Dual-Phase Hot-Press Forming Alloy

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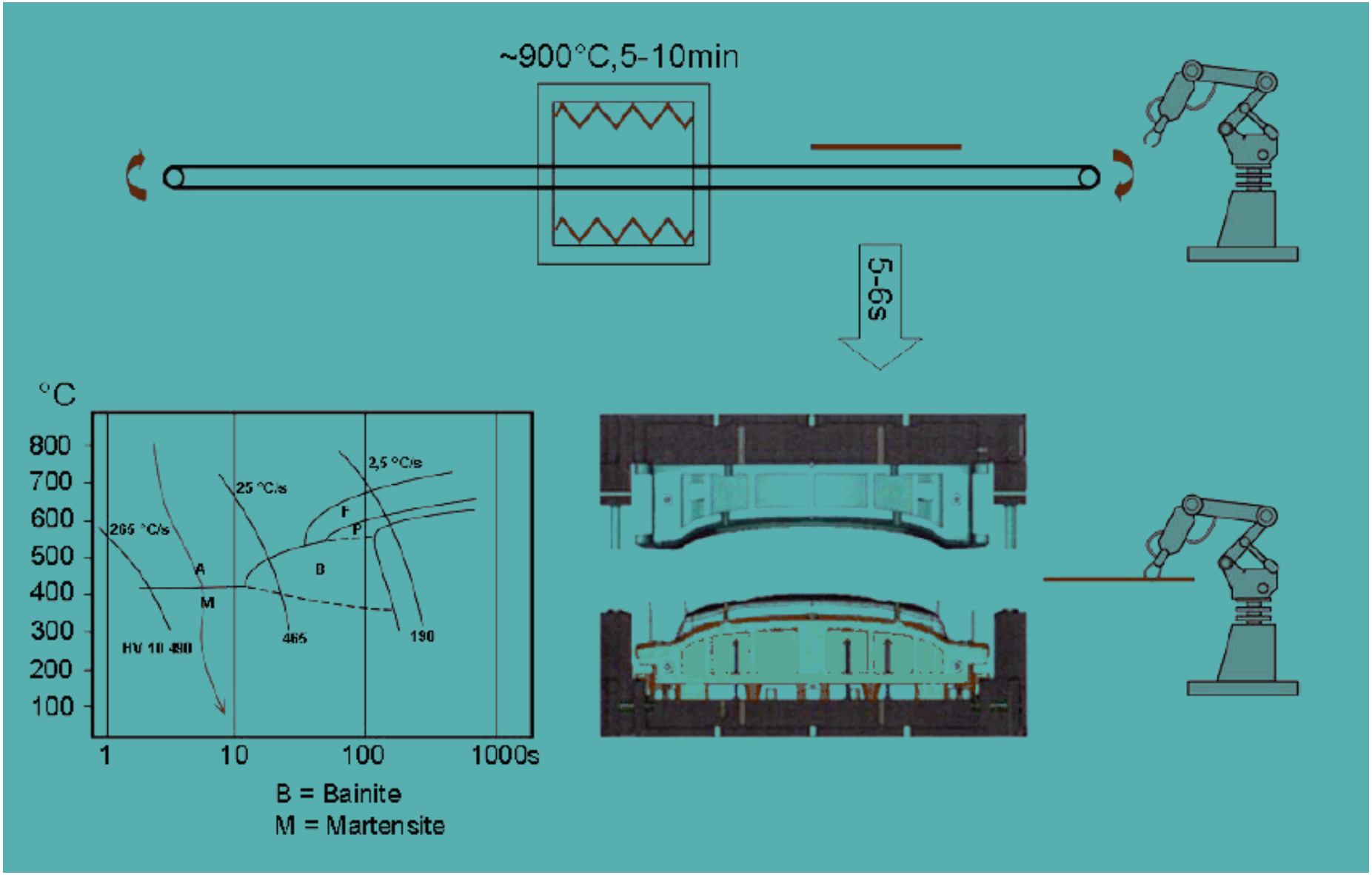
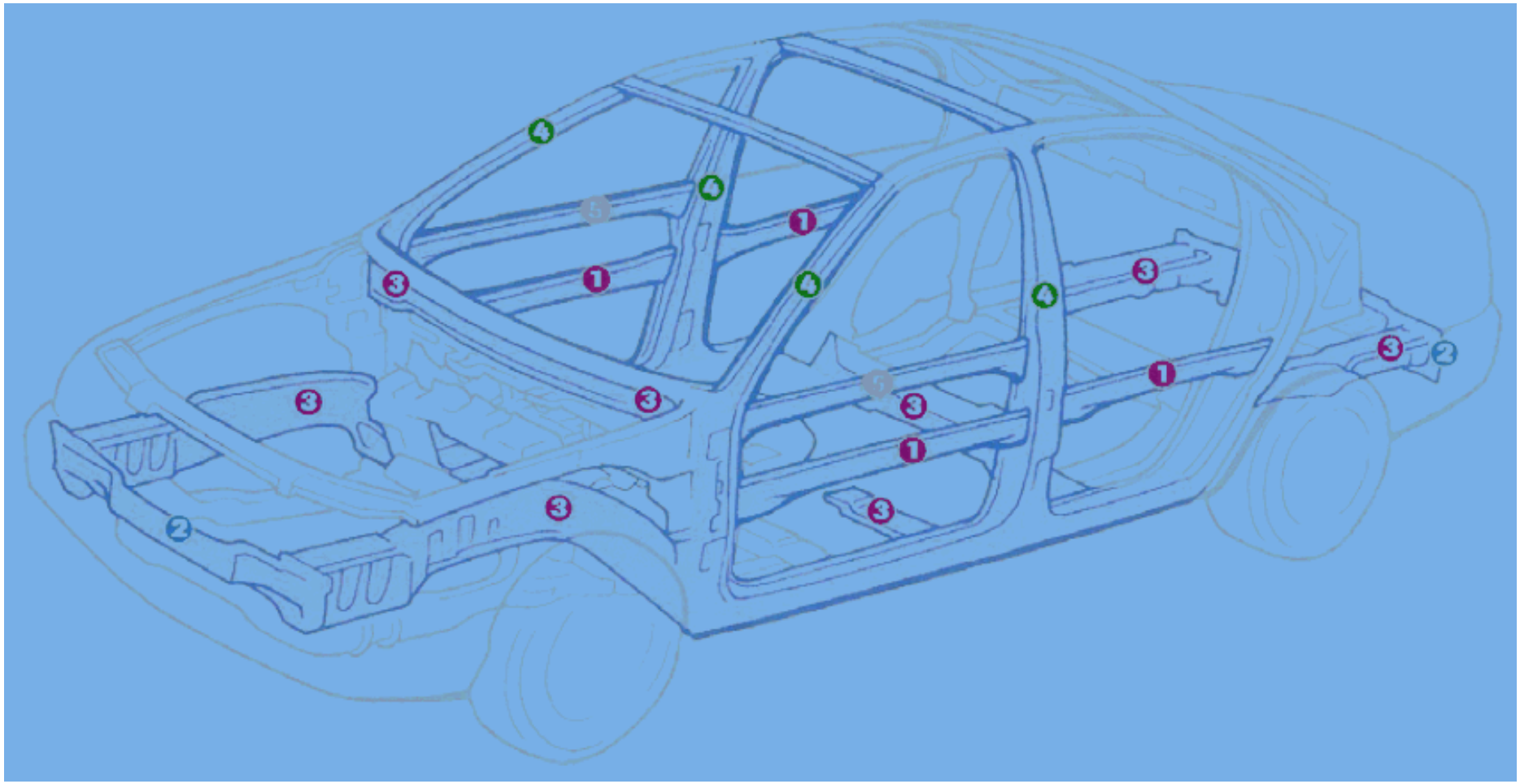
Computational Metallurgy

Graduate Institute of Ferrous Technology
GIFT
POSTECH

Hot-press forming



Typical applications



Conventional HPF alloys

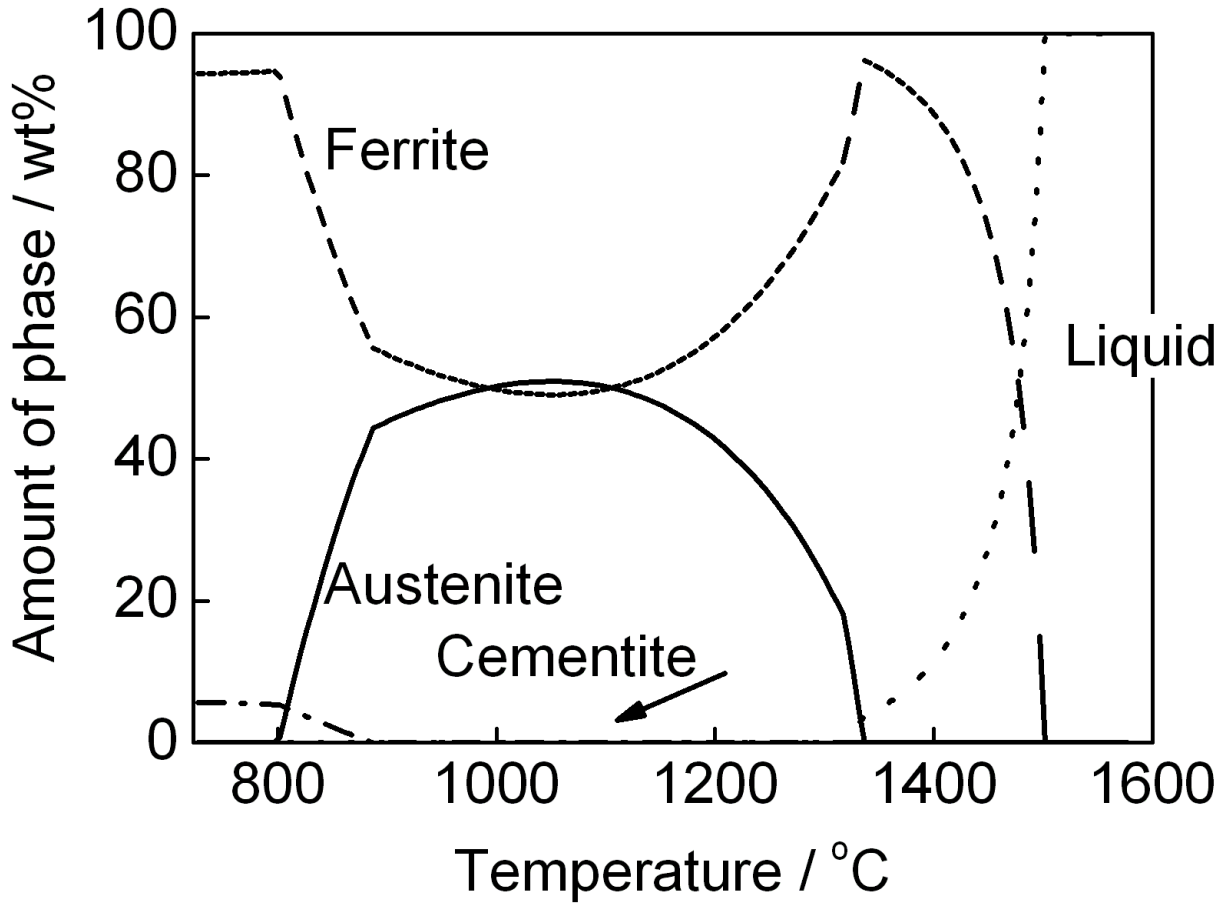
- Before heat treatment: ferrite+pearlite
- After heat treatment: martensite
- Mechanical property:

  UTS ~1500 MPa, TEL ~7%

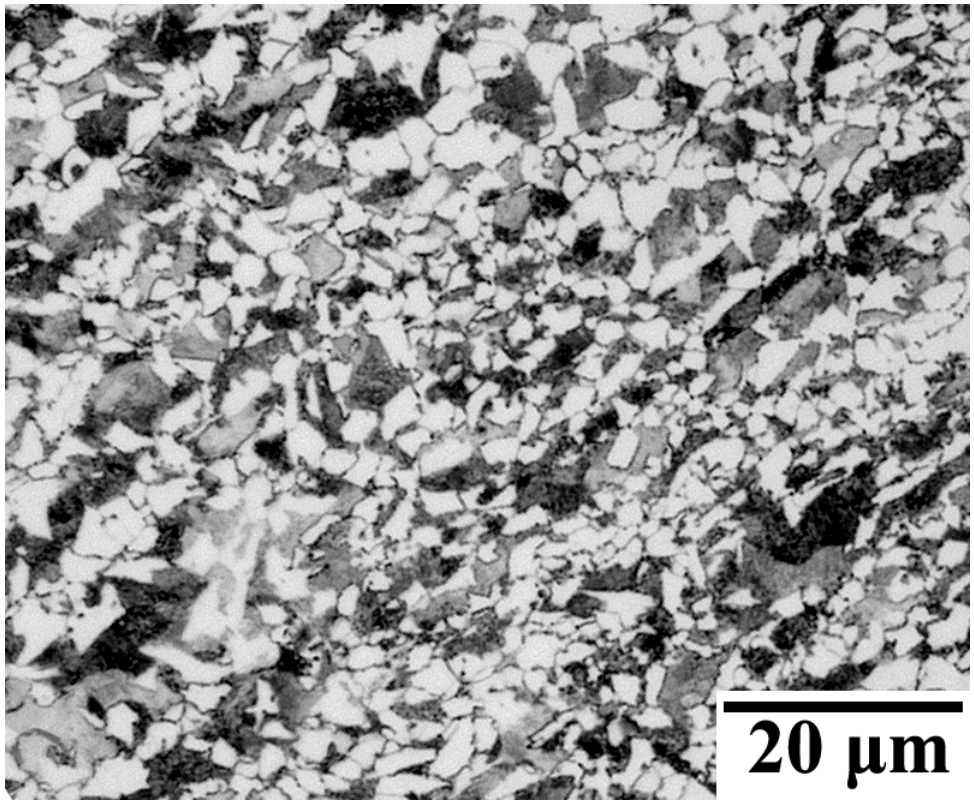
Advantage and shortage

- Advantages: accurate shape forming
  non spring back
  high strength for anti-intrusion
- Shortages: low ductility for energy absorption
- Solution: keeping the high strength level
  improving the ductility

Wt%	C	Si	Mn	Al	P	S	N
Alloy	0.40	0.26	2.02	2.50	0.02	0.0013	0.0032

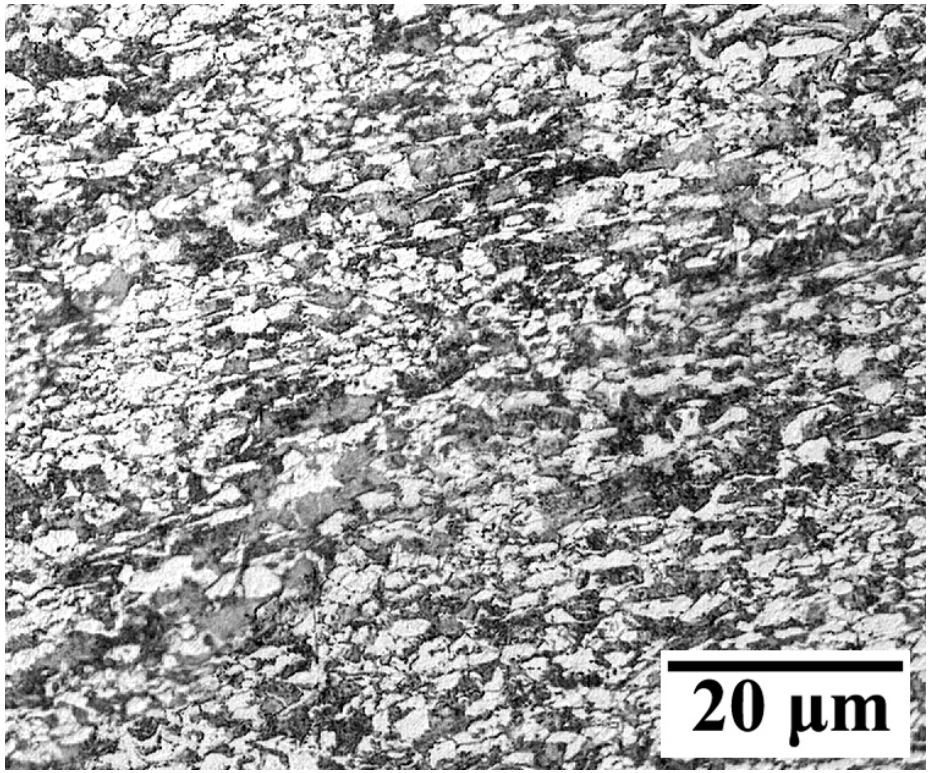


Before heat treatment



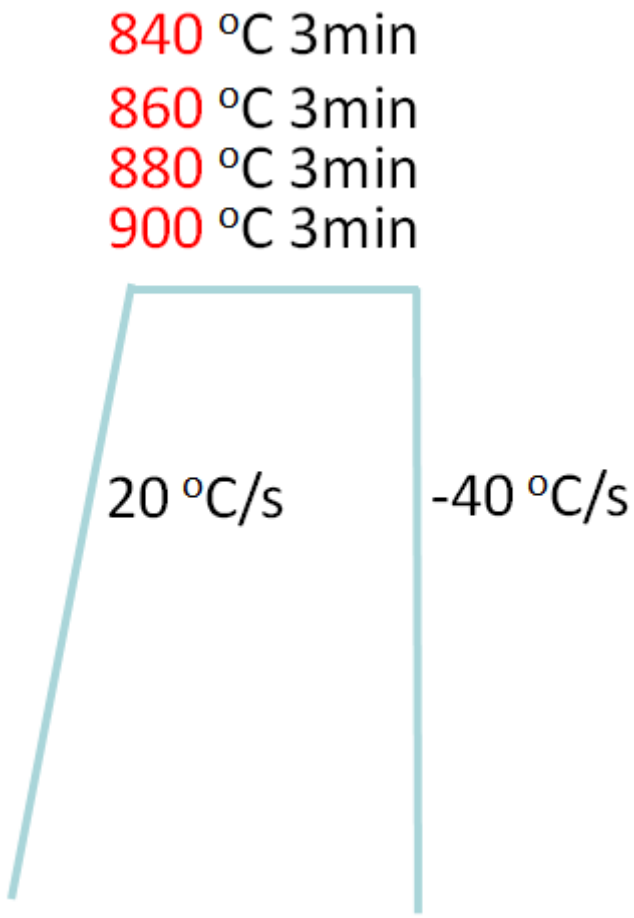
Hot-rolled

Ferrite: 3.1 ± 0.2 µm



Cold-rolled

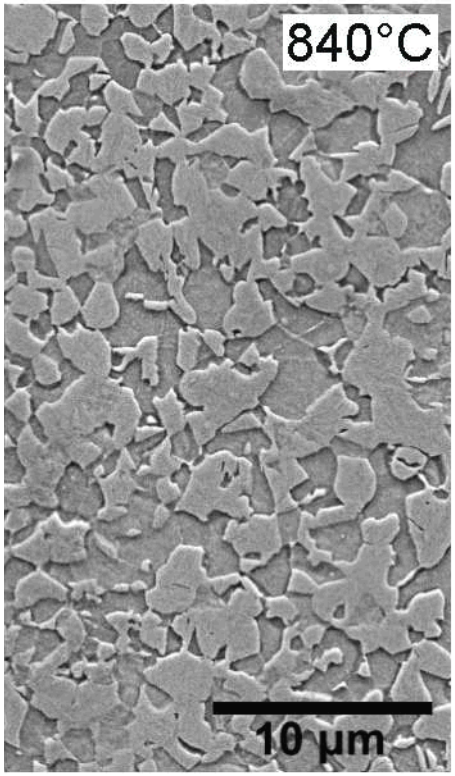
Heating cycles

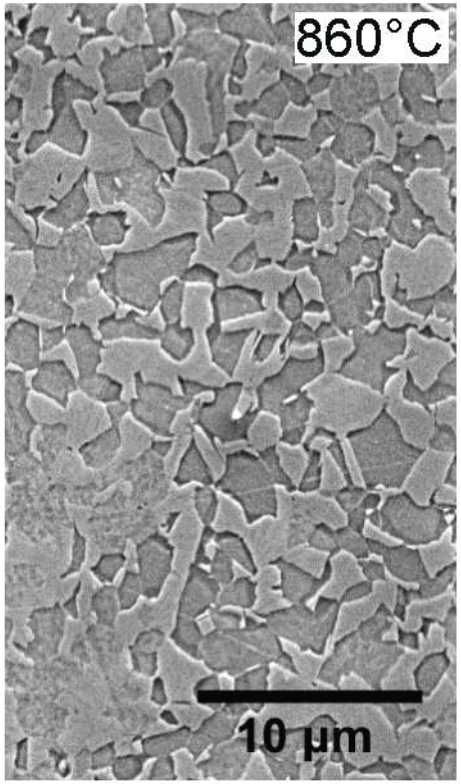


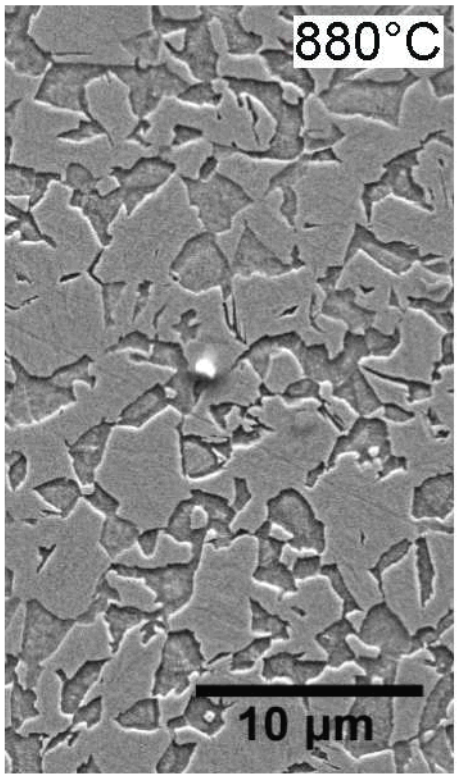
Standard metallographic theory [DeHoff 1968]

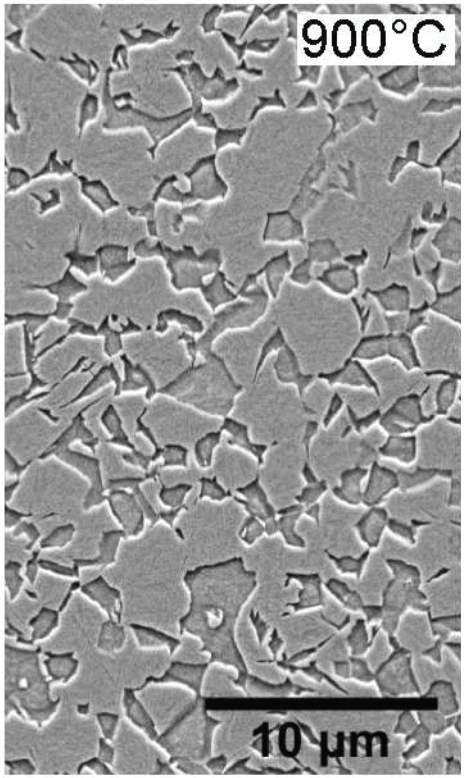
$$\overline{L}_\alpha = \frac{L V_V^\alpha}{N^\alpha} \qquad \overline{L}_{\alpha'} = \frac{L V_V^{\alpha'}}{N^{\alpha'}}$$

Heat–treatment T / °C	$100 V_V^\alpha$	$C_{\alpha'}$ / wt%	$\overline{L}_\alpha$ / μm	$\overline{L}_{\alpha'}$ / μm
840	38 ± 5	0.64 ± 0.05	1.2 ± 0.1	1.7 ± 0.3
860	34 ± 9	0.60 ± 0.07	1.1 ± 0.1	1.9 ± 0.1
880	32 ± 6	0.58 ± 0.05	1.1 ± 0.2	2.4 ± 0.2
900	26 ± 6	0.54 ± 0.05	1.0 ± 0.1	2.5 ± 0.4

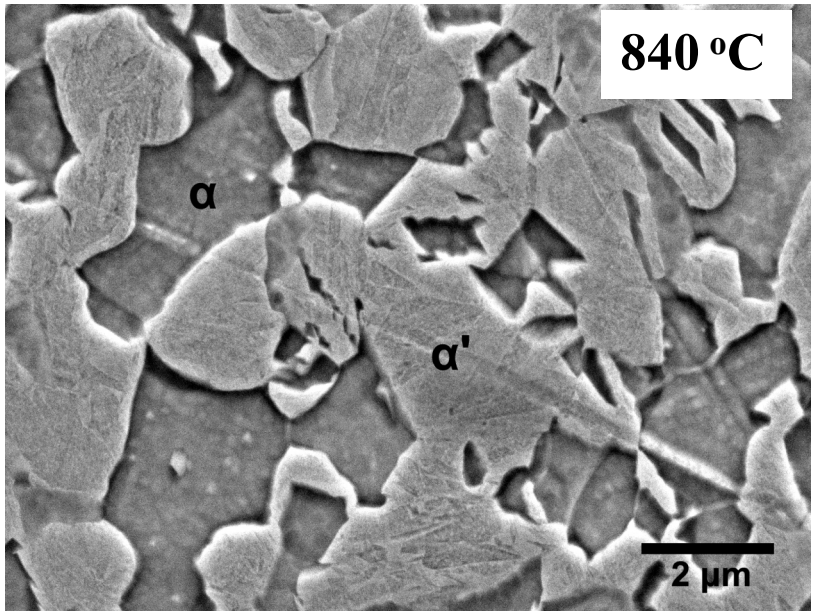


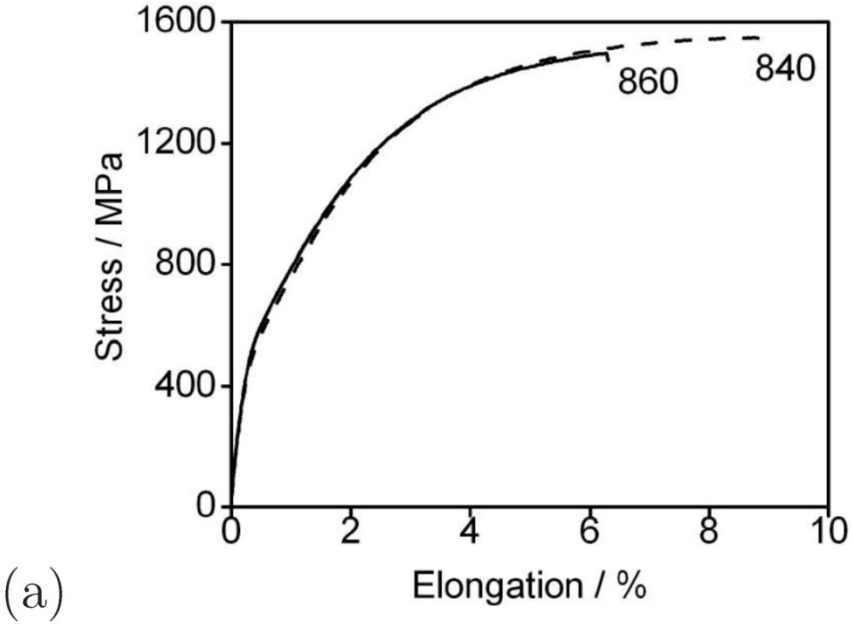




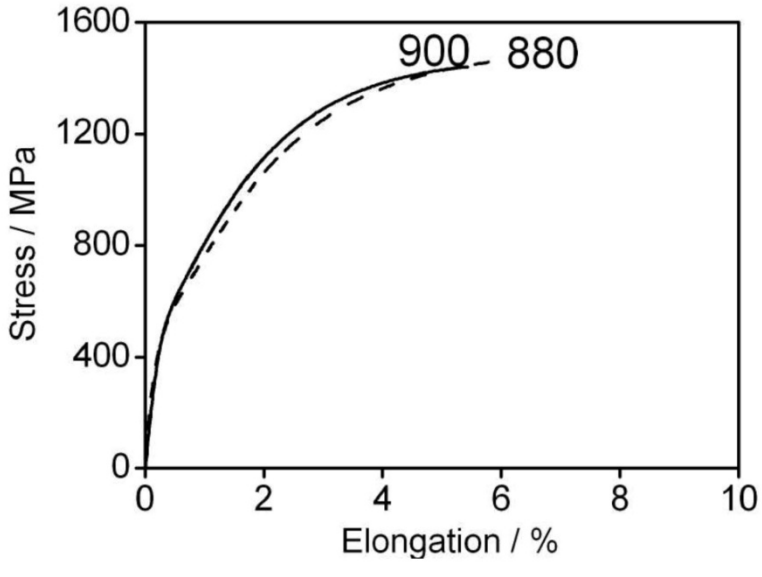


Heat-treated

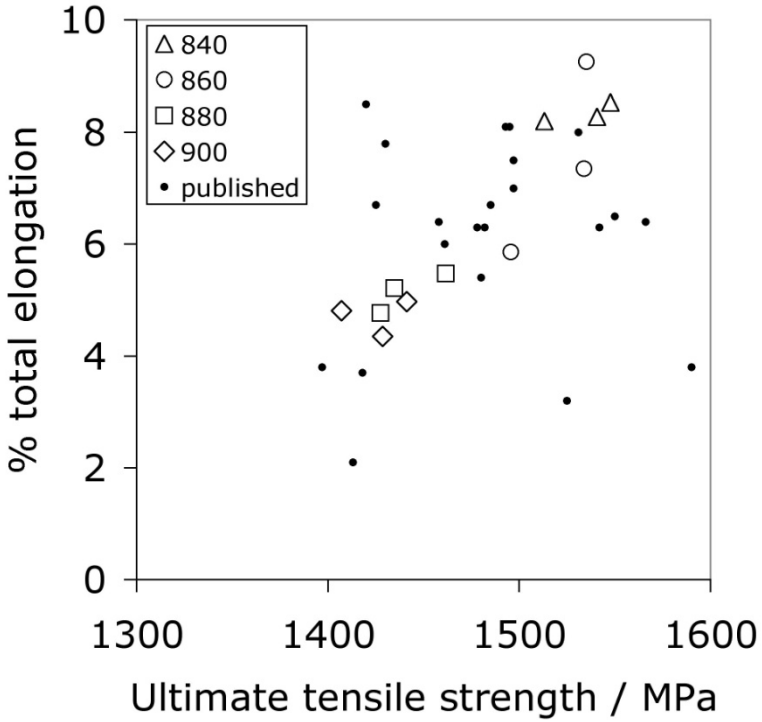



1600
1200
800
400
0
Stress / MPa
860
840
0
2
4
6
8
10
Elongation / %

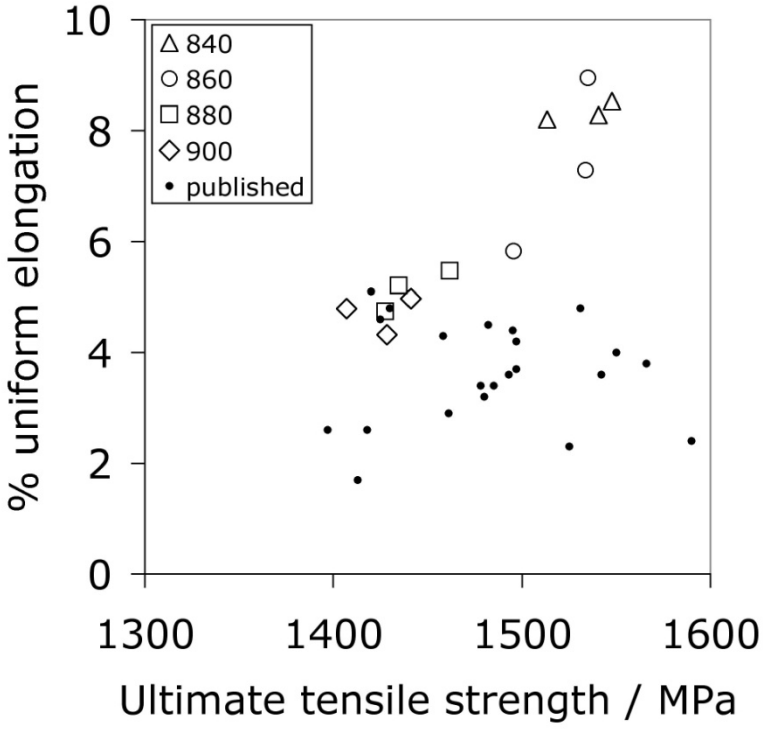
(a)


1600
1200
800
400
0
Stress / MPa
900
880
0
2
4
6
8
10
Elongation / %

(b)

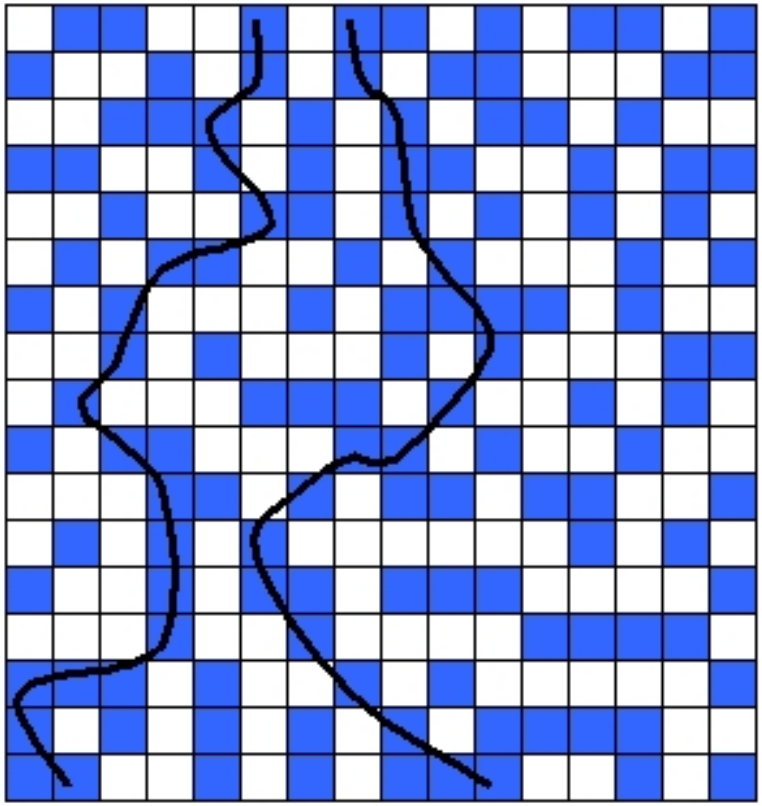

840
860
880
900
published
10
8
6
4
2
0
% total elongation
1300
1400
1500
1600
Ultimate tensile strength / MPa

(c)


840
860
880
900
published
10
8
6
4
2
0
% uniform elongation
1300
1400
1500
1600
Ultimate tensile strength / MPa

(d)

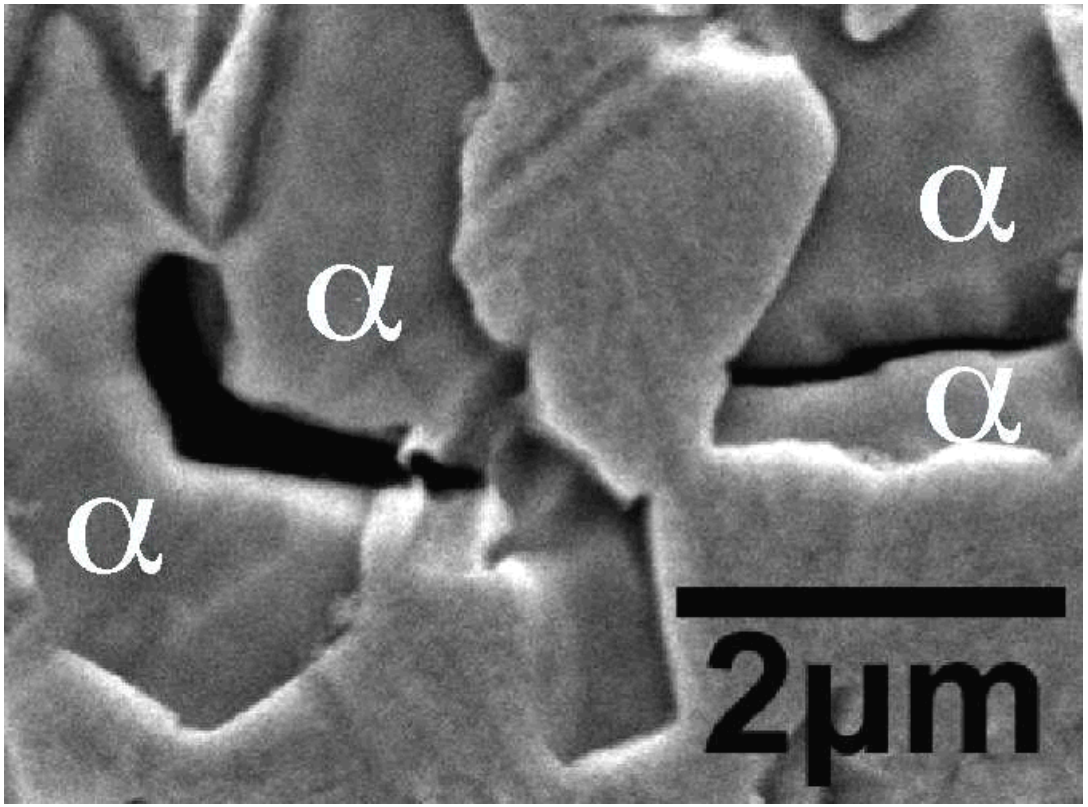
Percolation theory [Garboczi *et al*., 1995]



$$V_V^{\alpha} = 0.29$$

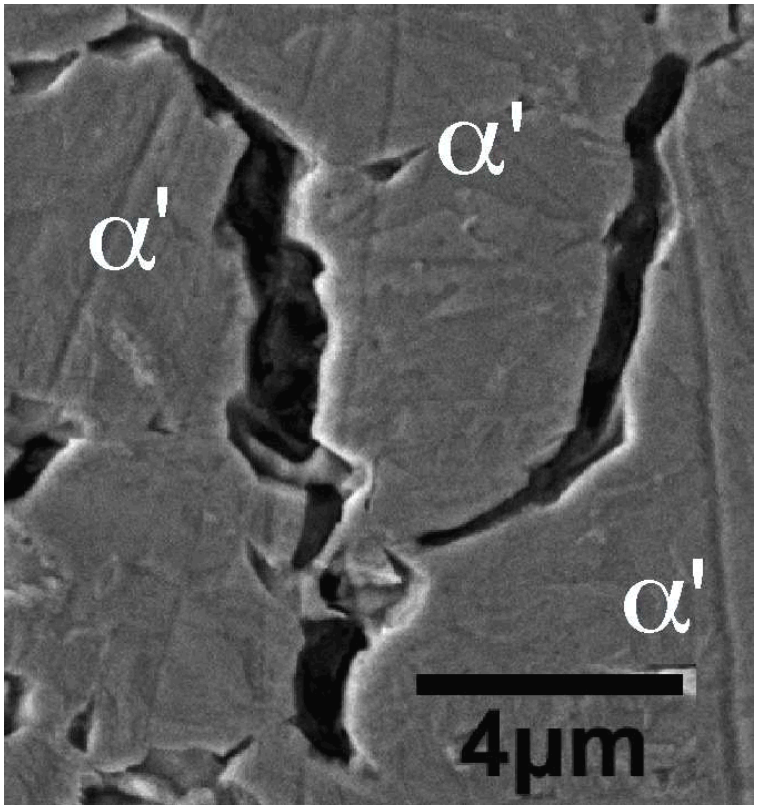
Fracture

840 °C



Non-propagating cracks in ferrite

880 °C



Cracks in martensite

Conclusion 6

- Conventional HPF steels: fully martensitic
- Novel structure: at the forming temperature, allotriomorphic ferrite + austenite, the latter changing into martensite on quenching
- Commercial advantage: maximum heat treatment temperature is at least 20-60 ^{o}C lower than convention
- Mechanical property advantages: total elongations are slightly better than those of the fully martensitic alloys; In terms of uniform elongation, the dual–phase steel significantly outperforms the fully martensitic counterparts
- Interpretation of the mechanisms of ductility and strength suggest that there is room for improvement

Thank you