K. 6/115 amended

High-strength lightweight steels for low emission automobiles

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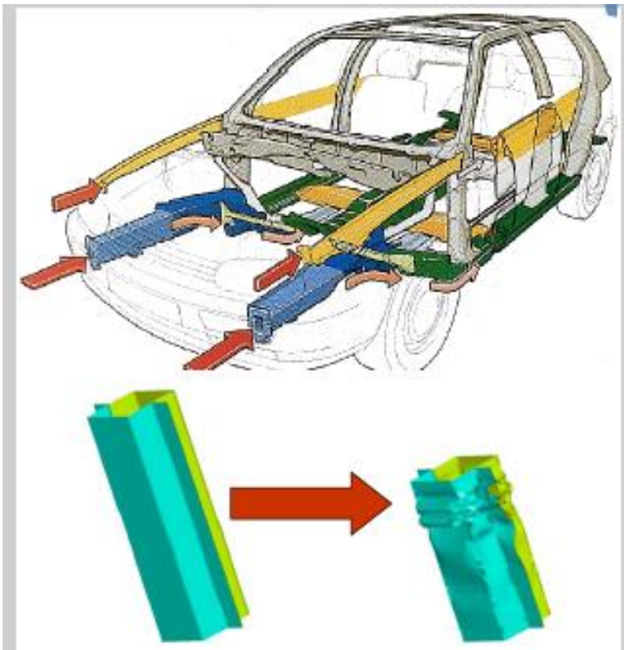
26 May 2017

Introduction: Weight saving



Crash Performance

$F \propto \sqrt{\mathrm{UTS}} \cdot t^2$

$F \propto \sqrt{\mathrm{YS}} \cdot t^{1.75}$

Energy Absorption → Crash in compression

$$\frac{\Delta m}{m} = -\frac{1}{4}\cdot\left(\frac{\Delta \mathrm{UTS}}{\mathrm{UTS}}\right)$$

600MPa → 1000MPa

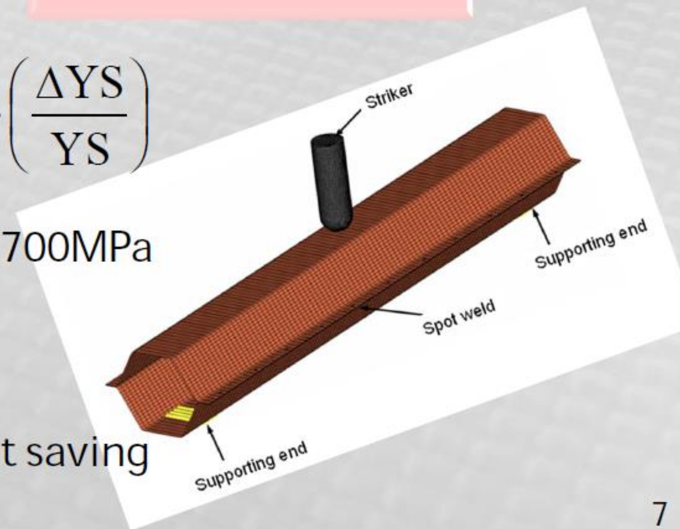
~ 17% weight saving

Anti-intrusion → Crash in bending

$$\frac{\Delta m}{m} = -\frac{2}{7}\cdot\left(\frac{\Delta \mathrm{YS}}{\mathrm{YS}}\right)$$

400MPa → 700MPa

~ 21% weight saving



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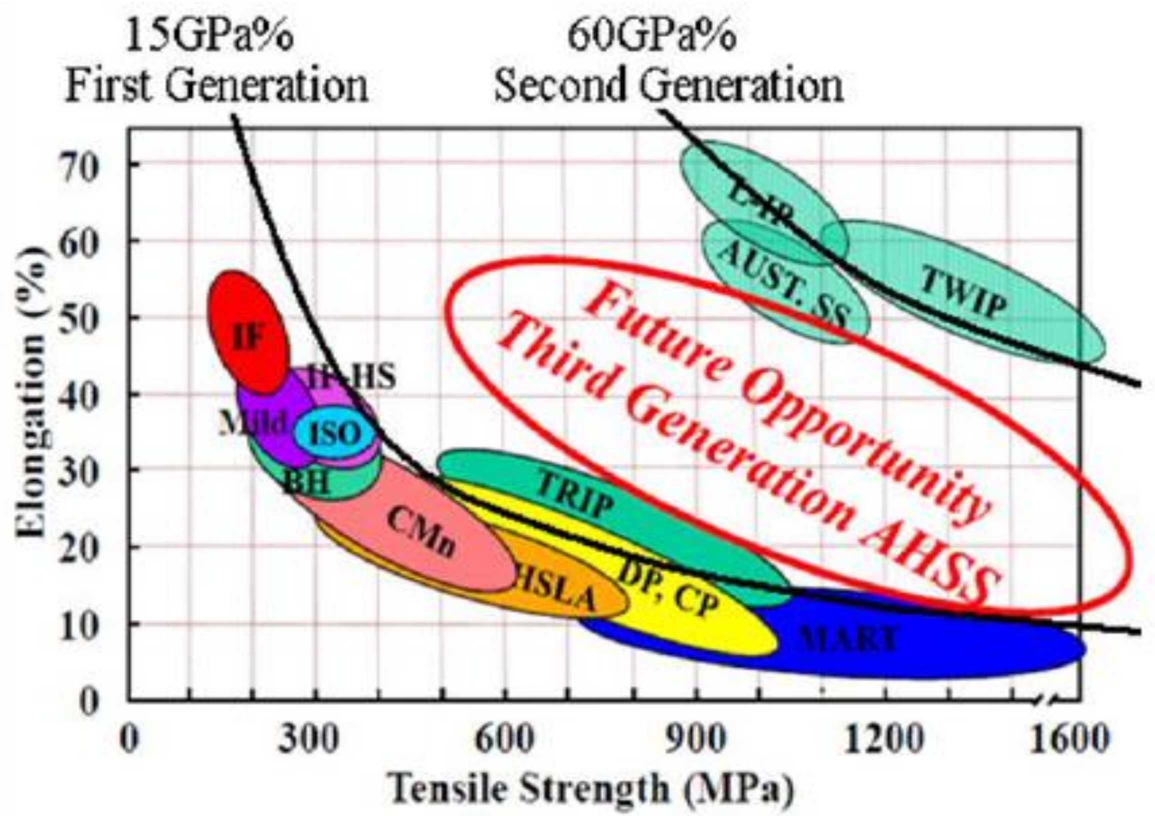
Source: General Motors; M.X. Huang et al., Steel International

Current Advanced High Strength Steels



Source: WorldAutoSteel

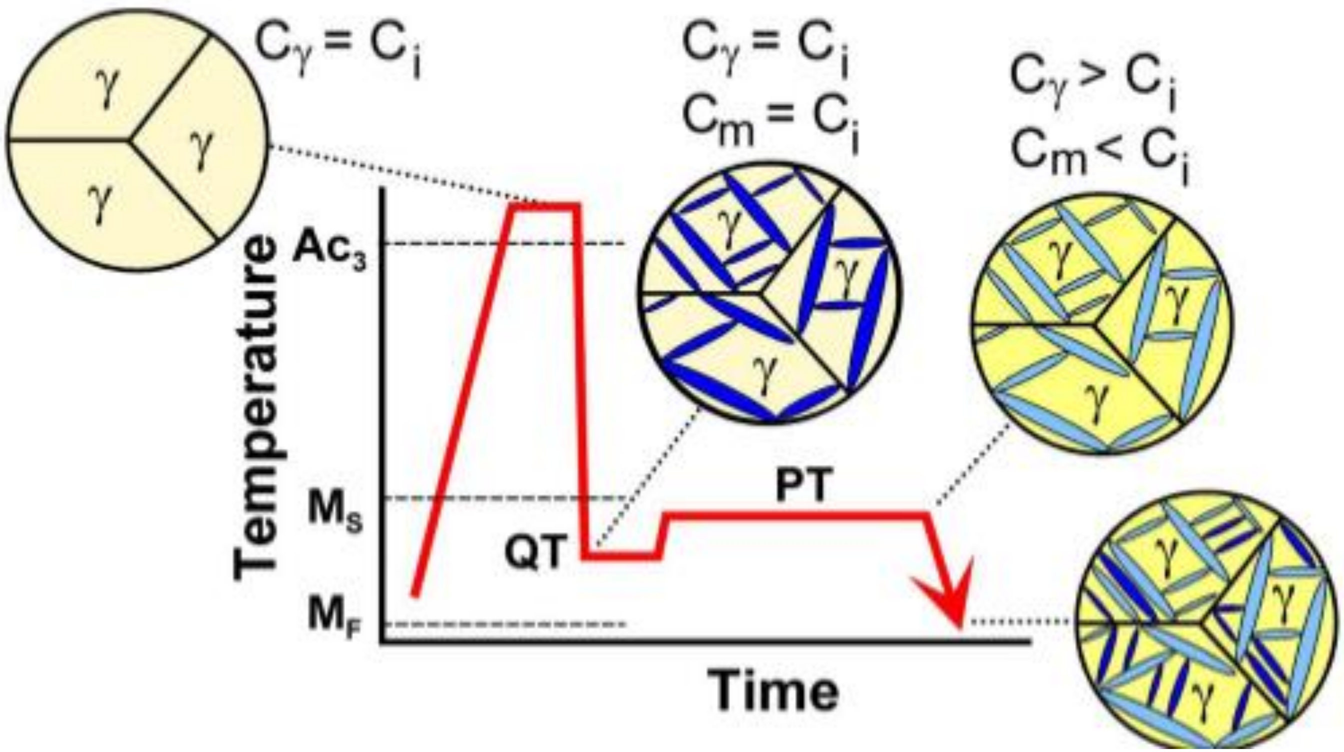
http://www.worldautosteel.org/s

Advanced High Strength Steels (AHSS):

Dual Phase steels (DP); Transformation Induced Plasticity steels (TRIP)

Complex Phase steels(CP); Martensitic steels (MS)

Introduction to Q&P steel



Speer JG, et al. Acta Mater, 2003.

Underpinning Research

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Scripta Materialia 68 (2013) 321–324

Scripta MATERIALIA

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The effect of morphology on the stability of retained austenite in a quenched and partitioned steel

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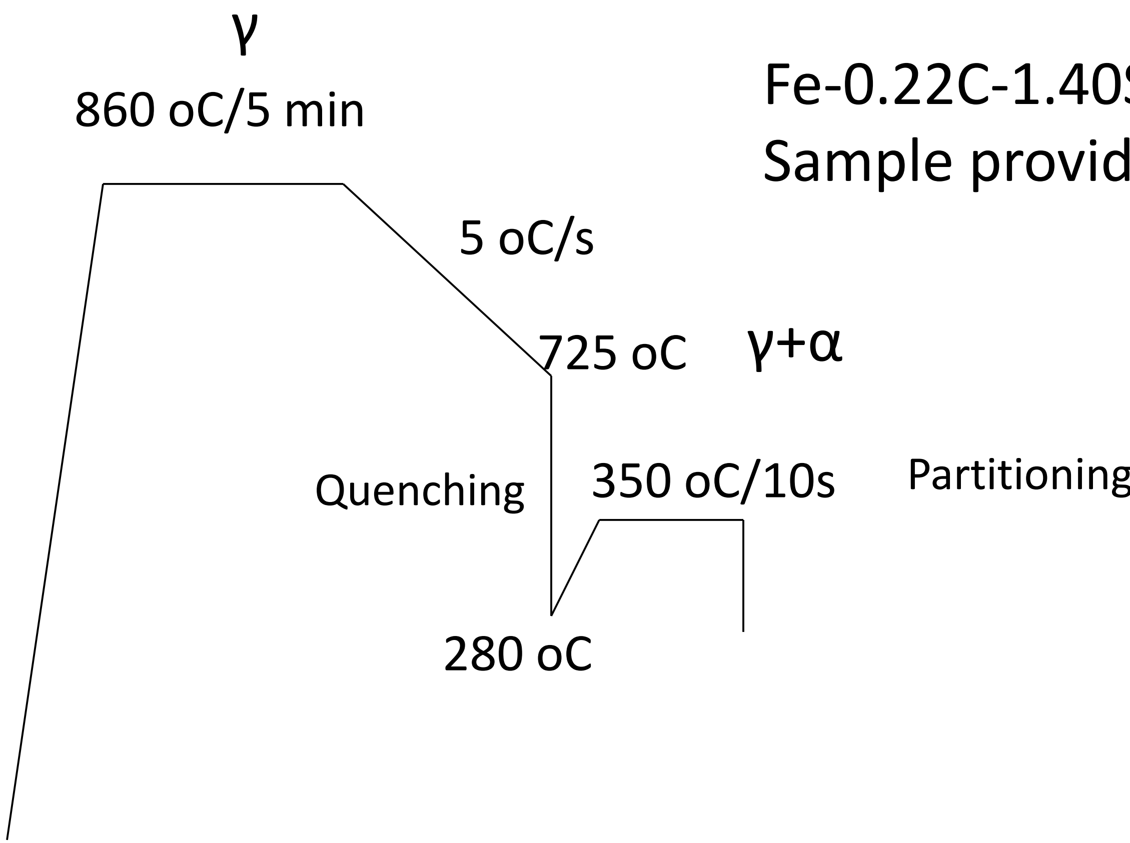
Received 14 August 2012; revised 24 September 2012; accepted 7 November 2012
Available online 10 November 2012

Citation: ~100

Underpinning Research

Fe-0.22C-1.40Si-1.8Mn (in wt.%)
Sample provided by Baosteel.



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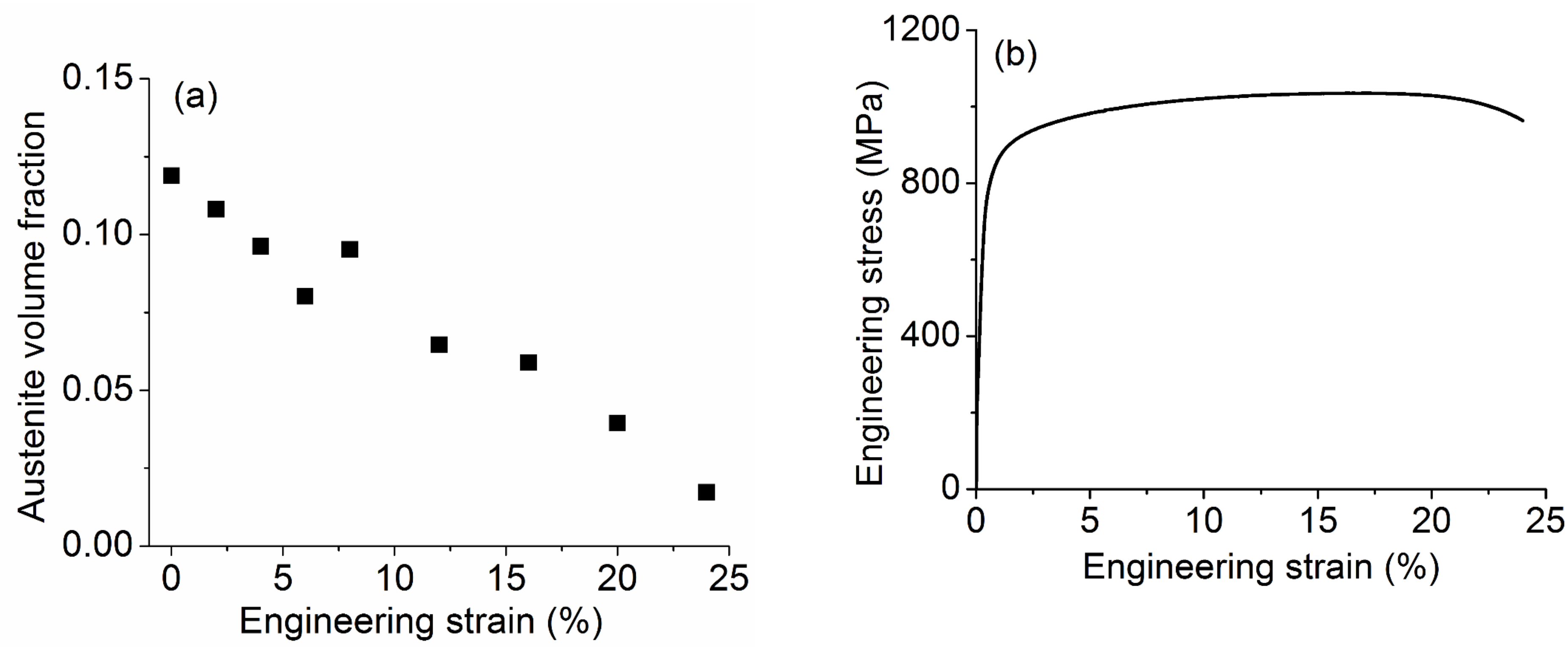
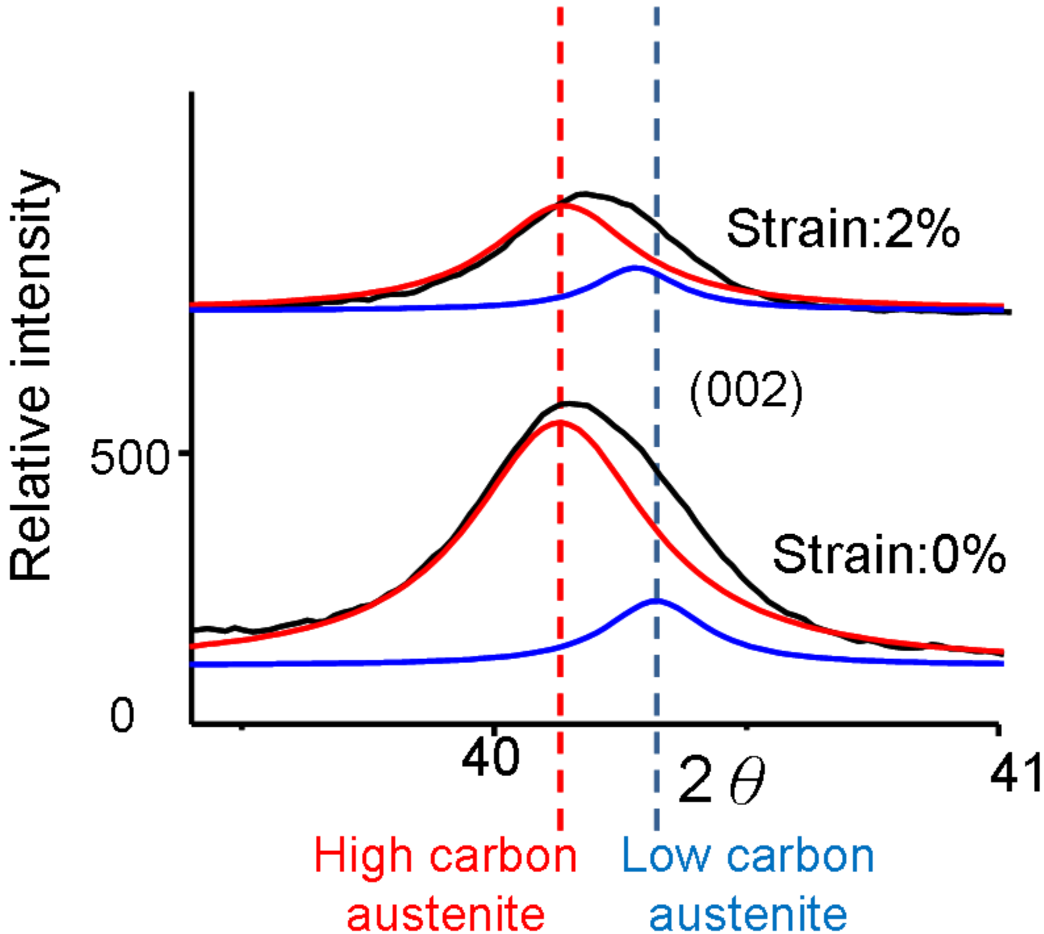


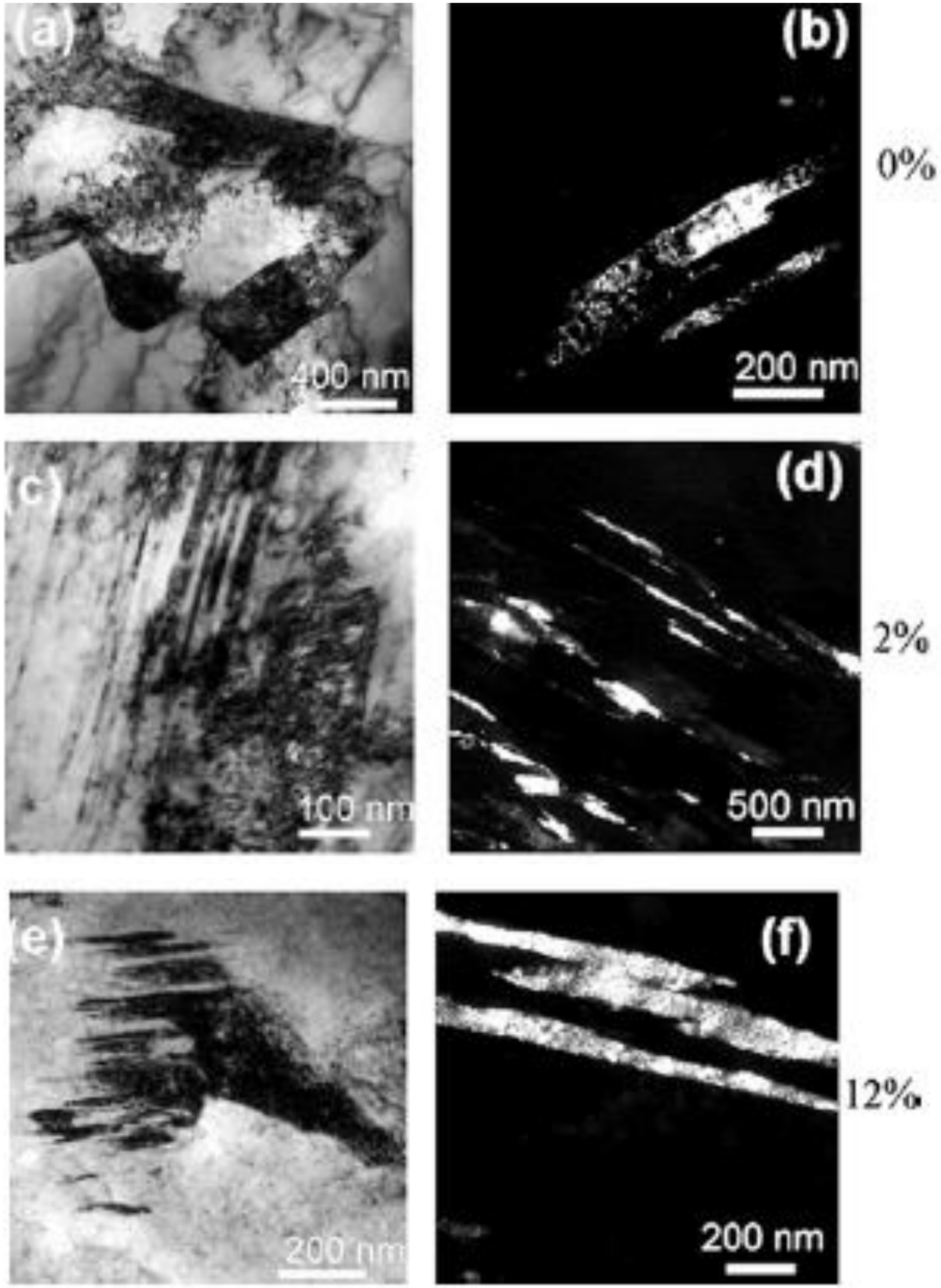
Synchrotron measurement



High C austenite
estimated 1.14wt%.
Ms: -8.4 ^{o}C

Low C austenite
estimated 0.64wt%.
Ms: 203 ^{o}C

Low carbon is more stable.



Left: blocky austenite
Rright: film-like austenite

Blocky austenite transformed to twinned martensite from 2%
Film-like austenite is stable up to 12%

Martensitic transformation of blocky austenite

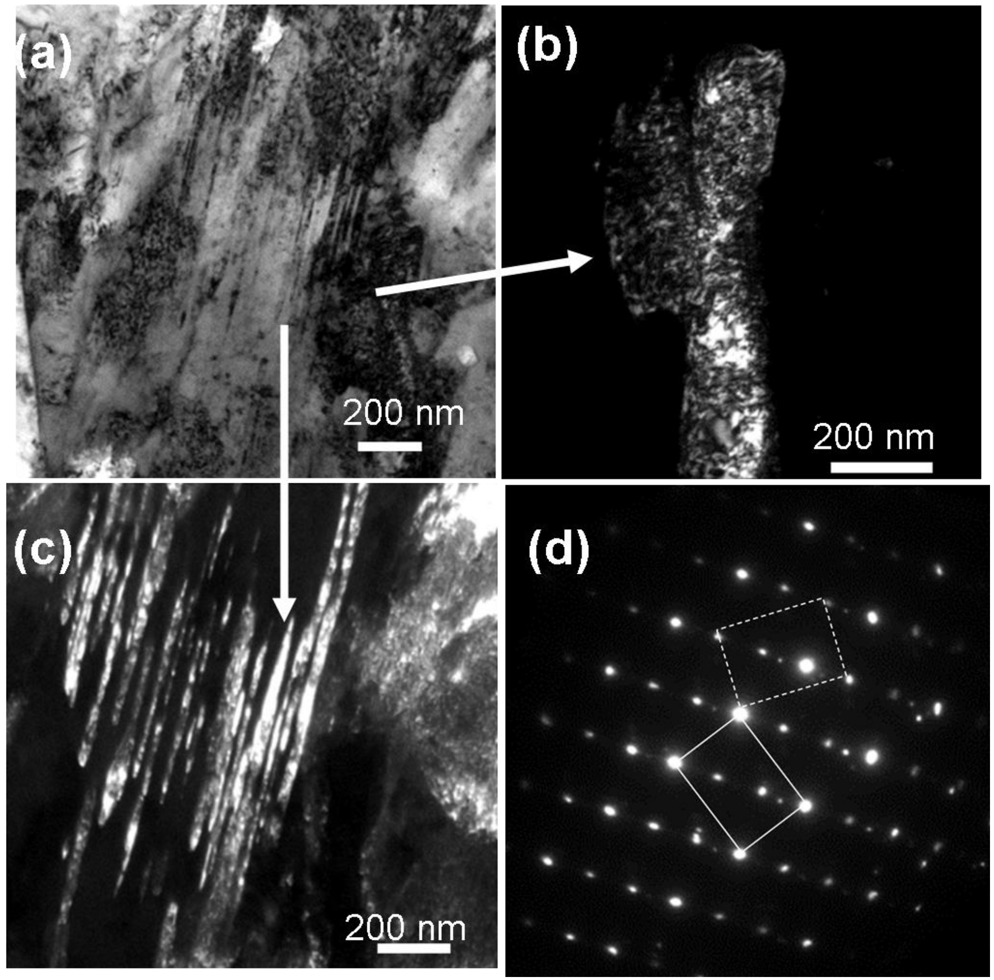
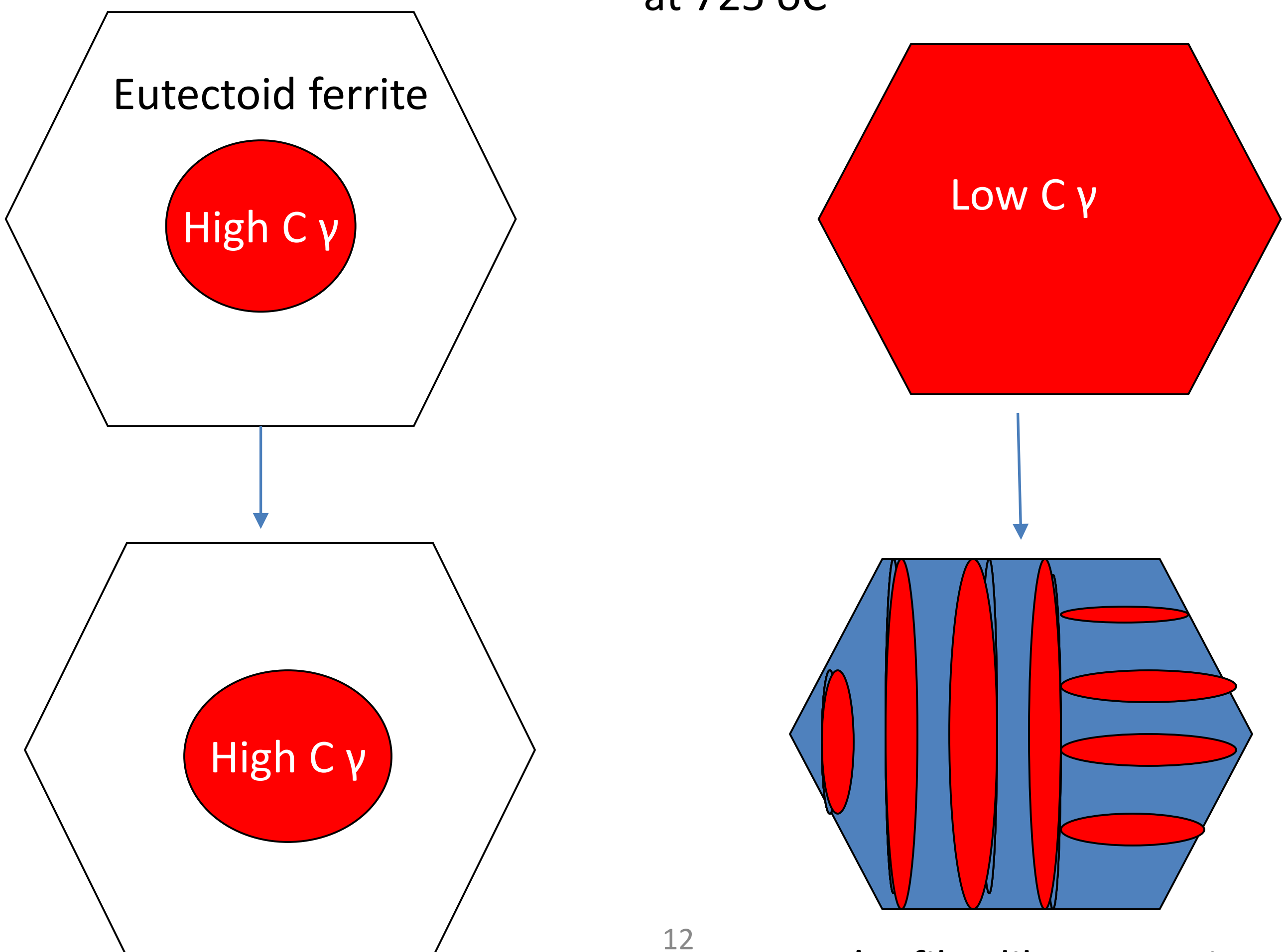


Figure 4. (a) A blocky retained austenite grain was partially transformed to martensite; (b) dark field image of the untransformed part; (c) dark field image of transformed part; (d) diffraction pattern on the [0 1 1] zone axis of the transformed part showing a typical (1 1 2)-type bcc twin reciprocal lattice.

Phase transformation mechanism

Two phases region: some austenite grains have high C (surrounded by eutectoid ferrite) while others have lower C content.
After quenching to 280 oC

at 725 oC



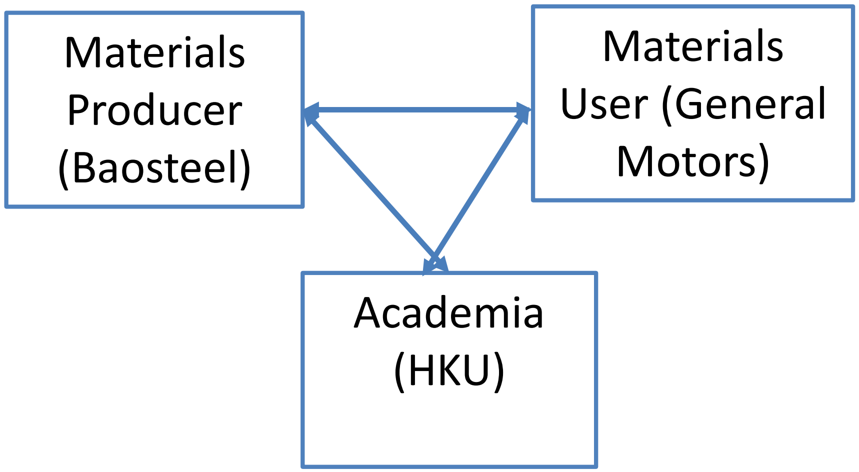
α’ + film-like austenite

Underpinning Research

- Based on these findings, we proposed a new process to produce Q&P steel.
- The modified process uses two-phase region annealing instead of Speer's fully austenitisation annealing process, and results in a more uniform distribution of carbon content in the retained austenite grains.
- This leads to a better TRIP effect and larger uniform elongation, satisfying the requirement of automotive applications.
- Steel produced using this modified process have been used in passenger cars worldwide.

Engagement

- The research was performed in collaboration with General Motors and Baosteel Group.
- The research results were published in a top journal [1].
- Baosteel adapted the research results to produce the new Q&P steel.
- General Motors utilized the Q&P steel for its new cars for weight saving.
- An excellent example of golden-triangle collaboration relationship.



[1] X.C. Xiong*, B. Chen, **M.X.Huang***, J.F. Wang, L. Wang, *Scripta Materialia*, 68, 321-324 (2013)

Impacts Achieved

1. Baosteel has adapted the research results to produce new Q&P steel.
2. The sales of Q&P steel coils produced by this modified process were **414, 520, and 3,300 tons** in 2014, 2015 and 2016, respectively, with expected sales of **10,000-15,000 tons** in total in China, Japan and the USA in 2017 [Source: Baosteel Corroborating letter].

BAOWU

13 Feb. 2017

To whom it may concern

Corroborating statement

Quenched and partitioned (Q&P) steel was firstly proposed by Prof. John Speer and co-workers in 2003. Nevertheless, the capability of existing industrial production lines cannot fulfil the required cooling rate proposed in the original Q&P process. The research findings resulted from the collaborative work between University of Hong Kong, General Motors and Baosteel (Xiong et. al, *Scripta Materialia*, 68, 321-324, 2013) showed that such slow cooling rate in the industrial production line leads to the formation of proetutectoid ferrite as well as a non-uniform carbon distribution in the retained austenite, leading to unsatisfied mechanical properties. Based on the above research findings, a modified process was proposed to improve the properties of Q&P steels. The modified process employs a two phase region annealing instead of fully austenitisation annealing, which results in a more uniform distribution of carbon content in the retained austenite grains and therefore a better mechanical properties which meet the requirement of automotive applications.

Baosteel has employed such modified process to produced new Q&P steels since the publication of the research results. Q&P steels produced by the modified process have been used by major car makers worldwide including General Motors, Ford, Toyota, Nissan and several Chinese car makers. The sales of Q&P steels produced by this modified process were 414, 520, 3300 tons in 2014, 2015 and 2016, respectively, and it is expected to sell 10000-15000 tons in Japan, USA and China in 2017.

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Impacts Achieved

3. The new Q&P steels have better mechanical properties, and have been used by major car manufacturers worldwide including General Motors, Nissan and several Chinese car makers.
4. For example, the new Chevrolet LOVA RV launched in 2015 by General Motors utilises this new steel for producing critical crash resistance parts, resulting in the weight reduction of these parts by approximately 20% [2, 3].

Source: Internet

[2]http://media.gm.com/media/cn/zh/gm/news.detail.html/content/Pages/news/cn/zh/2015/dec/1201_advanced-steel.html (last accessed on 21 April 2017)
[3] http://www.greencarcongress.com/2015/12/20151203-gmqnp.html (last accessed on 21 April 2017)

Thank you!