Quenching and Partitioning: *Science and Technology*

by

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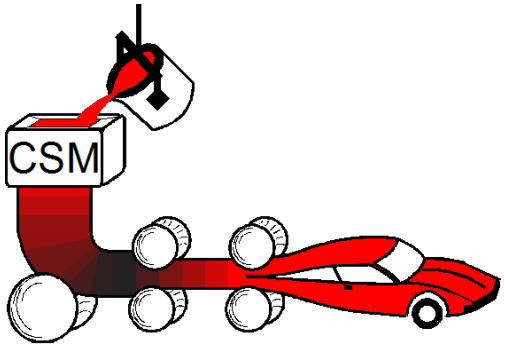
July 23, 2013



Advanced Steel Processing and Products Research Center

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Acknowlegements

INSPIRATION FROM GIANTS OF THE LITERATURE:

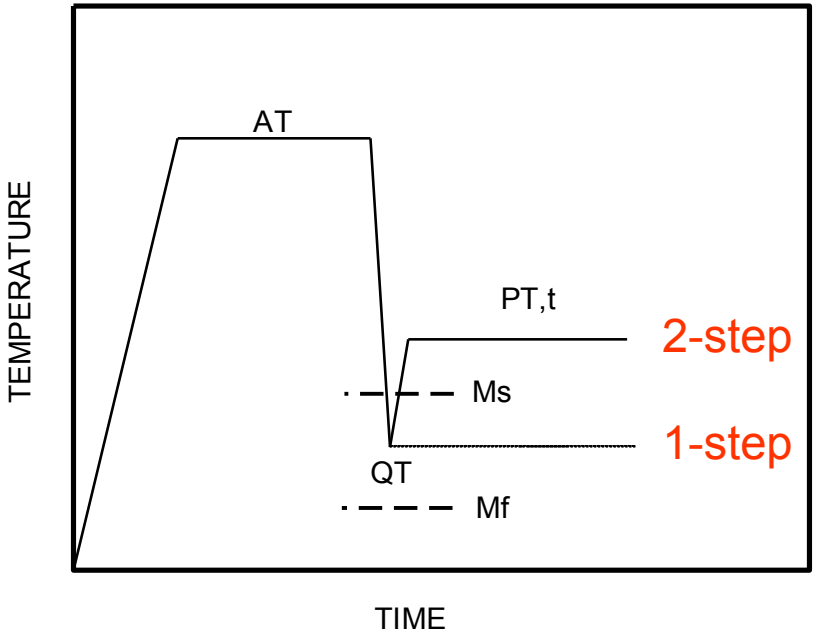
- **TRIP (Olson, Cohen *et al*.)**
- **Bainite (Bhadeshia, Edmonds, Christian *et al*.)**
- **Martensite and Tempering (Krauss, Cohen *et al*.)**
- **Thermodynamics and Diffusion (Hillert, Aaronson, Ågren et al.)**

COLLABOATORS AND STUDENTS:

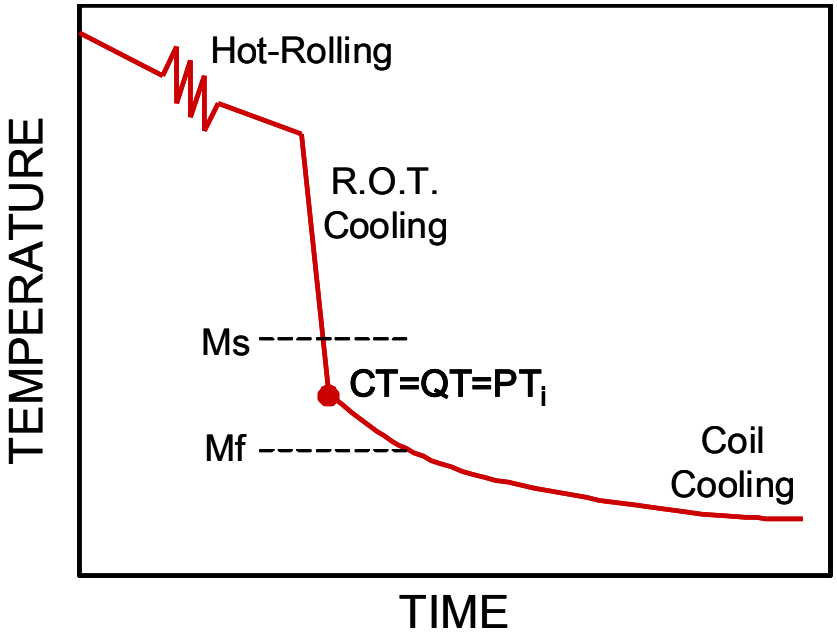
- **too numerous to mention !**

A Little Background…

"Q&P" - A "New" Concept for Control of Retained Austenite

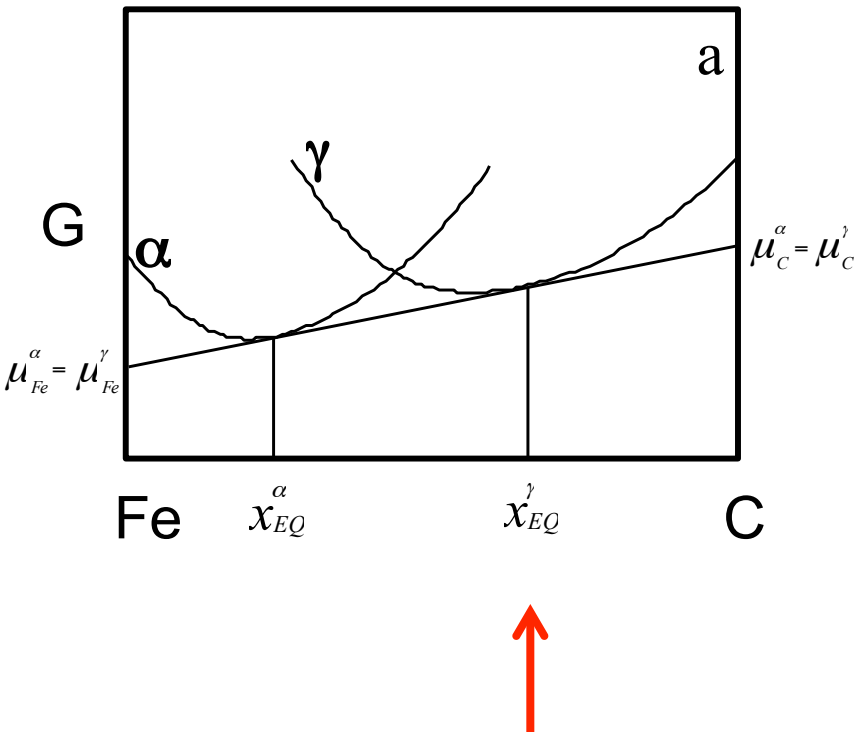


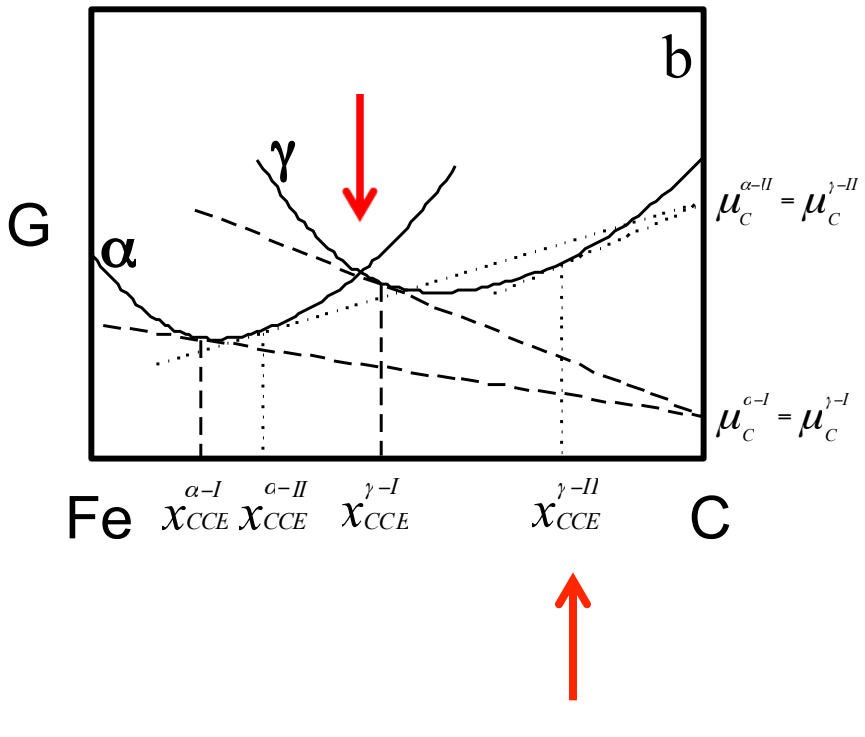
Speer *et al*., 2003



Thomas *et al.*, 2008, 2011

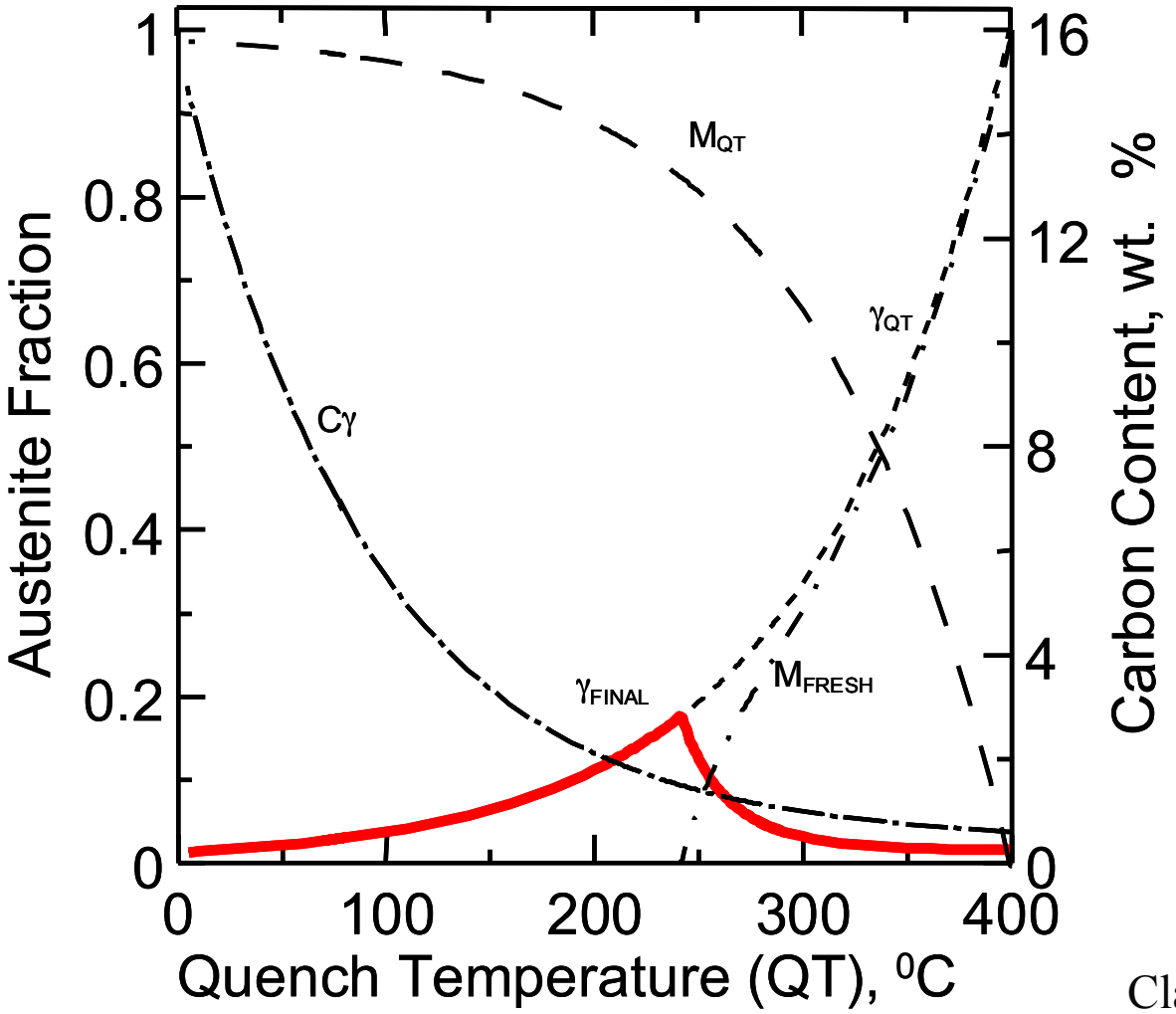
"Interesting" Levels of Austenite Carbon Enrichment May be Possible





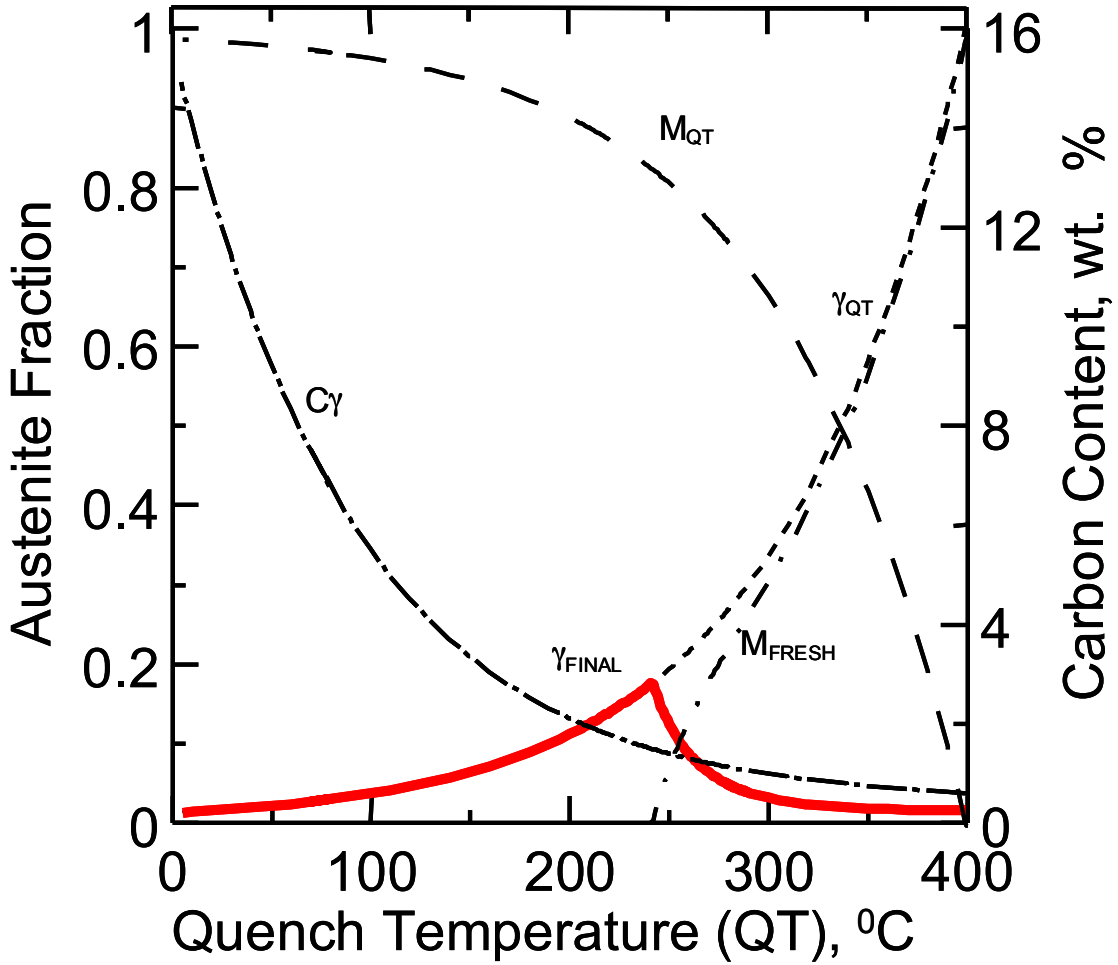
Speer *et al*., 2003

Process Design Methodology and "Ideal Quench Temperature"



Clarke, 2006. (0.19C-1.59Mn-1.63Si)

Key Assumptions for Simple Model

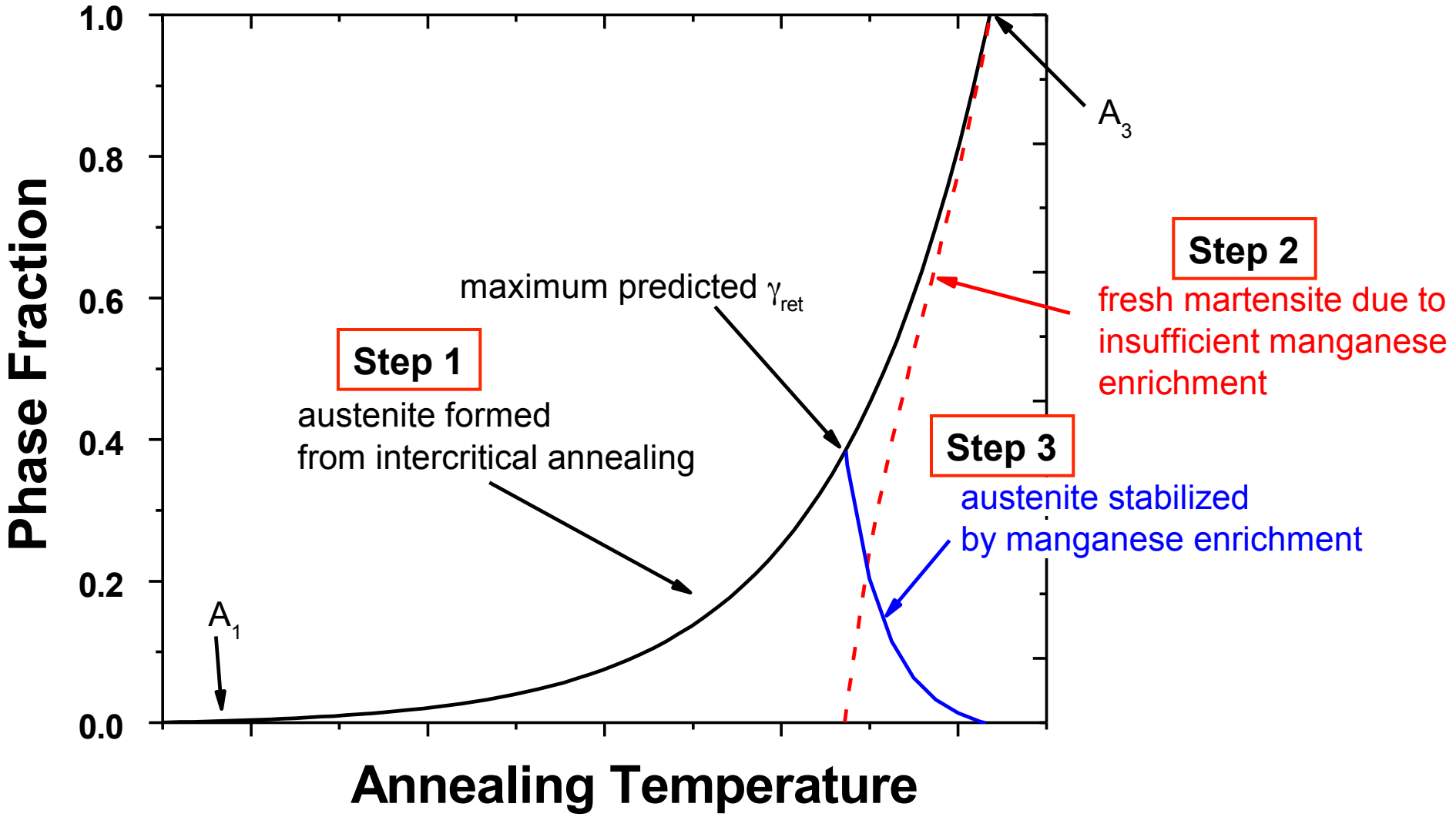


- "Ideal" partitioning
- Suppression of carbides
- Immobile α/γ interfaces
- No bainite formation

Clarke, 2006. (0.19C-1.59Mn-1.63Si)

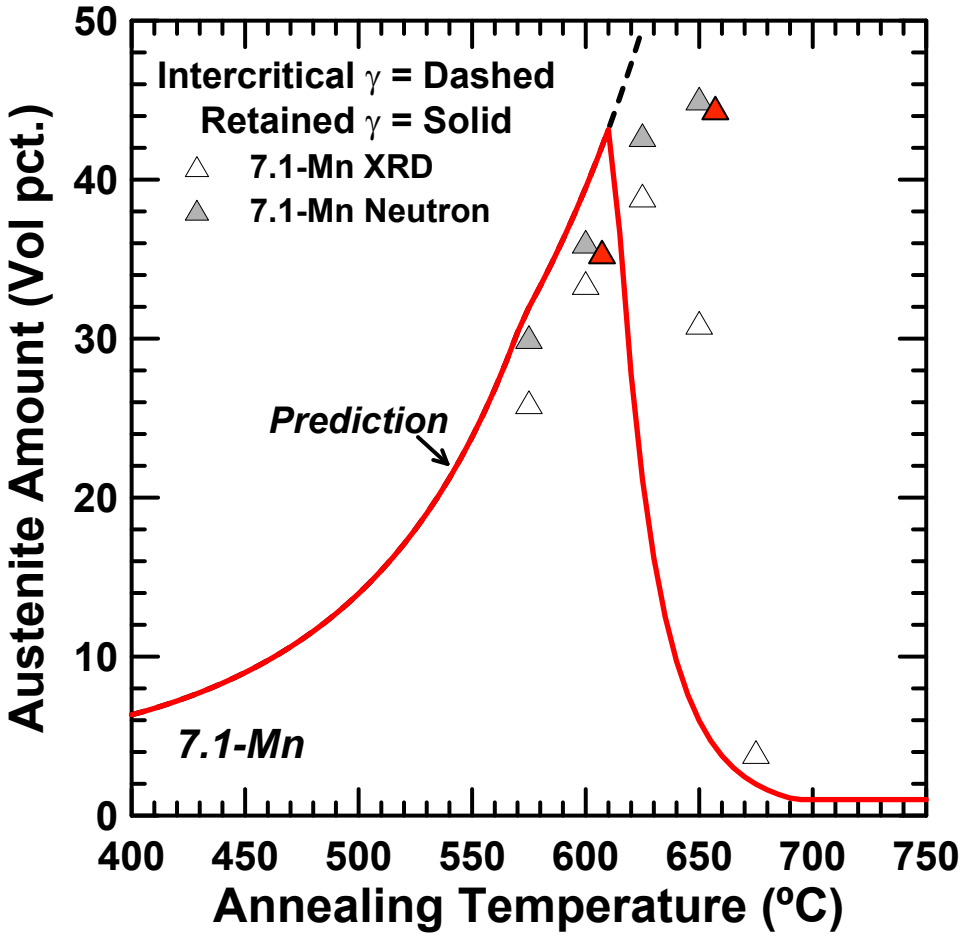
Parallel Concepts Applied to “Medium-Mn” Steels

Predicted Partitioning Behavior (Medium-Mn Steel)

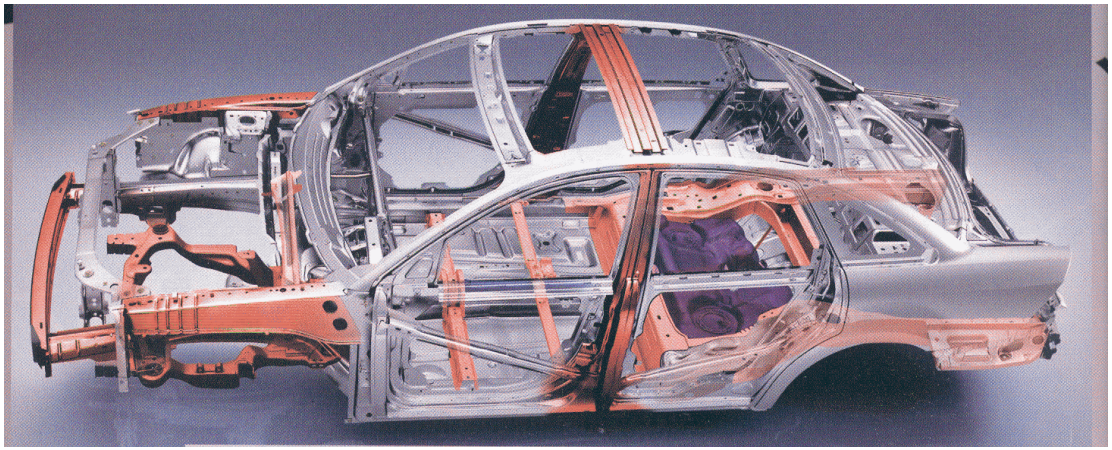


E. De Moor, et al., 2011.

Retained Austenite vs. Annealing Temp.



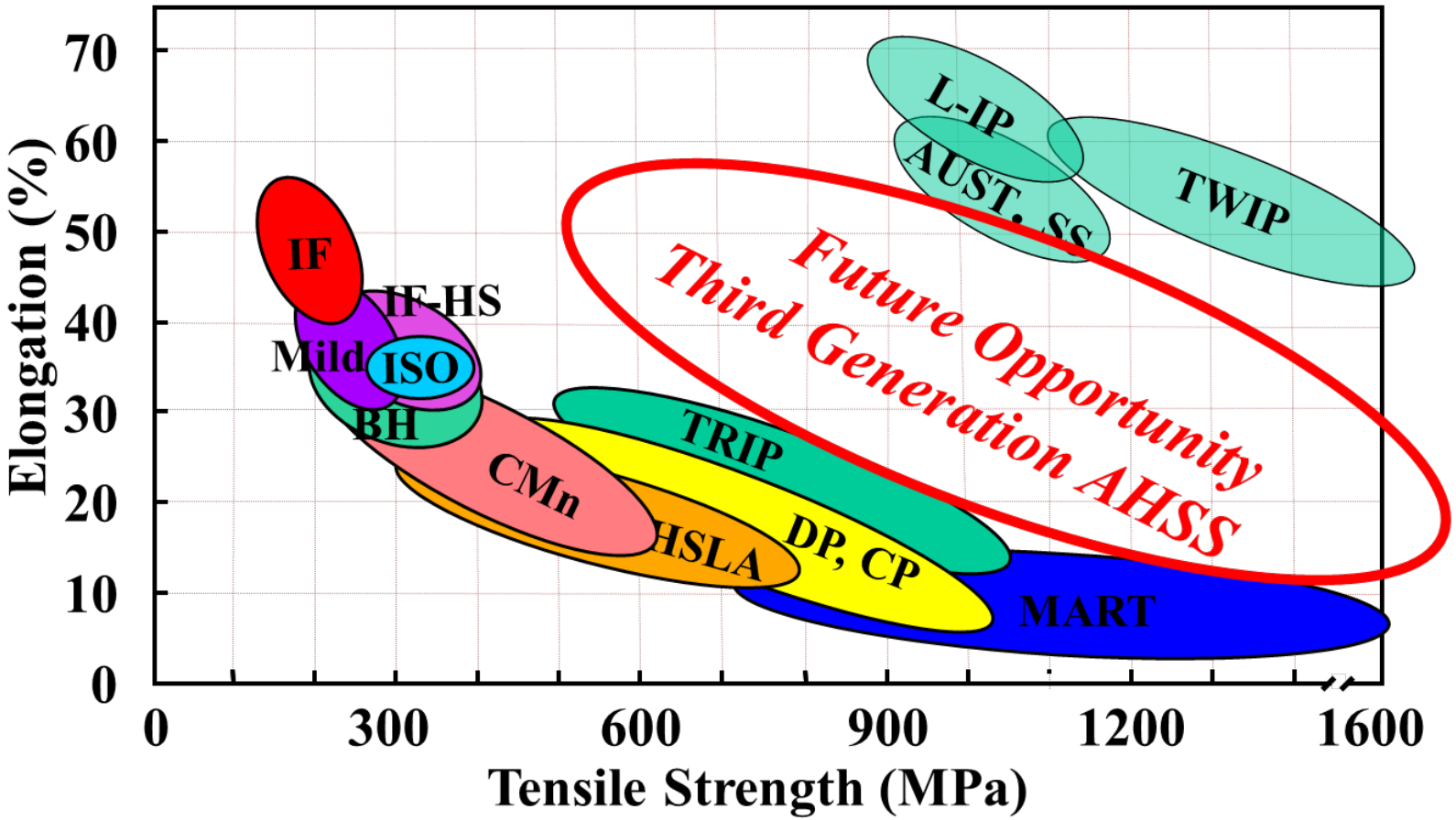
P. J. Gibbs, *et al*., 2011.



Relevance to AHSS Needs and Development Philosophy

Vehicle performance and weight reduction are driving steel research !

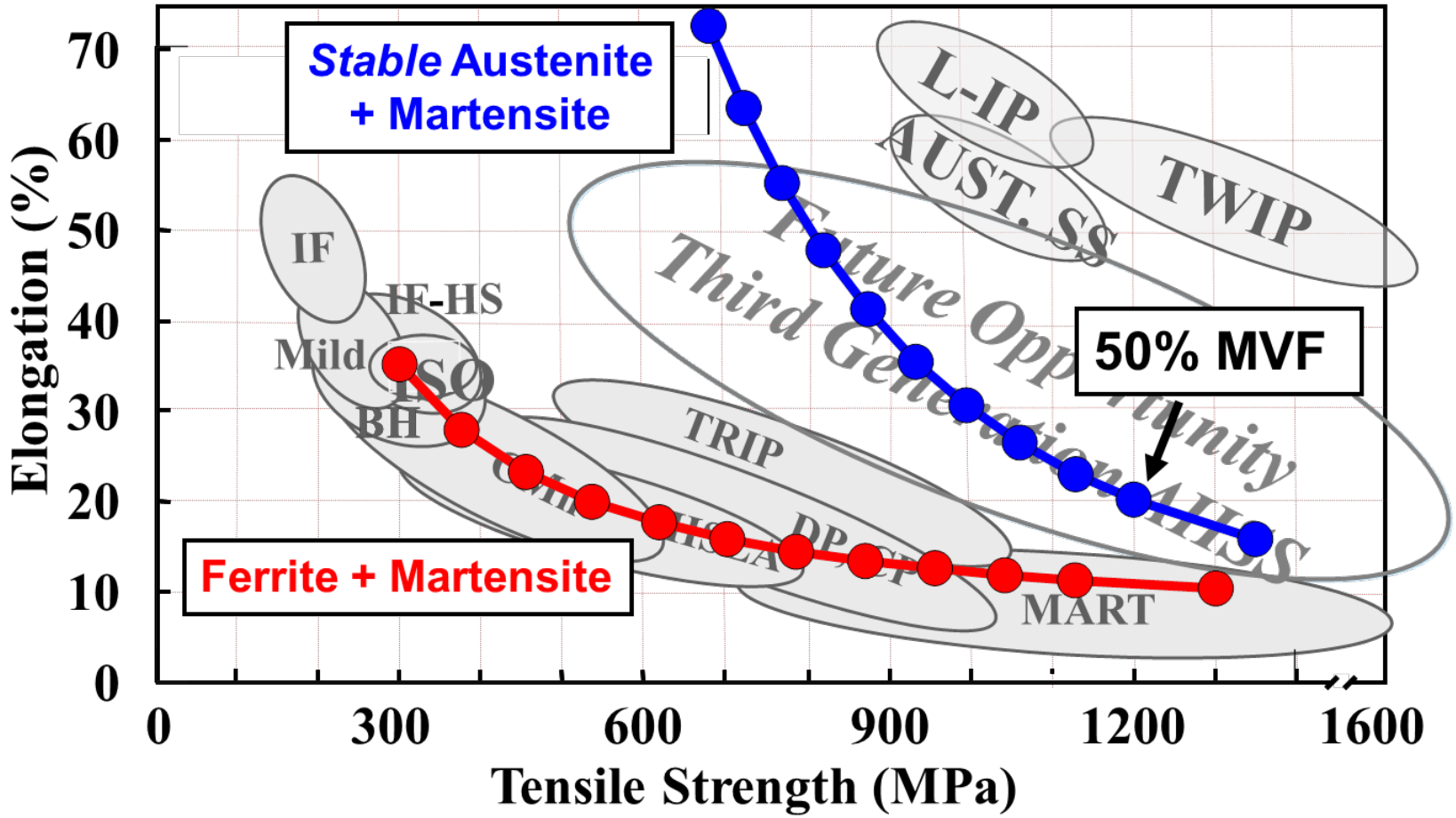
"3rd Generation" AHSS



The "Miracle" of Steel

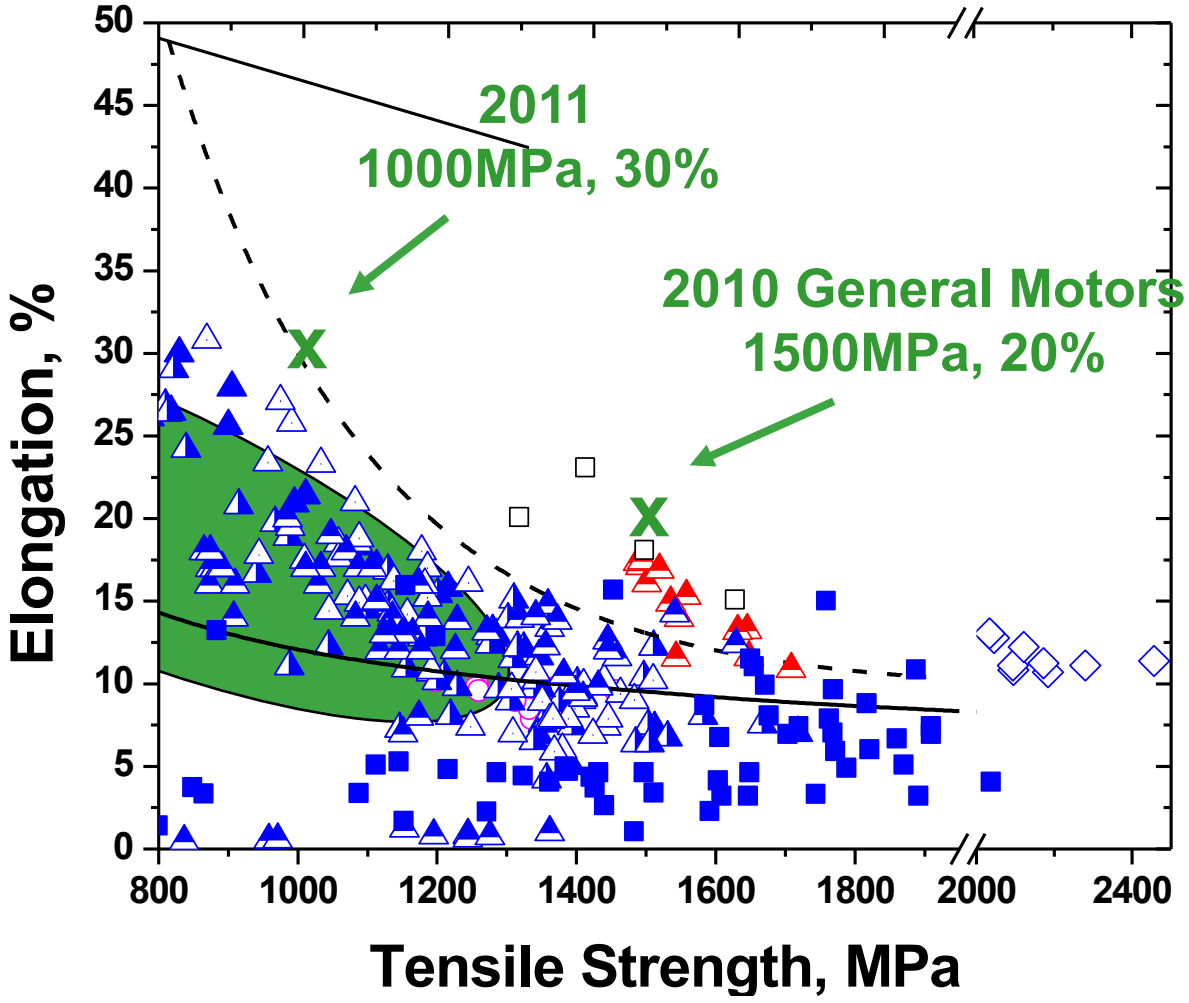
- Anil K. Sachdev, General Motors, 2013

How do we get there ?



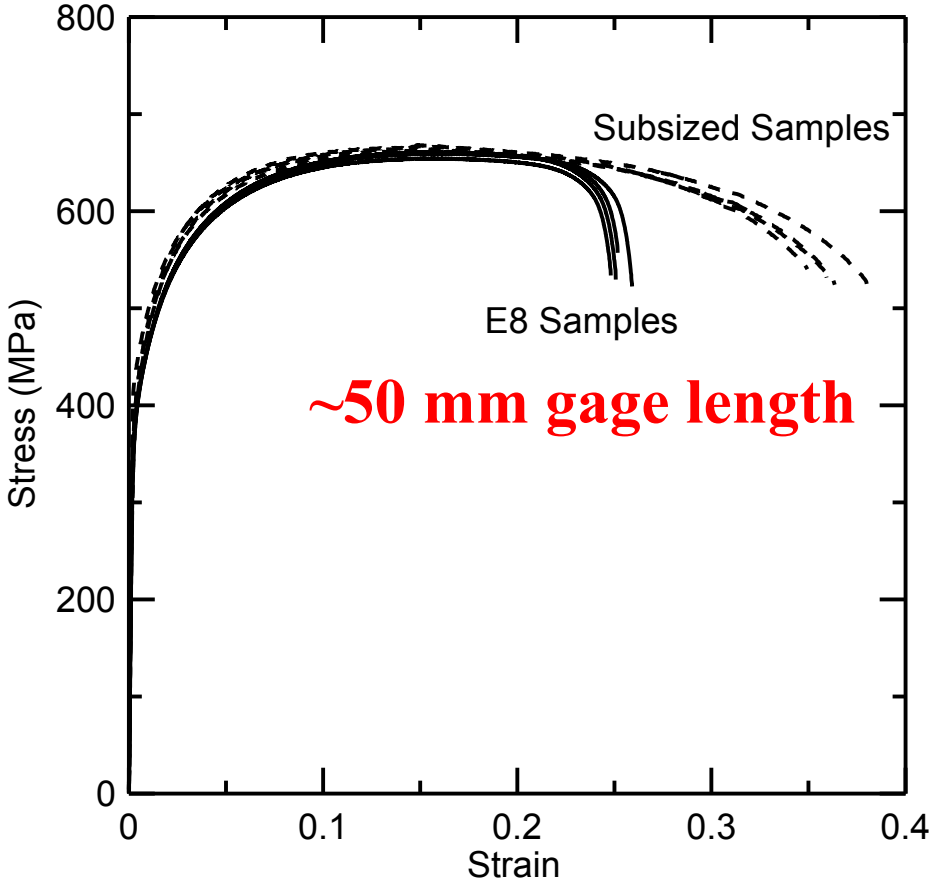
Matlock & Speer, 2006.

"A Moving Target"



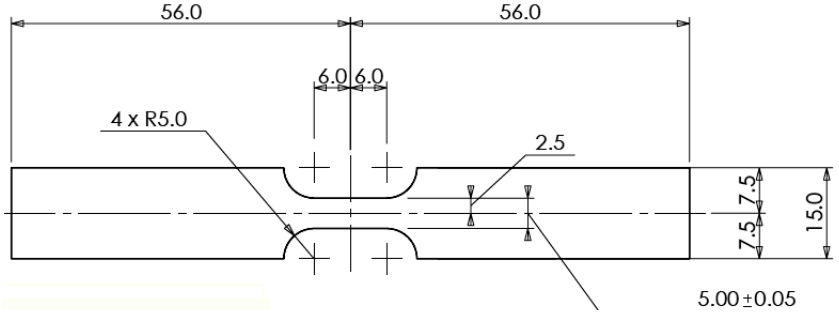
US – DOE Targets (2012) are even greater (30%/1200MPa and 25%/1500MPa)

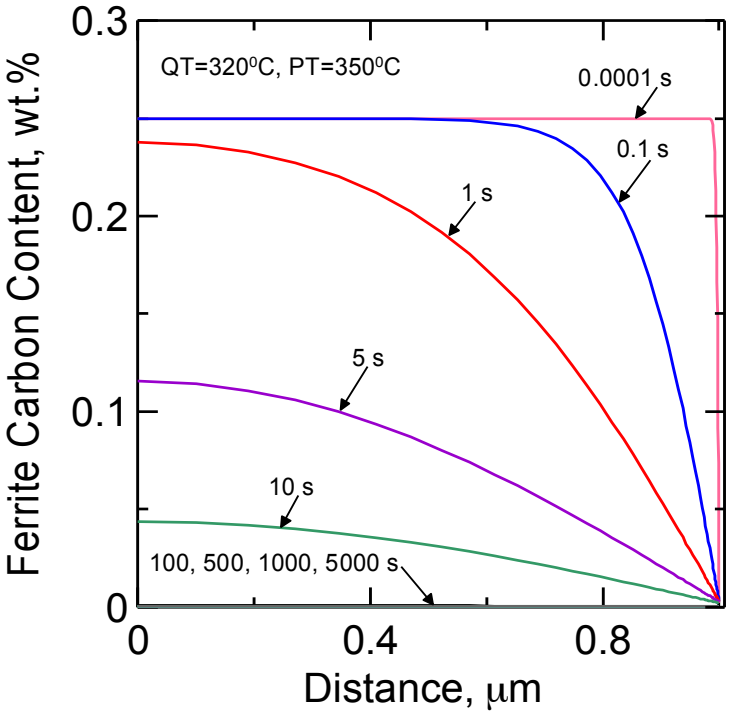
Specimen Geometry Effects

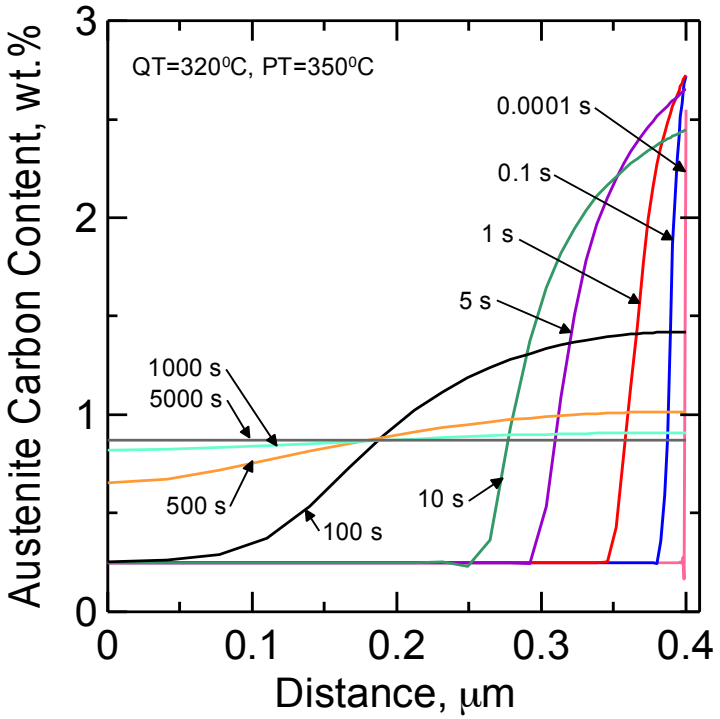


~12 mm gage length

G.A. Thomas, M.S. Thesis, 2009.

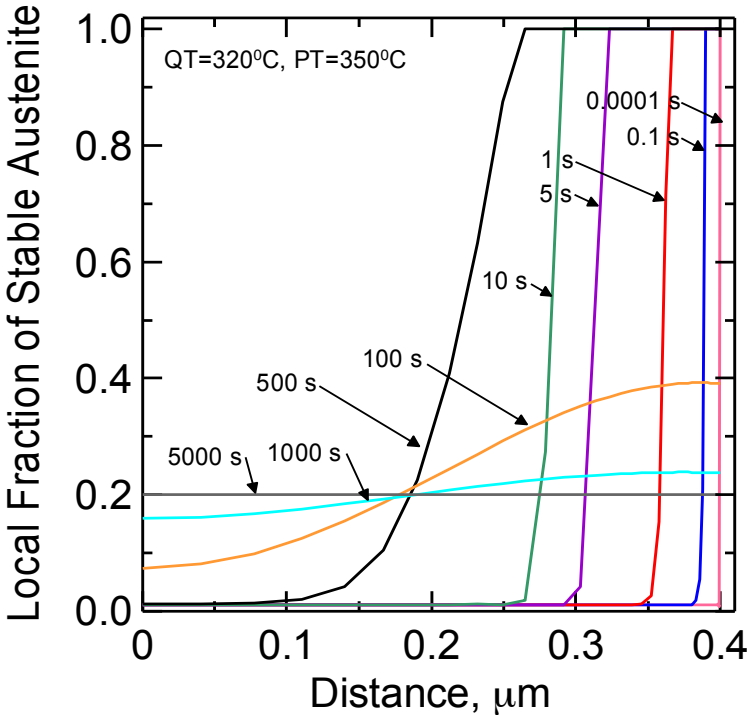






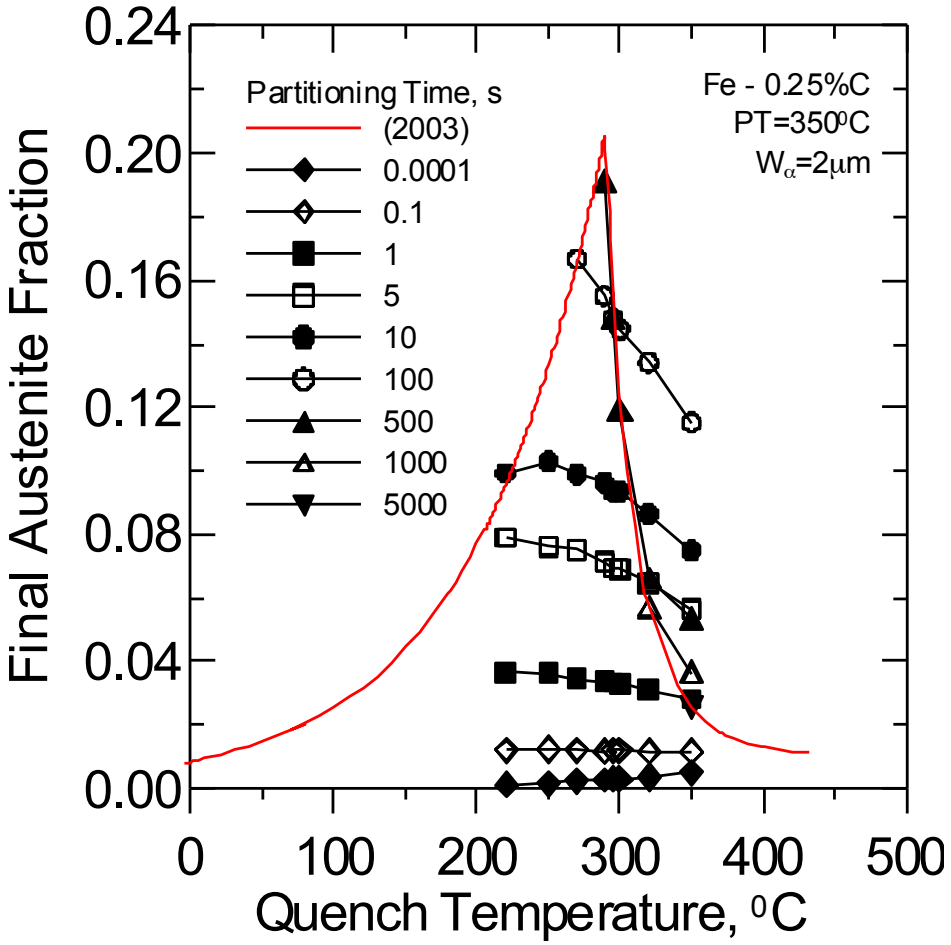
Partitioning Kinetics DICTRA®

(Fe-.25C, 350°C)



Clarke, 2006.

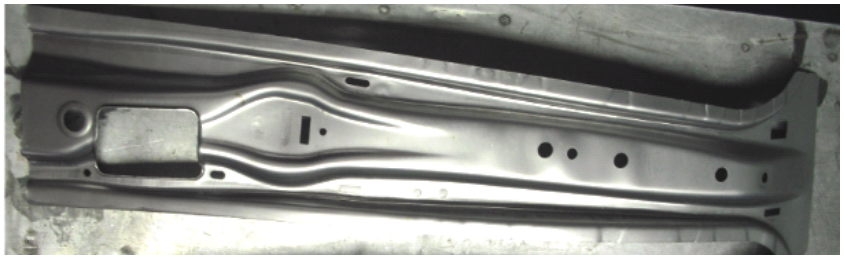
Partitioning Kinetics and Quench Temperature ?



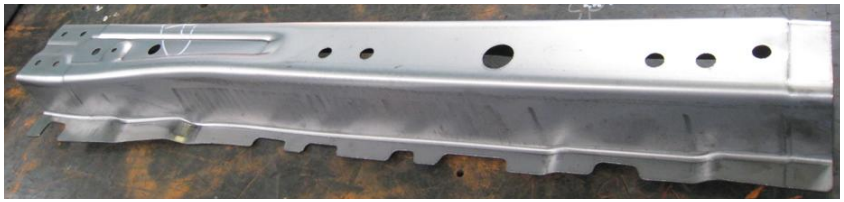
Clarke, 2006.

Application of Q&P…

B-pillar Reinforcement L/R
Gauge: 2.0 mm



B-Pillar Inner
Gauge: 1.2 mm



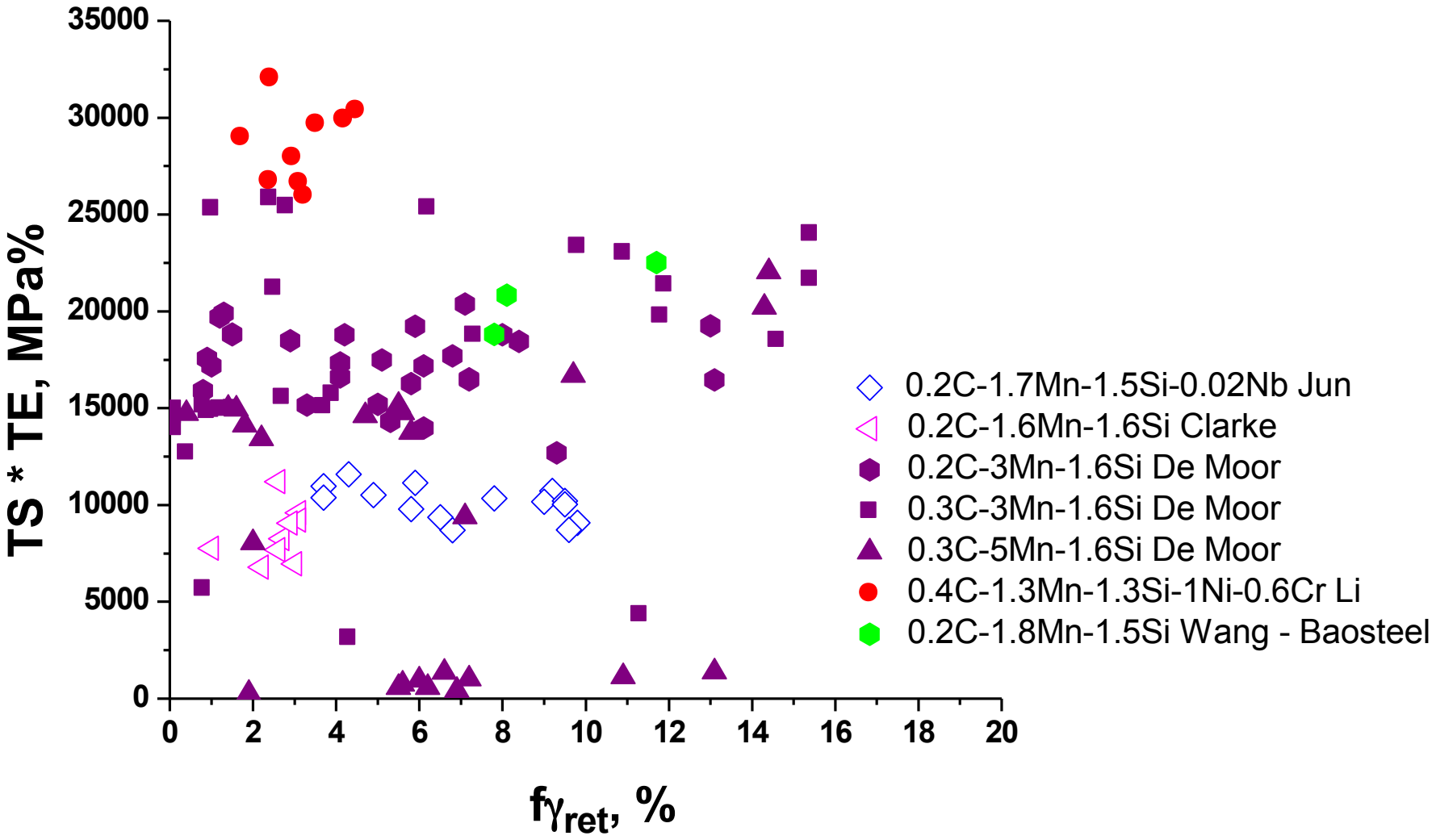
Side Member Front Floor LH
Gauge: 1.8 mm

Door Panel Inner L/R
Gauge: 1.0 mm

Photographs courtesy of L. Wang, Baosteel

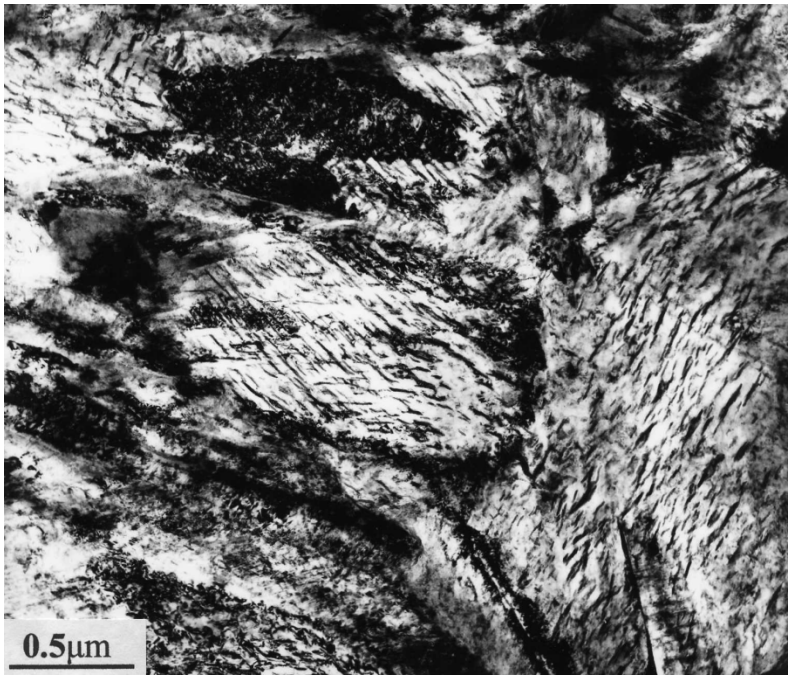
Some Curiosities, Challenges and Opportunities

Structure/Property Relationships Not Fully Understood…



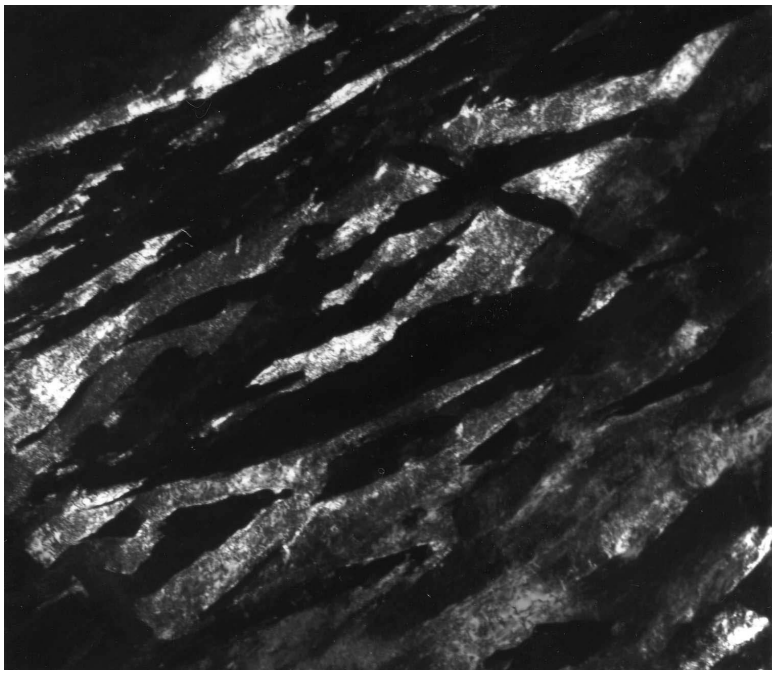
Partitioning Temperature Effects in AISI 9260

QT 150ºC, PT 250ºC

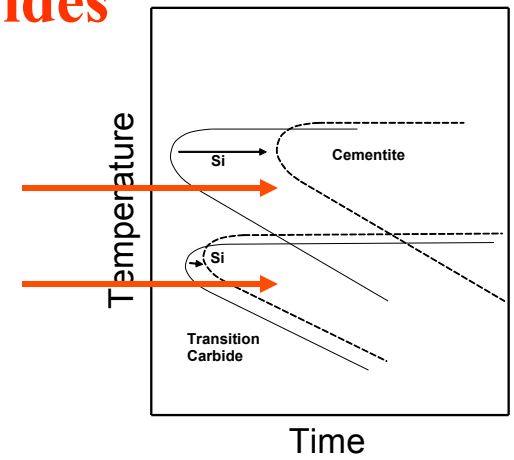


Transition Carbides

QT 190ºC, PT 400ºC



Retained Austenite

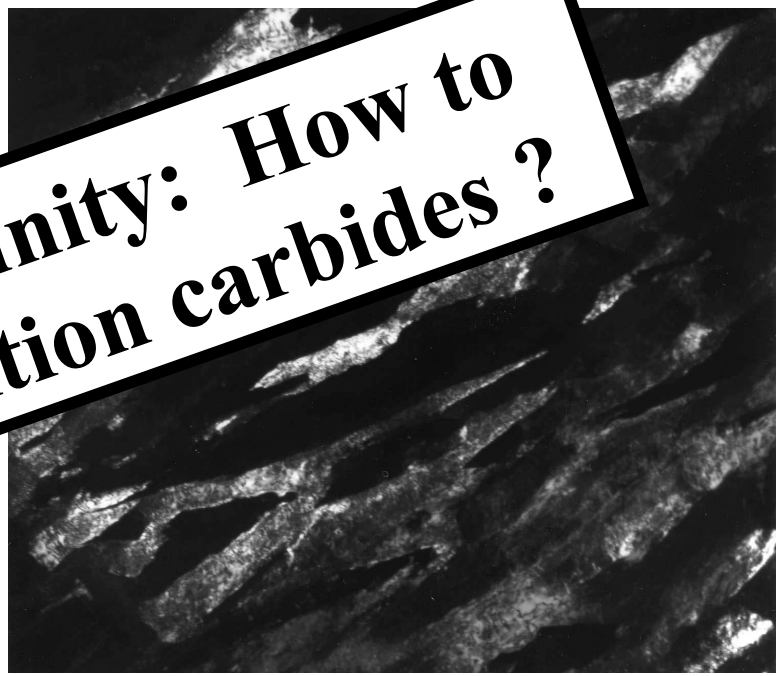


He, *et al.* 2006

Partitioning Temperature Effects in AISI 9260

QT 150ºC, PT 250ºC

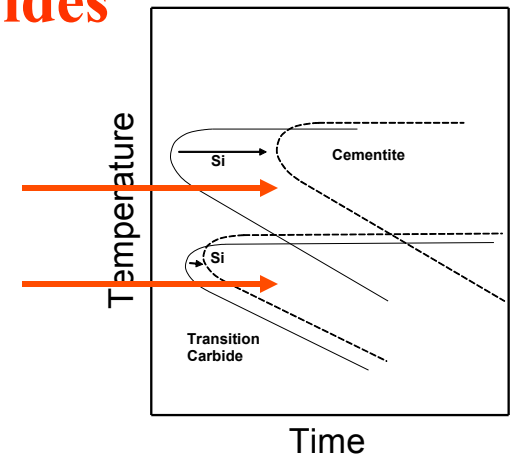
QT 190ºC, PT 400ºC



Research Opportunity: How to destabilize transition carbides ?

Transition Carbides

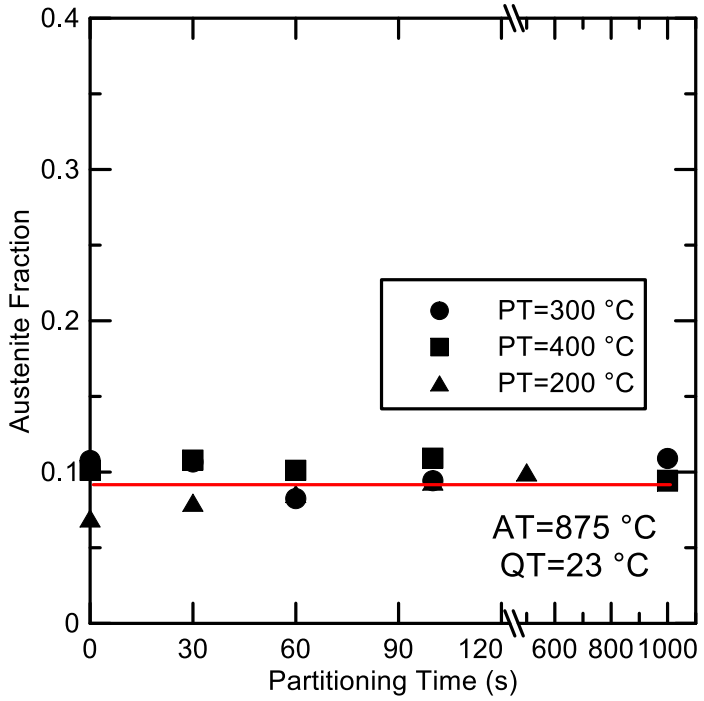
Retained Austenite



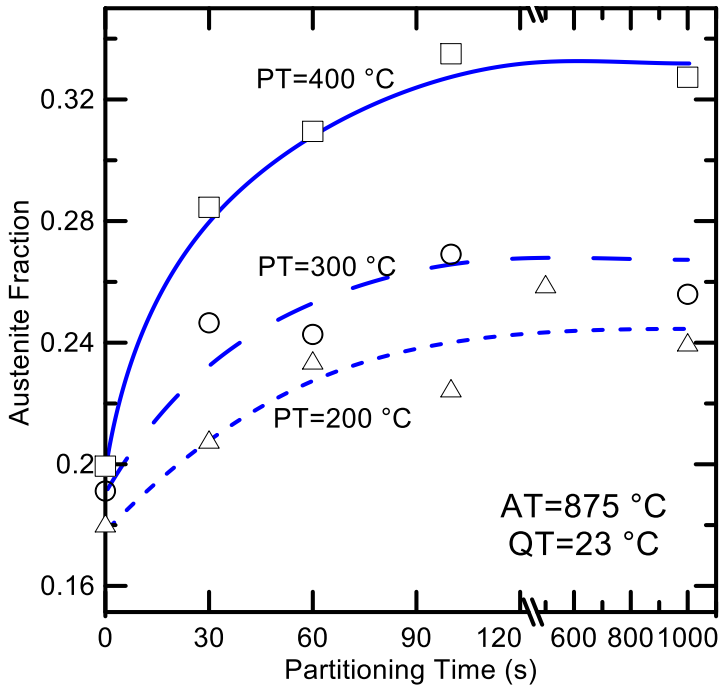
He, *et al.* 2006

γ/α' Interface: Stationary or Mobile ?

~ 0.3C, 14Ni

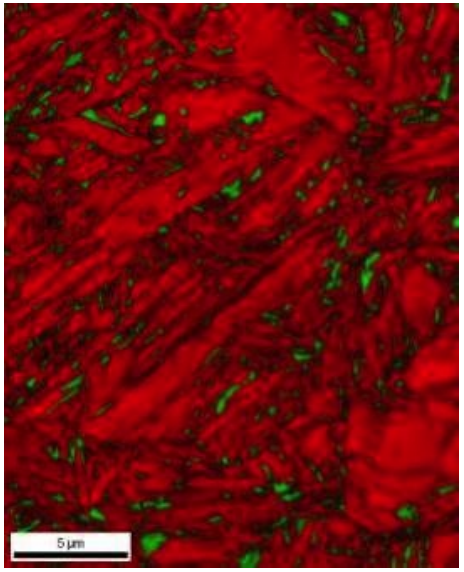


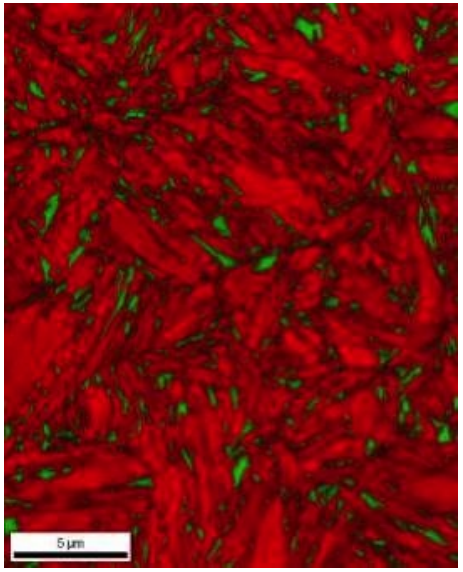
~ 0.3C, 8Mn



Thomas, *et al.* 2013.

Confirmation via EBSD Phase Maps



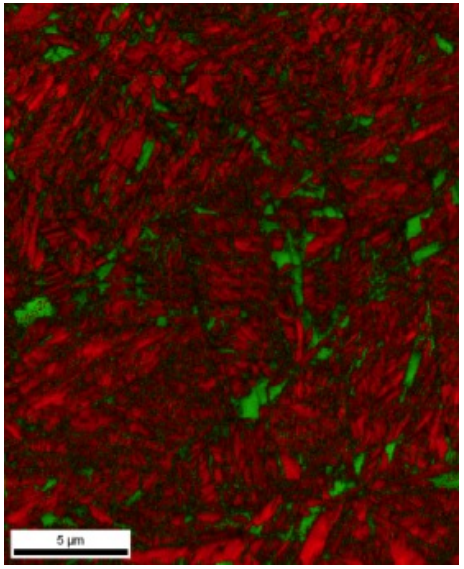


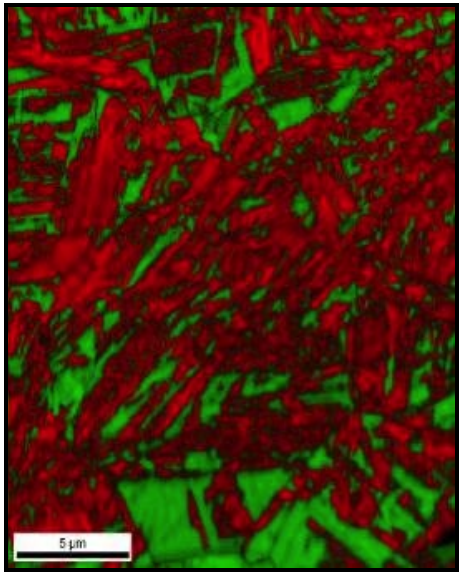
10 µm

Austenite

Ferrite

~ 0.3C, 14Ni

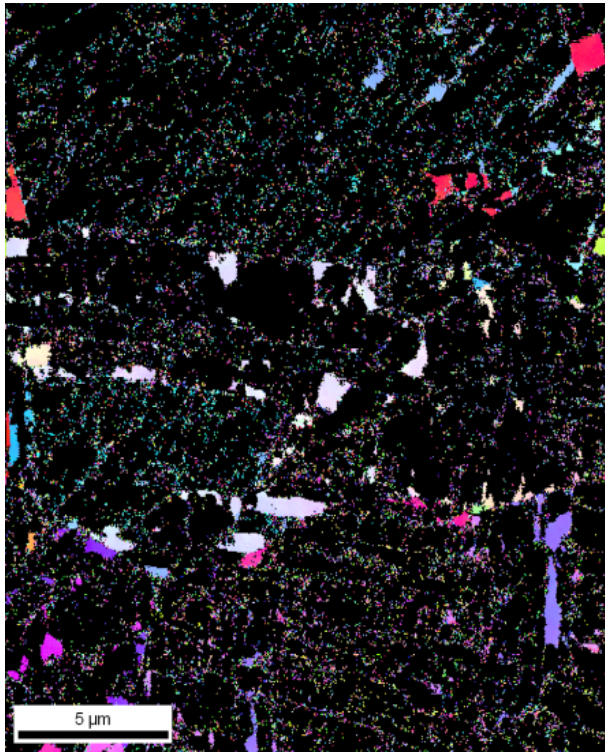




~ 0.3C, 8Ni

G.A. Thomas, 2012.

Austenite Growth…

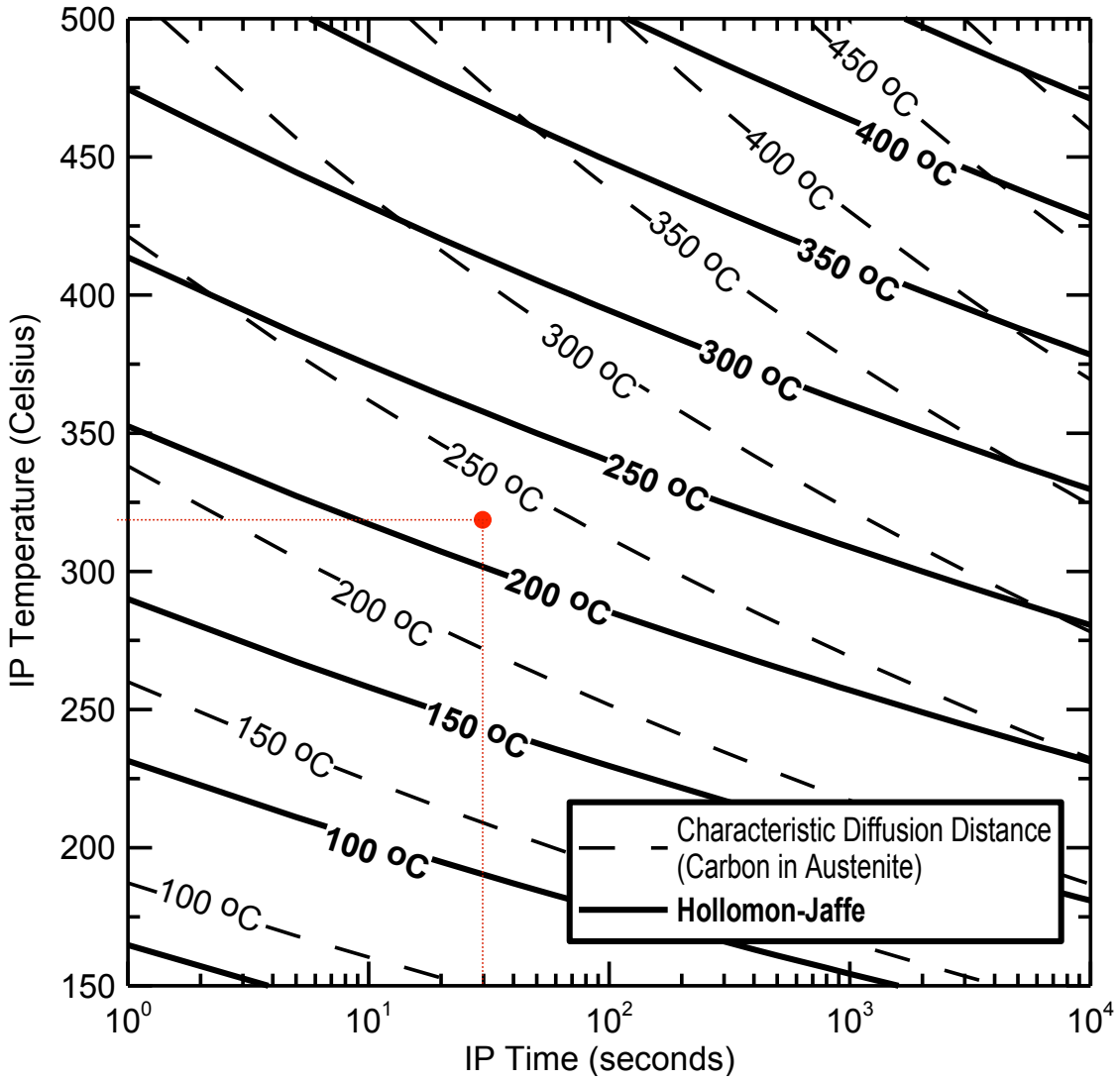


As-Quenched

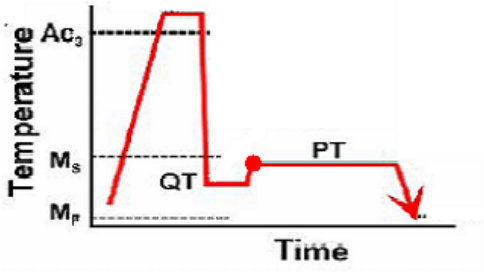
Partitioned (400 °C, 60 s)

Thomas, *et al*., 2013.

Time/Temperature "Equivalence"…

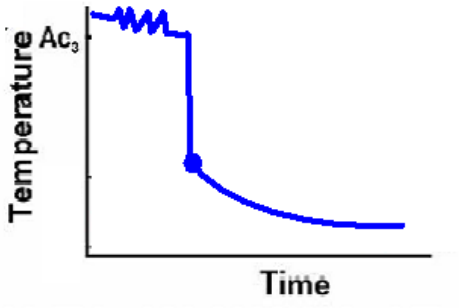


Annealed (conventional) Q&P



isothermal

Hot-rolled Q&P

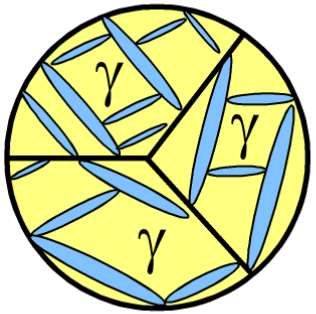


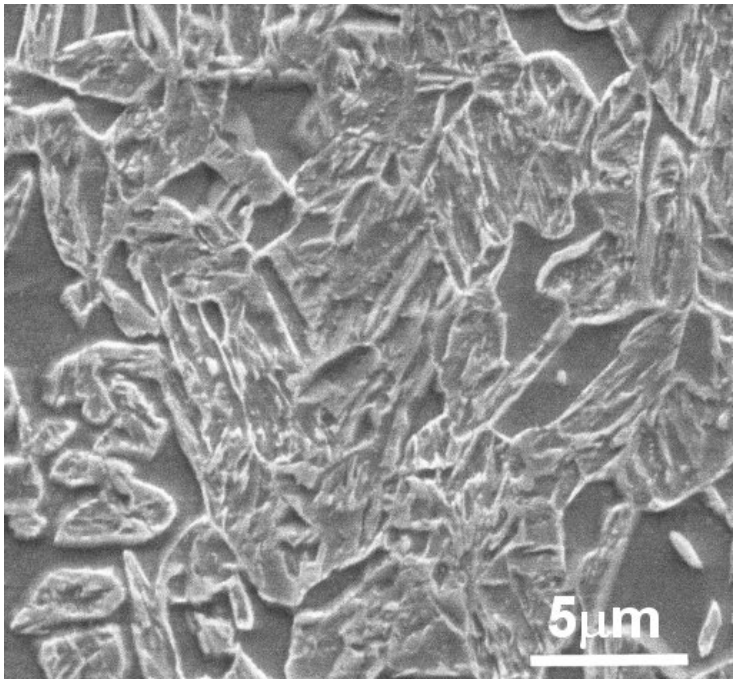
non-isothermal

Summary

Q&P science and technology continue to advance.

Challenges & opportunities remain in both domains !





820°C-180s IAT, QT=200°C, PT/t=400°C-10s

Feng, 2010