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EFFECT OF A MANGANESE CONTENT ON THE KINETICS OF NANOBAINITE FORMATION IN MEDIUM-MN STEELS WITH RETAINED AUSTENITE

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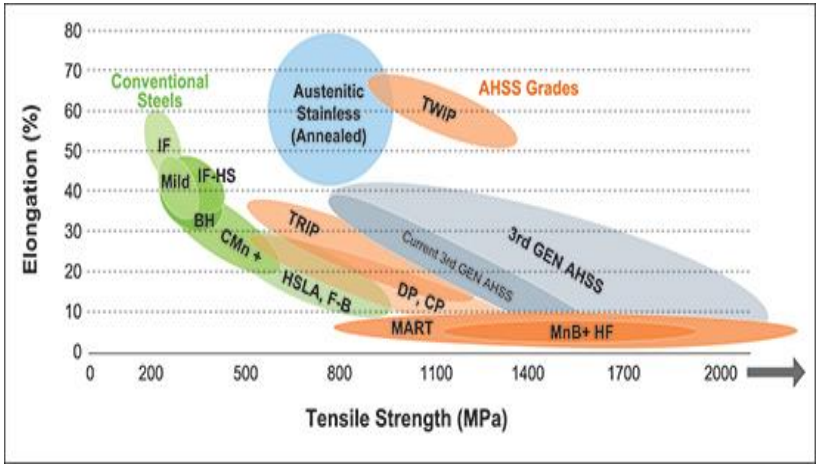
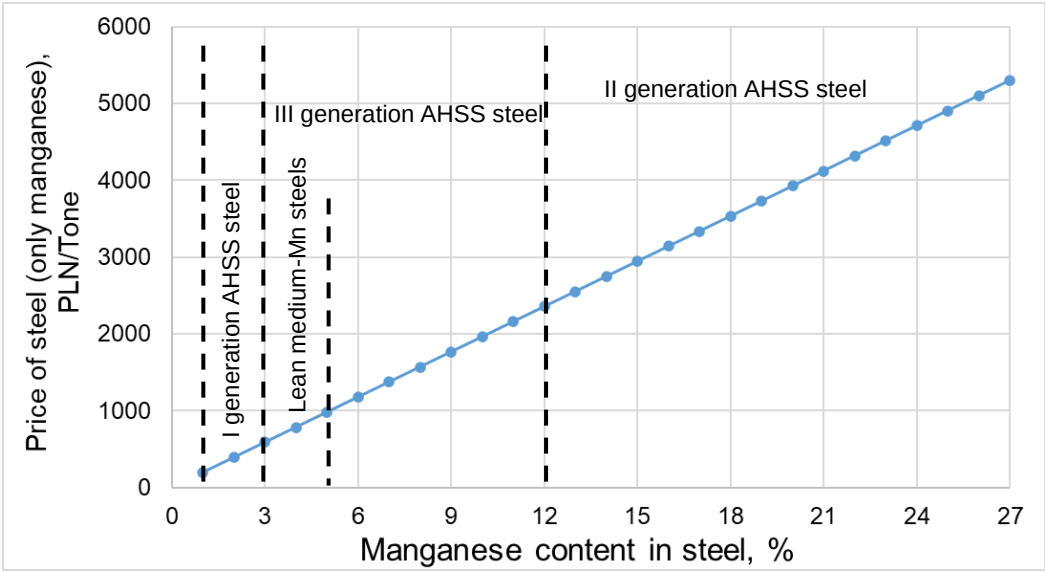
INTRODUCTION



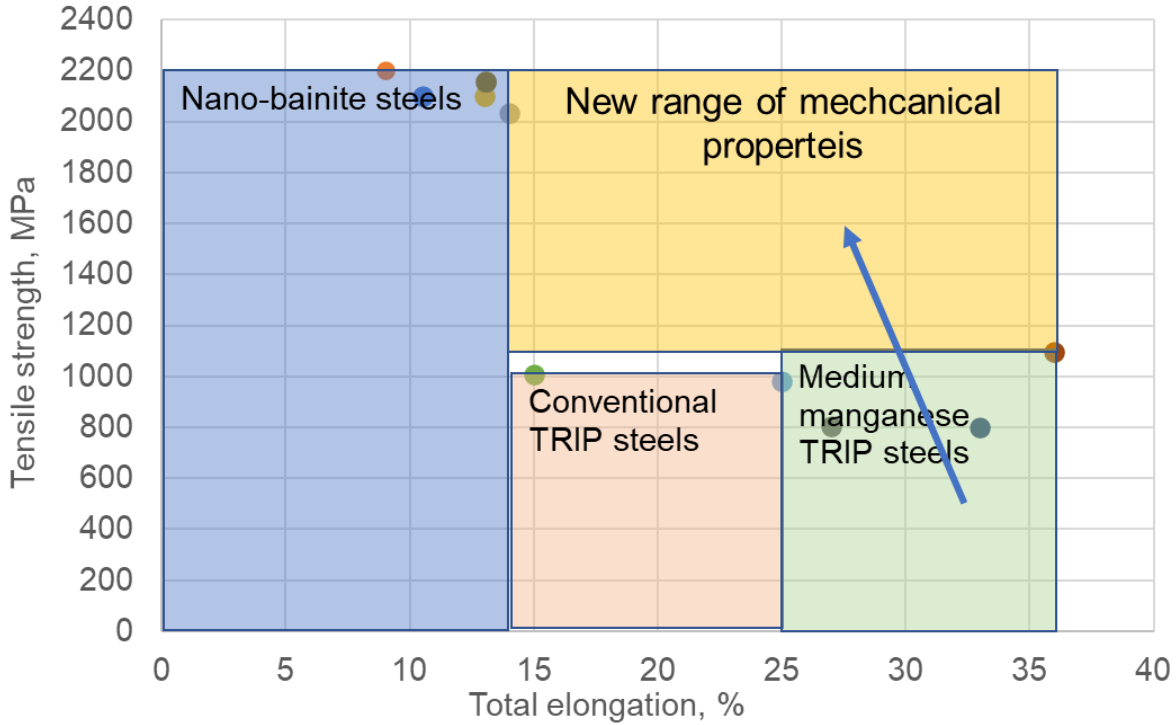
	Mid-Range CO_2e	Estimated Part Weight (kg)	kg CO_2e
Mild Steel	1.9	100	190
AHSS	1.9	75	143
Aluminum	8.9	67	596
Magnesium	46	50	2300
CFRP	22	45	990

Figure 9. LCA Emissions from Material Production



The price of 1 ton of steel increase 5 times, when the Mn content is increased from 5 to 24%

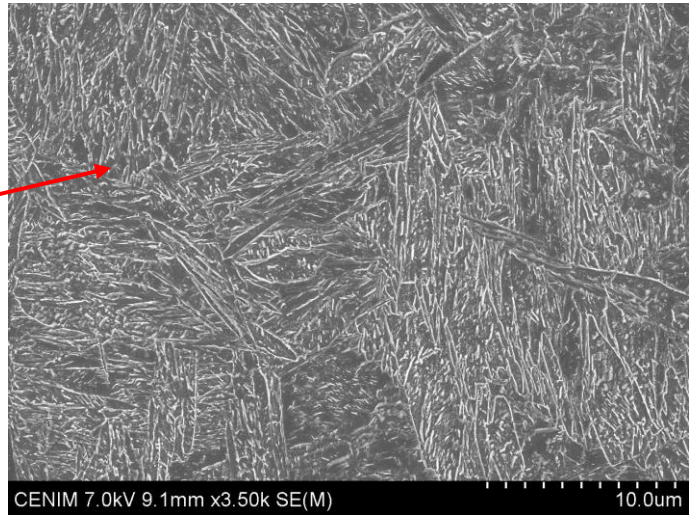
INTRODUCTION



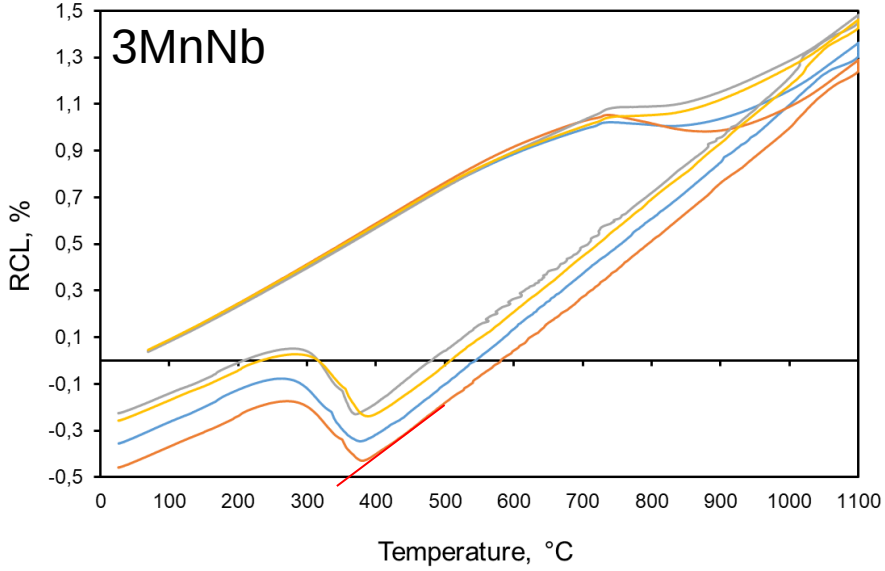
MATERIAL

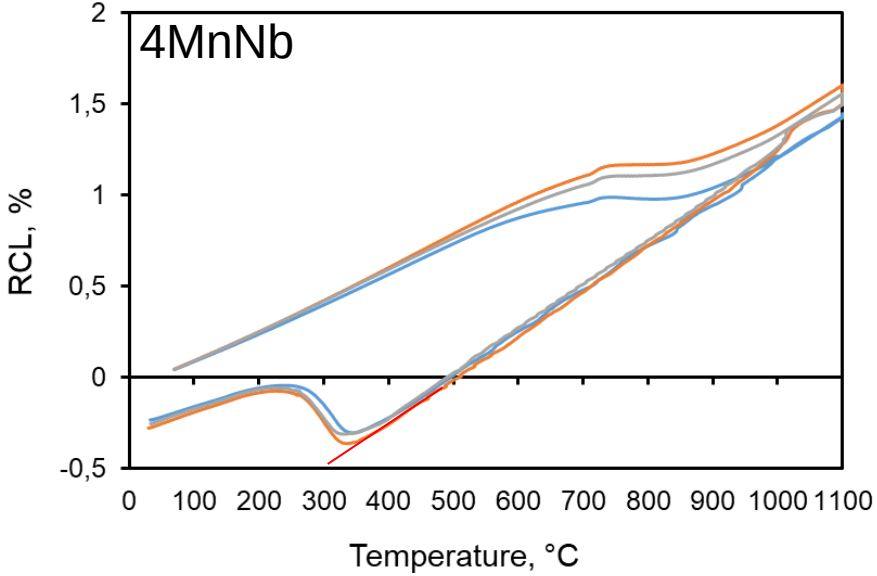
Steel grade	C	Mn	Al	Si	Mo	Nb
3MnNb steel	0.17	3.1	1.6	0.20	0.20	0.04
4MnNb steel	0.17	3.6	1.6	0.20	0.20	0.04

100% Martensite structure



INITIAL RESEARCH – DETERMINATION OF Ms TEMPERATUE

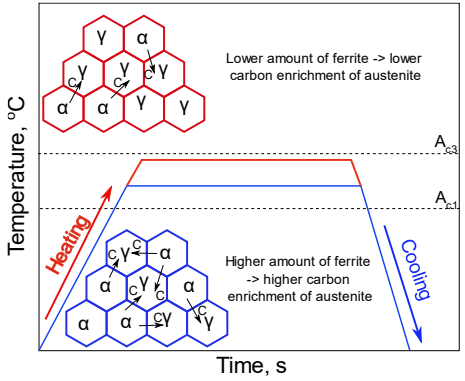


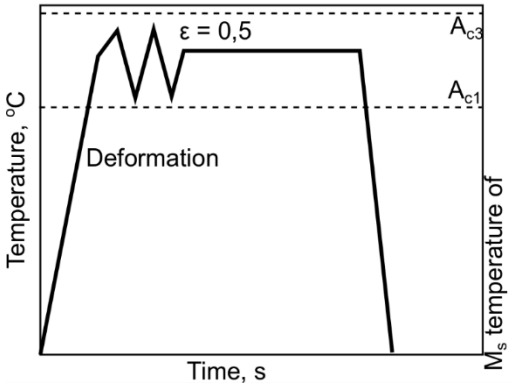


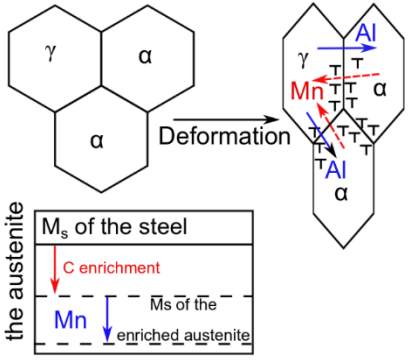
	Ms of the steel, °C
3MnNb	390 ± 7
4MnNb	356 ± 5

To high Ms temperature for nanobainite formation!

WAYS TO INCREASE THE THERMAL STABILITY OF AUSTENITE



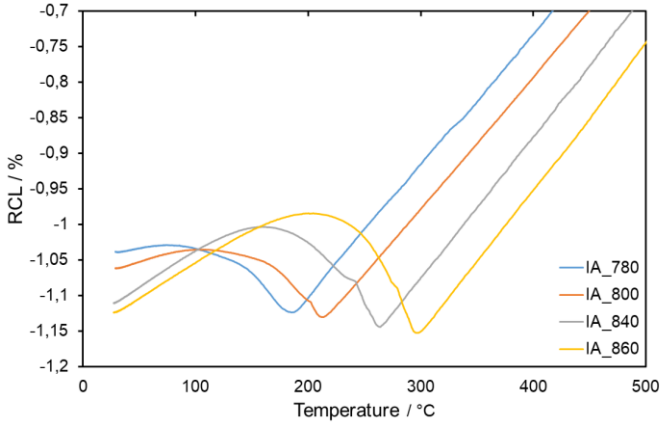




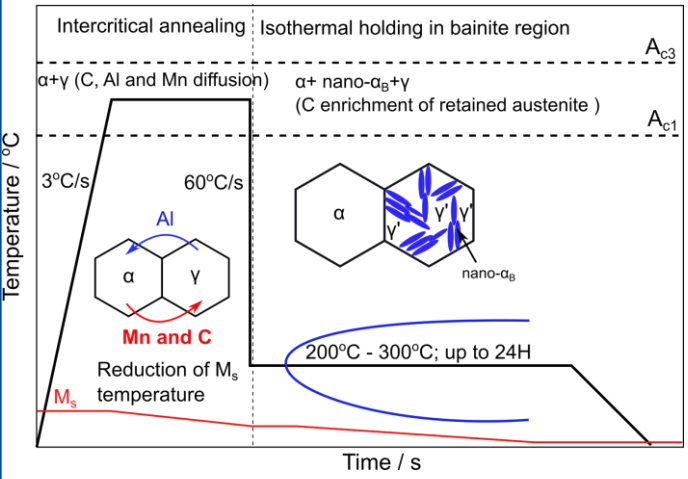
Austenite thermal stability controlled by the chemical composition

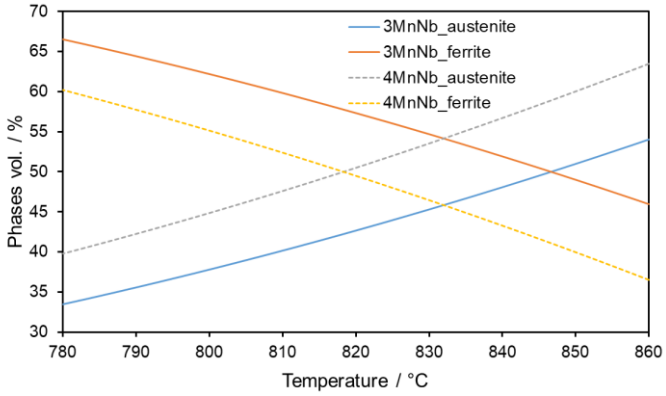
Austenite thermal stability controlled by the plastic deformation and grain refinement

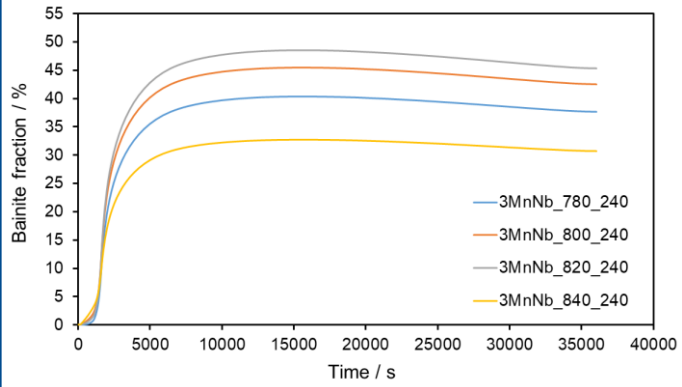
IA, °C	780	800	840	860
3MnNb Ms, °C	170	210	270	295
4MnNb Ms, °C	160	195	260	280

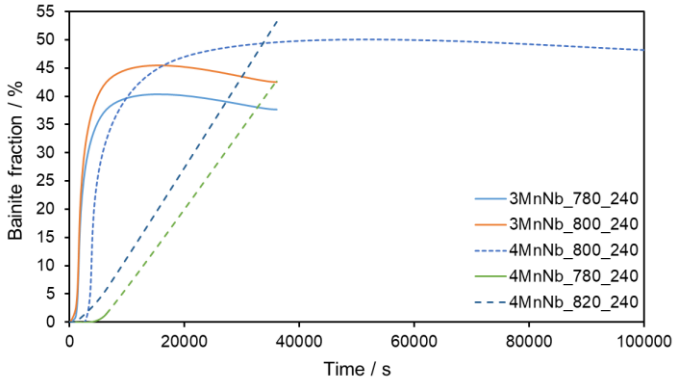


THEORETICAL CALCULATIONS

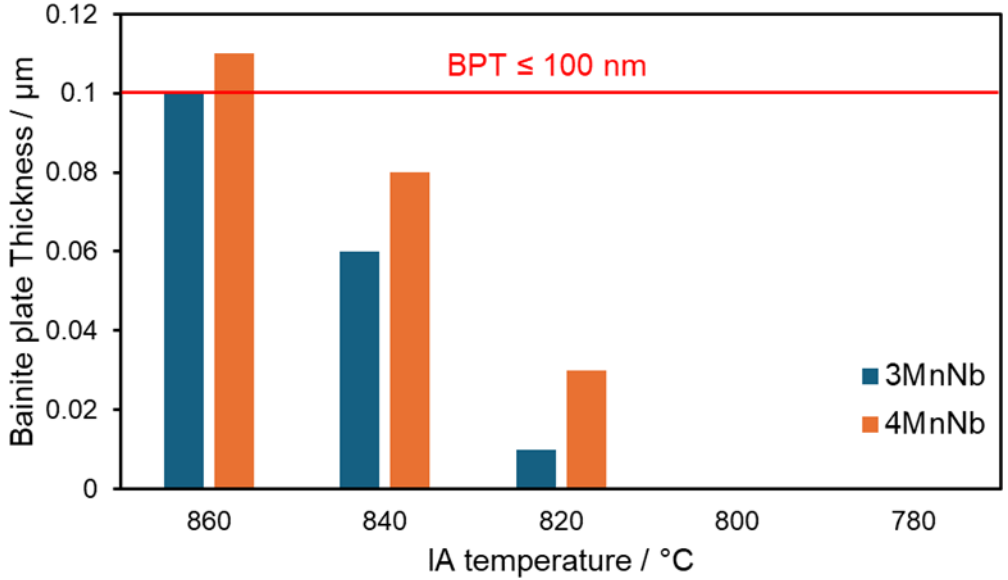








THEORETICAL CALCULATIONS – BAINITE PLATE THICKNESS

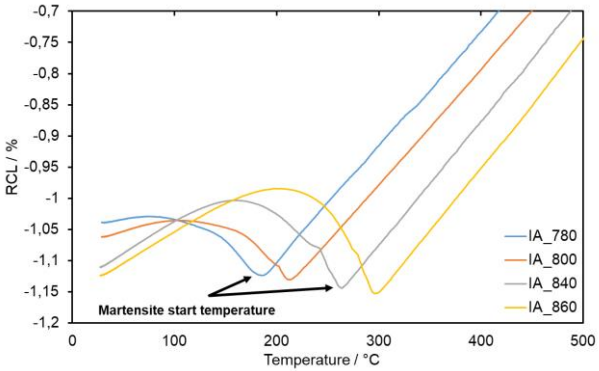


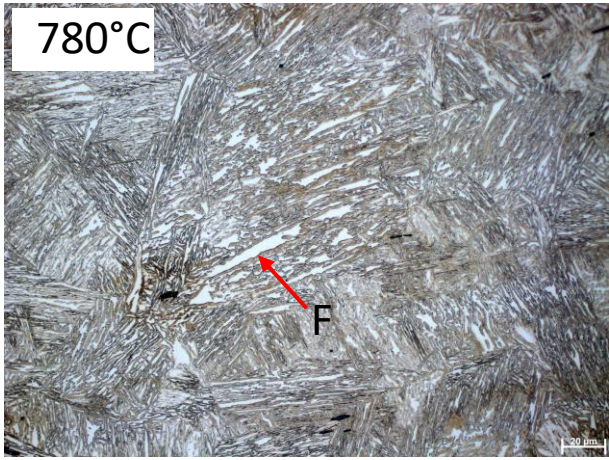
Azuma M., Fujita N., Takahashi M., Senuma T., Quidort D., Lung T. Modelling upper and lower bainite transformation in steels. ISIJ Inter. 2005; https://doi.org/10.4028/www.scientific.net/MSF.426-432.1405

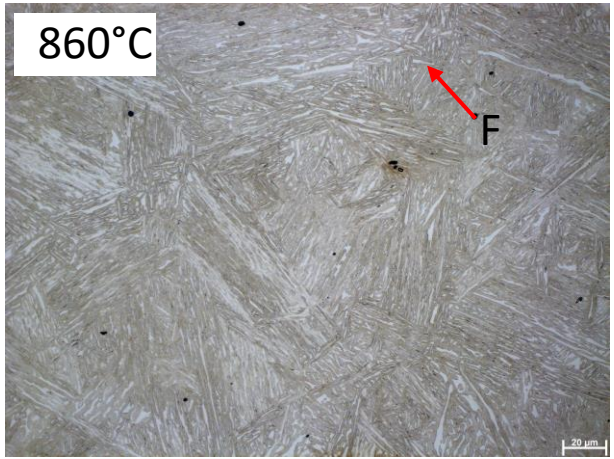
$$w_{\alpha_B} = 0.478 + 1.20 \times 10^{-4} T + 1.25 \times 10^{-4} \Delta G_{max}^{\gamma \to \alpha} - 2.20 \times 10^{-3} S_\gamma$$

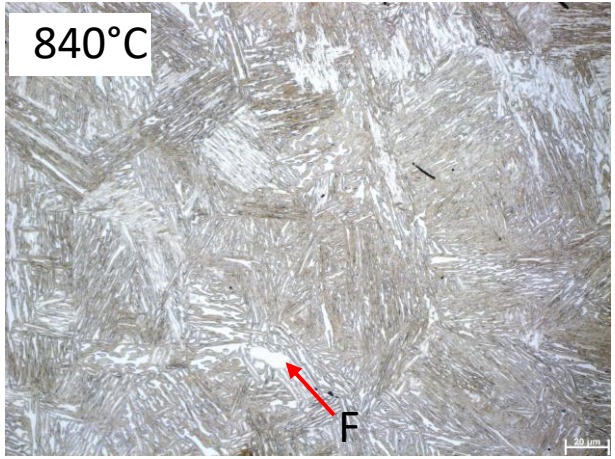
$$S_\gamma = [1 - 0.26 \times 10^{-2}(T - 25) + 0.47 \times 10^{-5}(T - 25)^2 - 0.326 \times 10^{-8}(T - 25)^3] \times 15.4(3.6 + 23C + 1.3Si + 0.65Mn)$$

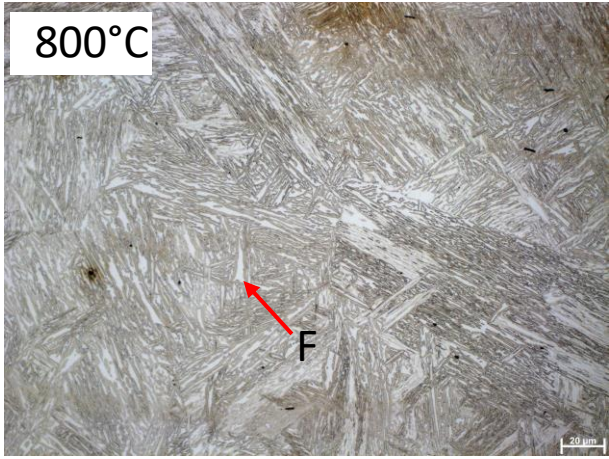
DILATOMETRY STUDY - IA



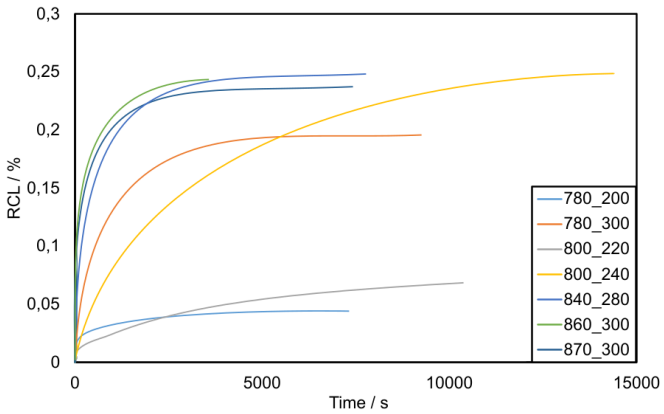


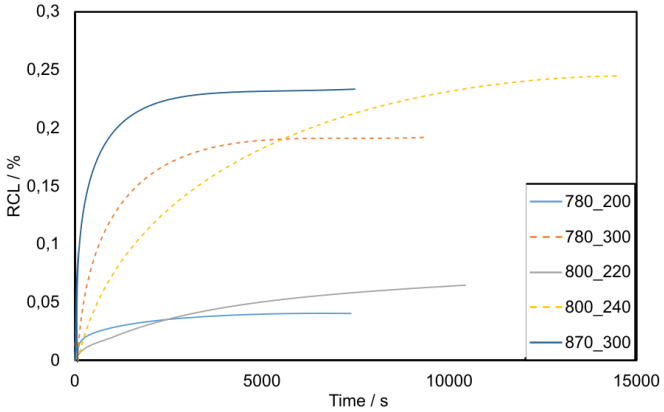




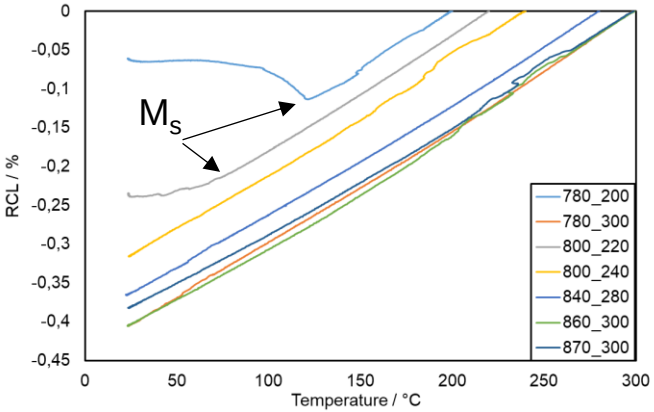


DILATOMETRIC STUDY – NANOBAINITE FORMATION 3MnNb STEEL



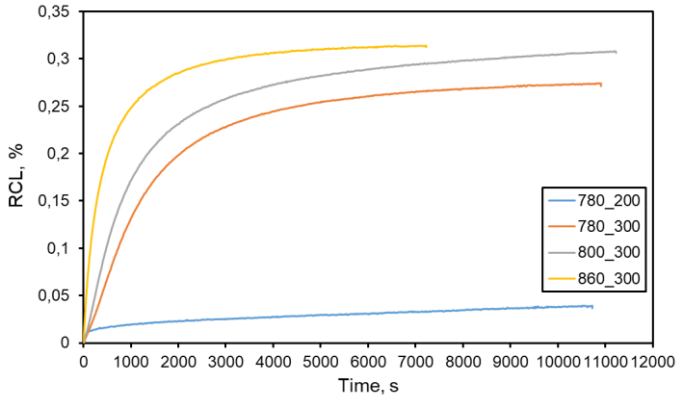


The IBT around 200 °C, exhibit sluggish transformation kinetic for independently of the IA temperature. Together with increase of IBT temperature, the transformation is much faster and more nanobainite is forming.

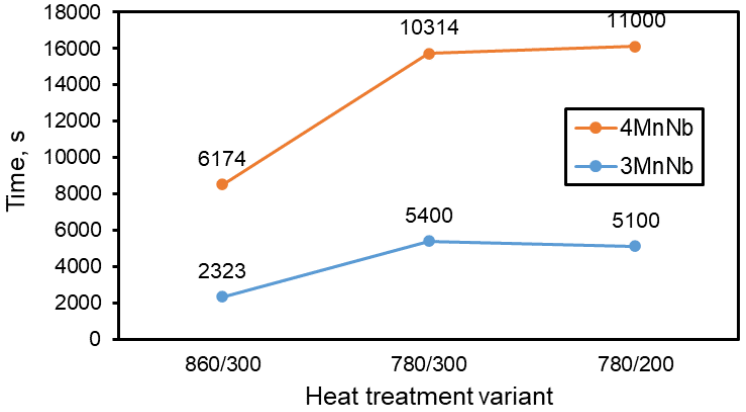


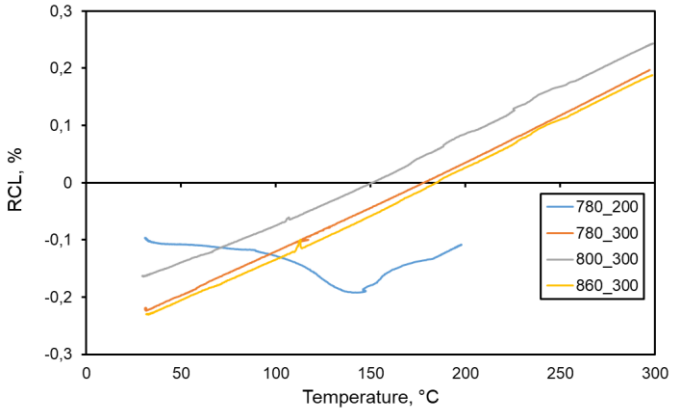
For low IBT temperatures, the formation of martensite was detected. Which means that the austenite was not fully stabilized during the nanobainite formation

DILATOMETRIC STUDY – NANOBAINITE FORMATION 4MnNb STEEL

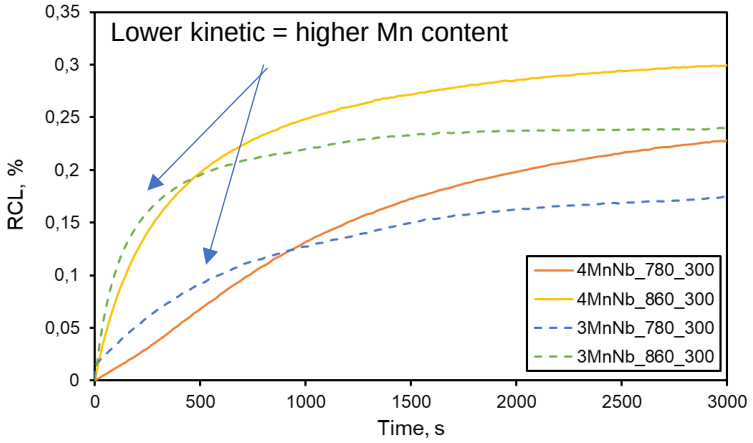


Comparing the 4MnNb steel with the 3MnNb steel, it can be seen that the formation of nanobainite is much slower. The difference in time of the transformation finish is around 2,5 higher.

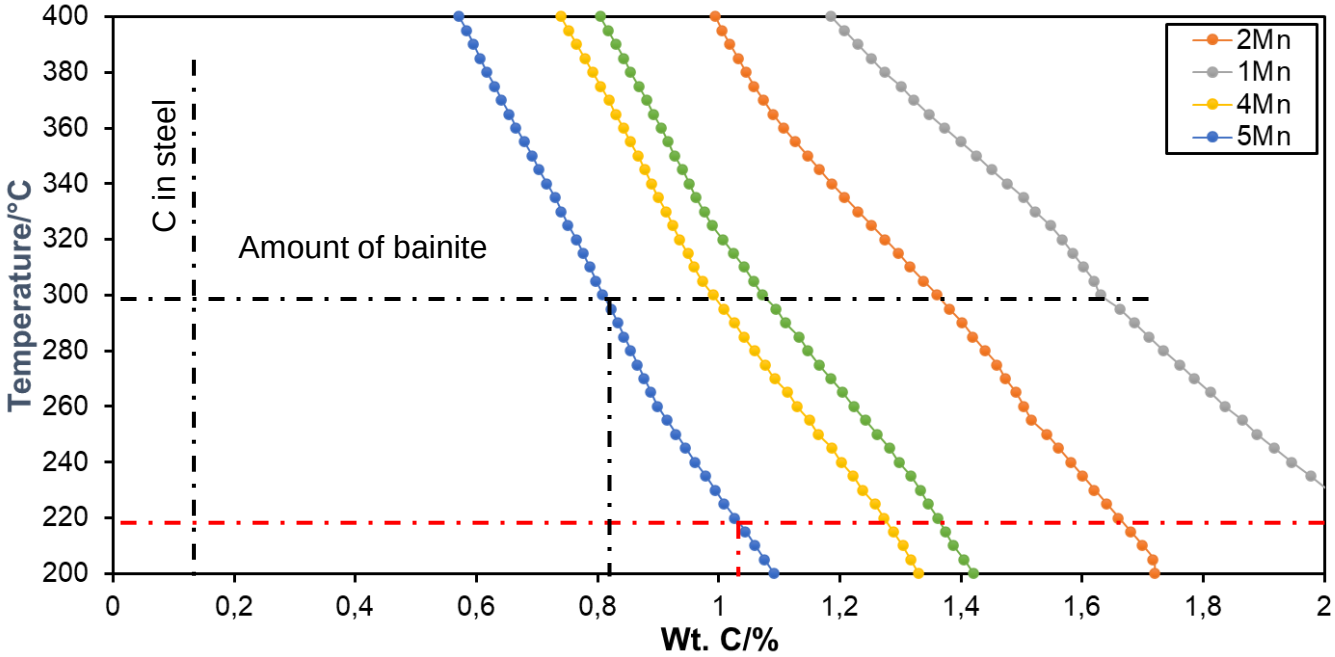




Moreover, the kinetic of the transformation at the beginning is lower for 4MnNb steel, and it speed up after some time. This speed up correspond to higher austenite fraction that can undergo nanobainite formation.



MANGANESE INFLUENCE ON BAINITE FORMATION KINETIC

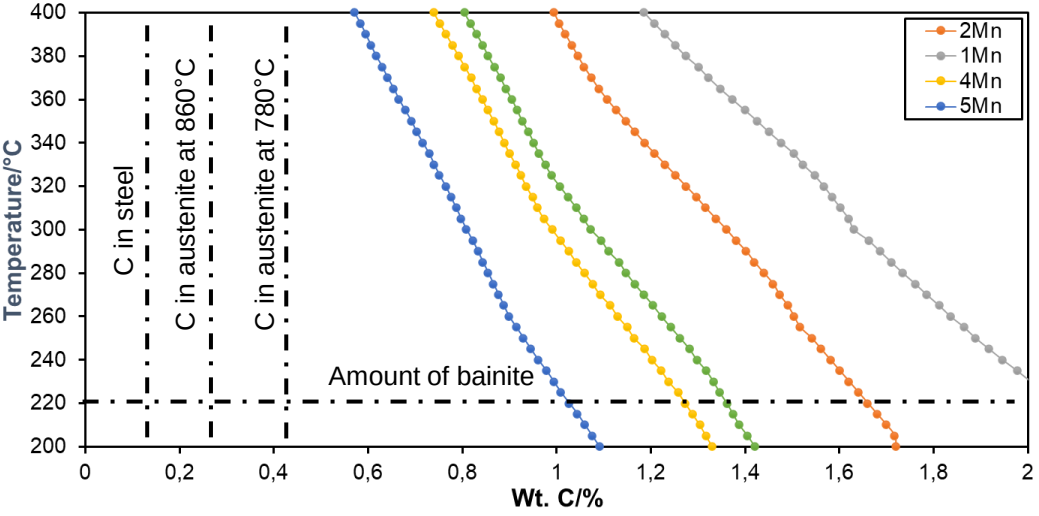


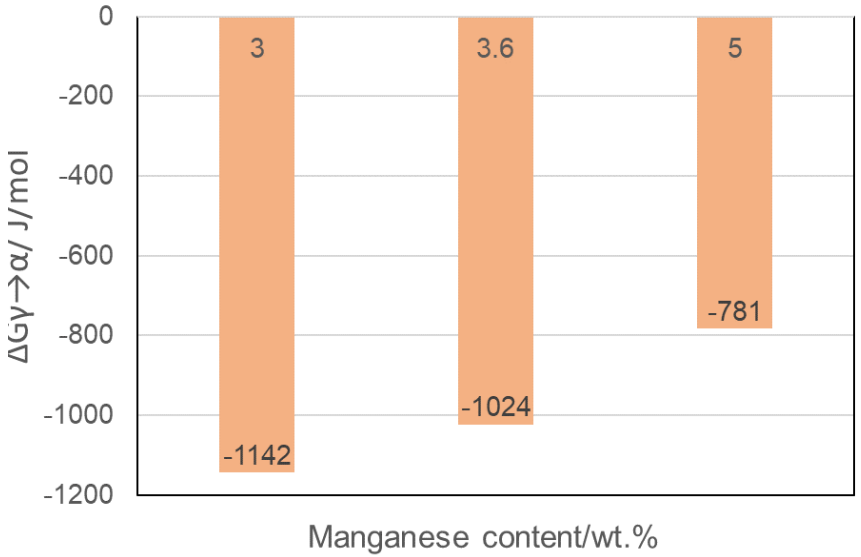
Manganese decreases the amount of bainite, by decreasing the equilibrium carbon concentration in austenite

A decrease of isothermal holding temperature results in the increase of equilibrium carbon concentration in austenite

Temp. [°C]	Fe [wt.%]	Al [wt.%]	Mn [wt.%]	Mo [wt.%]	Nb [wt.%]	Si [wt.%]	C [wt.%]
860	94,153087	1,363202	3,826821	0,184148	0,000197	0,205275	0,26727
840	93,950813	1,319163	4,04244	0,182759	0,000125	0,206326	0,298374
820	93,707943	1,277219	4,29103	0,18213	0,000078	0,207366	0,334234
800	93,416821	1,237621	4,579343	0,182343	0,000048	0,208423	0,375401
780	93,067285	1,200506	4,916719	0,183479	0,000029	0,209568	0,422414

CARBON INFLUENCE ON BAINITE FORMATION KINETIC





Carbon concentration in austenite after IA, strongly influences the amount of bainite

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Conclusions

1. Two step heat treatment allows for the formation of bainite at lower isothermal holding temperatures without martensite (in most cases). It is possible to form nanobainite at the temperatures from 200 to 300°C,
2. Decreasing the IA temperature, results in the lower bainite amount after isothermal holding. This correspond to the amount of austenite and its chemical composition prior to the isothermal holding,
3. As the IA temperature increase, the nanobainite transformation kinetics accelerate too. The fastest transformation occurs at the IA temperatures of 840, 860 and 870°C,
4. The manganese content has a big impact on the kinetic of nanobainite formation. For 4MnNb steel, the kinetic is much slower, however it is possible to form more nanobianite, as more austenite is available before IBT.
5. The proposed heat treatment, need to be optimized, as not only manganese but also carbon strongly influence the kinetic of the nanobainite formation as well the amount of it.

Thank you for your attention!

ACKNOWLEDGEMENTS

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NARODOWE CENTRUM NAUKI