797	1,636	1,088	0,477	0,049	0	0,027	6,40

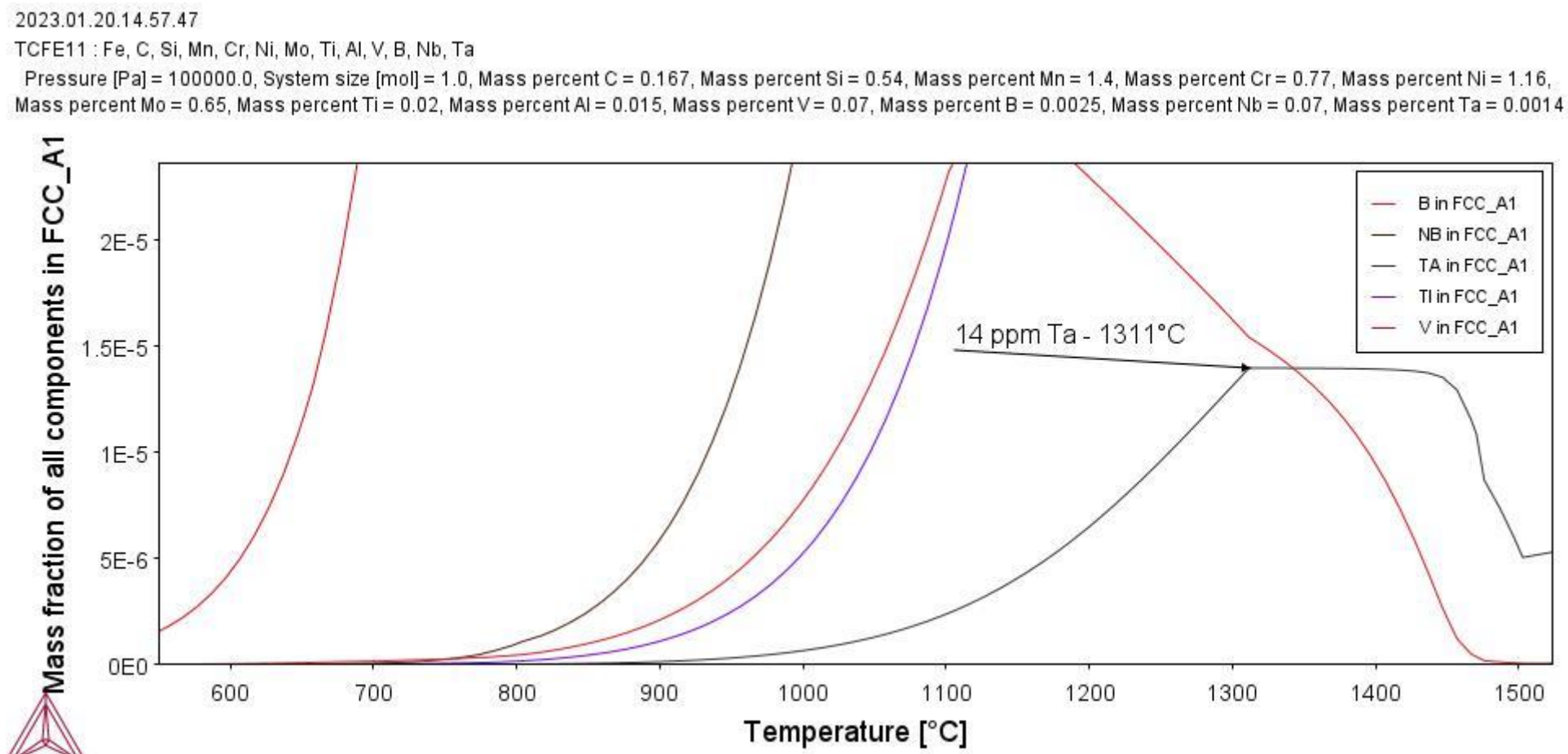
THERMODYNAMIC PREDICTIONS THERMOCALC

- LG960QT – Nb in austenite



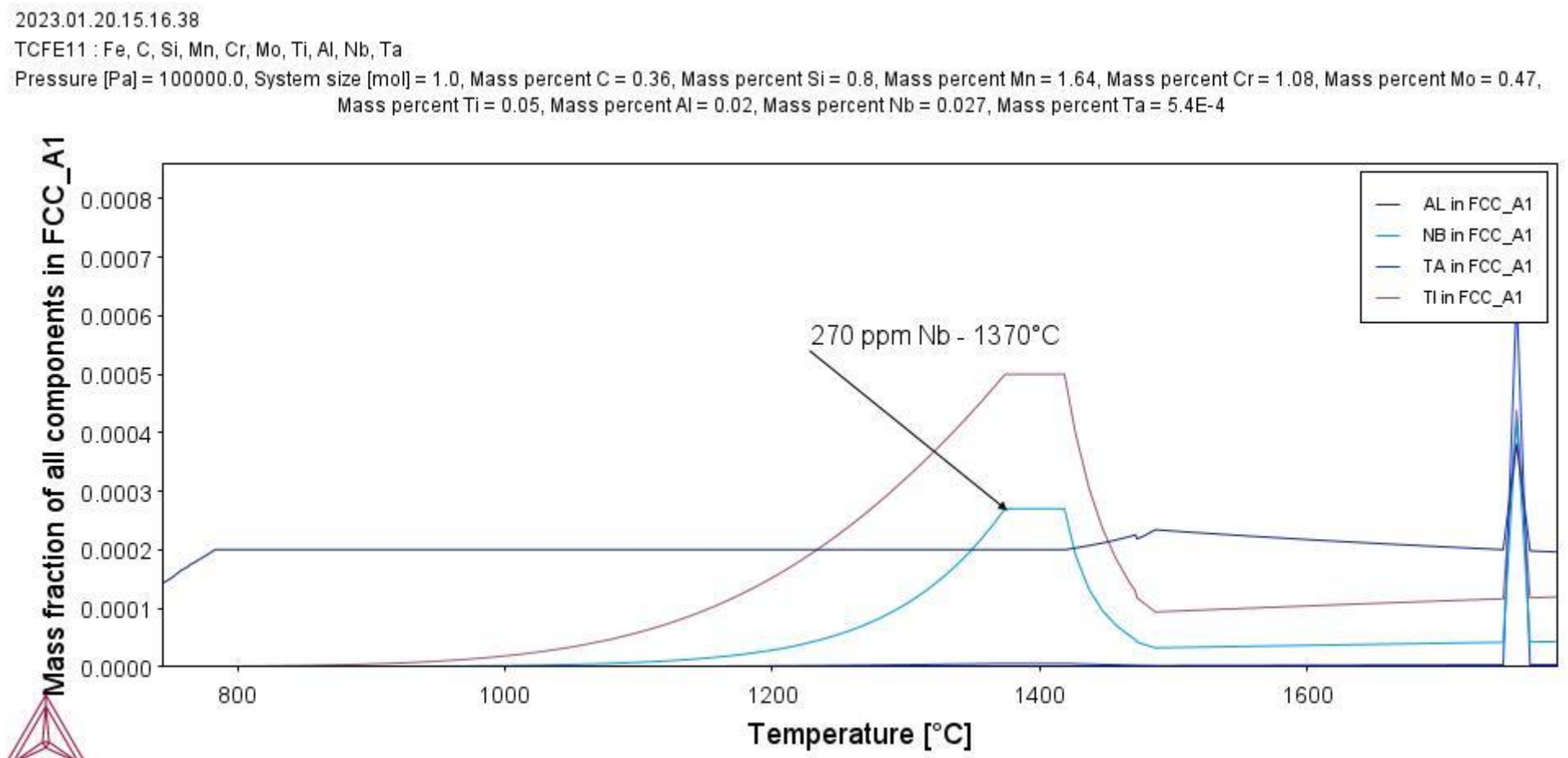
THERMODYNAMIC PREDICTIONS THERMOCALC

- LG960QT – Ta in austenite



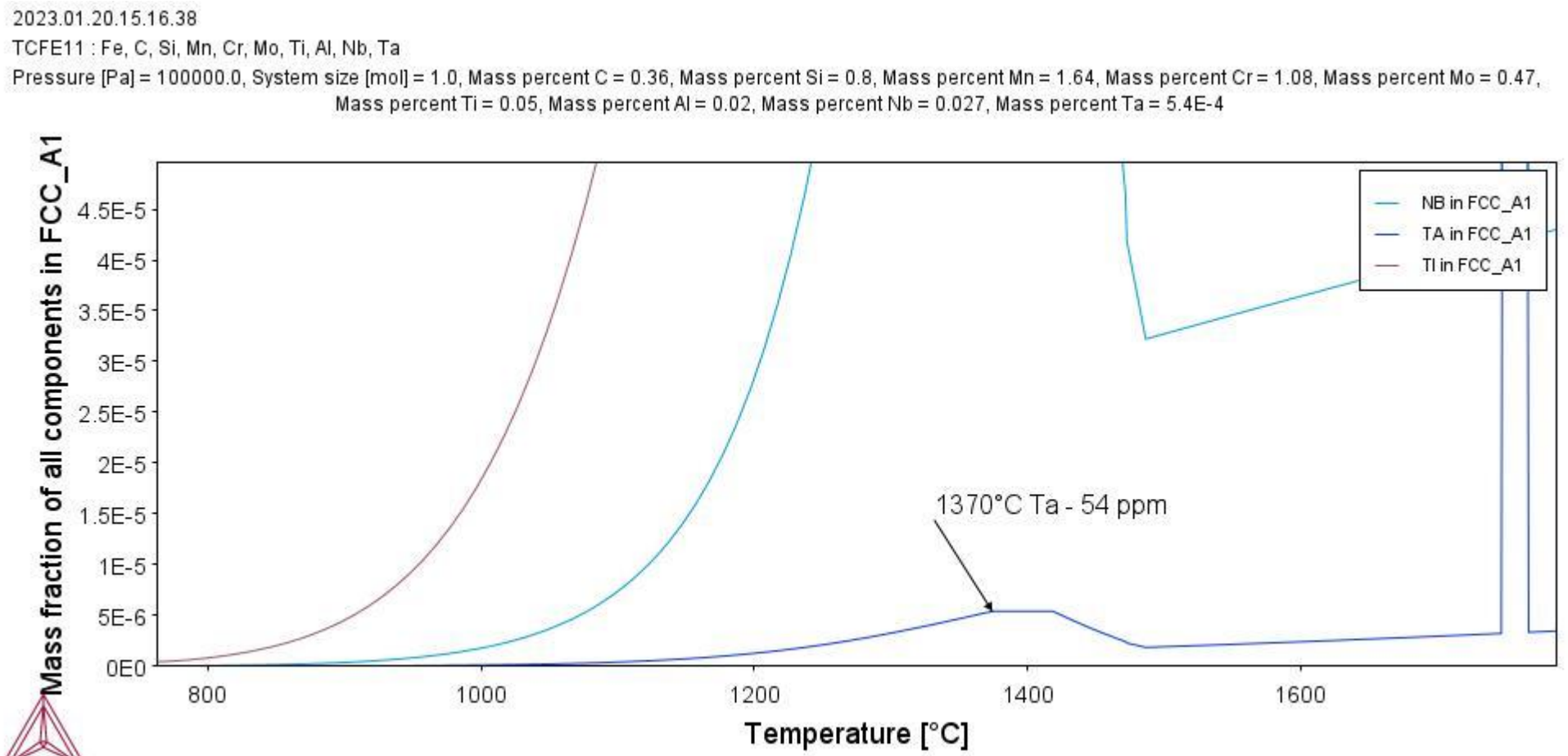
THERMODYNAMIC PREDICTIONS THERMOCALC

- NM450 – Nb in austenite



THERMODYNAMIC PREDICTIONS THERMOCALC

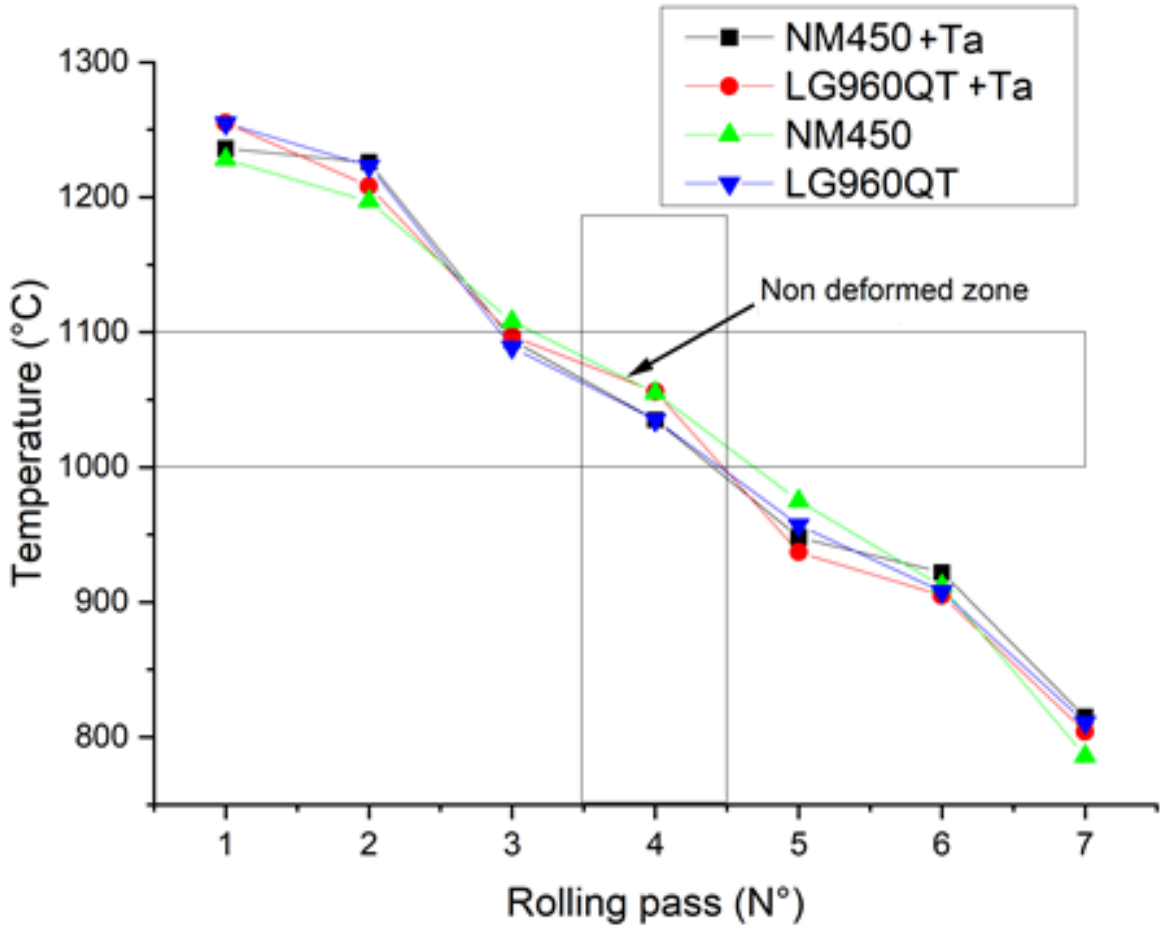
- NM450 – Ta in austenite



HOT ROLLING PARAMETERS

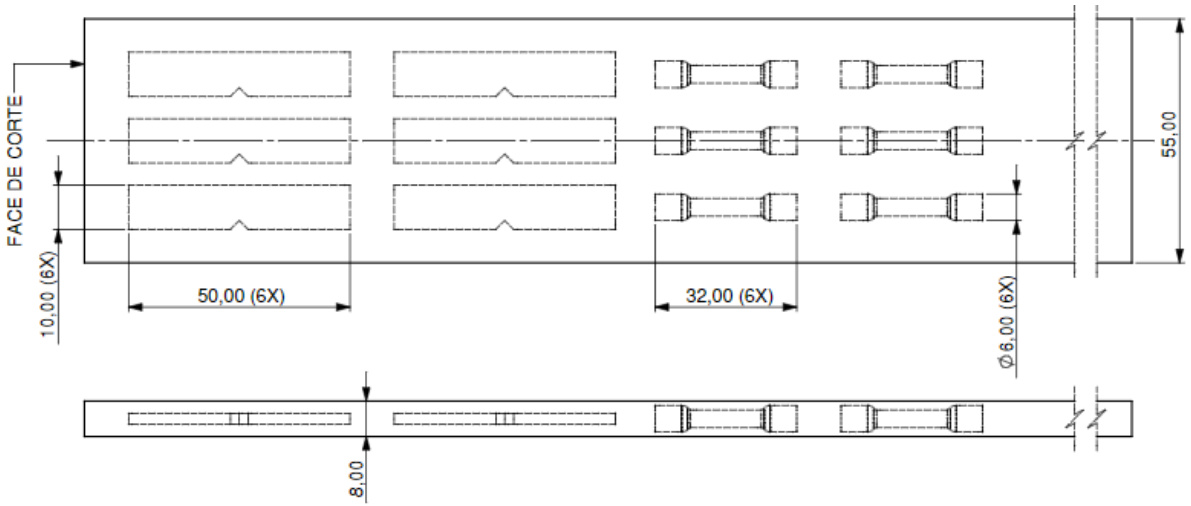
Pass	Thickness (mm)	Strain	Strain rate (s-1)	Temperature (°C)	Time between passes (s)
0	19	-		1330	-
1	14,82	22%	4,99	1278	-
2	11,56	22%	5,66	1168	10,77
3	9,02	22%	6,41	1178	8,99
4	9,02	0%	-	1020	9,94
5	7,03	22%	7,26	941	10,9
6	5,49	22%	8,22	849	11,18
7	4,28	22%	9,32	779	8,89

HOT ROLLING


NM450 +Ta
LG960QT +Ta
NM450
LG960QT
Non deformed zone
Temperature (°C)
1300
1200
1100
1000
900
800
1
2
3
4
5
6
7
Rolling pass (N°)

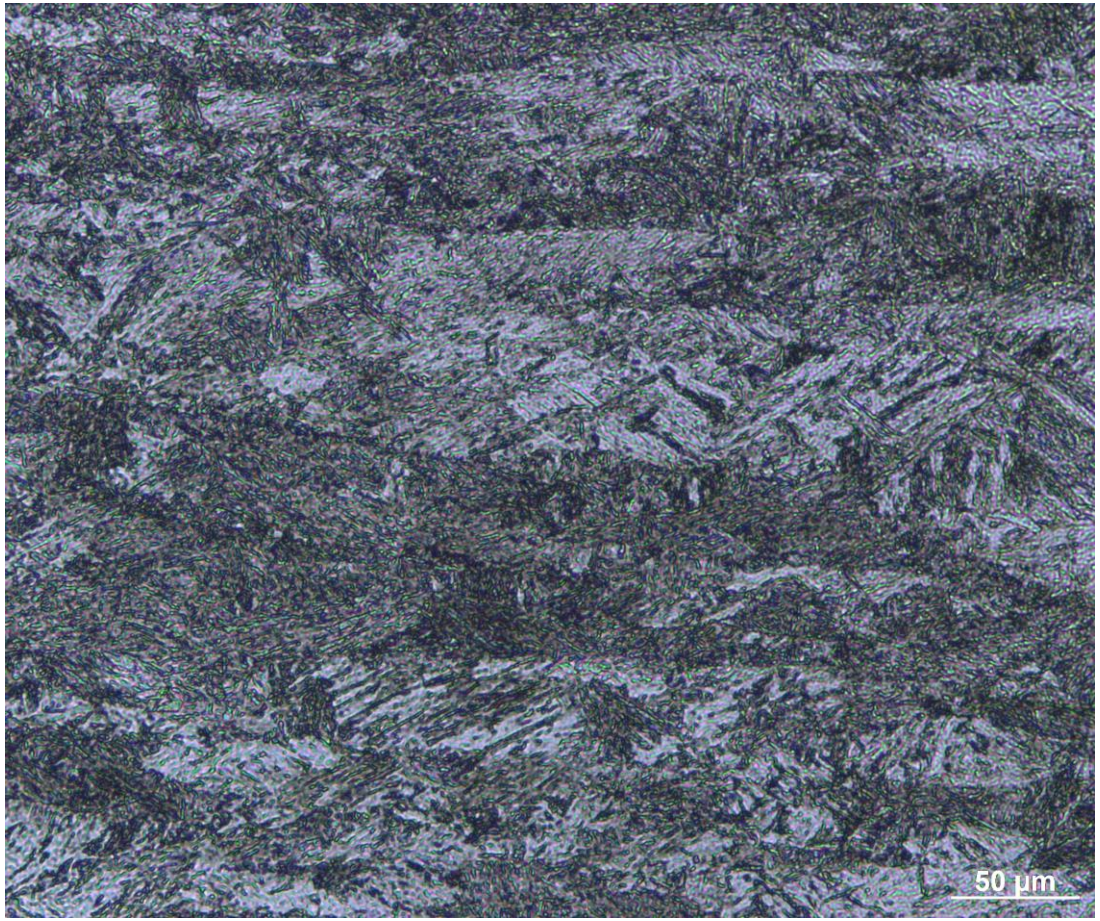
SPECIMENS PRODUCTION

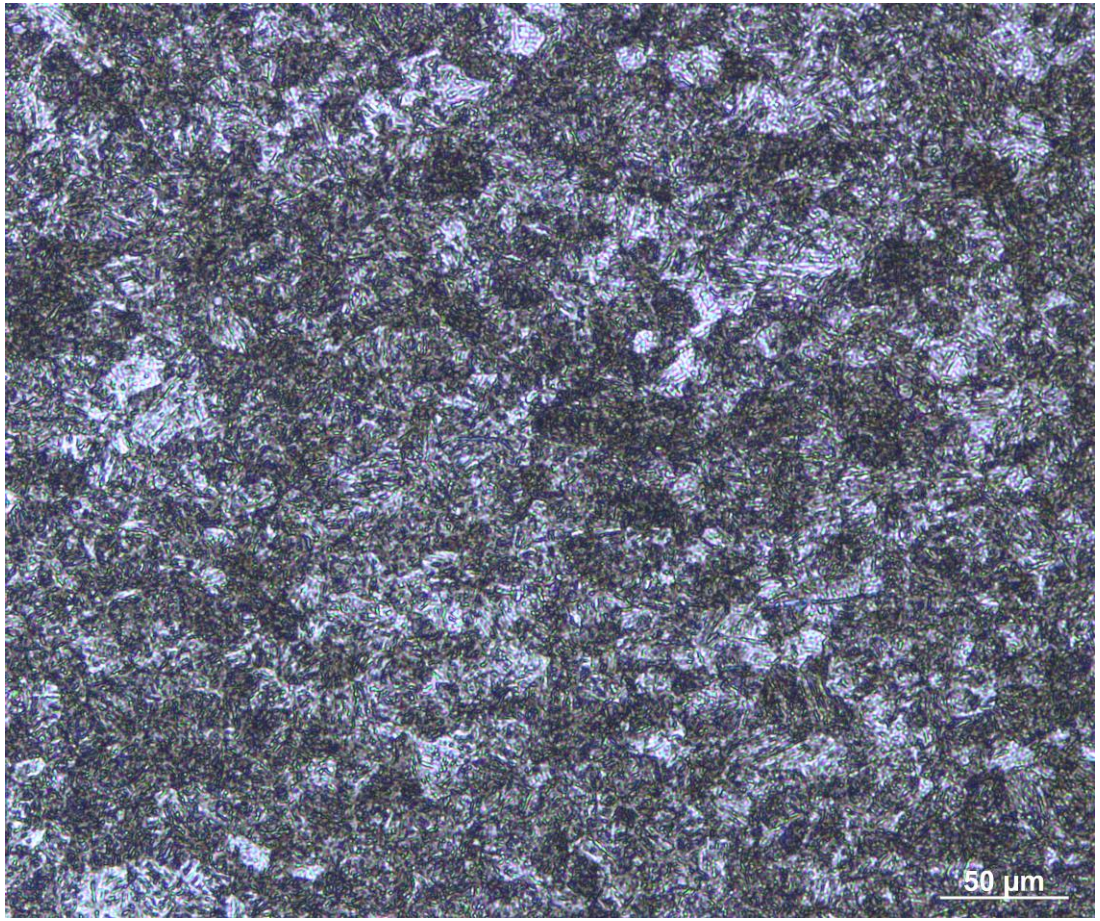
- Specimens for tensile and impact test were machined from the plates after hot rolling process



MICROSTRUCTURE - NM 450

200 x





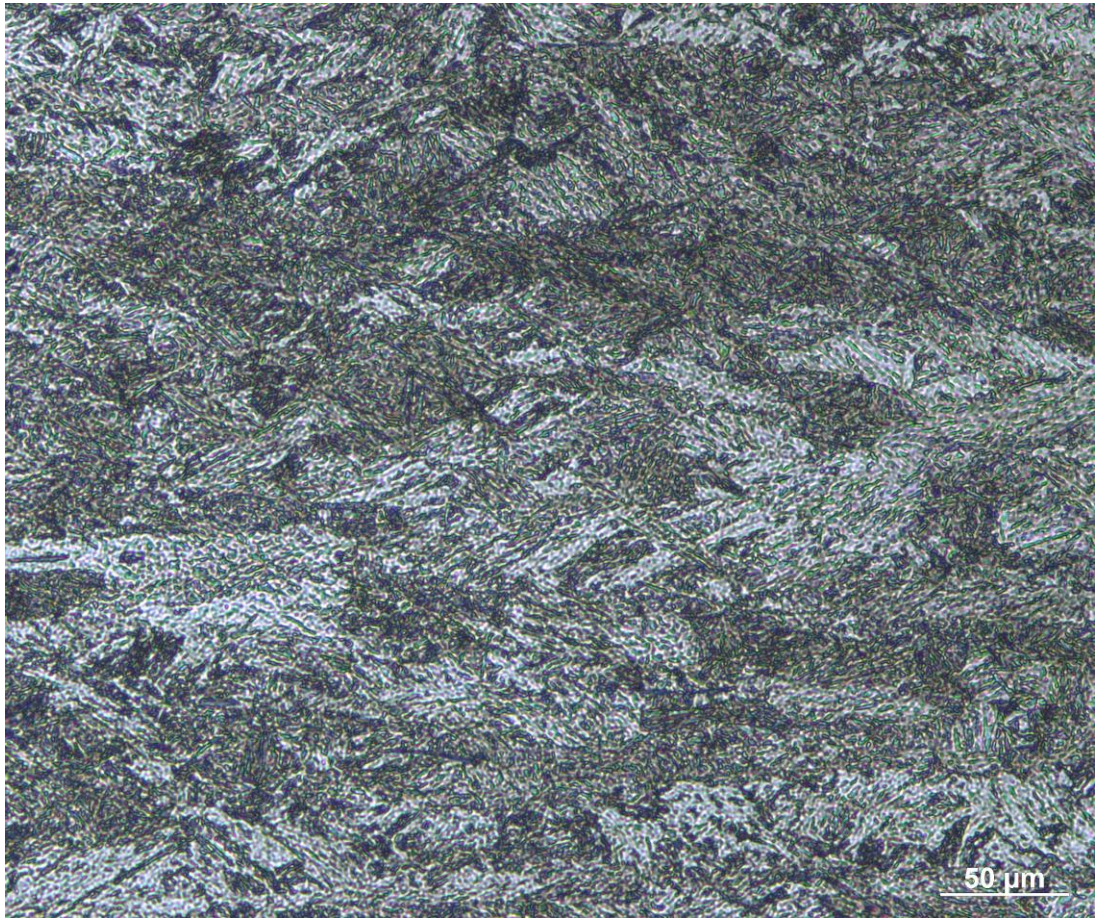
NM 450 – No Ta

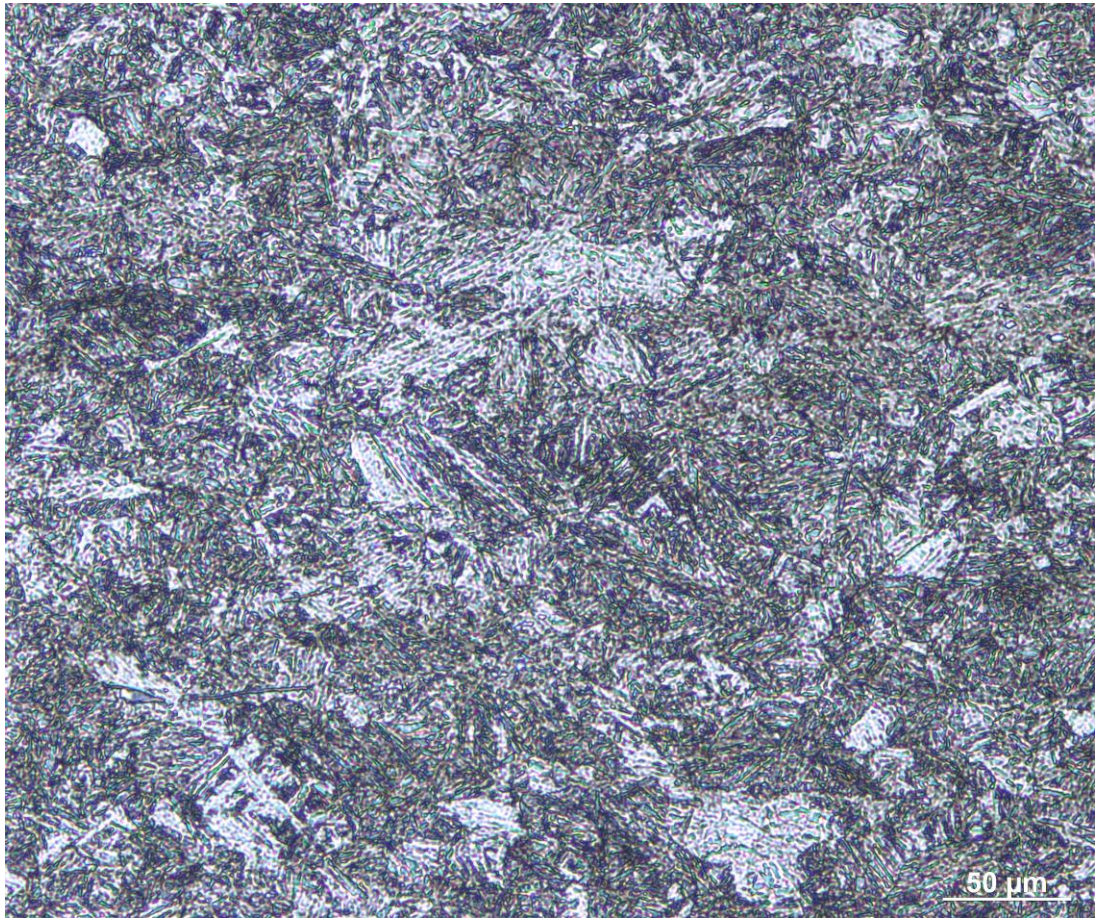
As rolled

NM 450 – With Ta

MICROSTRUCTURE – LG960QT

200 x



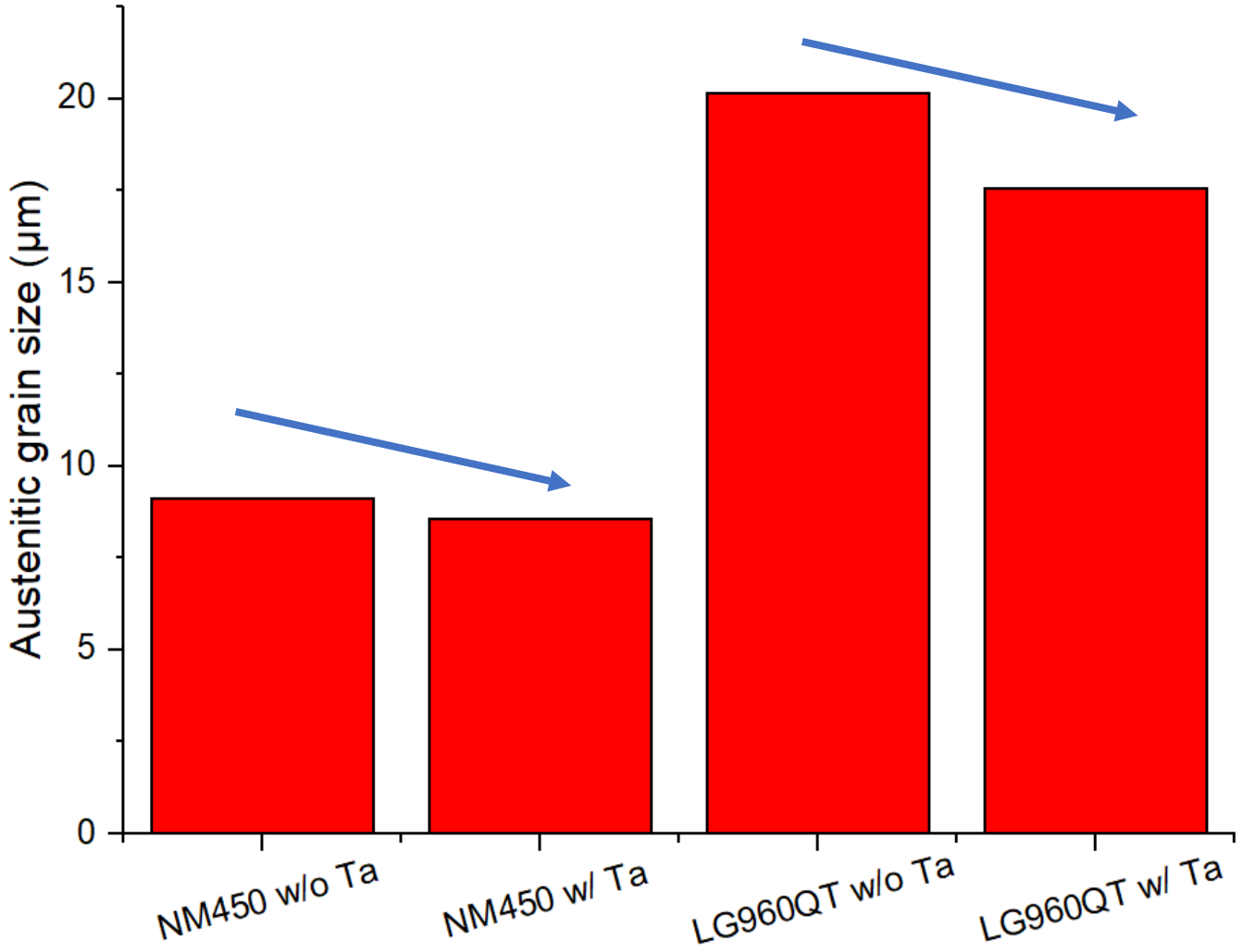


LG960QT – No Ta

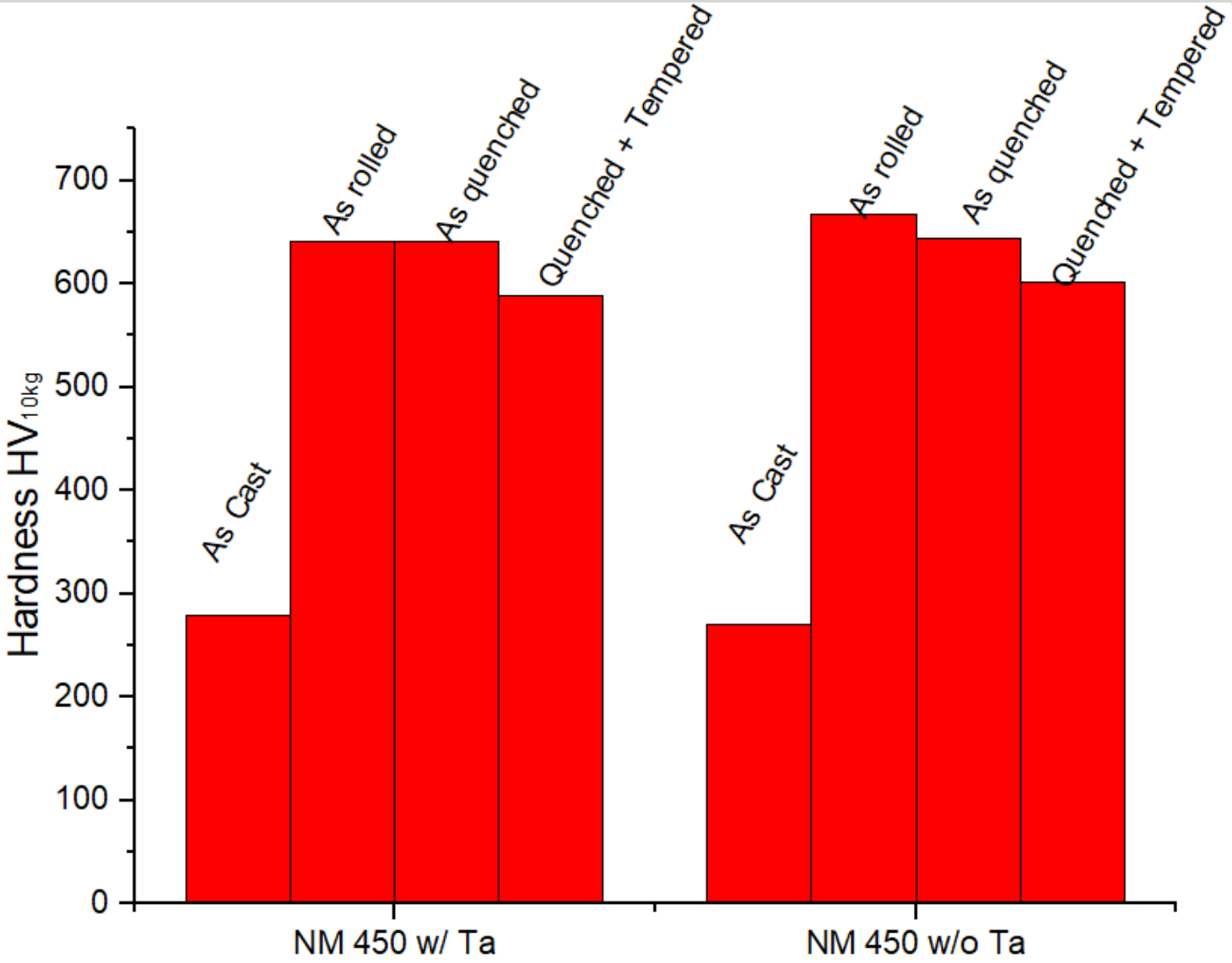
As rolled

LG960QT – With Ta

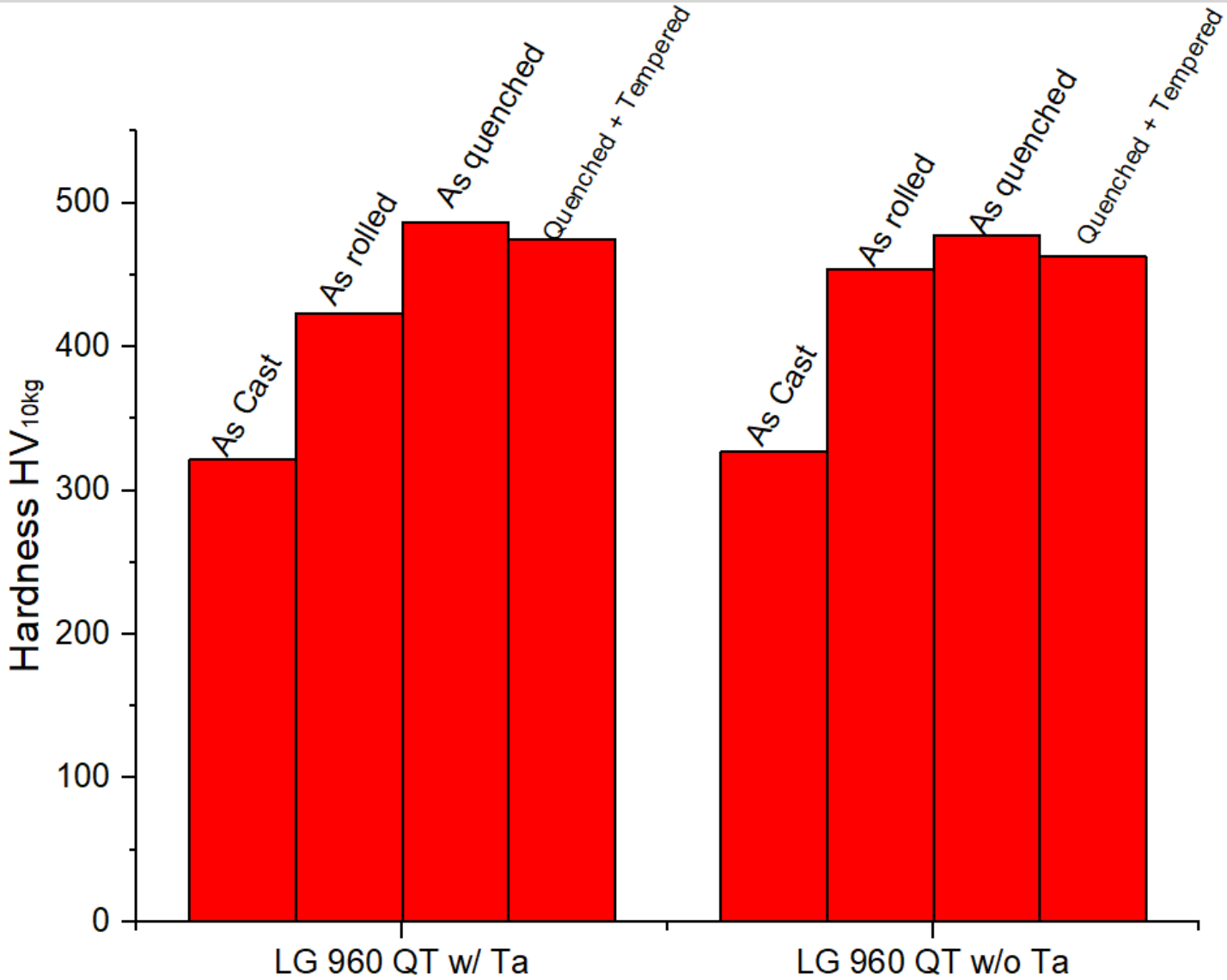
AUSTENITE GRAIN SIZE – AFTER HEAT TREATMENT



HARDNESS - NM 450



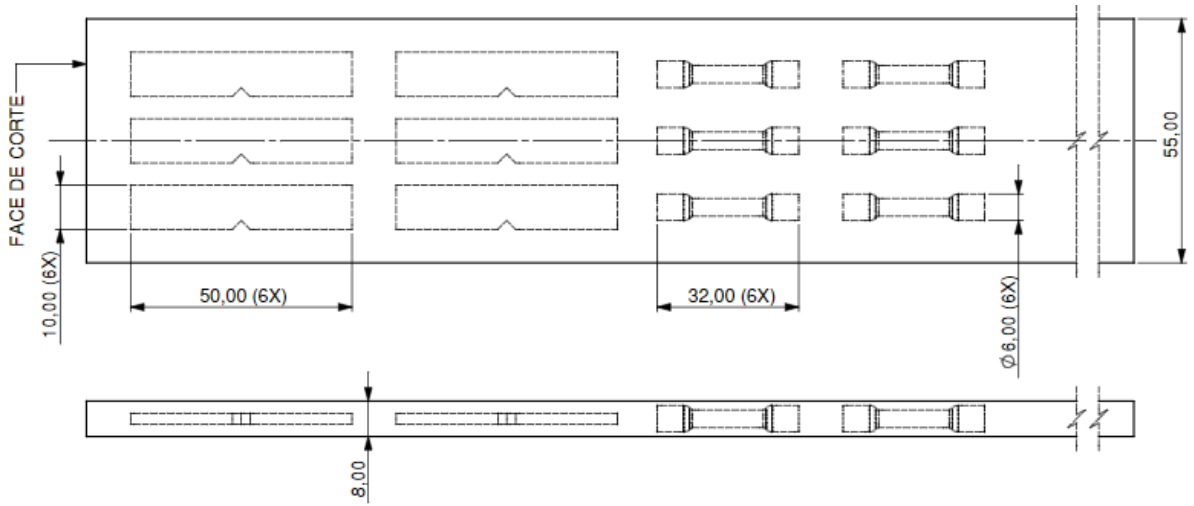
HARDNESS - LG960QT



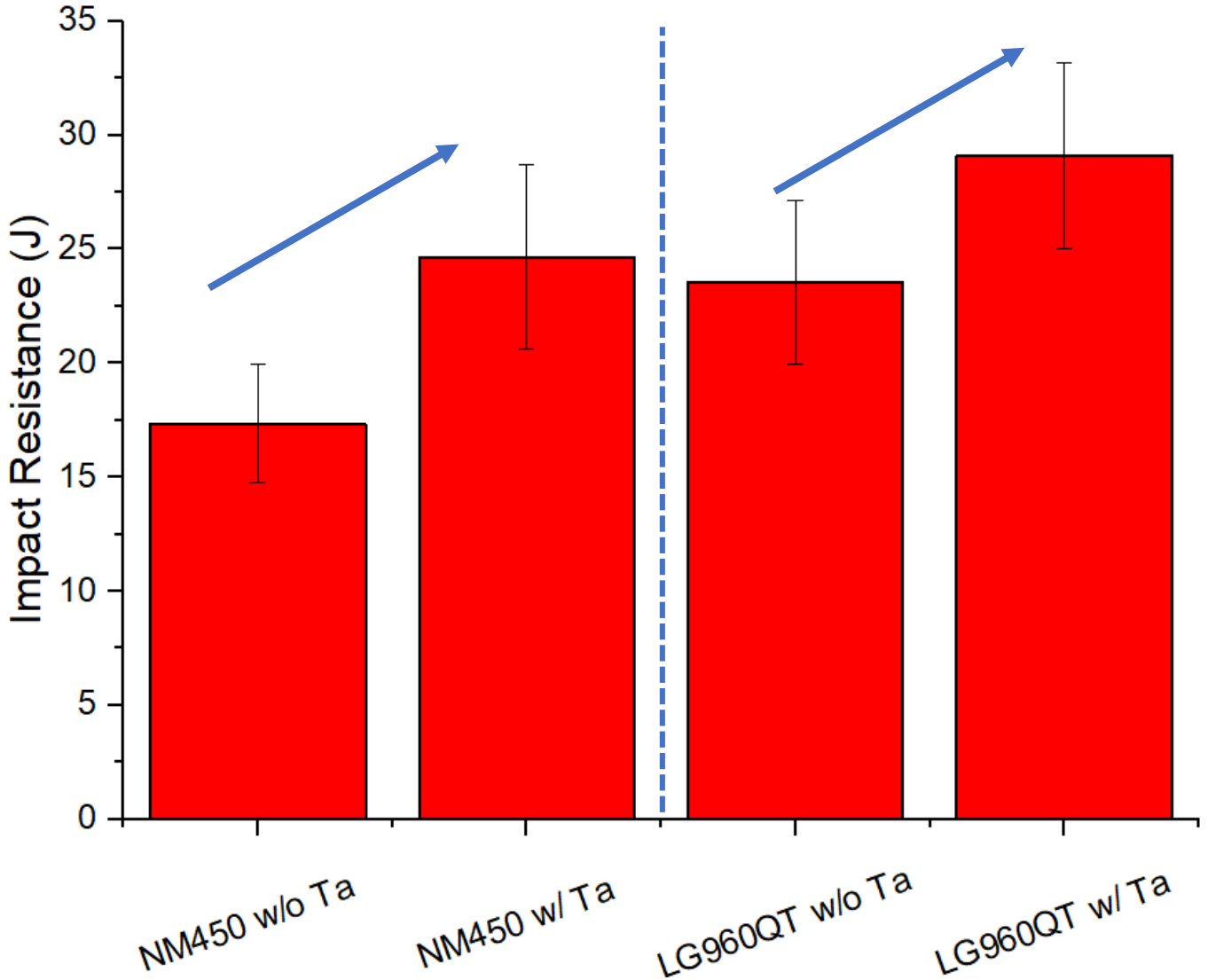
HARDNESS COMPARISON

	Vickers hardnes 1 kg (heat treated samples)			
	No Ta		With Ta	
NM450	588	± 4	601	± 3
LG960QT	463	± 2	475	± 3

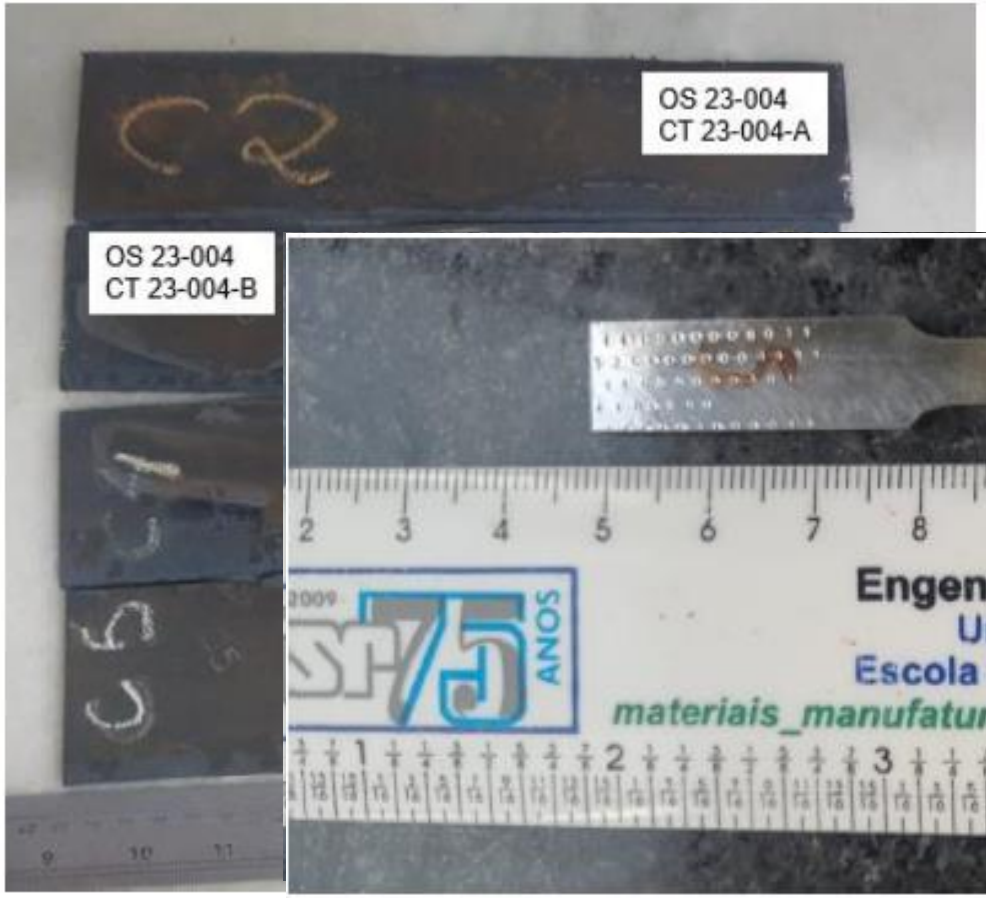
CHARPY V-NOTCH TEST

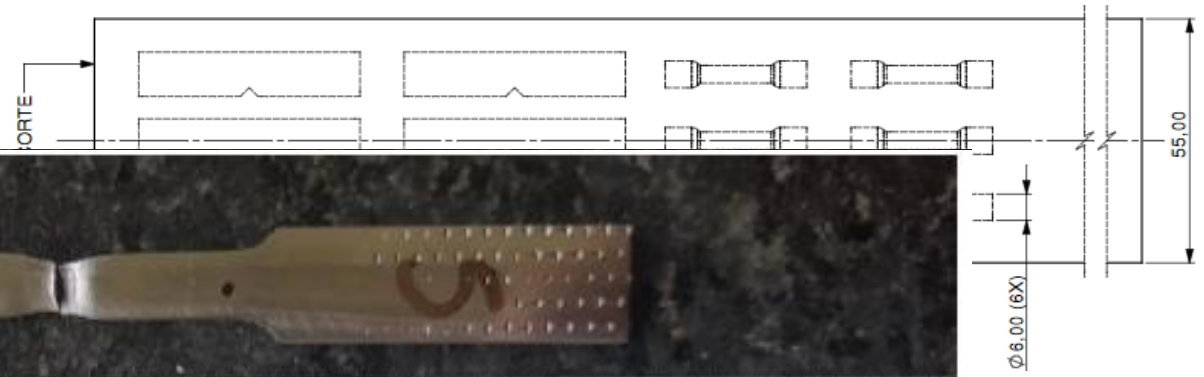


CHARPY V-NOTCH TEST RESULTS



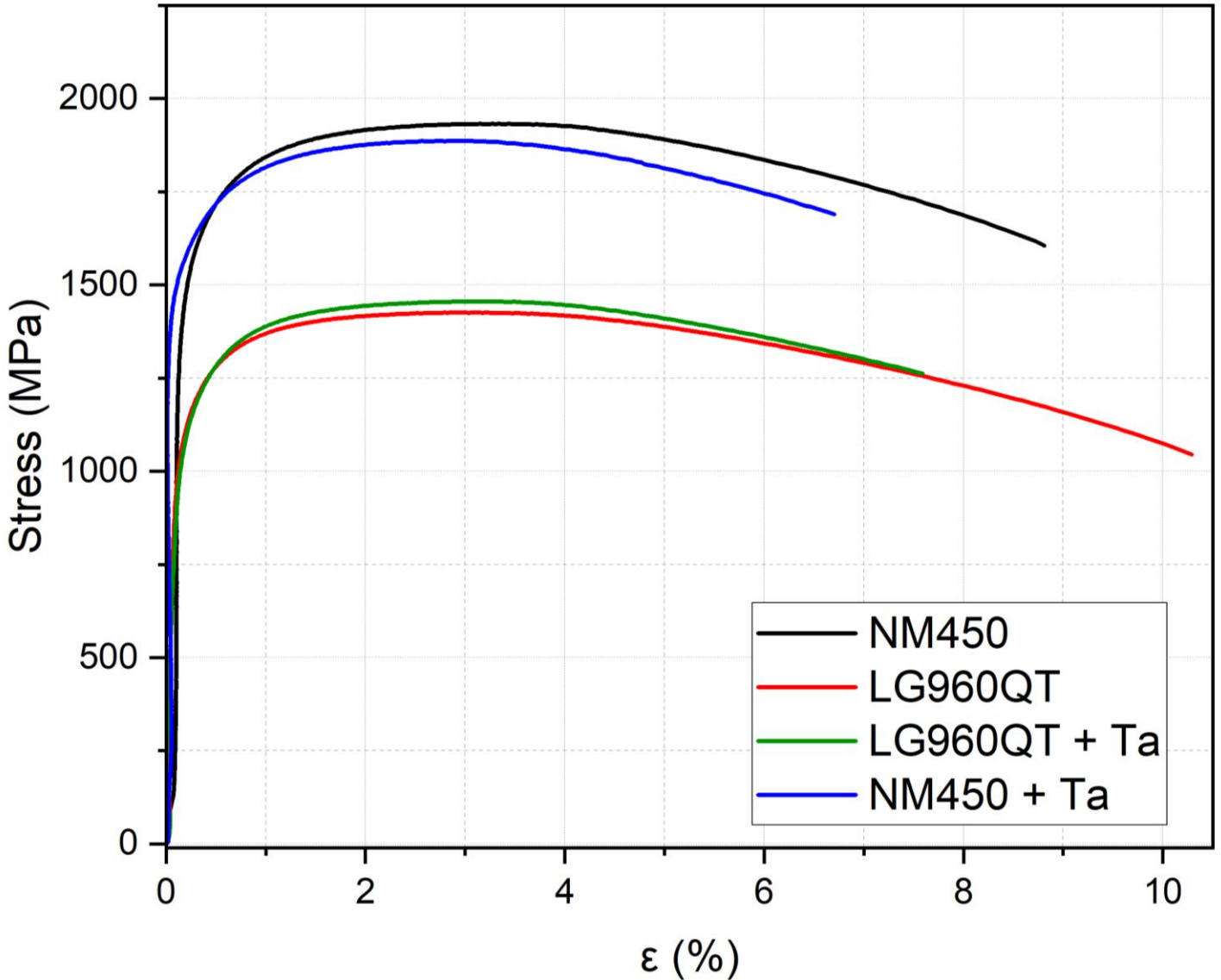
RESULTS – TENSILE TEST





		Subsize Specimen
		6 mm [0.250 in.] Wide
		mm [in.]
		25.0 ± 0.1 [1.000 ± 0.003]
		6.0 ± 0.1 [0.250 ± 0.005]
R—Radius of fillet, min (Note 6)	25 [1]	6 [0.250]
L—Overall length, min (Note 2, Note 7, and Note 8)	450 [18]	100 [4]
A—Length of reduced parallel section, min	225 [9]	32 [1.25]
B—Length of grip section, min (Note 9)	75 [3]	30 [1.25]
C—Width of grip section, approximate (Note 4 and Note 9)	50 [2]	10 [0.375]

TENSILE TEST - RESULTS

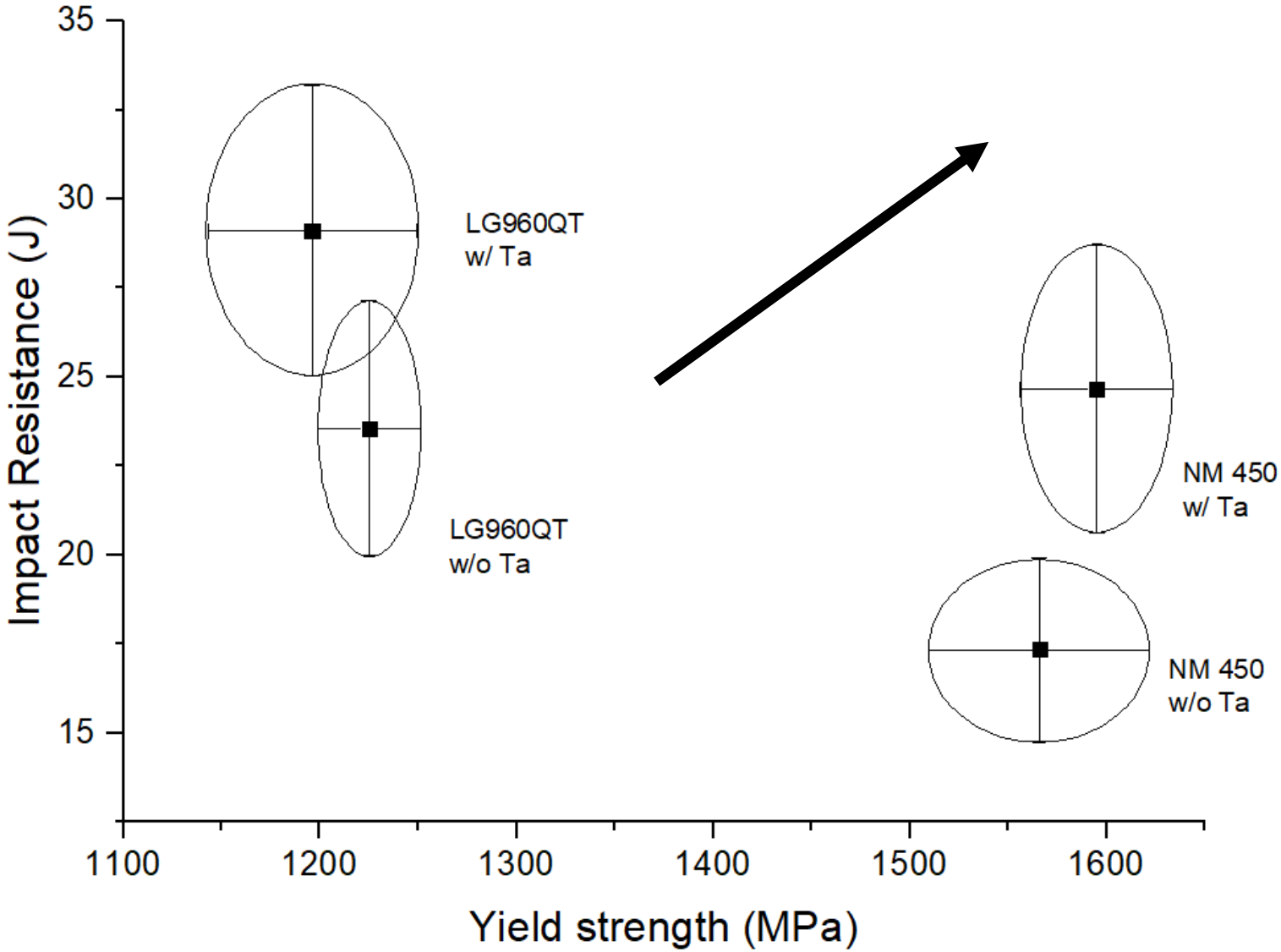


TENSILE TEST - RESULTS

	NM 450		LG960QT	
	W/ Ta	W/o Ta	W/ Ta	W/o Ta
Yield strenght (MPa)	1480	1413	980	963
Elongation at failure (%)	6,5	8,7	7,5	10,46

	%C	%Si	%Mn	%Cr	%Ni	%Mo	%Ti	%Al	%V	%B	%Nb
LG960QT	≤ 0,18	≤ 0,5	≤ 1,5	≤ 0,8	≤ 1,2	≤ 0,7	≤ 0,03	≥ 0,015	≤ 0,08	≤ 0,003	≤ 0,07
NM450	≤ 0,35	≤ 0,7	≤ 1,7	≤ 1,1	-	≤ 0,55	≤ 0,05	≥ 0,01	-	-	≤ 0,03

MECHANICAL TESTS - SUMMARY



CONCLUSIONS

- Effect of Residual Tantalum:
  - The Tantalum present in FeNb had a **positive effect** on NM450 and LG960QT steels, promoting greater **microstructural refinement**.
- Impact on Mechanical Properties:
  - Impact Toughness: Increased by **40%** for NM450 and **26%** for LG960QT when using FeNb with residual tantalum.
- Yield Strength:
  - Maintained for both steels, with a slight reduction in elongation at fracture.
- Hardness Comparison:
  - No significant difference was observed in hardness among the samples of the same steels, regardless of the FeNb source.
- Final Conclusion:
  - The residual Tantalum present in FeNb has positive effects on Nb-microalloyed steels. Further studies are needed to explore other mechanisms of Tantalum's action in steels.

Thank you!

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