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Regeneration treatment on welding of nanostructured bainite

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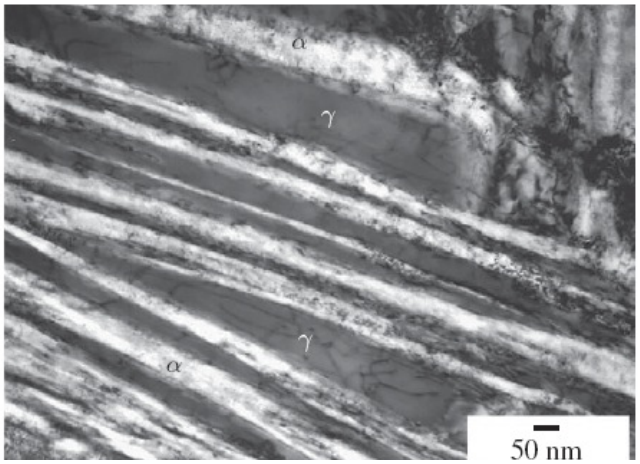
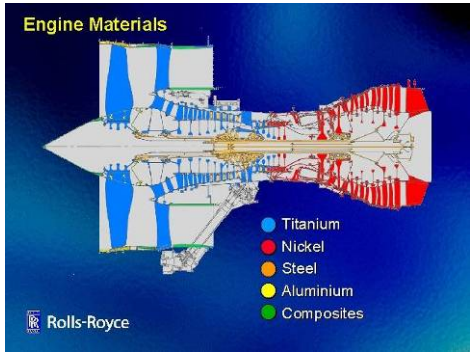
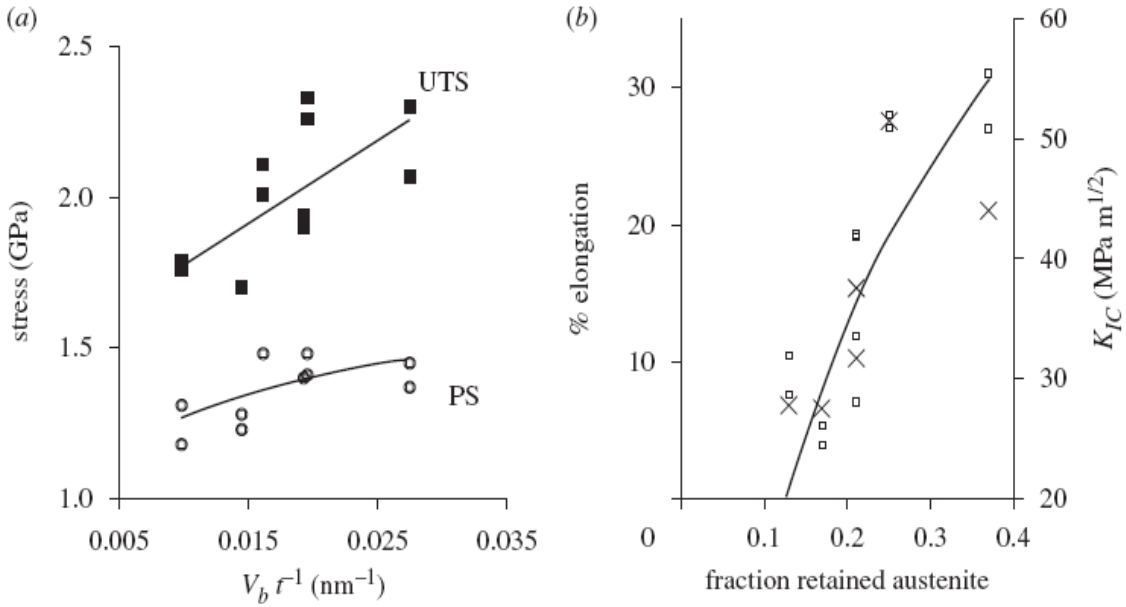
Outline

- What's nanostructured bainite ?
- What are the welding problems ?
- Previous welding method
- New method—regeneration technique

What’s nanostructured bainite ?





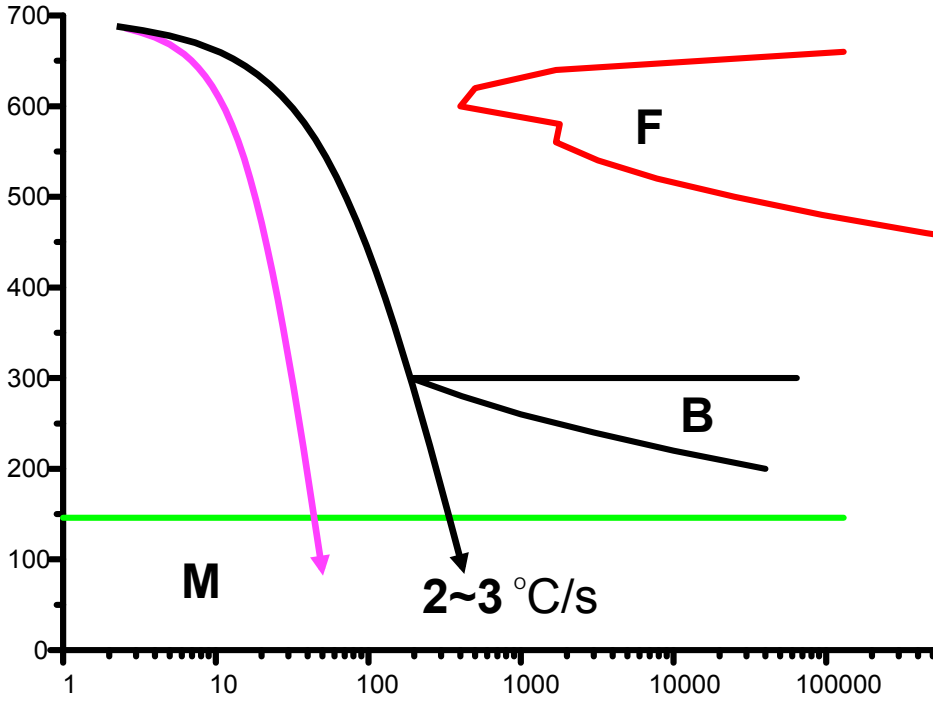


H.K.D.H. Bhadeshia, Proc. R. Soc. 466 (2010) 3–18.

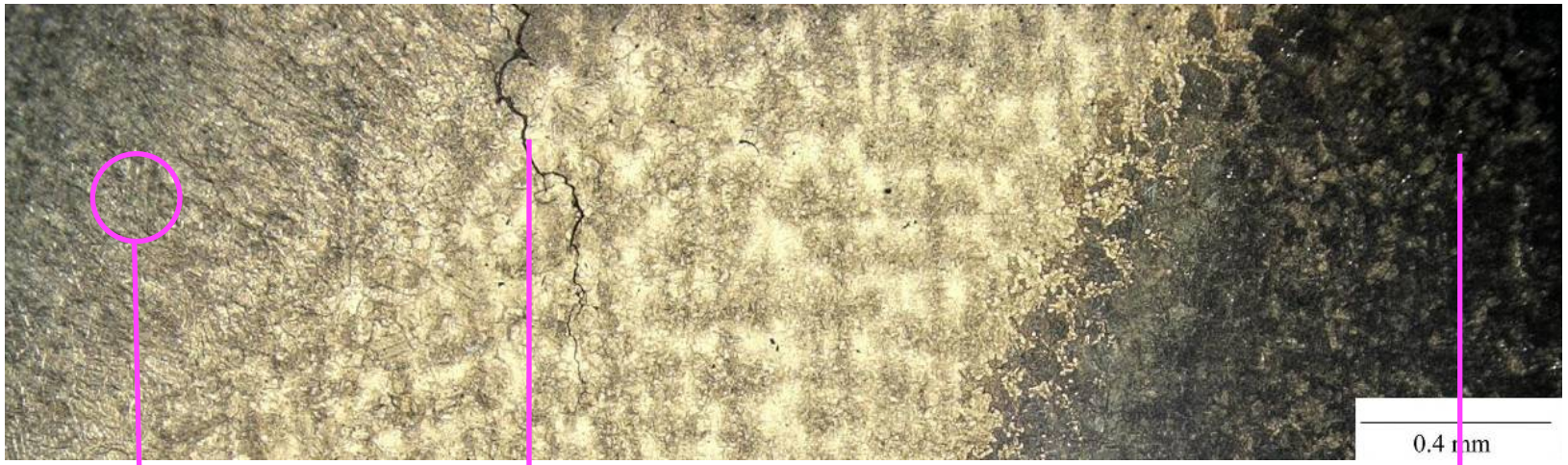
What are the welding problems ?

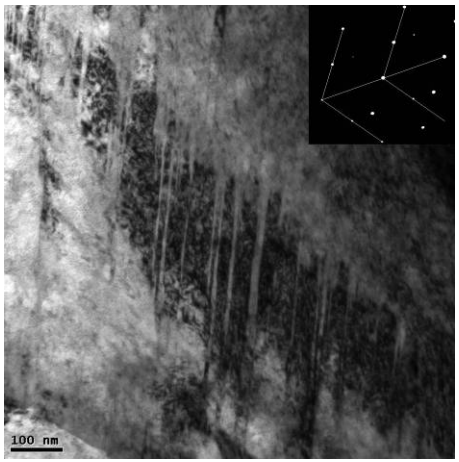
Steel	C	Si	Mn	Cr	Mo	V	Co	Al
A	0.79	1.59	1.94	1.33	0.30	0.11	-	-
B	0.98	1.46	1.89	1.26	0.26	0.09	-	-
C	0.83	1.57	1.98	1.02	0.24	-	1.54	-
D	0.78	1.49	1.95	0.97	0.24	-	1.60	0.99

Weldability



What are the welding problems ?





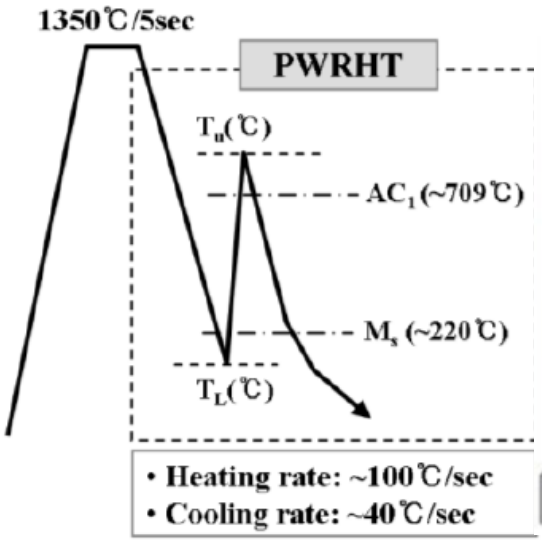
Brittle martensite

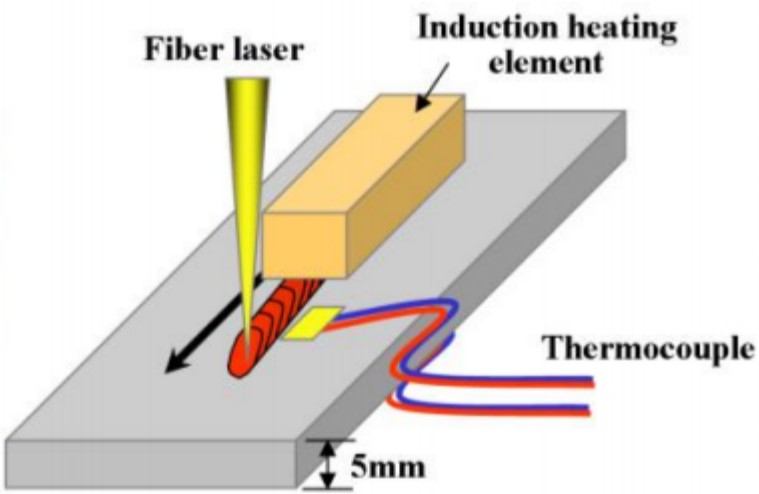
Cold cracks

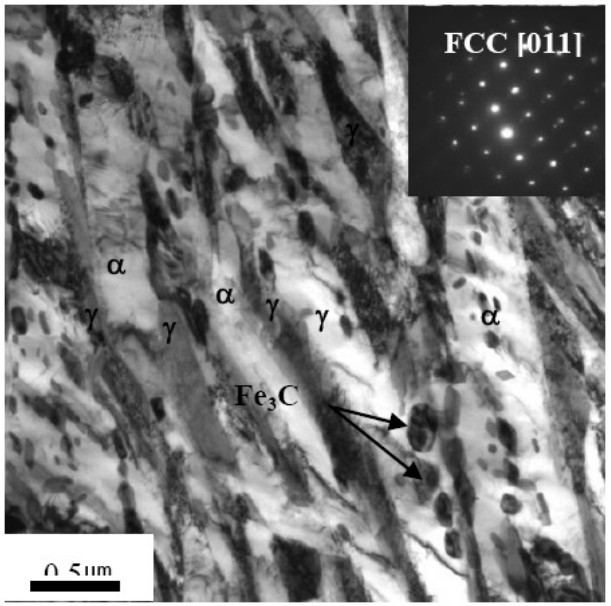
Cementite

Previous welding method

Post Weld Rapid Heat Treatment (PWRHT)







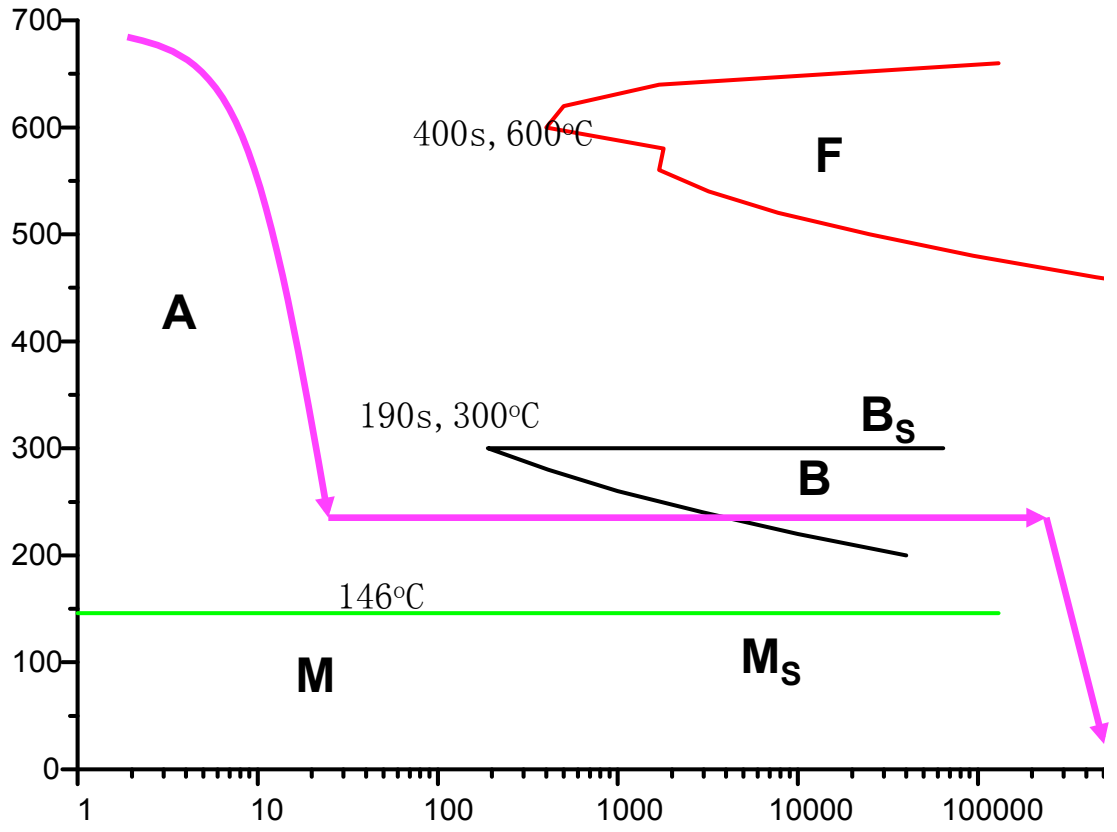
Hong SG, in: 63rd Annual Assembly & International Conference of the International Institute of Welding, Istanbul, Turkey, 11–17 July, 2010.

Regeneration treatment

Martenite

High quality welded joint

Nanostructured bainite

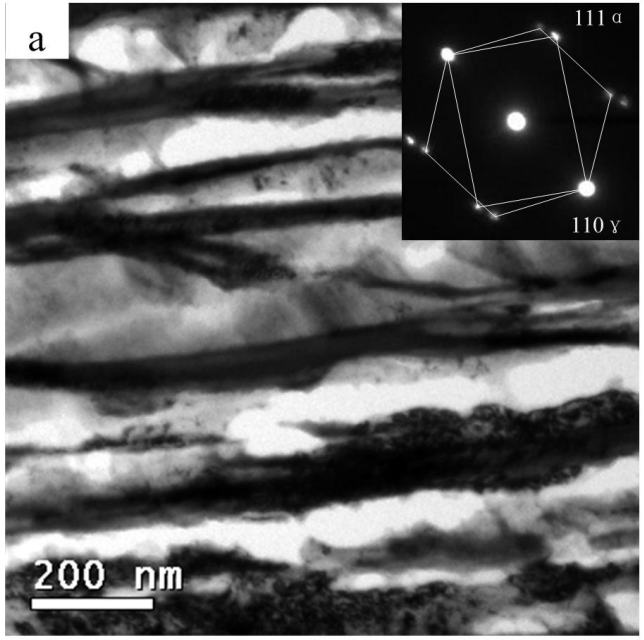


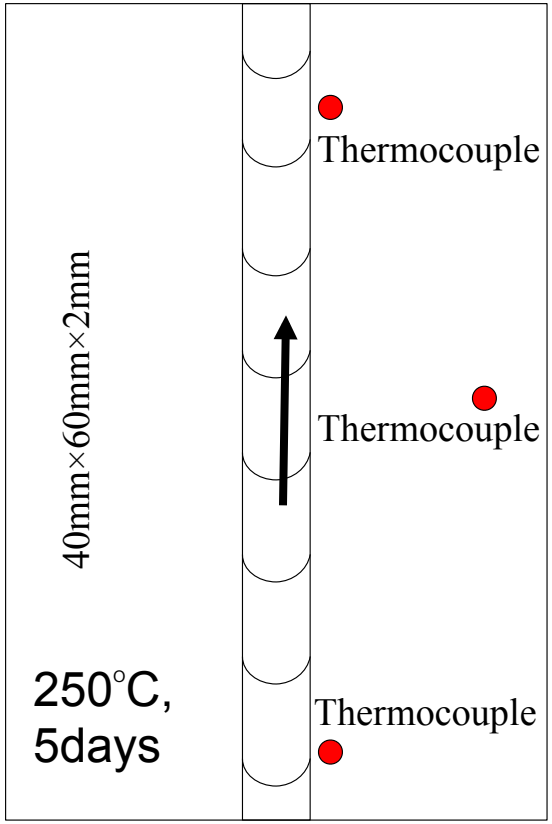
Regeneration treatment

Regeneration treatment

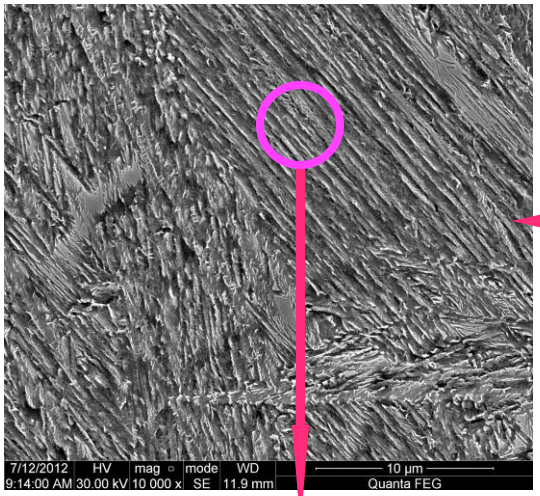
Chemical compositions of alloys investigated in the present work (wt%)

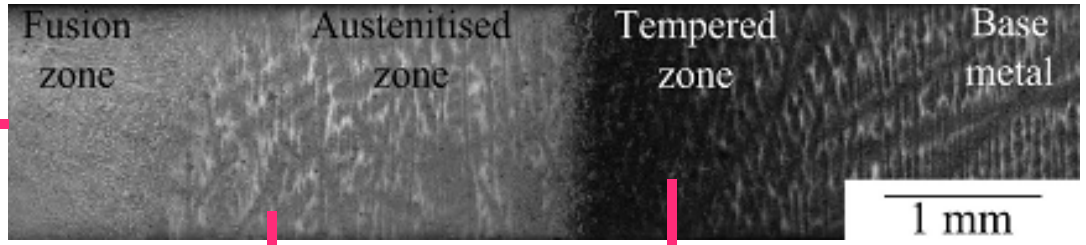
C	Si	Mn	P	Cr	Mo	Ni	N	Cu	Sn	Al	Co	V
0.82	1.66	2.05	0.009	0.22	0.36	1.06	0.002	0.04	0.003	0.051	0.003	0.002

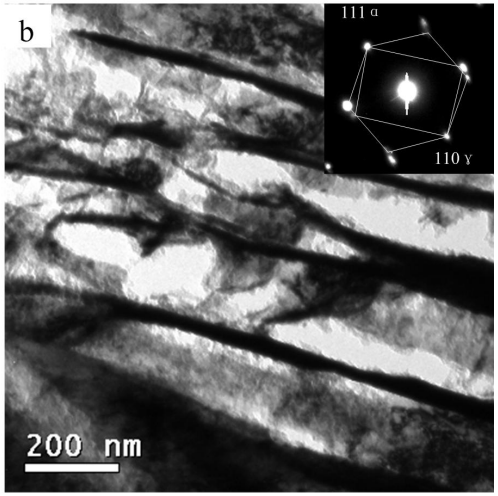


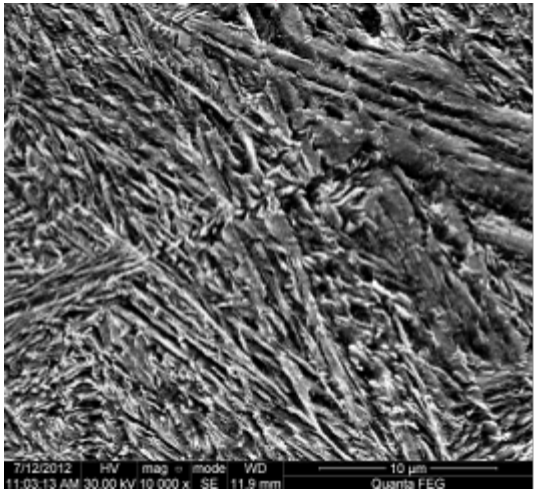


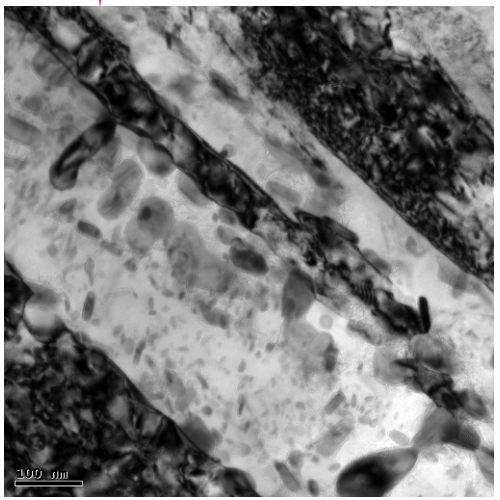
Regeneration treatment



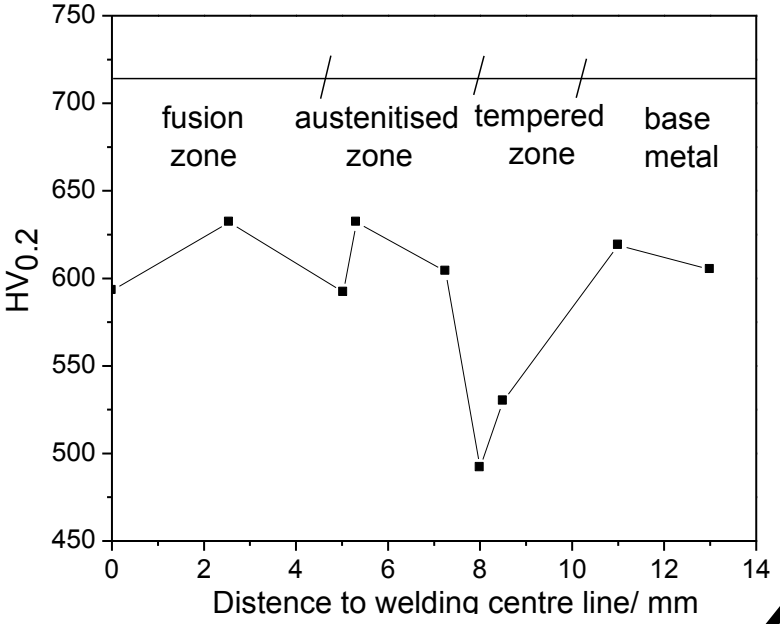


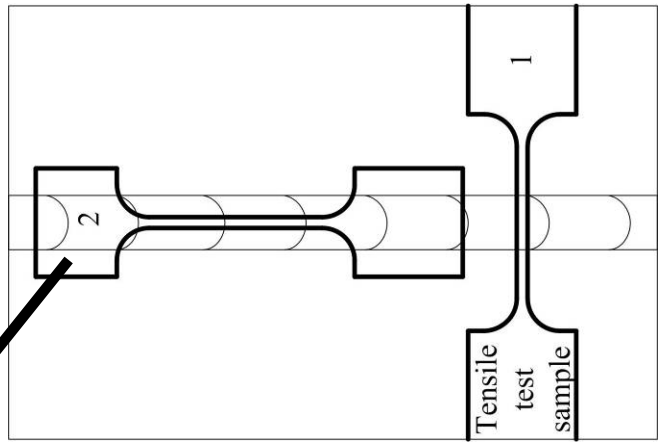


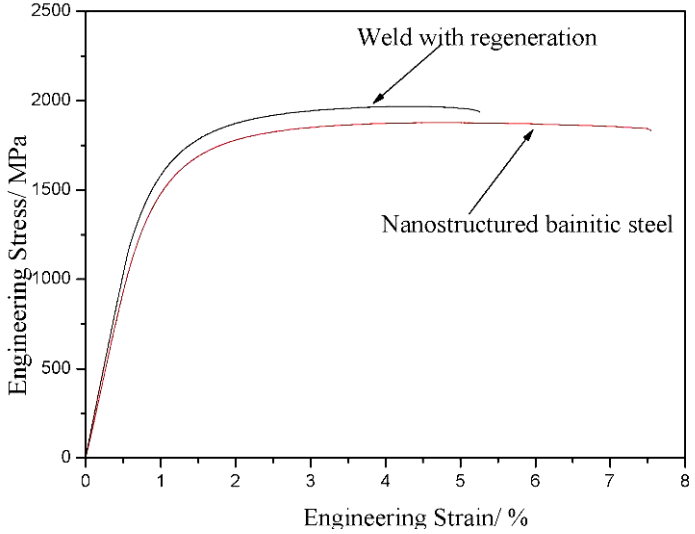




Regeneration treatment







	Tensile strength	ε_T
1	1680MPa	2.24%
2	1970MPa	5.28%
Base metal	1880MPa	7.53%

Regeneration treatment

Differences of microstructure

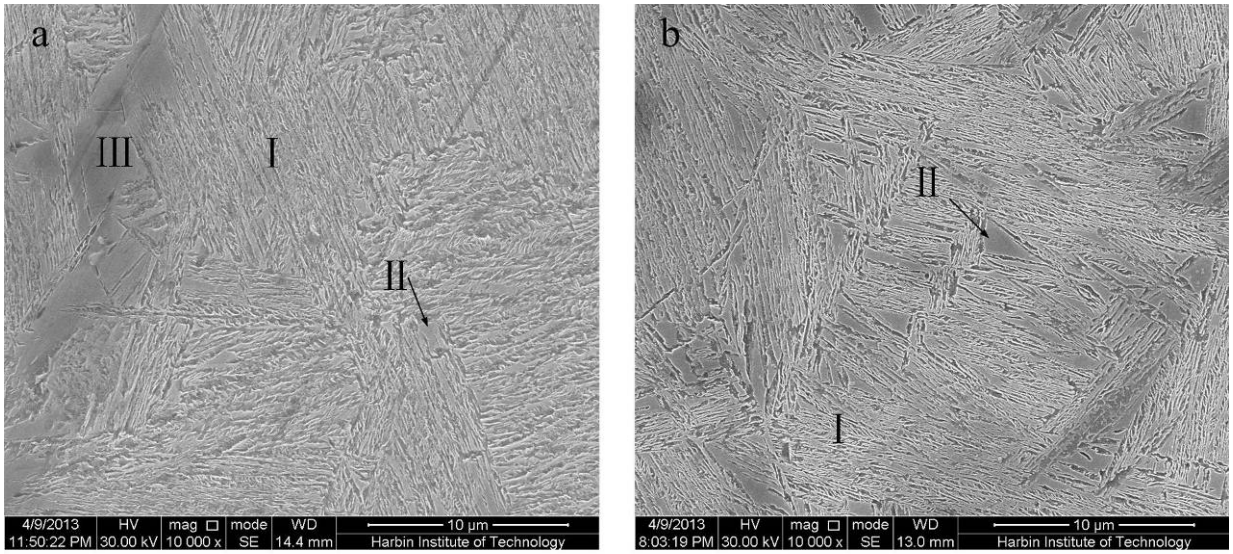


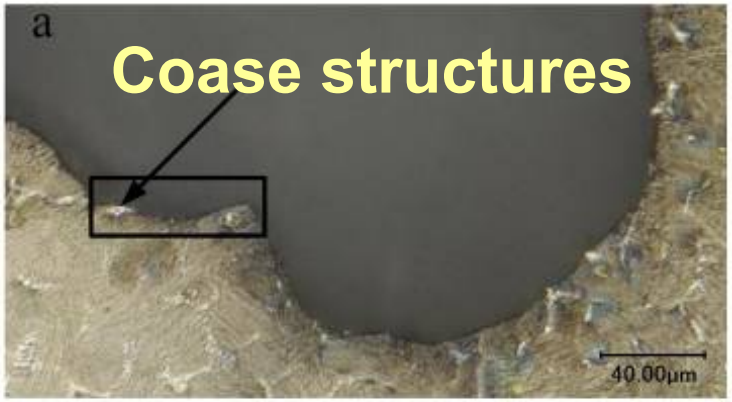
Fig.2 Magnified views of (a) the weld (b) base metal.

The alloying elements compositions of each zone in the weld (wt%)

	Si	Cr	Mn	Mo	Ni
zone Ⅰ	1.97	0.37	2.09	0.56	0.85
zone Ⅱ	2.14	0.28	2.14	0.78	0.82
zone Ⅲ	3.45	0.54	3.91	2.10	0.90

Regeneration treatment

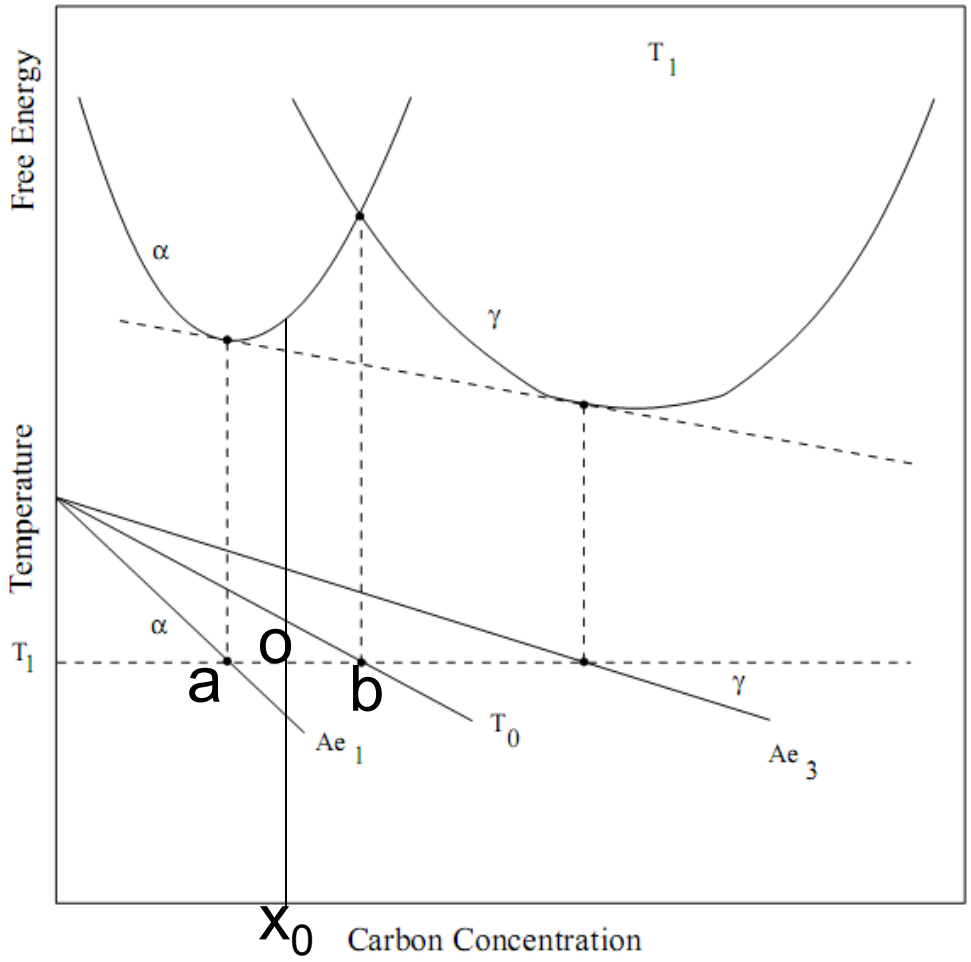
Differences of microstructure



VγC/ VγTotal=40%

Regeneration treatment

Effect of regeneration temperature



$x_\gamma/x_\alpha = oa/ob$

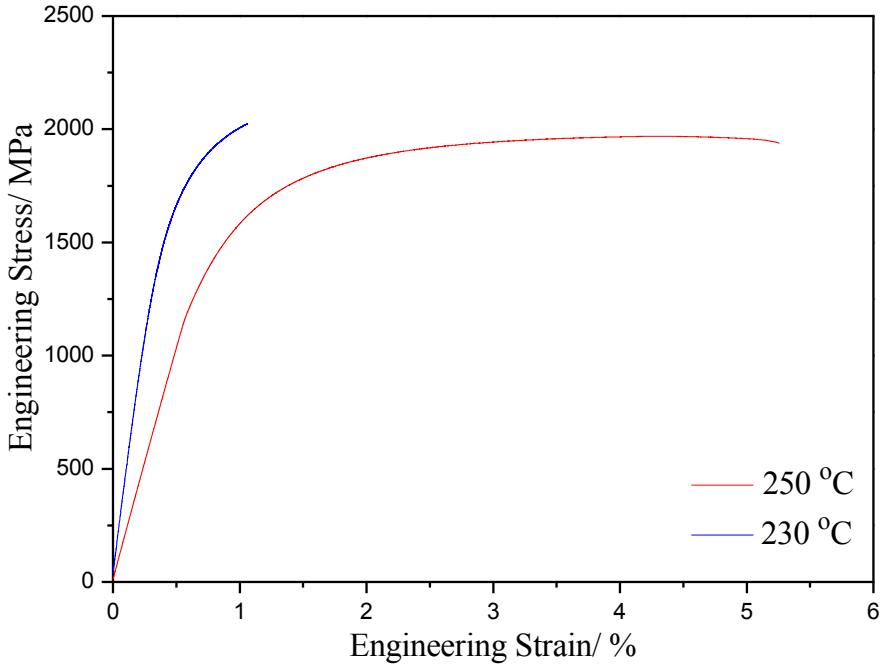
$x_\gamma = oa/ab$

$T \downarrow,\ x_\gamma \uparrow$

The phase diagraph of bainite and austenite

Regeneration treatment

Effect of regeneration temperature

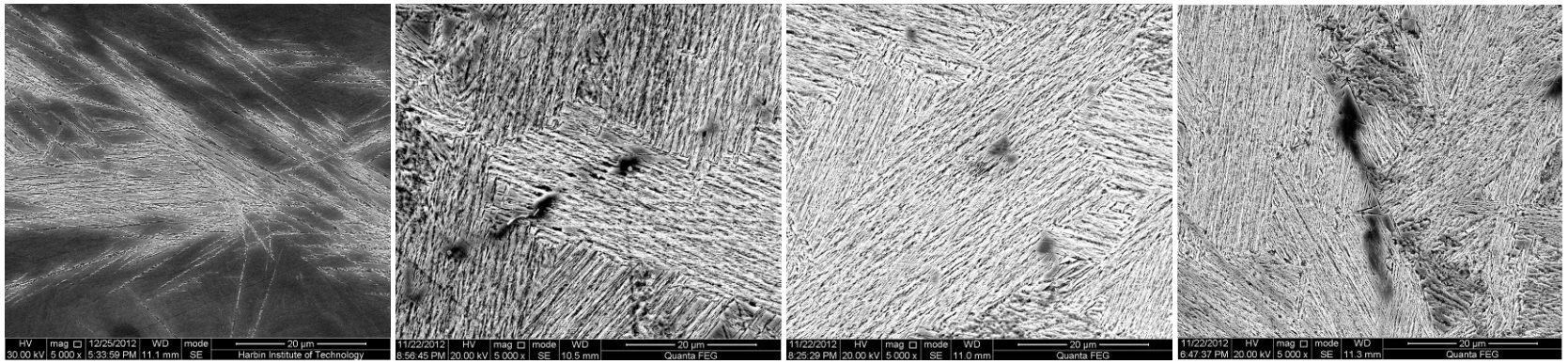


Regeneration Temperature	250 ℃	230 ℃
Austenite Fraction	0.214	0.199
Lattice Parameter / Å	3.614	3.623
UTS/MPa	1950	2020
ε_T /%	5.28	1.06

Regeneration treatment

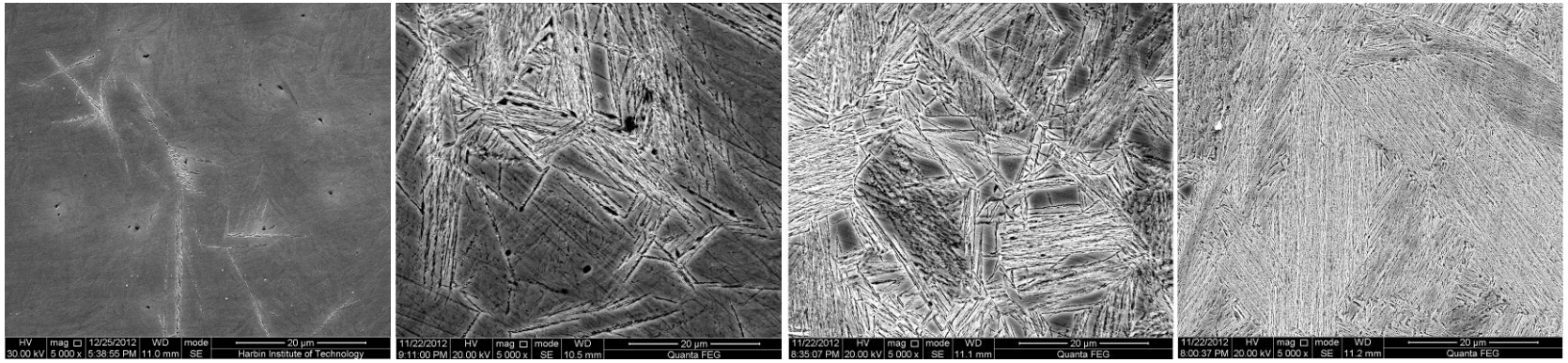
Effect of regeneration time

Fusion zone



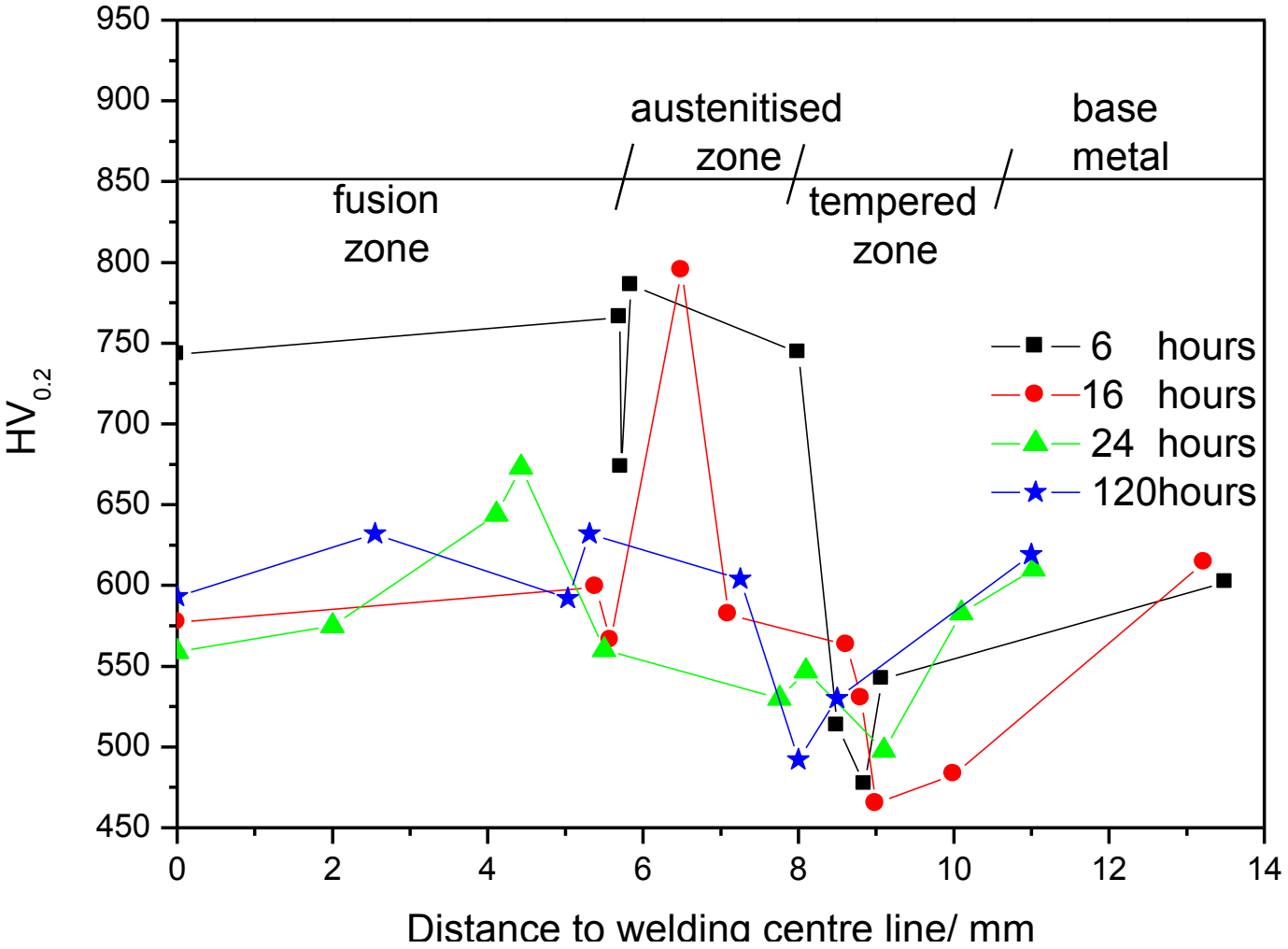
6h 16h 24h 120h

Austenitised zone



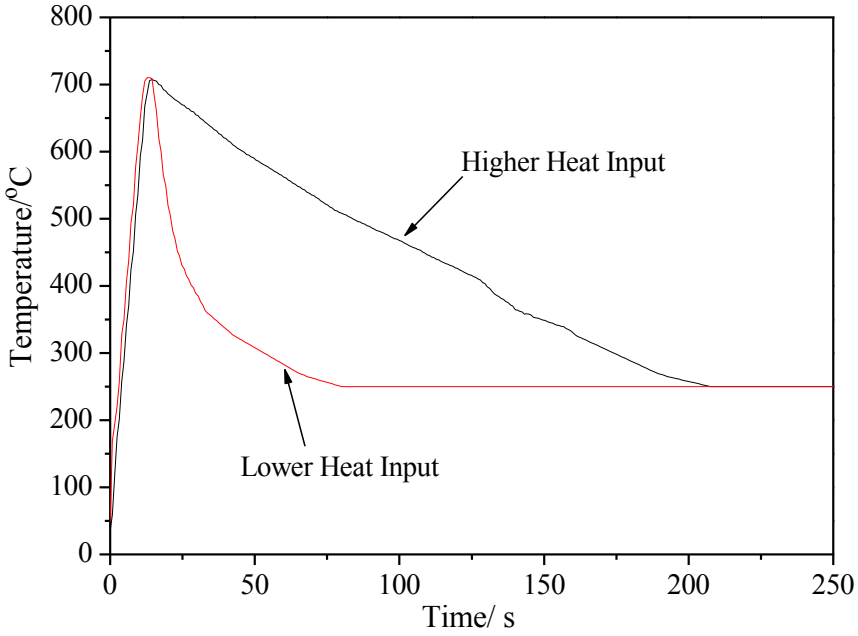
Regeneration treatment

Effect of regeneration time



Regeneration treatment

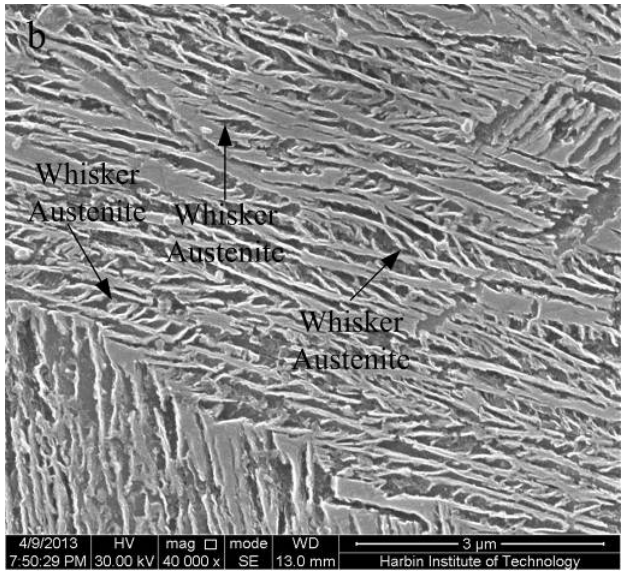
Effect of welding heat input on microstructure in tempered zone

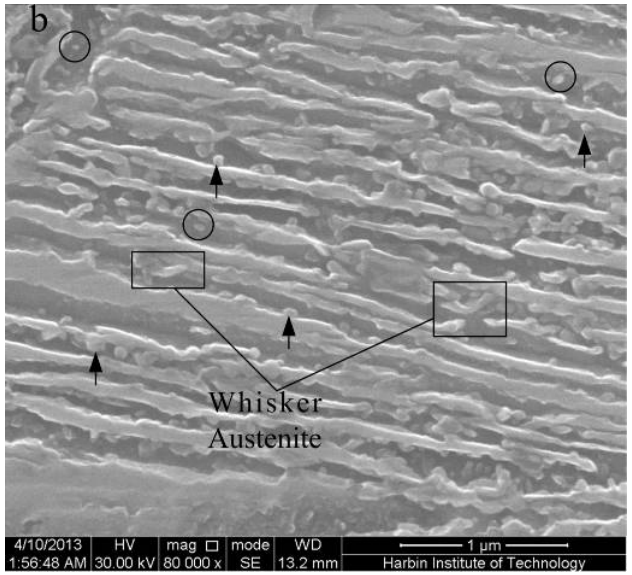


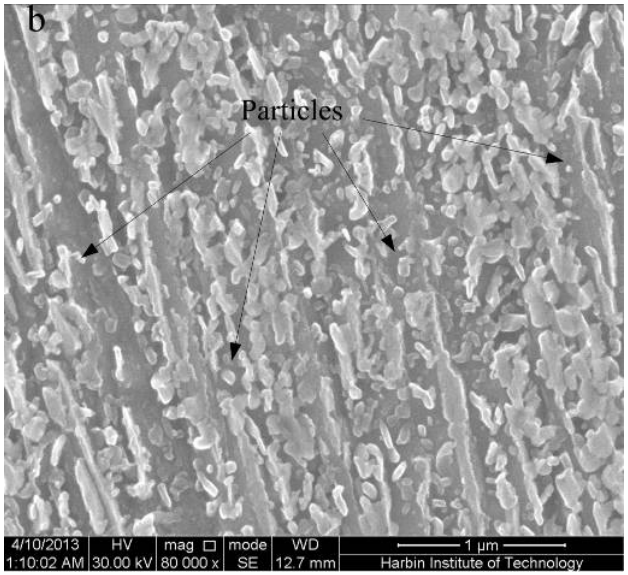
	a_γ (Å)	V_γ (%)	a_α (Å)
Base metal	3.6223	27.8	2.8709
Low heat input	3.6195	13.5	2.8708
High heat input	3.6037	8.9	2.8651

Regeneration treatment

Effect of welding heat input on microstructure in tempered zone







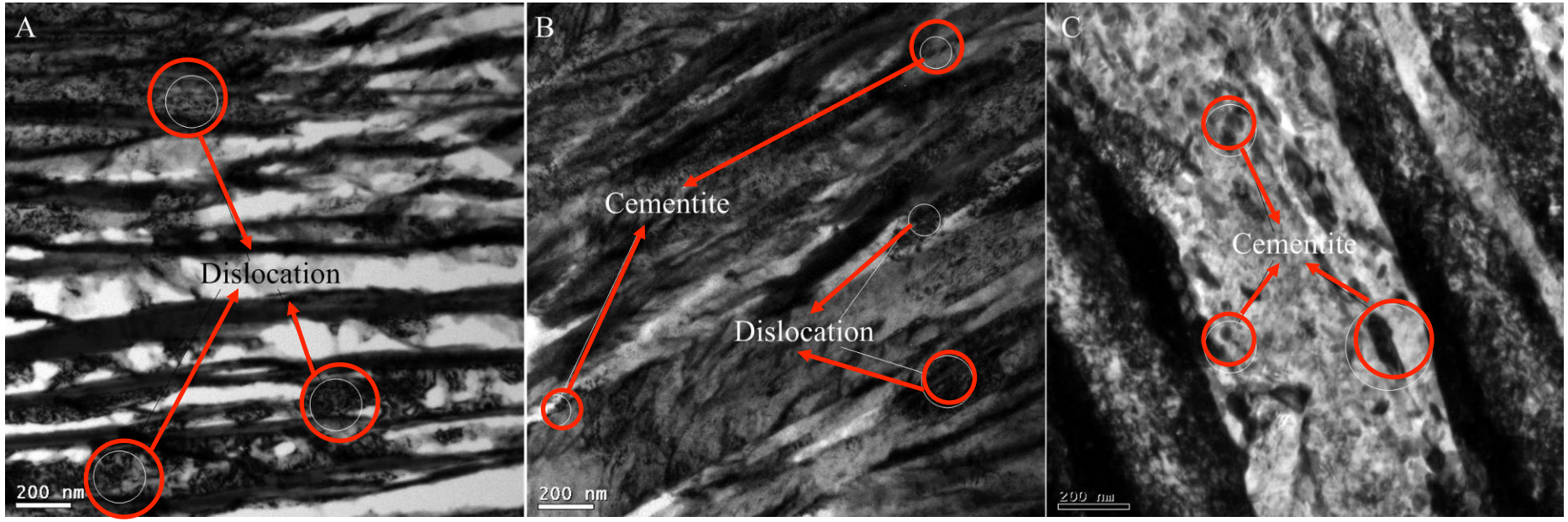
Original

Low heat input

High heat input

Regeneration treatment

Effect of welding heat input on microstructure in tempered zone



Original

Low heat input

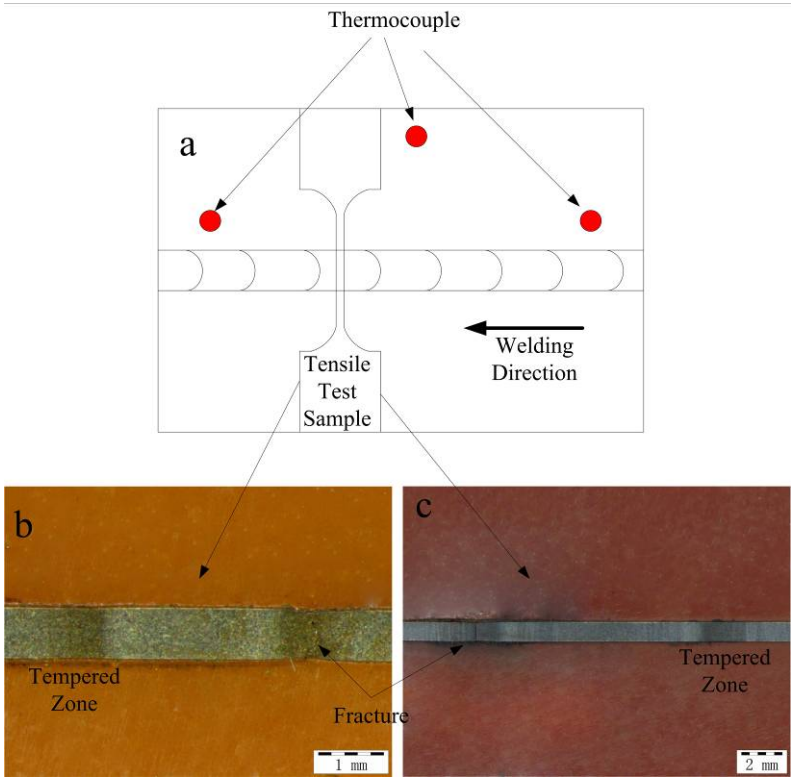
High heat input

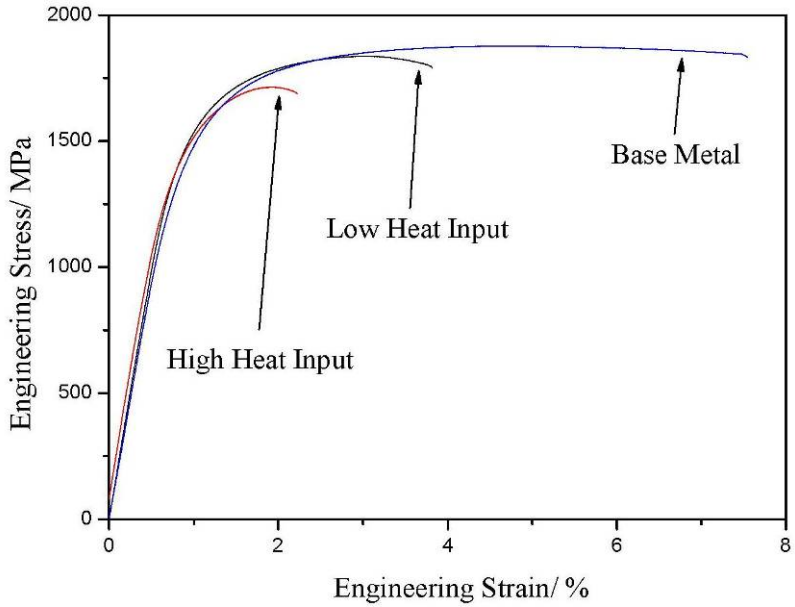
Regeneration treatment

Effect of welding heat input on microstructure in tempered zone

	Welding speed/mmmin^{-1}	power/kJcm^{-1}	Tensile strength/MPa
TIG	185	9.1	1680
LBW	1000	0.6	1844

Base metal 1877MPa





Outlooks

1 Very long regeneration time

2 Hot cracks

3 Isothermal treatment for huge structure

Conclusion

- 1 There are three problems for the welding of strong bainite : (a) brittle martensite formation in both the fusion zone and the heat-affected zone in its close proximity; (b) the formation of cementite in the heat-affected zone further away from the weld, and (c) cold cracking in the weld itself.
- 2 Regenration technique has been designed to weld the strong bainite. A similar bainite structure to the original base metal has been obtained in the fusion and austenitised zones. The mechanical properties of the fusion and reaustenitised regions are promising.

Conclusion

- 3 The reasons for mechanical properties decreasing are carbide precipitation, dislocation recovery and austenite decomposing during rapid tempering and regeneration. By reducing welding heat input using LBW, mechanical properties decreasing has been successfully avoided by comparison with the original base metal.

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