Decomposing of austenite in ‘Q&P’ steels

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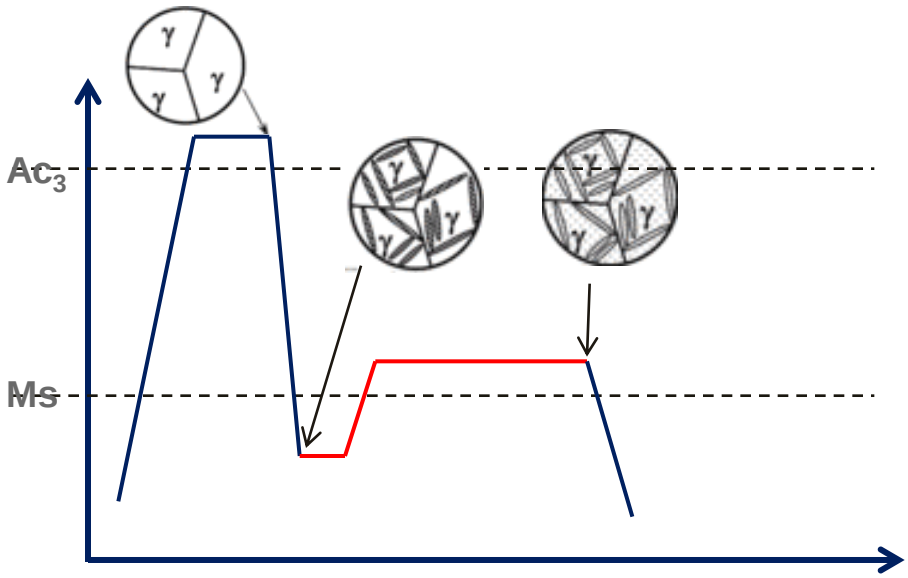
[4] **Dept. of Materials Science and Engineering, TUDelft, the Netherlands**

In the ideal Q&P concept



Assumptions:

On α':

- No cementite formation
- Full C partitioning from α' to γ

On γ:

NO DECOMPOSITION

?

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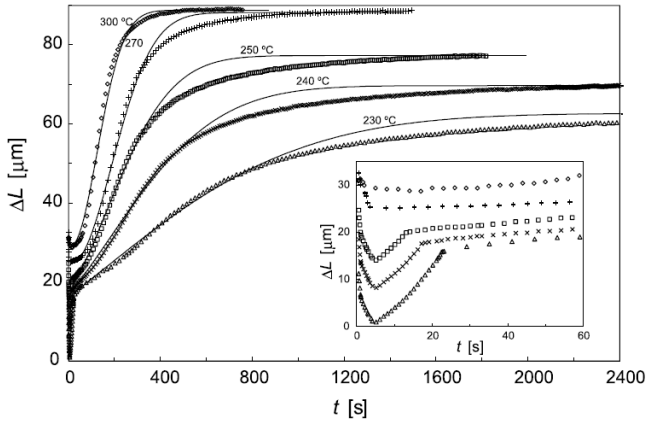
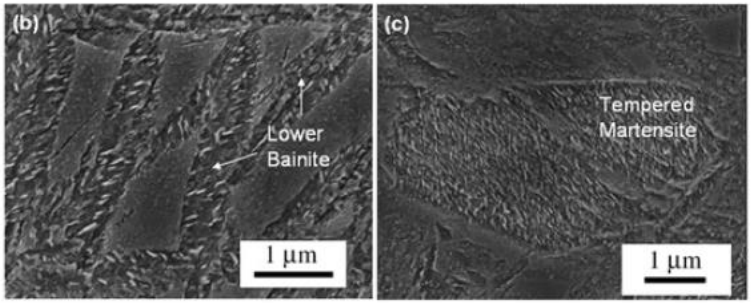
Isothermal Bainitic transformation?

Van Bohemen et al, in ***Fe-0.69Mn-0.66C***
The austenite decompose isothermally at a certain rate, which is in agreement with the kinetics of bainite formation above Ms





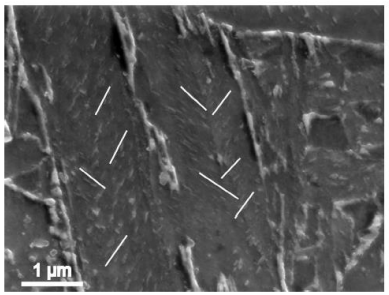
$$f = 1 - \exp(-(kt)^n), \qquad k = k_0 \exp(-E/RT),$$

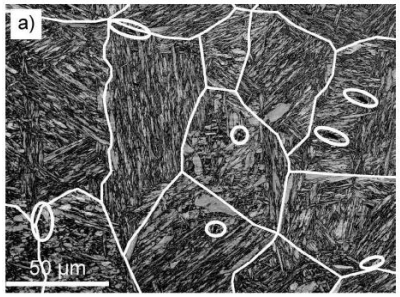
n=2, k_0=58.7 s^{-1} and E=43.6 kJ mol^{-1}

van Bohemen, TUDelft, Scripta, 2008

Hell et al, in ***Fe-0.2/0.3C-2.5Mn-1.5Si-0.8Cr*** (40mins)
A continuous increase of the austenitic lattice parameter as the isothermal transformation proceeded, and similar evolution at Ms+50°C

Steel	AT	α_B	γ_R	α_{ST}	α'	C_γ^C
	Ms–50°C	26.0	11.3	62.3	0.4	0.64
C2	Ms	77.3	15.1	4.2	3.4	1.04
	Ms+50°C	53.2	7.4	–	39.4	0.43
	Ms–50°C	18.5	18.3	62.1	1.1	0.59
C3	Ms	76.9	15.3	3.4	4.4	1.47
	Ms+50°C	63.3	21.5	–	15.3	0.80





Hell, U Metz & AM, ISIJ, 2011

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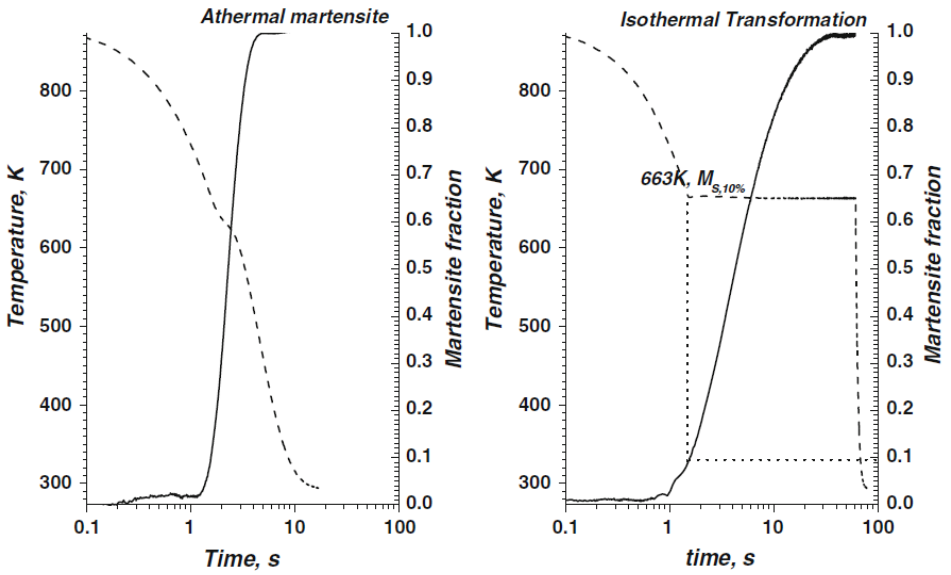
Isothermal Martensitic Trans?

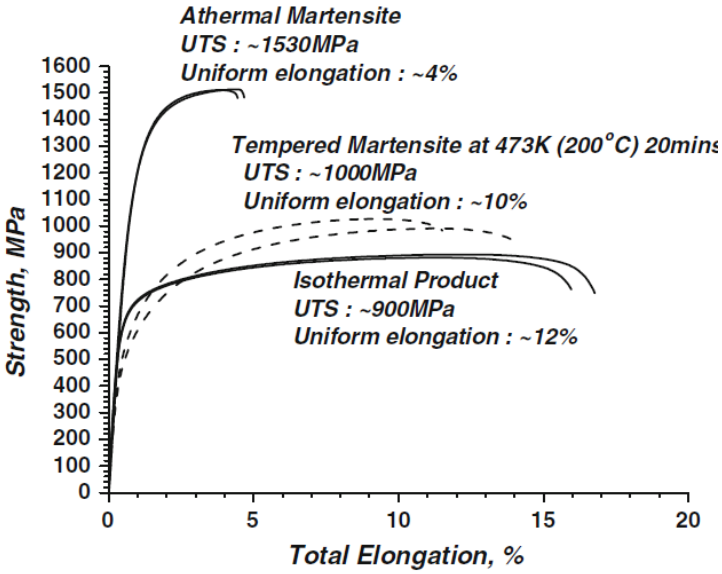
Normally occurs in high C, high alloyed steels @ low temperature

De Cooman et al in Fe-0.2C-1.5Mn-1.5Si

Similar athermal and isothermal transformation kinetics

But very different mechanical properties due to the C diffusion and dislocation recovery during the transformation





Kim, Postech, MMTA, 2011, 42, p1575

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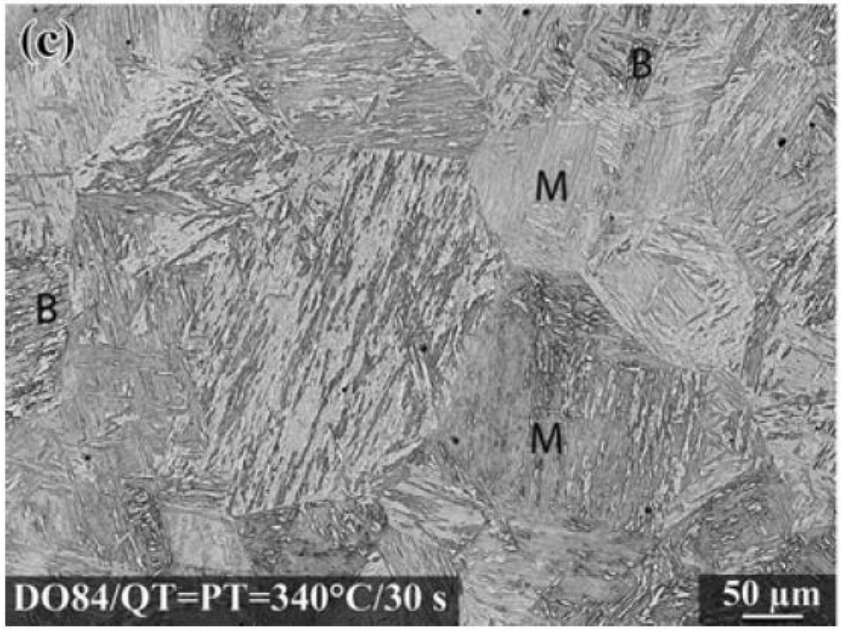
Transition in transformation machinisms?

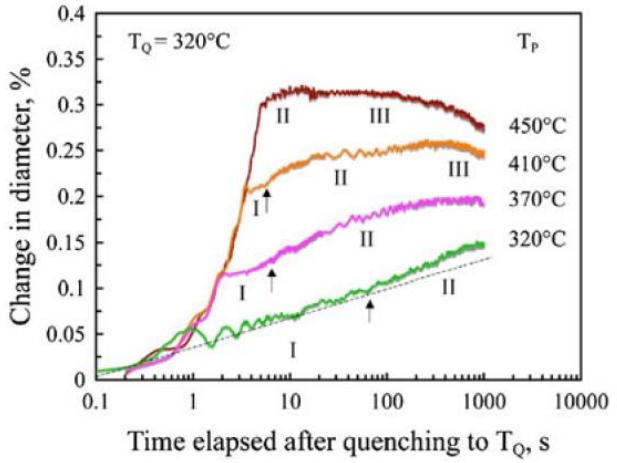
Somani et al in Fe-0.2C-2.0Mn-1.5Si-0.6Cr up to 1000s, both 1 and 2 steps Q&P

Isothermal martensite formation begins immediately after quenching

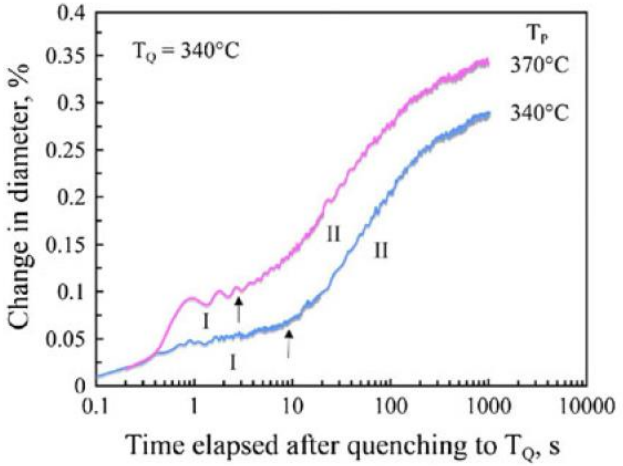
Followed by bainitic transformation with a faster kinetics (lower bainite, the same kinetic as TTT predicted)

Based on dilatation (greater than C portioning expansion)





(b) (ii)



Somani, U Oulu, MMTA, 2014, 45A, p1247

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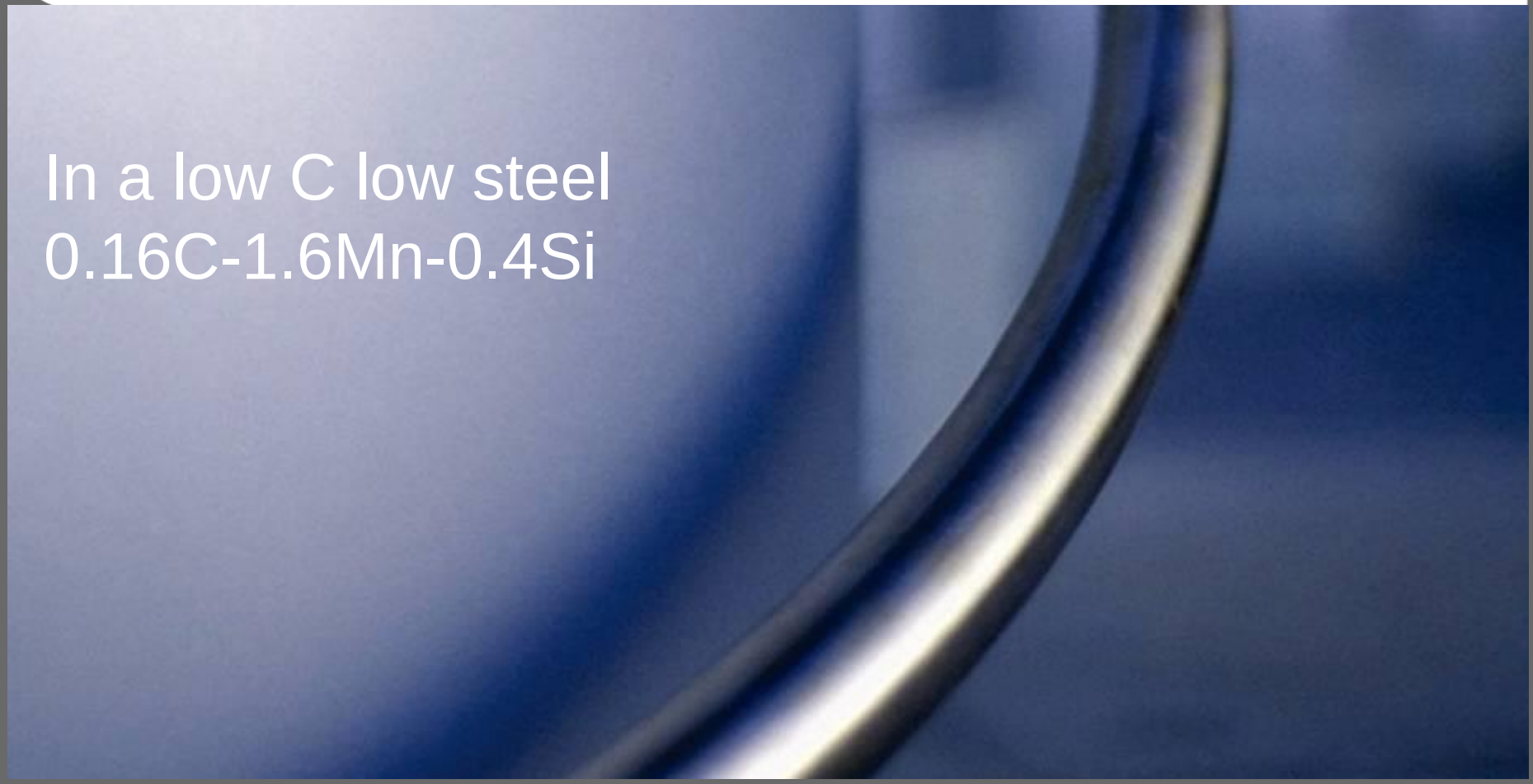
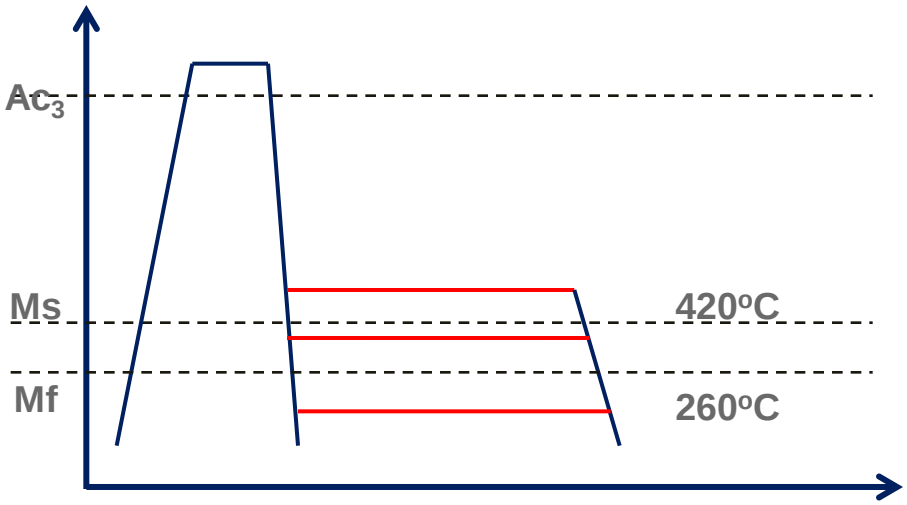
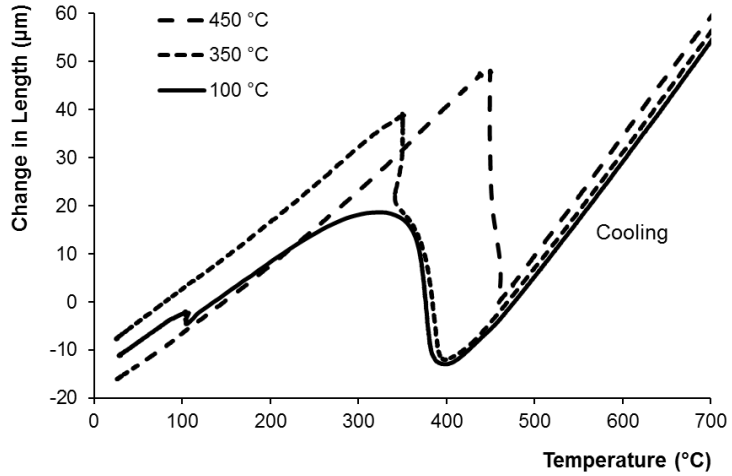
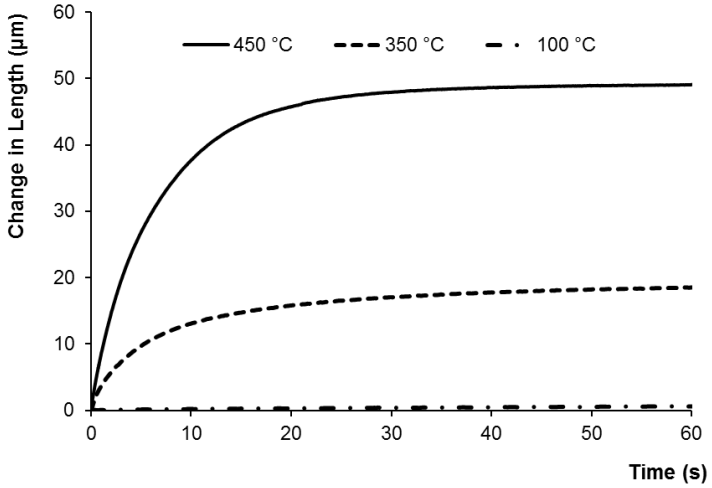

In a low C low steel
0.16C-1.6Mn-0.4Si

In a low C steel 0.16C-1.6Mn-0.4Si







Austenite fast transforms to lower bainite within the first minute!

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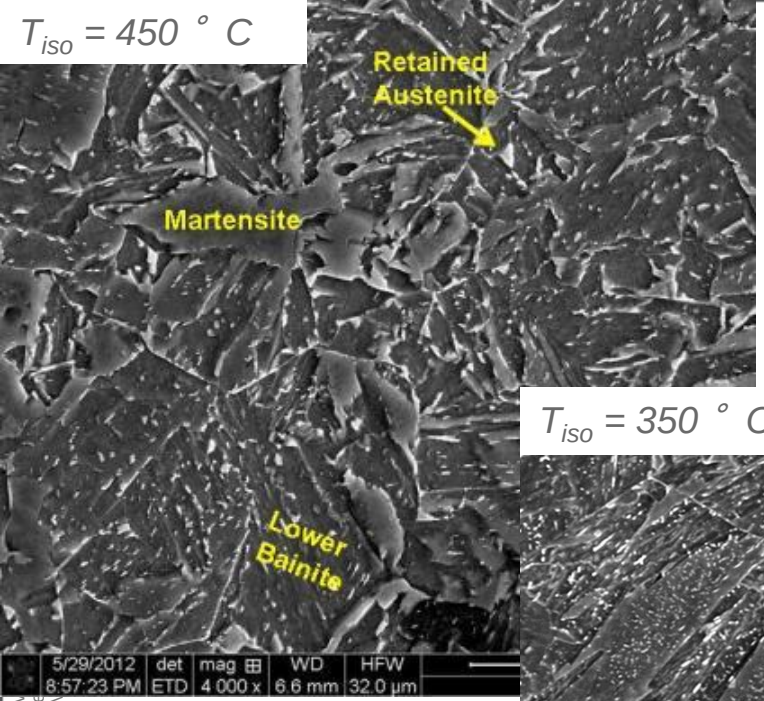

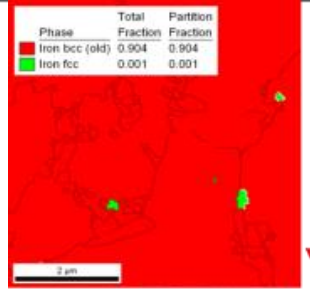

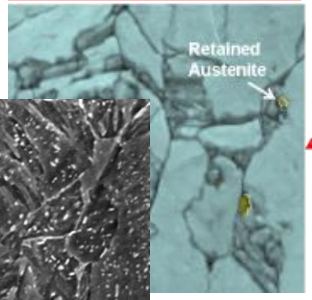

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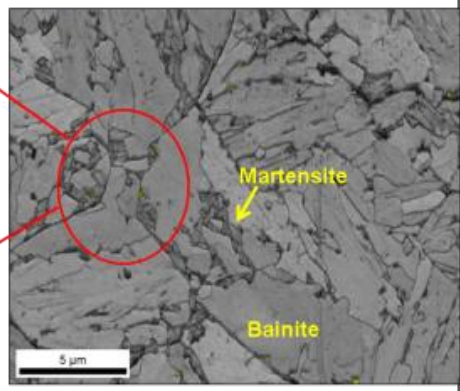

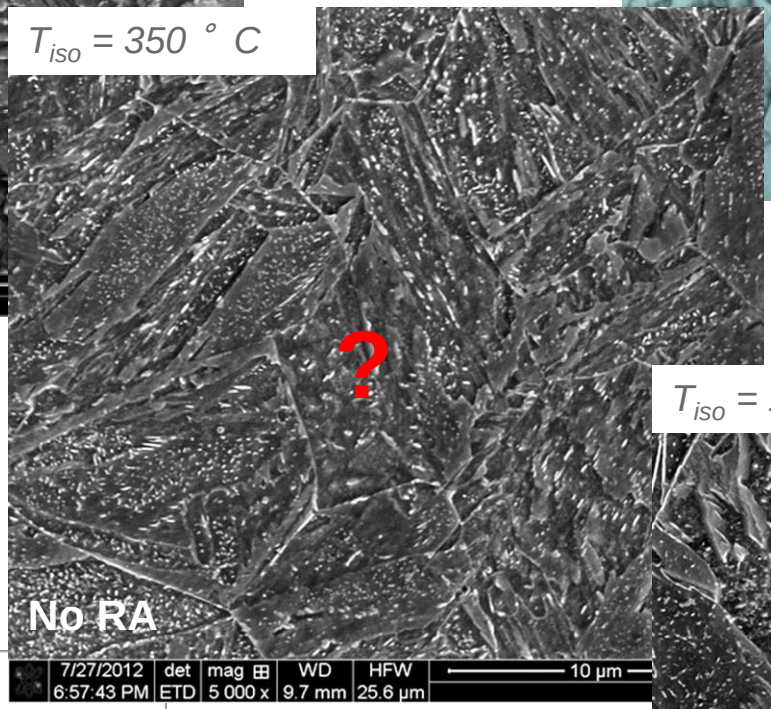

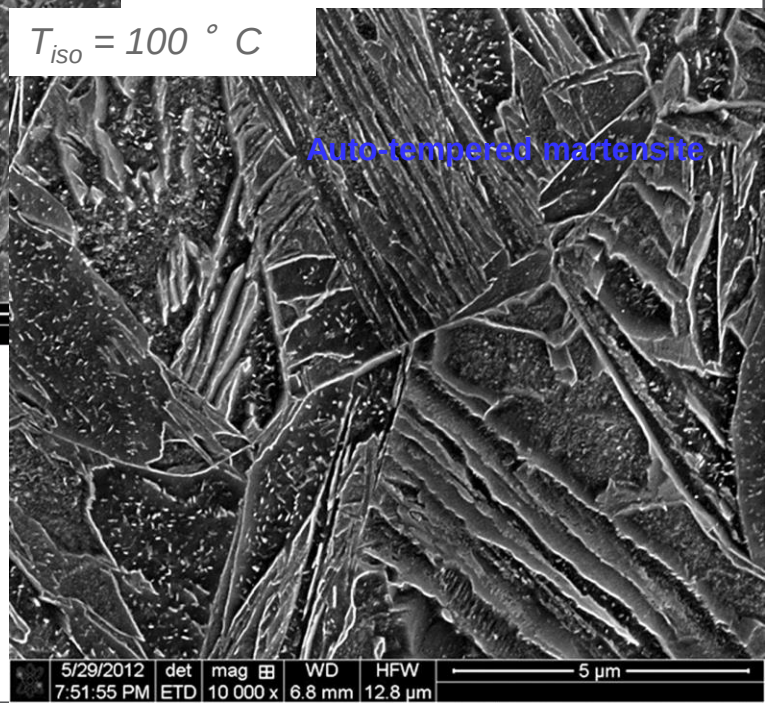

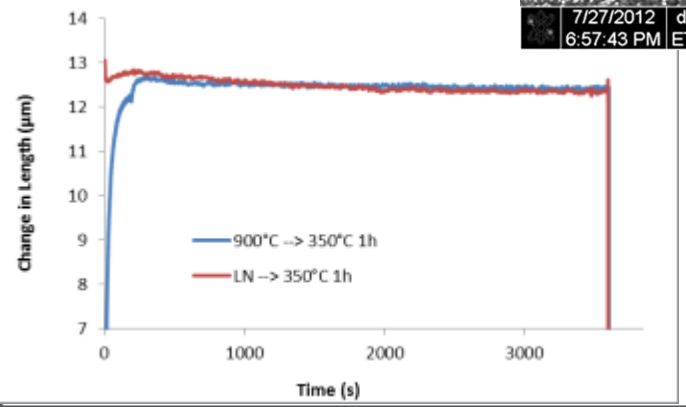

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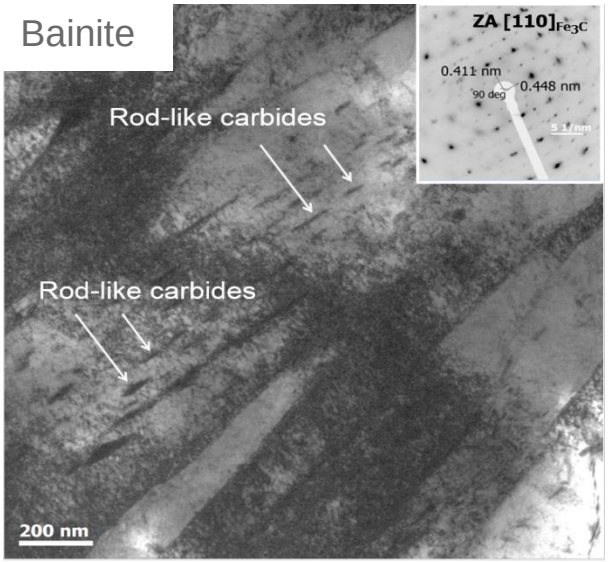
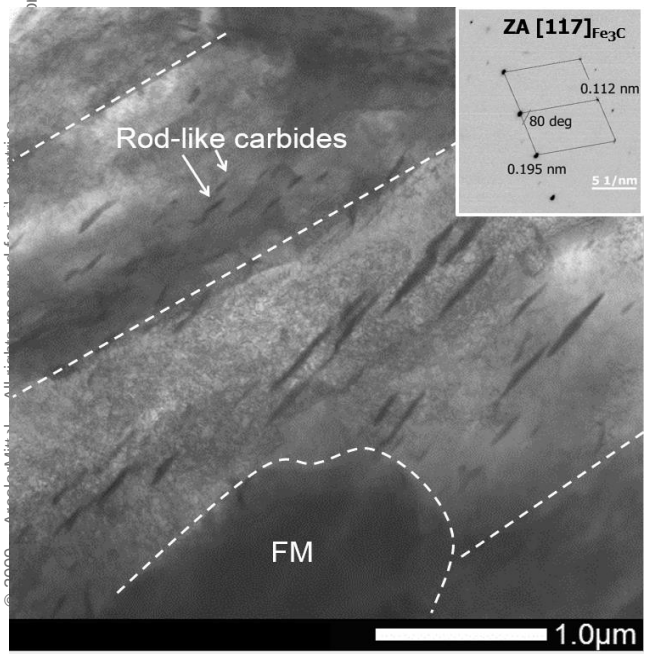
Precipitation analysis

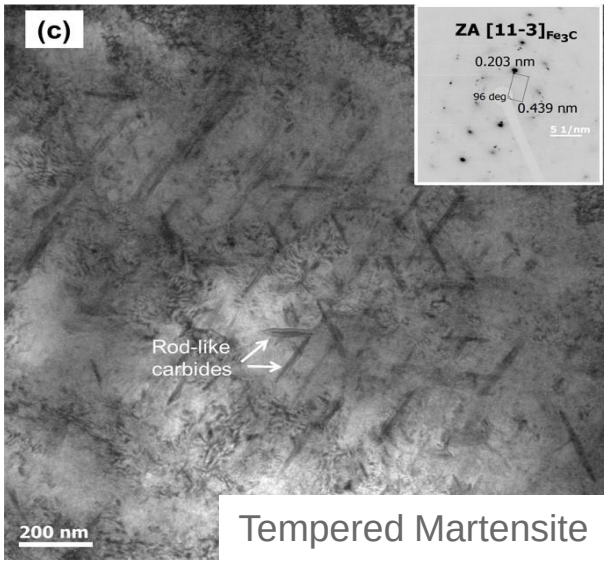
T_{iso} = 350 ^{o}C (below M_s)

Bainite



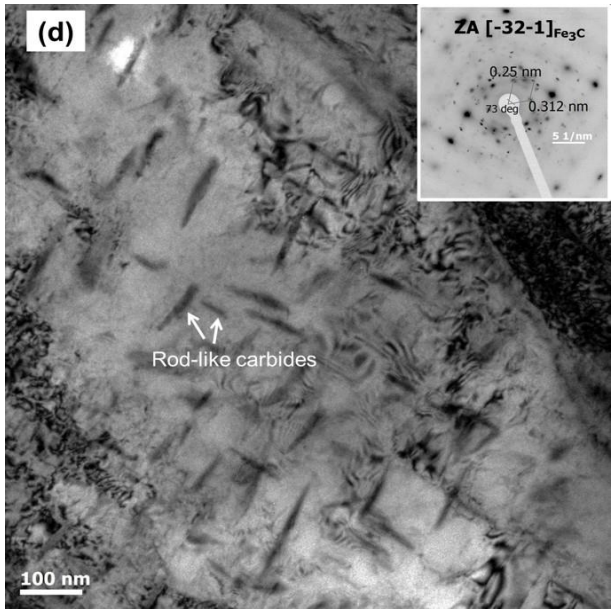
T_{iso} = 450 ^{o}C (bainite range)





Tempered Martensite

T_{iso} = 100 ^{o}C



Precipitation:

Fe_3C

Transf. Kinetics by Dilatometry

bainite forms below M_s?

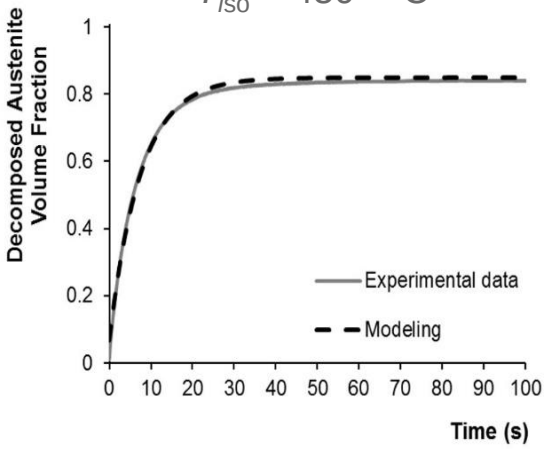
a modeling based on displacive mechanism was applied:

- Well described with 2 fit parameters:

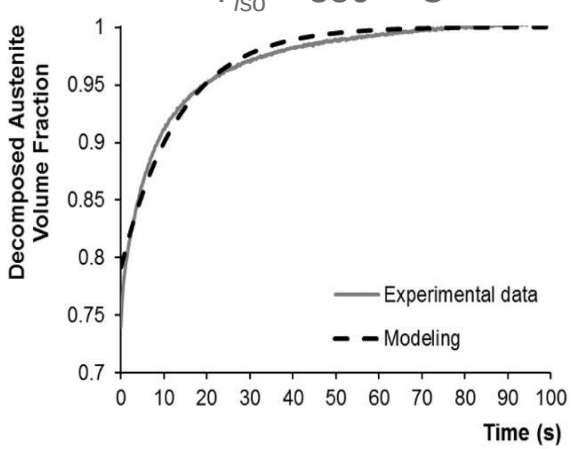
  κ: temperature-dependent rate

  λ: autocatalytic nucleation

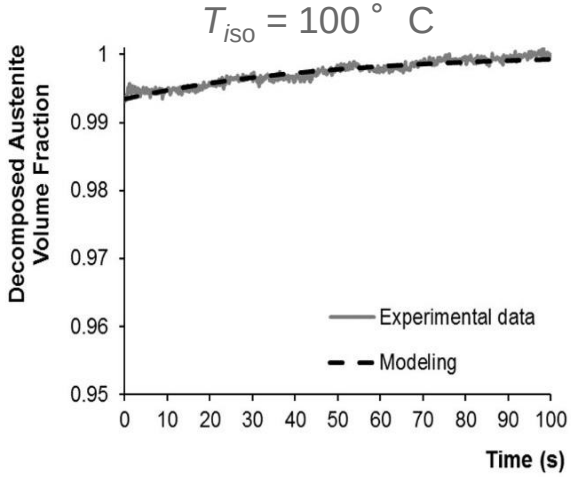
T_{iso} = 450 ° C

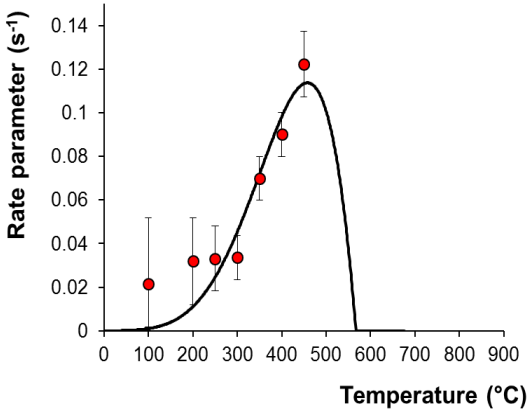


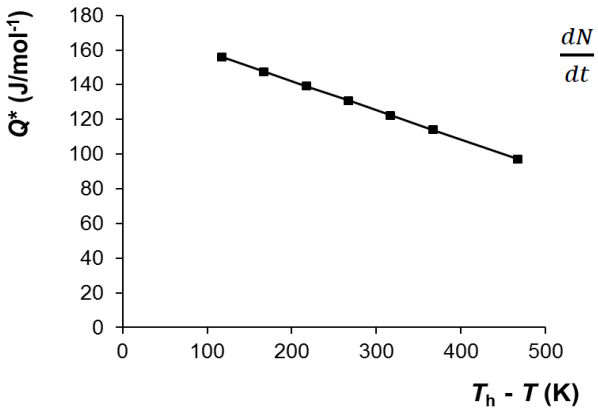
T_{iso} = 350 ° C



T_{iso} = 100 ° C







$$\frac{dN}{dt} = \frac{kT}{h}(1 - f - f_M)N_i(1 + \lambda f)exp\left(-\frac{Q^*}{RT}\right)$$

$$\kappa = \frac{kT}{h}\alpha^b(T_h - T)exp\left(-\frac{Q^*}{kT}\right)$$

$$\frac{df}{dt} = (1 - f)(1 + \lambda f)\kappa$$

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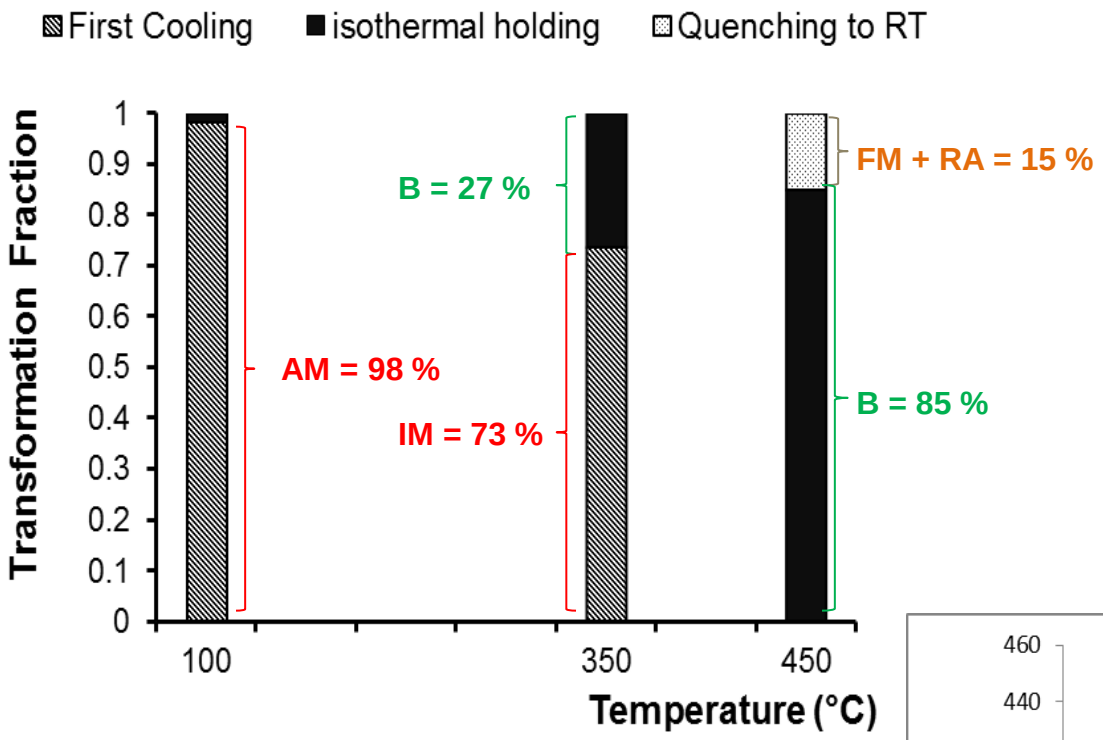
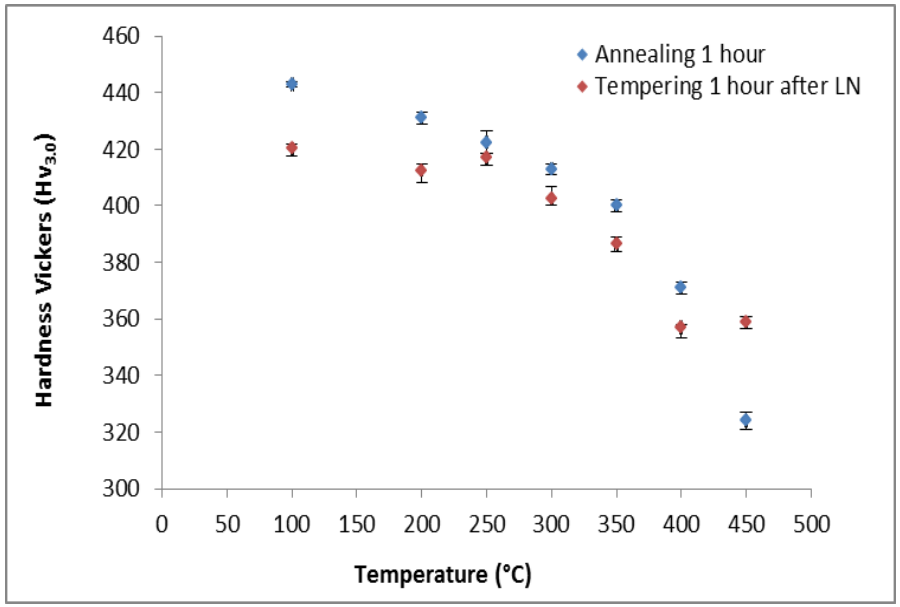
Microstructural Evolution





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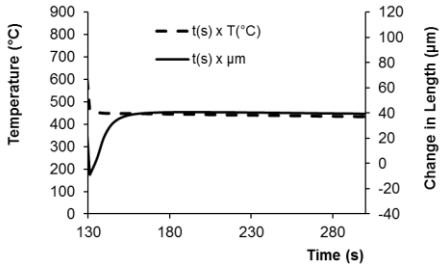
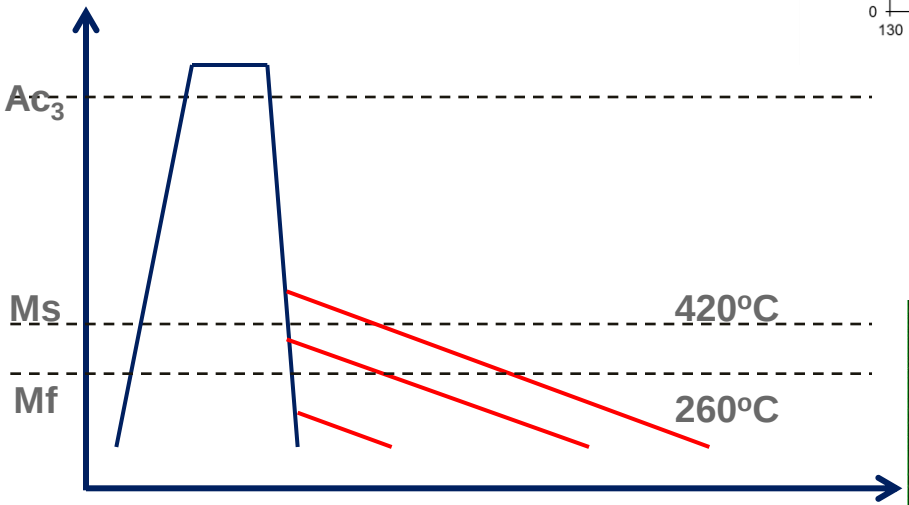
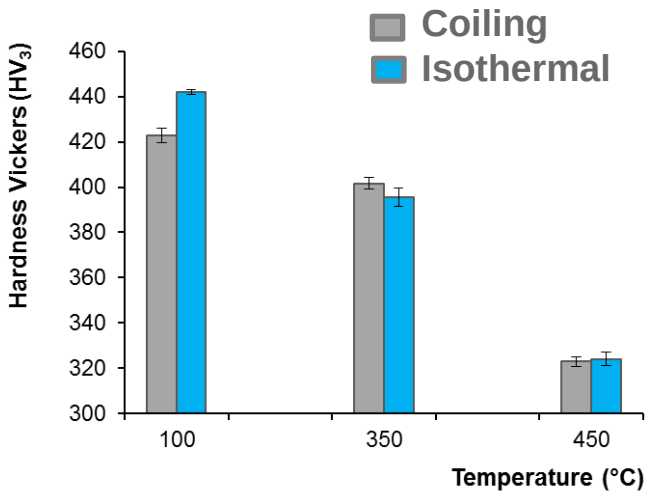
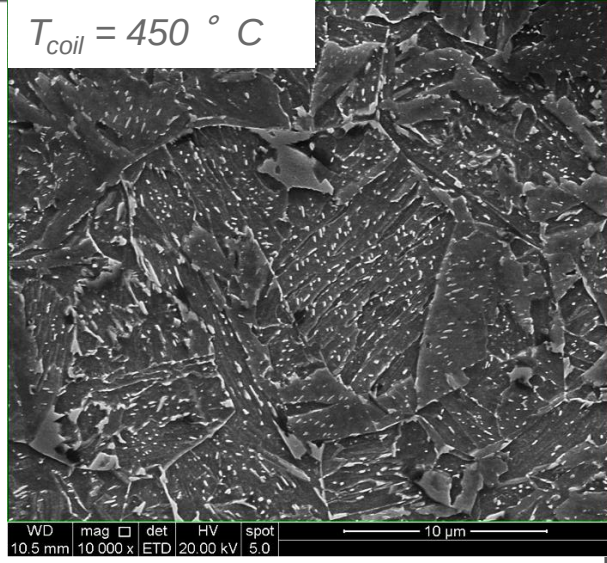
In a Q+C process?



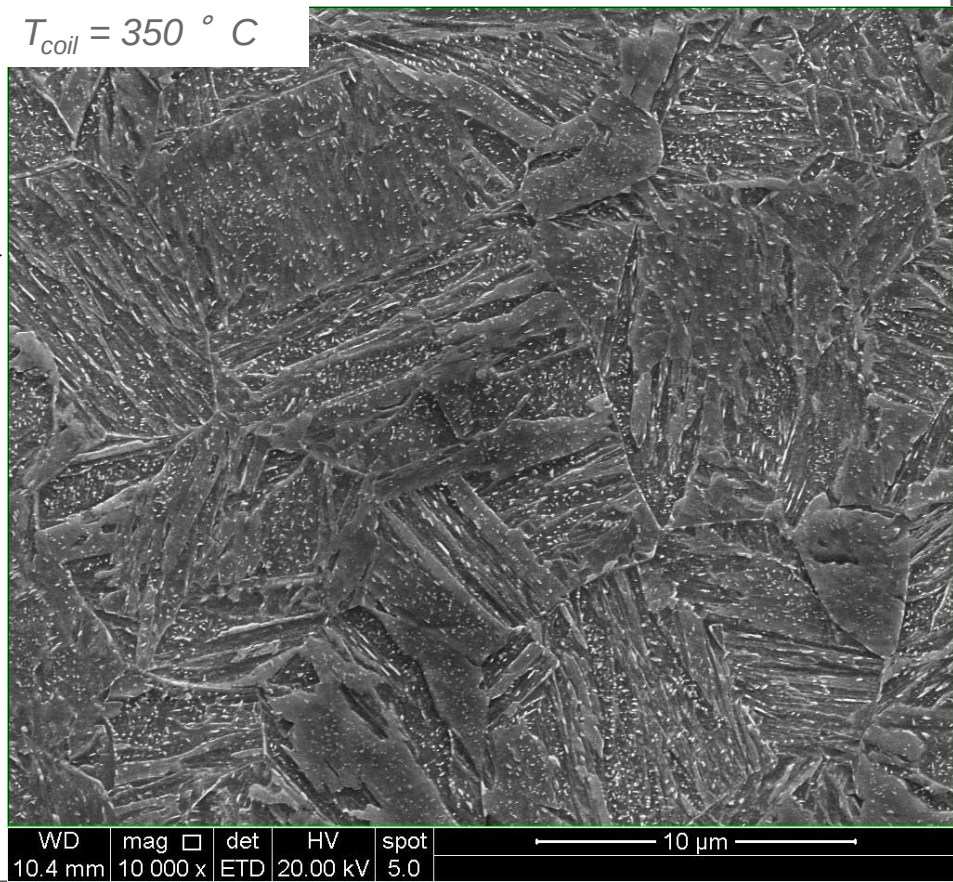




$T_{coil} = 450\ ^{\circ}C$



$T_{coil} = 350\ ^{\circ}C$



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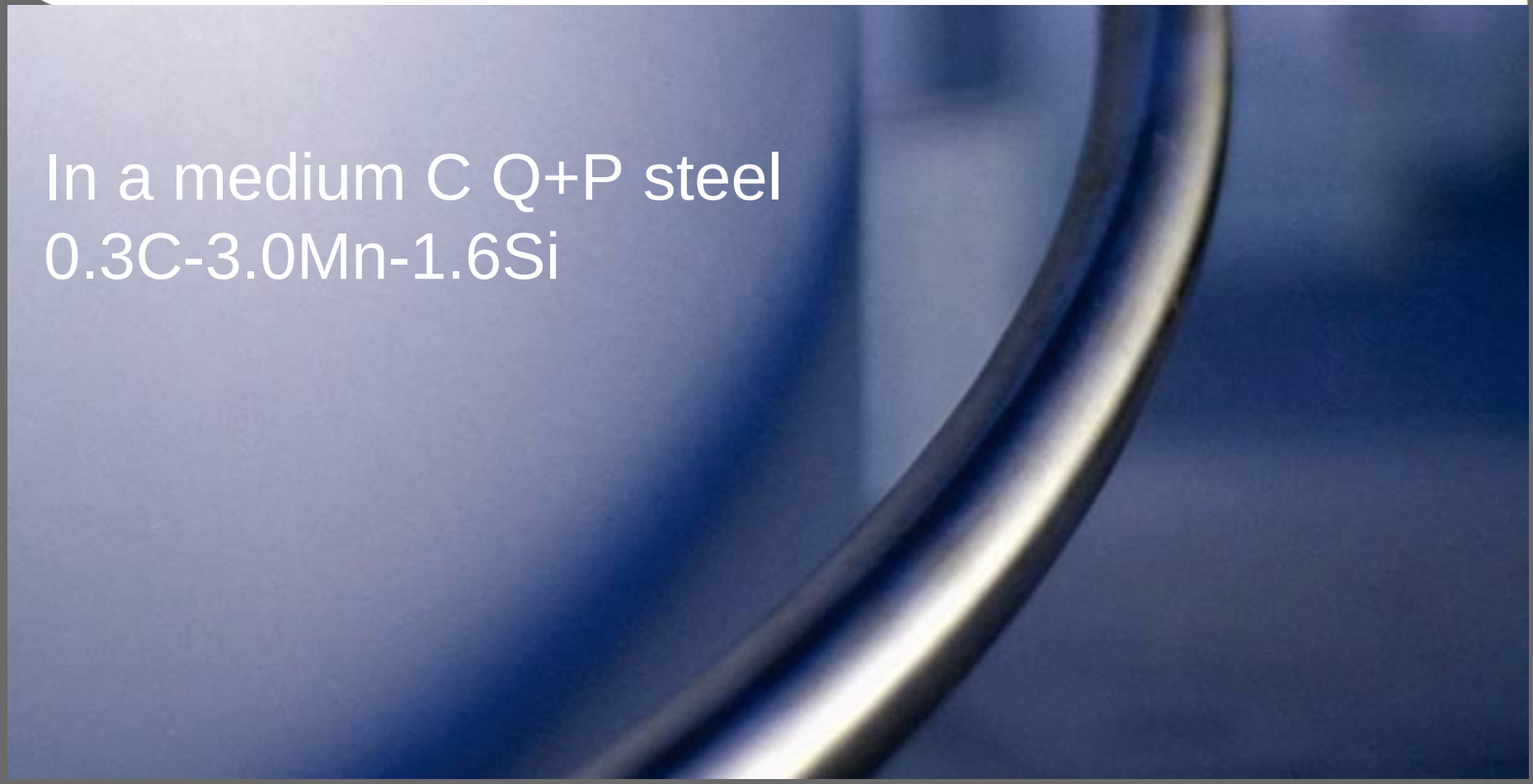
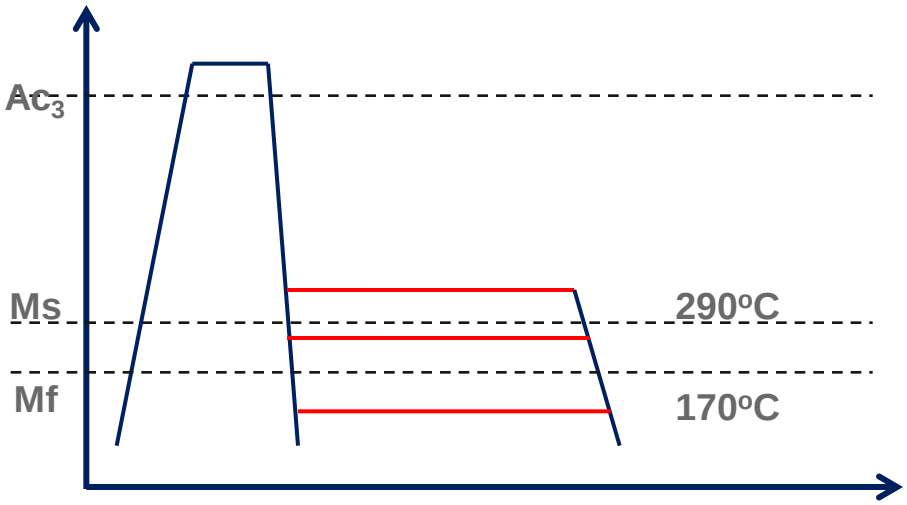
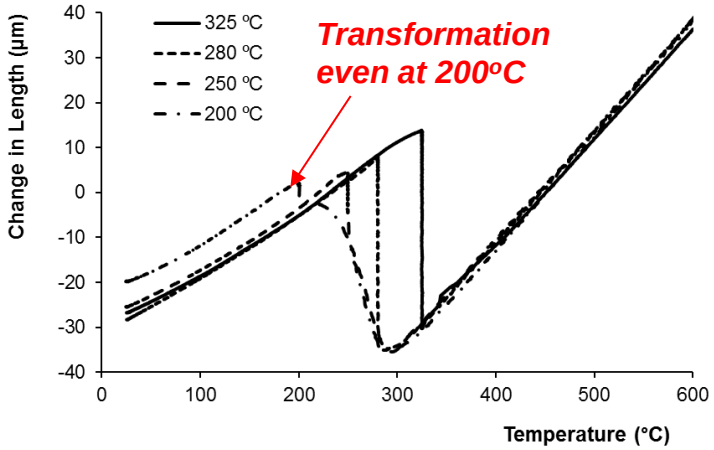
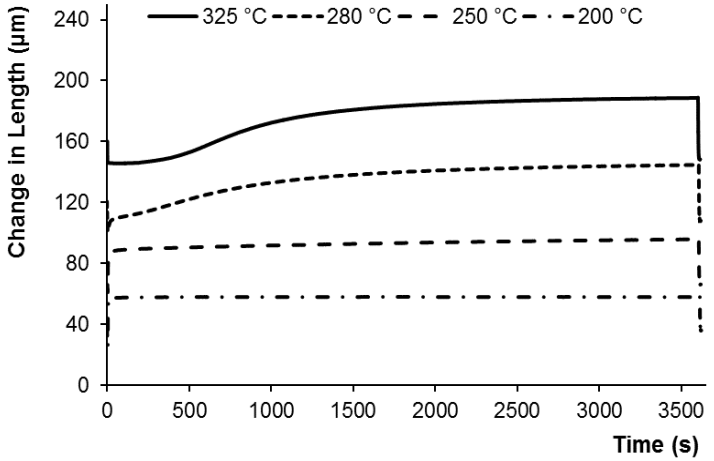

In a medium C Q+P steel
0.3C-3.0Mn-1.6Si

In a more alloyed Q&P steel 0.3C-3.0Mn-1.6Si







Austenite takes time to start transforming to lower bainite, being acelerarted by initial martensite

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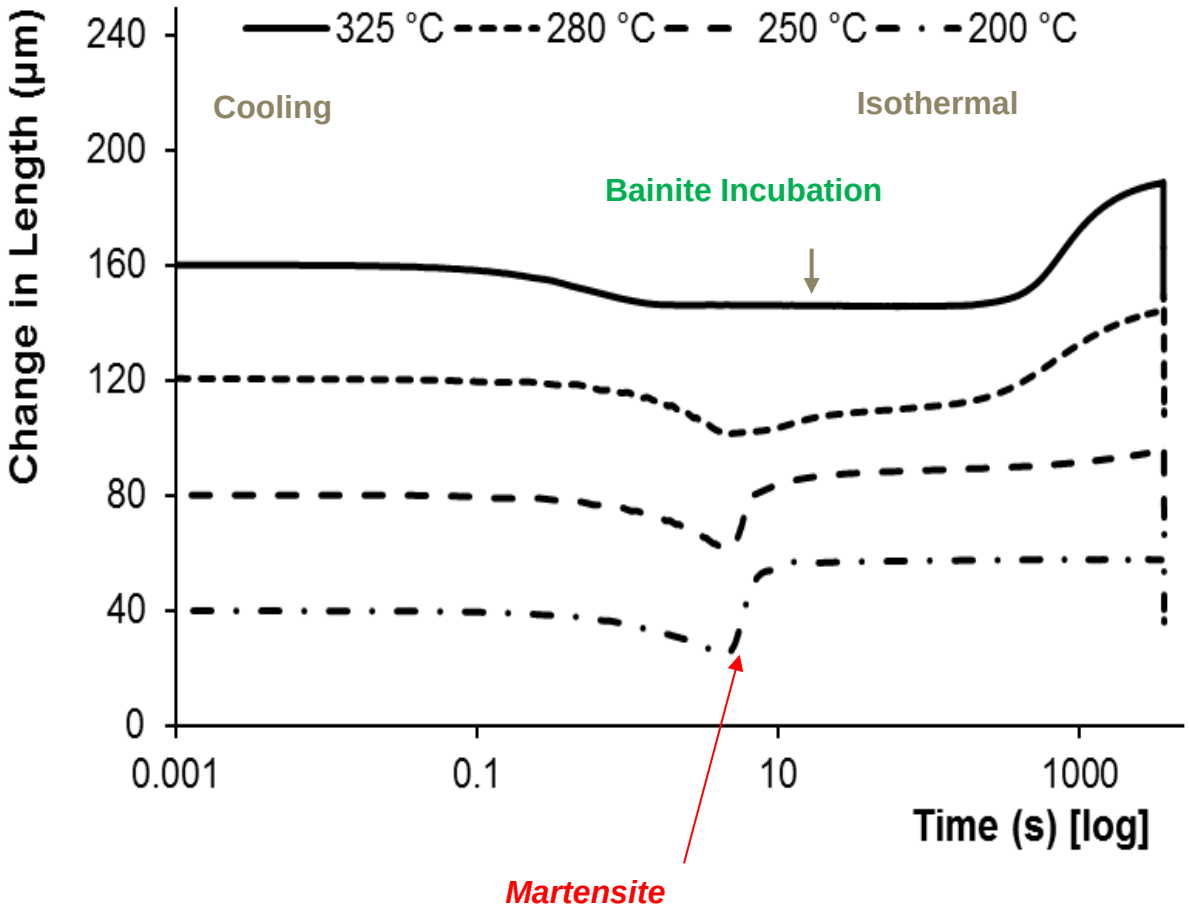
In a more alloyed Q&P steel 0.3C-3.0Mn-1.6Si



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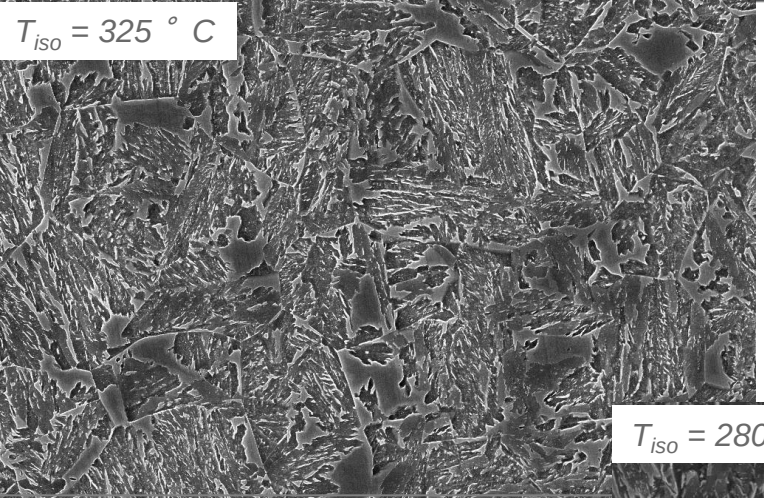

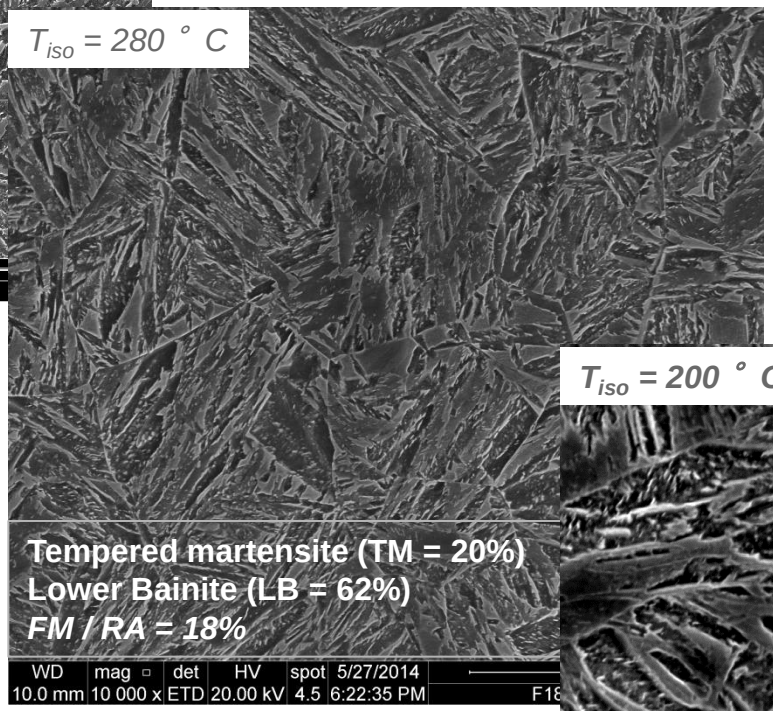

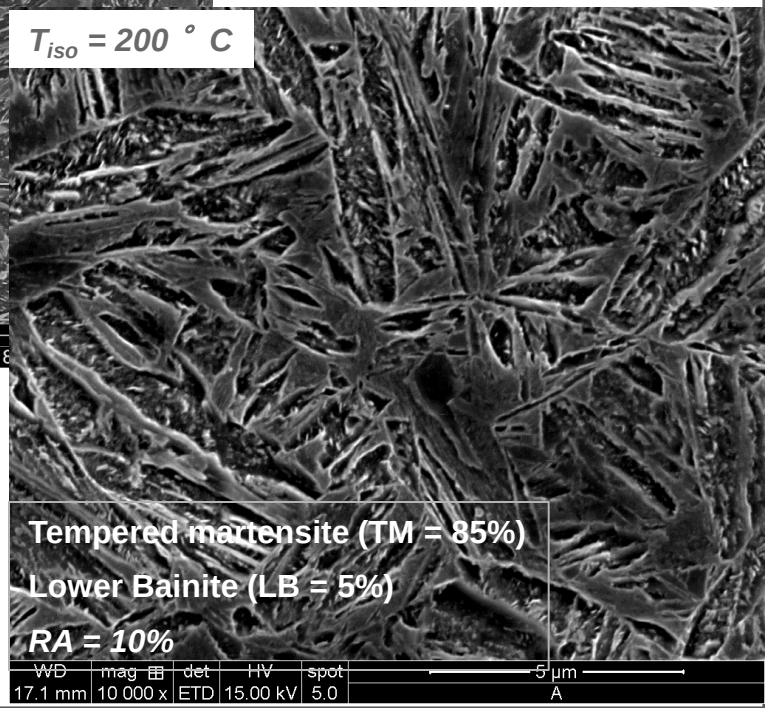

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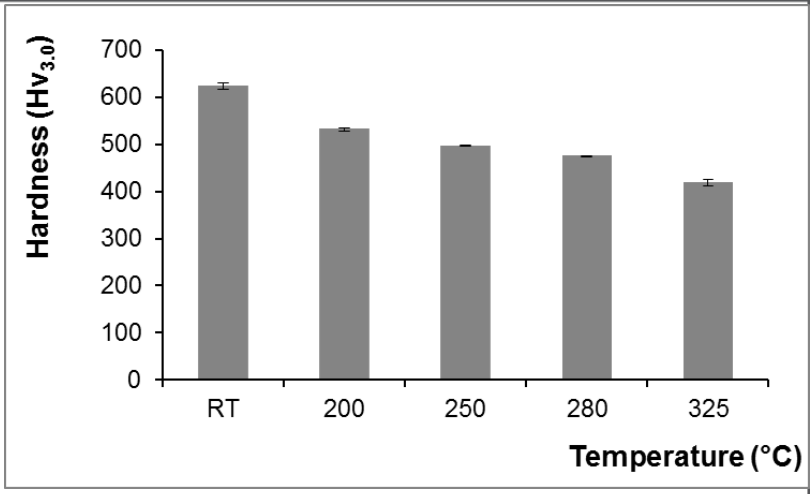
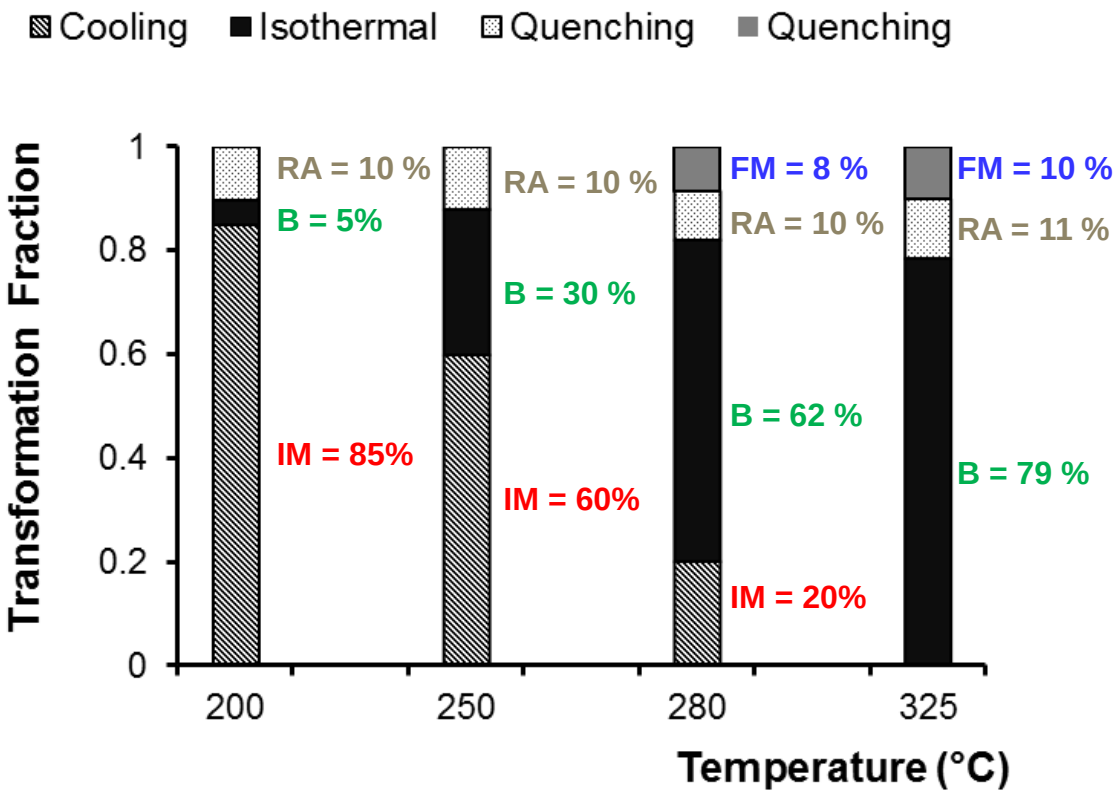
Transformation





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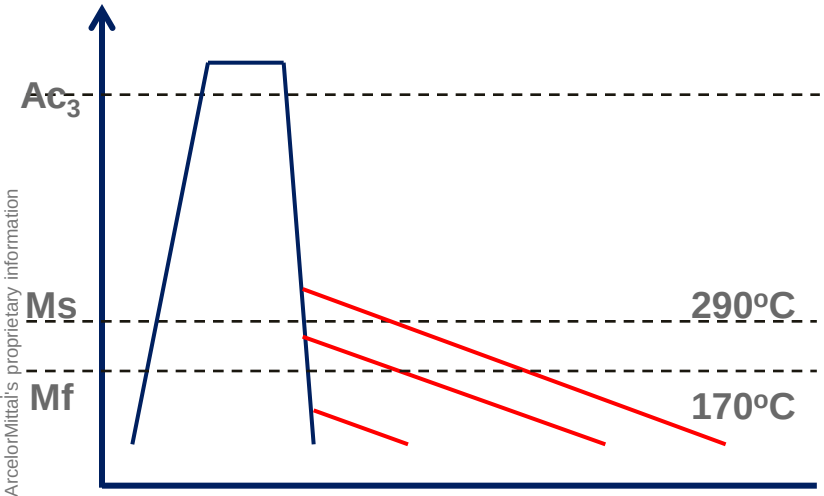
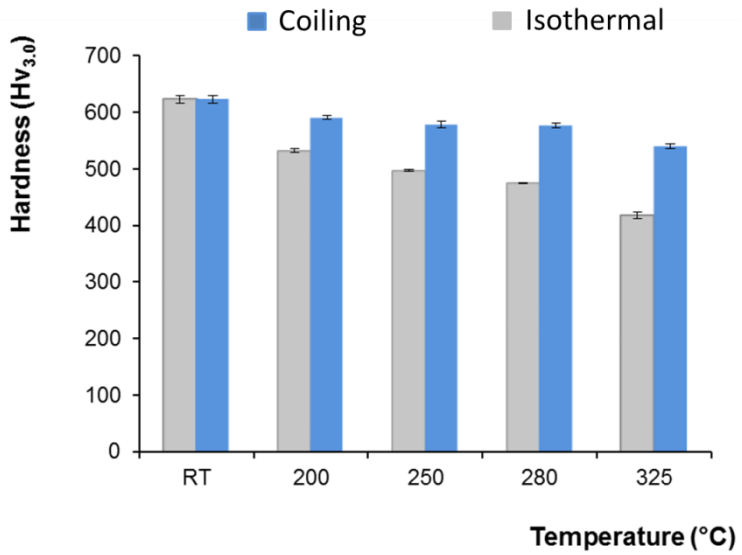
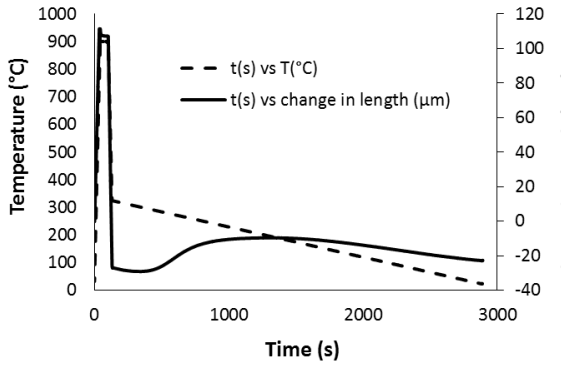
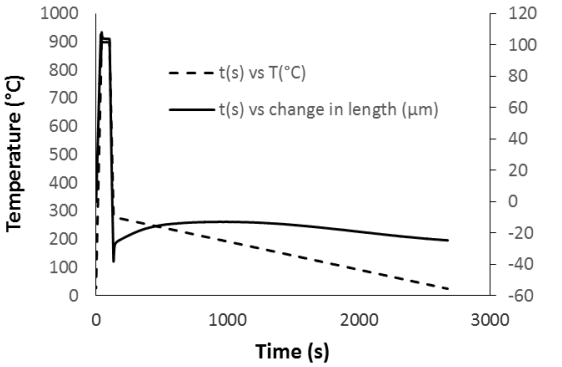
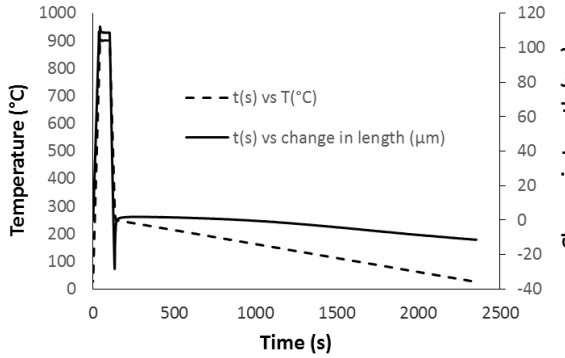
In a Q+C process?

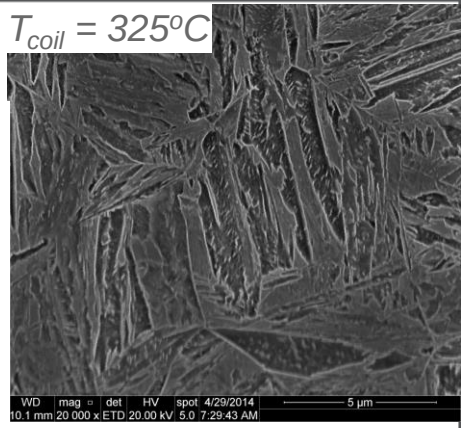


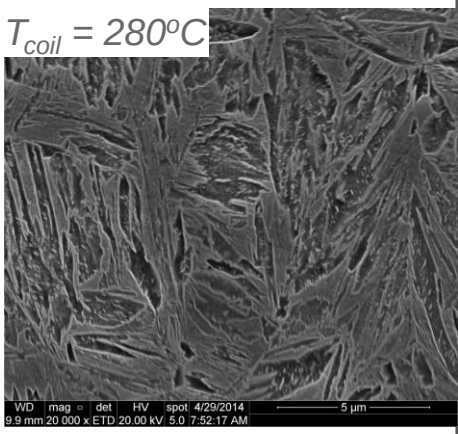


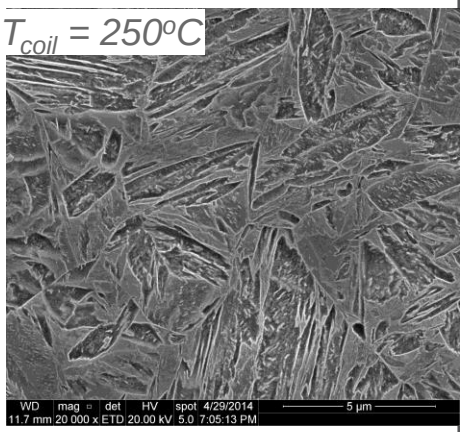












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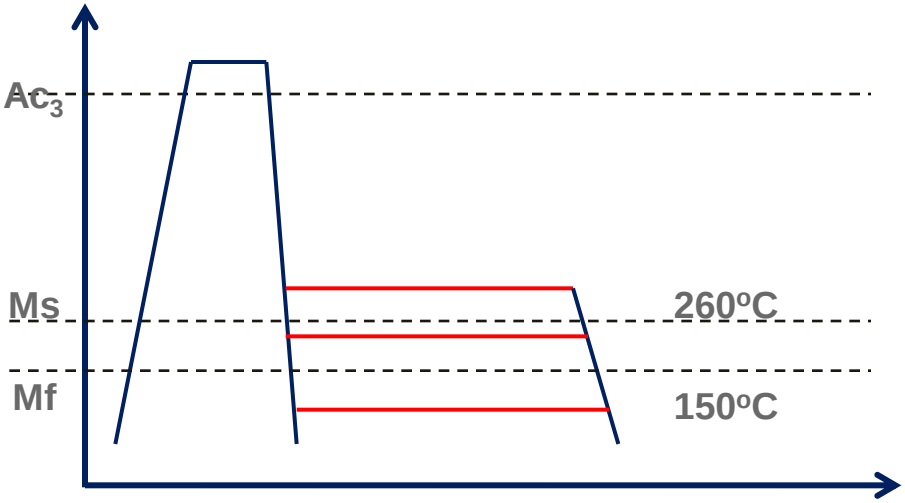
In a medium Mn steel 0.2C-5.0Mn-1.6Si

In a medium Mn steel



Medium Mn steel,
Air hardenable,
difficult to introduce bainite due to the slow kinetics

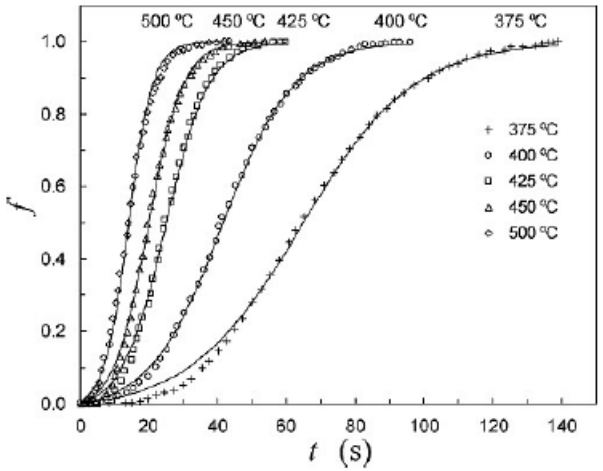
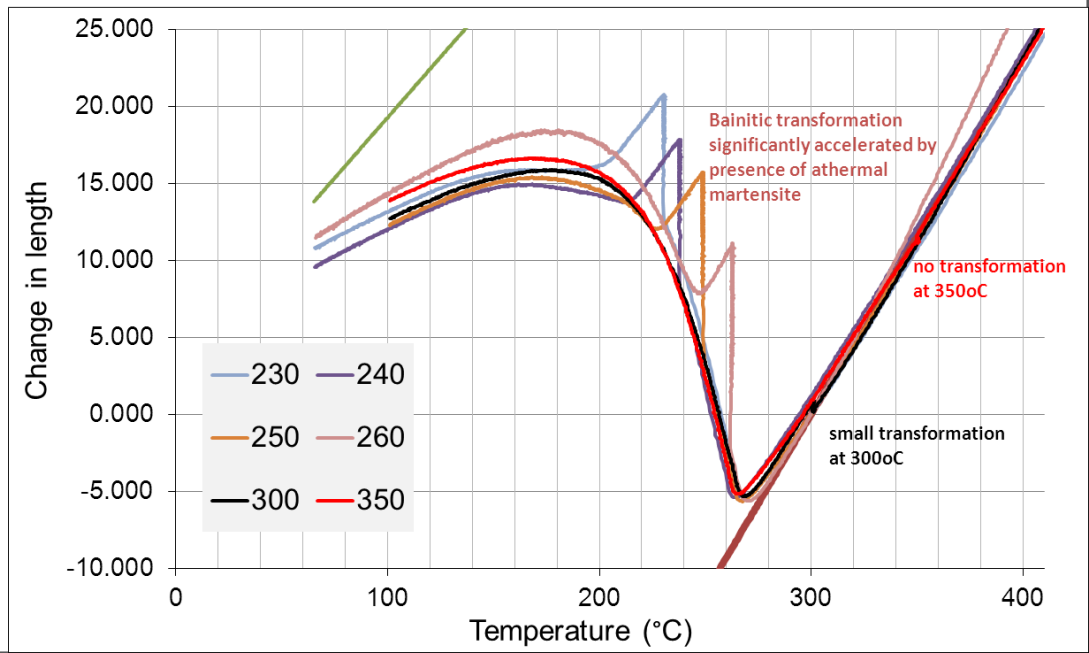


Fig. 2. Comparison between calculated kinetics of bainite formation in steel C50 and experimental data measured by Quidort and Brechet [9].



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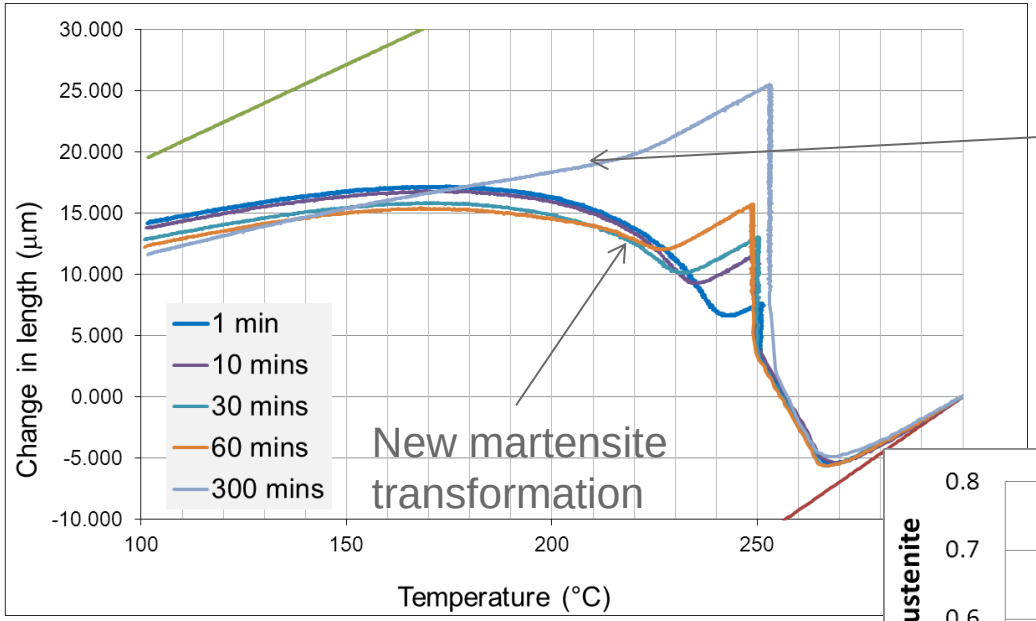
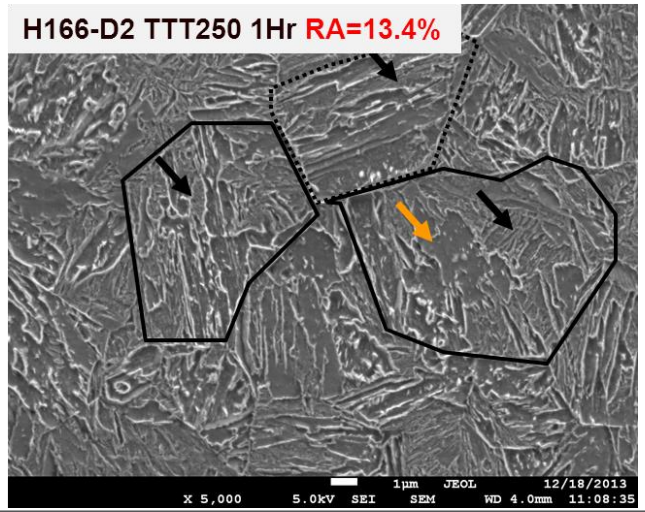
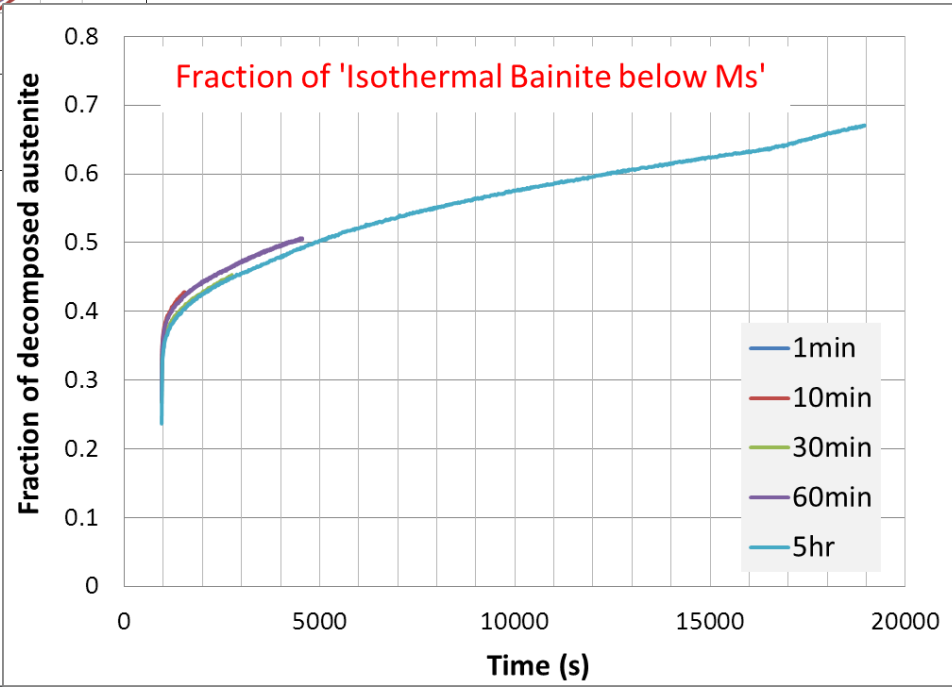
Introducing bainite to increase ductility?

- Isothermal transformation at 250°C (slightly below Ms)



Less martensite trans, possible way to stabilize RA by C diffusion during bainitic transformation.





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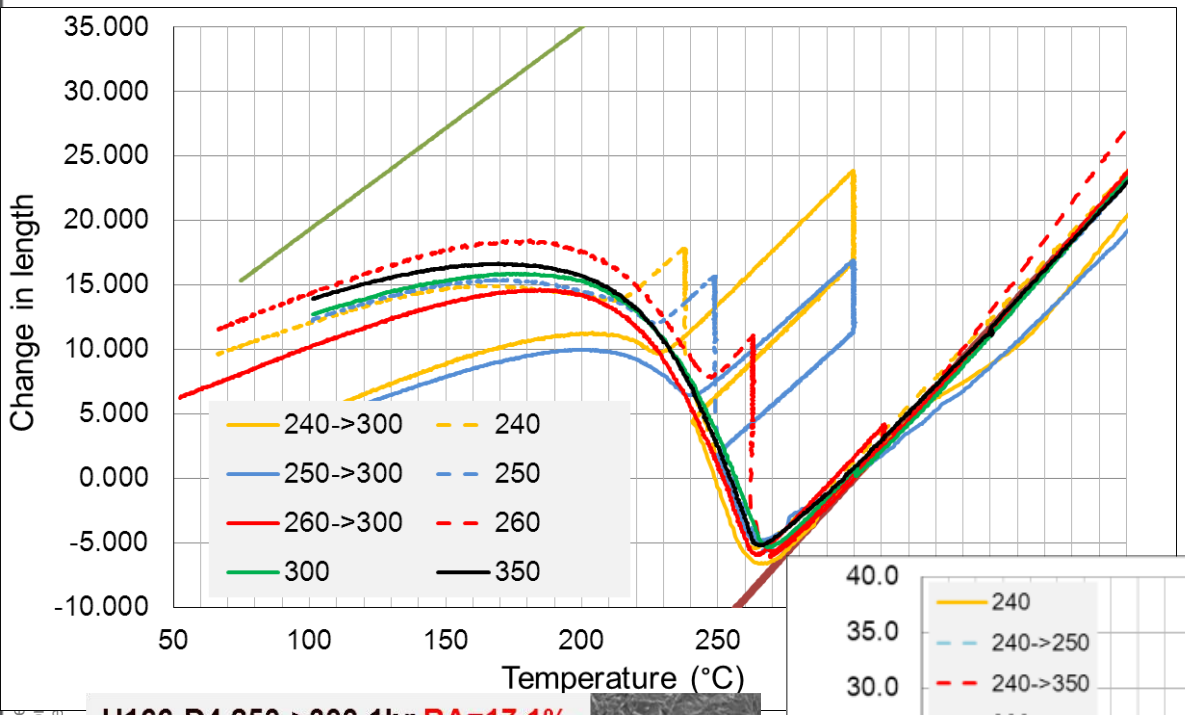
Can we further accelerate bainitic trans?

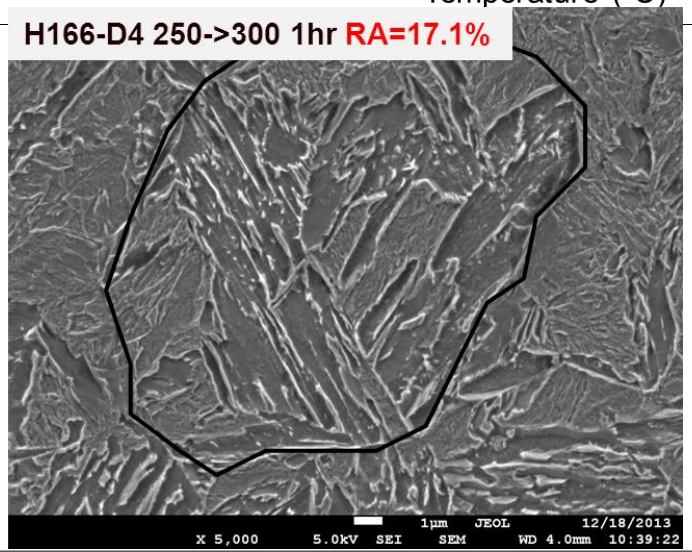


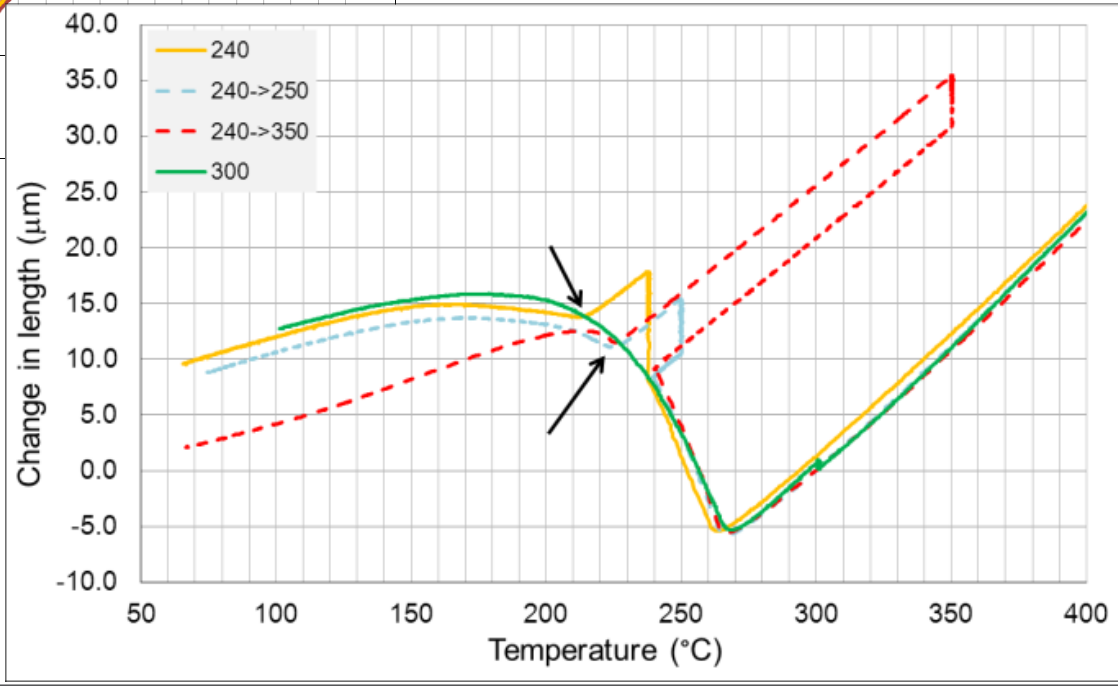
Higher QT, more Bainite trans.

Only need small amount of martensite to start bainite trans.

Bainitic transformation at higher temperature seems NOT accelerated further

To make the bainite, better isothermal.





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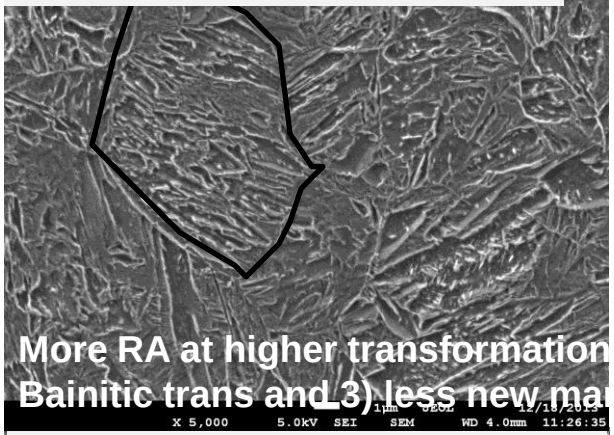
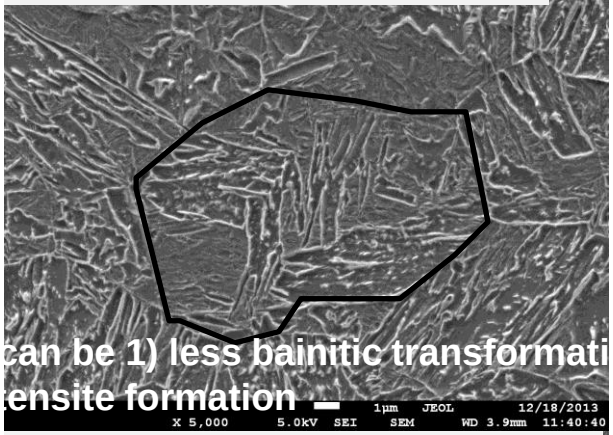
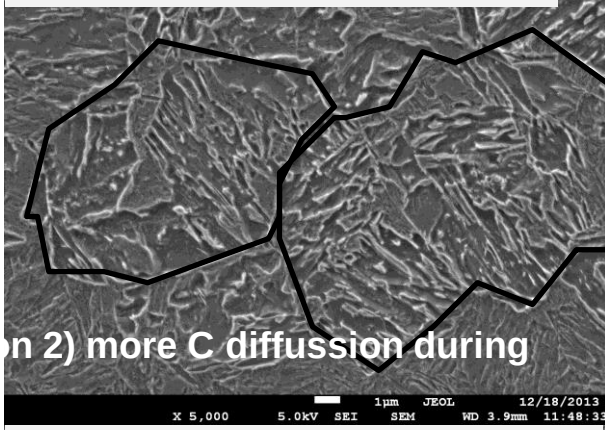
H166-D5 TTT240 1hr RA=15%



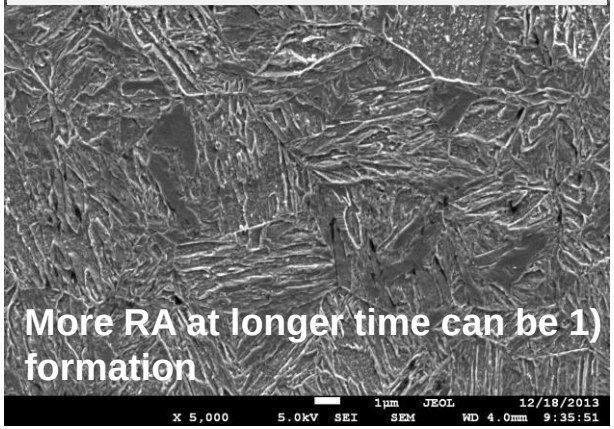
H166-D6 240->250 1hr RA=16.2%



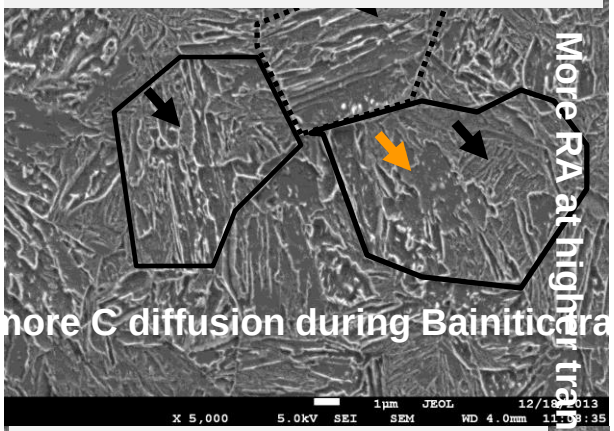
H166-D7 240->300 RA=26.1%



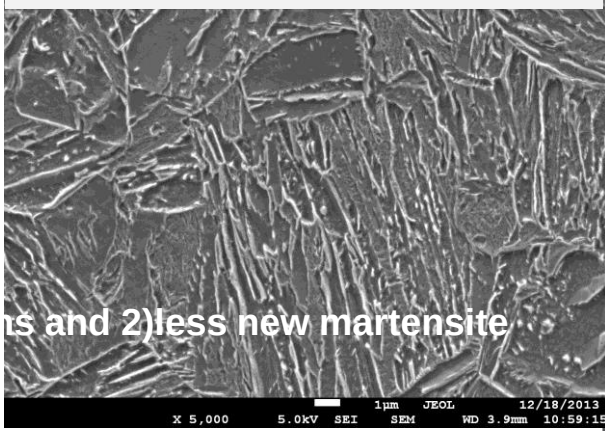
H166-D1 TTT250 1min RA=11%



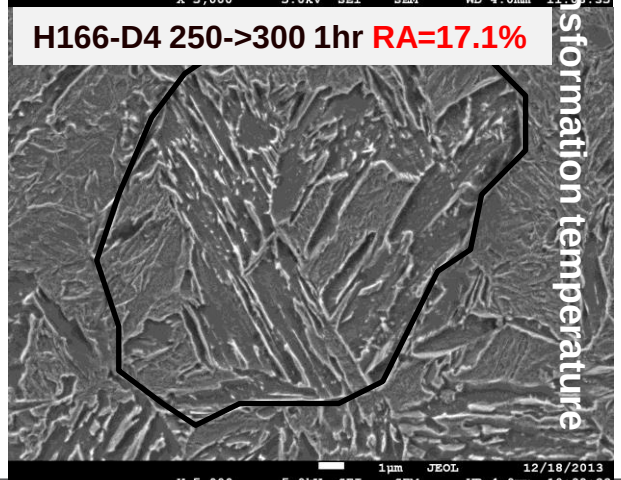
H166-D2 TTT250 1Hr RA=13.4%



H166-D3 TTT250 5Hr RA=15.8%



H166-D4 250->300 1hr RA=17.1%



Would the current microstructure increases YS~ Uel balance?

Conclusion remarks

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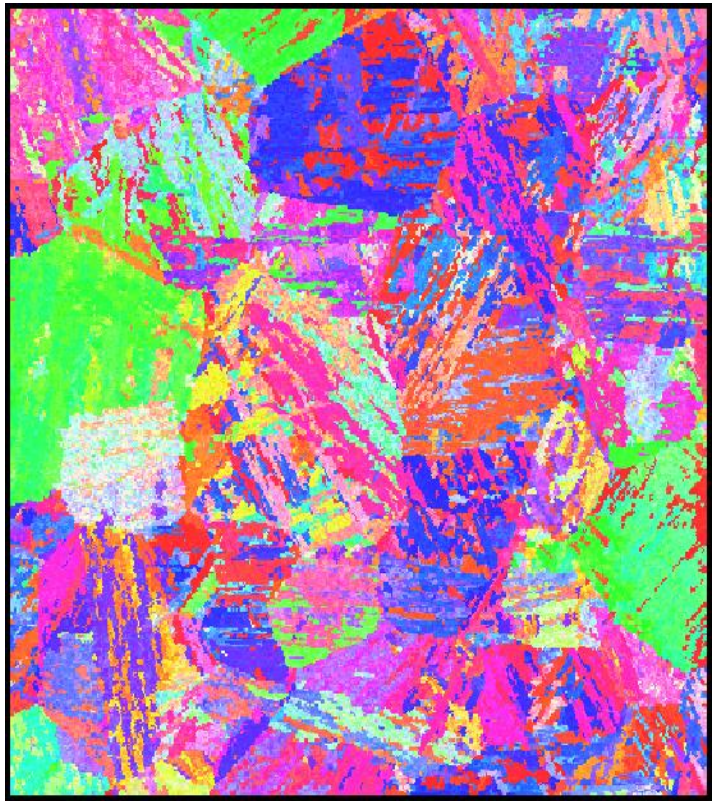
Pay attention to the possible isothermal decomposition of austenite during the isothermal stage

- Competing with C partitioning
- Effect on mechanical properties
- Optimal QT?
- Microstructure characteristics



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