High-strength lightweight steels for low emission automobiles

Mingxin HUANG
Department of Mechanical Engineering
HKU
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Introduction: Weight saving
Crash Performance

Energy Absorption

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

Crash in compression

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

600MPa $\rightarrow$ 1000MPa

$\sim 17\%$ weight saving

Anti-intrusion

Crash in bending

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

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

400MPa $\rightarrow$ 700MPa

$\sim 21\%$ weight saving

Source: General Motors; M.X. Huang et al., Steel International
Current Advanced High Strength Steels

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

Underpinning Research

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

X.C. Xiong, a, * B. Chen, b M.X. Huang, c, * J.F. Wang a and L. Wang d

a General Motors Global Research & Development, China Science Laboratory, 56 Jinwan Road, Shanghai, China
b School of Materials Science and Engineering, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai, China
c Department of Mechanical Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, China
d Baosteel Research Institute, 889 Fujin Road, Shanghai, China

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Underpinning Research

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

\[ \gamma \]
860 °C/5 min

5 °C/s

\[ \gamma + \alpha \]
725 °C

Quenching

350 °C/10s Partitioning

280 °C
Underpinning Research

(a) Austenite volume fraction vs. Engineering strain (%)

(b) Engineering stress (MPa) vs. Engineering strain (%)

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Synchrotron measurement

High C austenite estimated 1.14wt%. Ms: -8.4 °C

Low C austenite estimated 0.64wt%. Ms: 203 °C

Low carbon is more stable.
Left: blocky austenite
Right: 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 [011] zone axis of the transformed part showing a typical (112)-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 °C

Eutectoid ferrite

High C $\gamma$

Low C $\gamma$

$\alpha'$ + 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.

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].
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


Thank you!