Microstructure Evolution and Properties of Resistance Spot Welding of Press-hardened Steels

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Background

- PHS: Press-hardening steels
- RSW: Resistance spot welding

PHS: Press-hardening steels

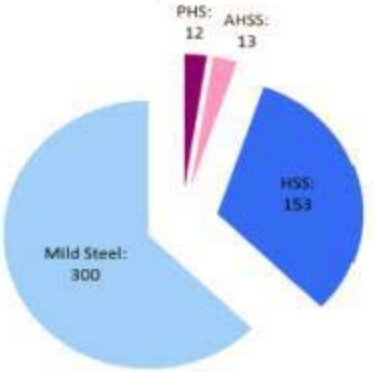
STEEL GRADE USAGE

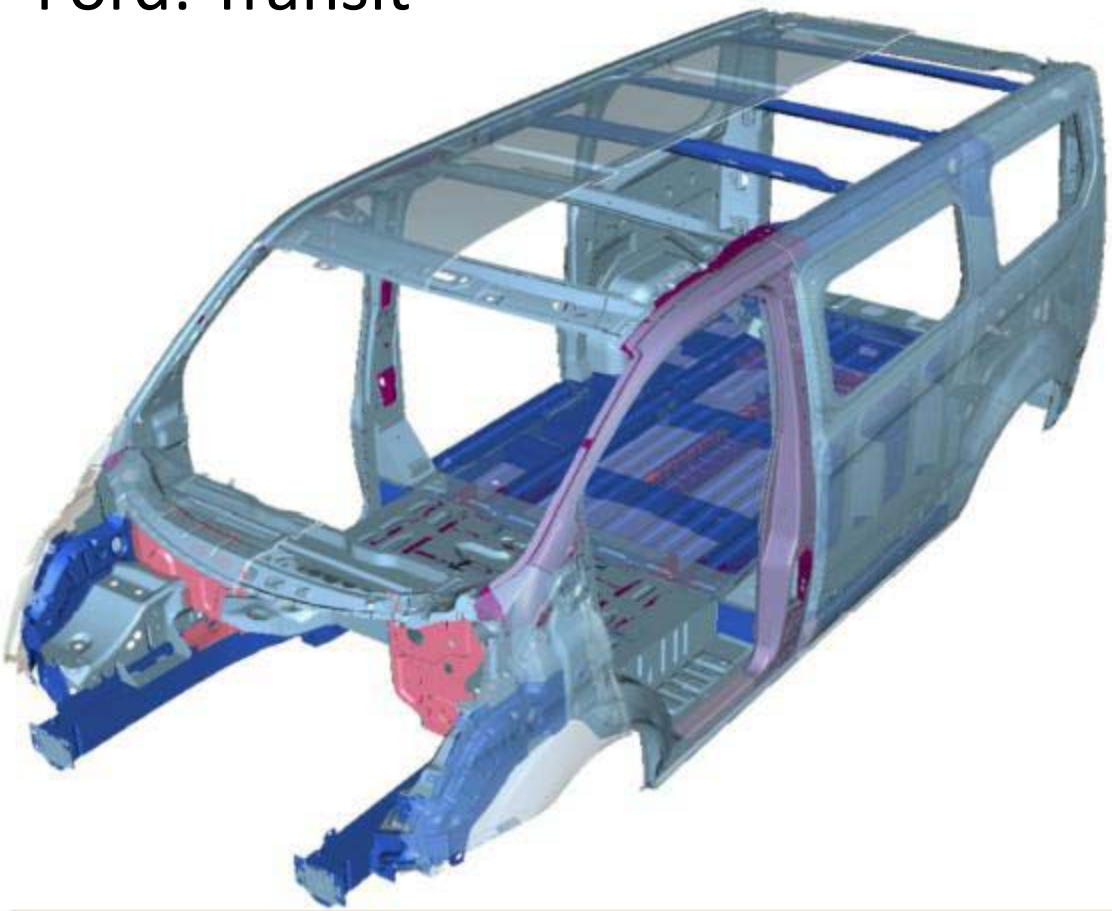
Ford: Transit

BIW: 492.1kg

PHS 8.19%

Number of parts: 478



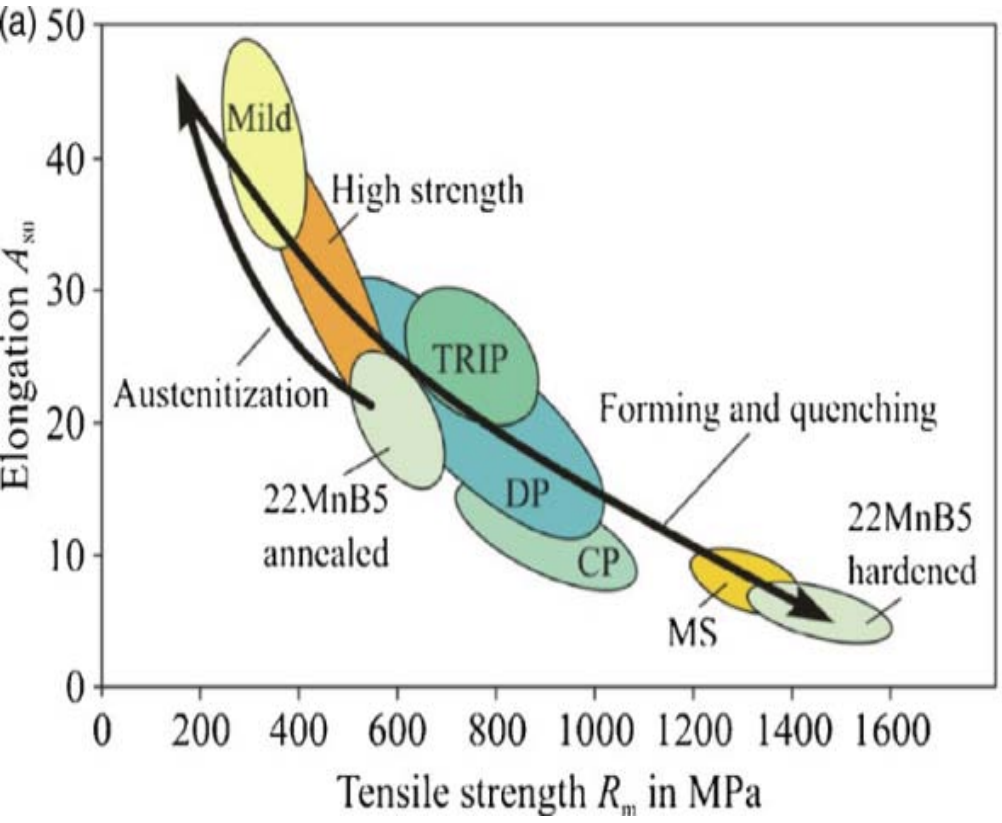


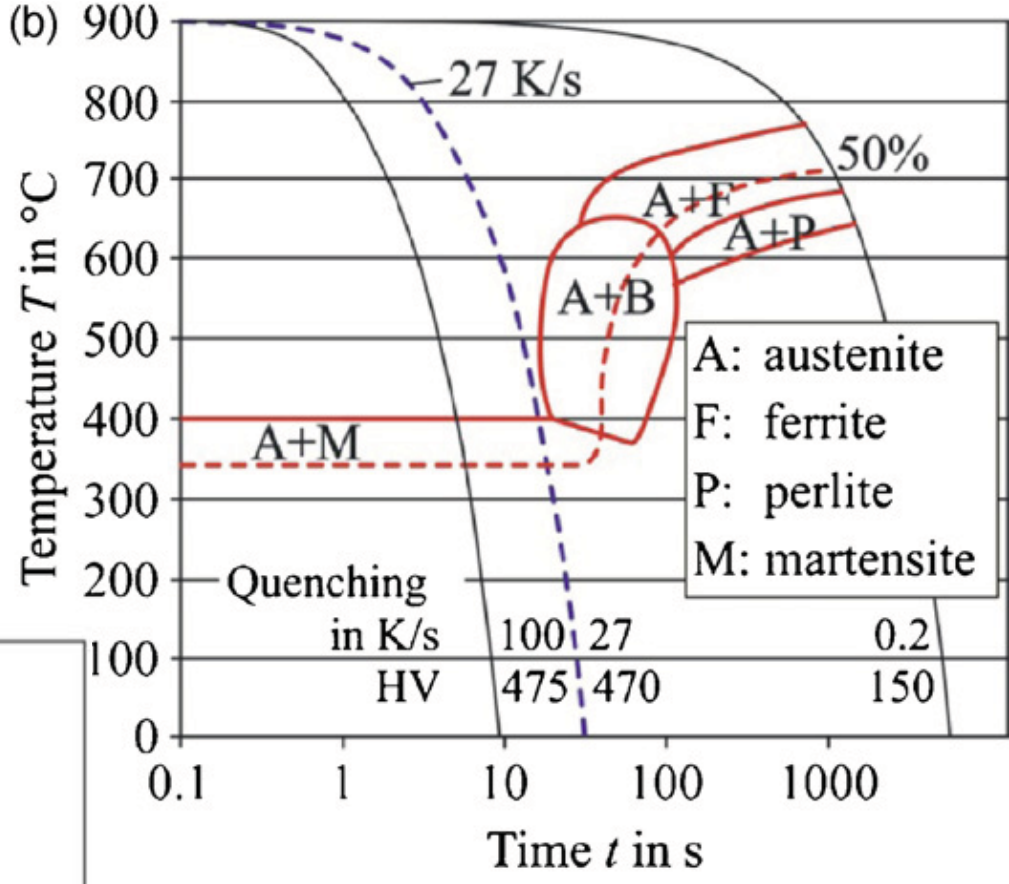
Ford
Go Further

J. Büchner / G Doğan / E. Yilmazer

EuroCarBody, October 22 – 24, 2013

Forming
Press hardening





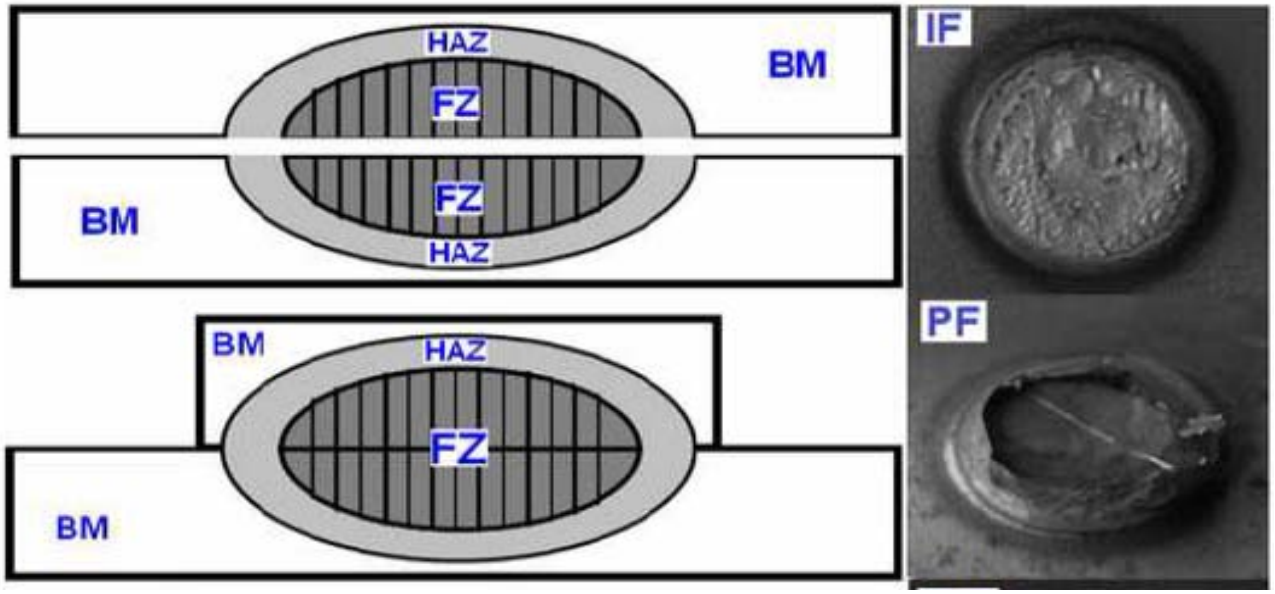
RSW: Resistance spot welding
Failure mode

- **Interfacial fracture (IF mode)**

  --Detrimental effect on welds

- **Pullout fracture (PF mode)**

  --Desired mode



RSW: Resistance spot welding Failure mechanism

- Tensile shear

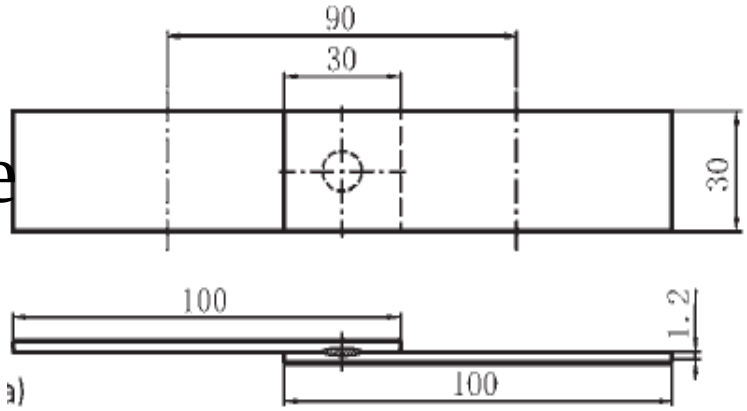
  1） Driving force for IF mode

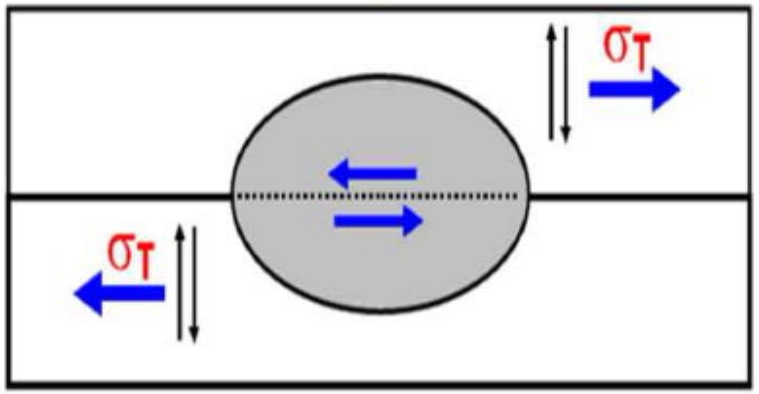
  ----Shear stress on interface

  2） Resistance for IF mode

  ----Increasing FZ size

  ----Increasing FZ strength





RSW: Resistance spot welding Failure mechanism

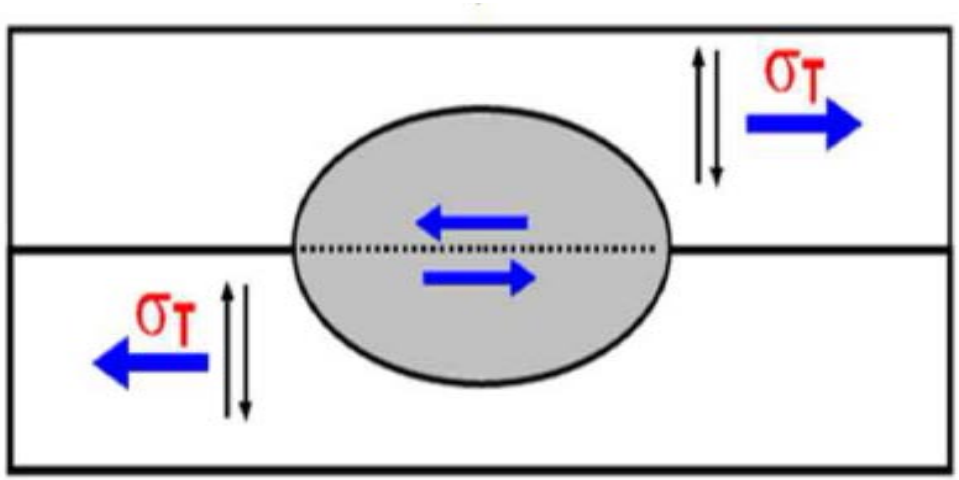
- Tensile shear

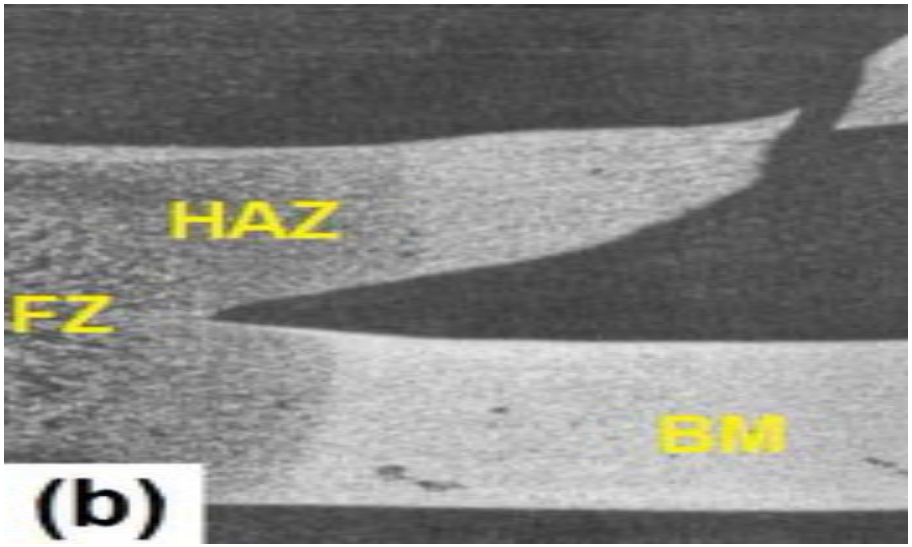
  1） Driving force for PF mode：

  ----Bending moment & tensile of HAZ and BM

  2） Driving PF mode：

  ----Decreasing strength of HAZ or BM





RSW: Resistance spot welding Failure mechanism

- **Cross tensile**

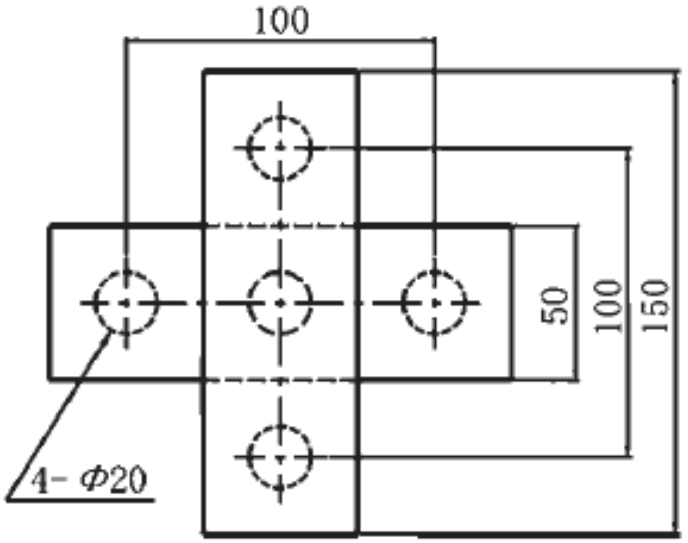
1）Driving force for IF mode：

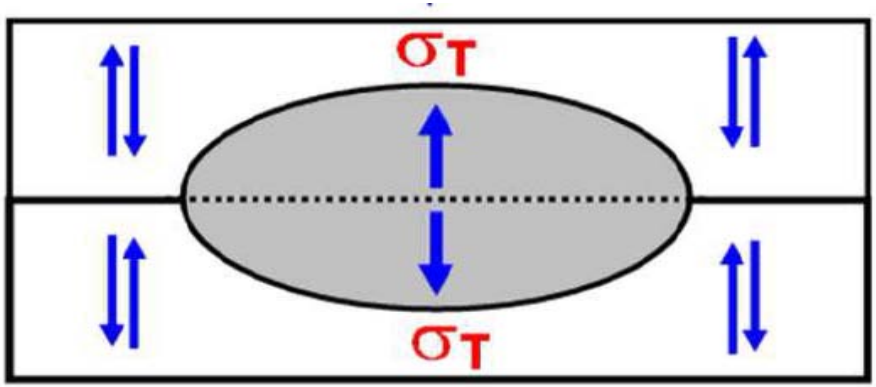
----Tensile stress on interface

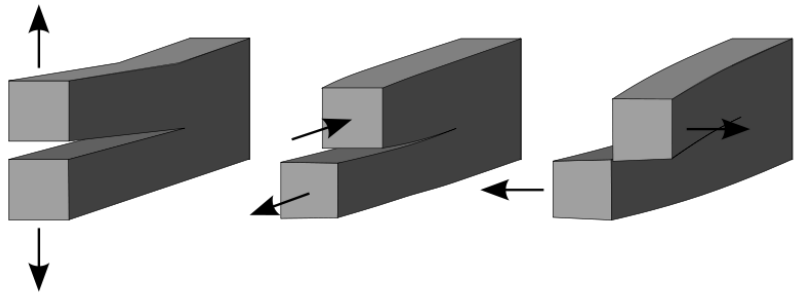
----Fracture mode: Mode I

2）Resistance for IF mode：

----Increasing facture toughness (K_{IC}^{FZ})

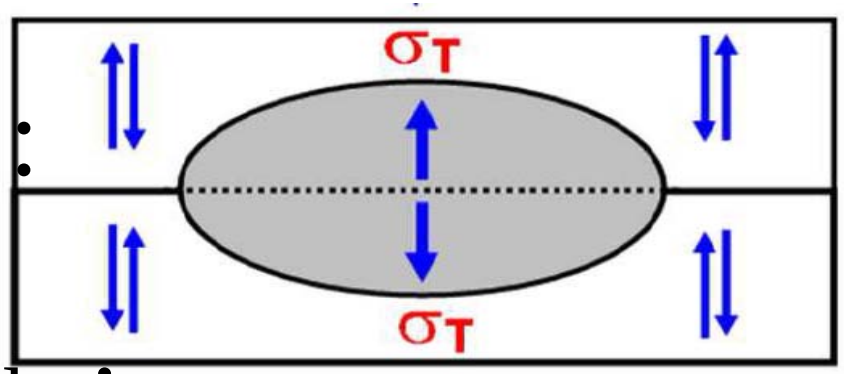






RSW: Resistance spot welding Failure mechanism

- **Cross tensile**



1） Driving force for PF mode：

----Shear stress on FAZ

2） Failure position for PE mode：

----Maximum stress in HAZ by FE modeling

3） Driving for PF mode:

----Decreasing strength of HAZ

----Decreasing strength of FZ for increasing fracture toughness (K_{IC}^{FZ})

RSW of PHS

- Materials: two 22MnB5 steels from industry
- RSW: welding parameters and properties
- Microstructures-properties relationship in spot welds
- Microstructural evolution in spot welds effected by reverse hardenability

Press-hardened steels

Alloy composition in wt %

	C	Mn	Si	Al	Cr	Mo	Ti	B	P	S
PHS1	0.23	0.95	0.17	0.03	0.24	0.21	0.023	0.0019	0.01	0.002
PHS2	0.24	1.2	0.25	0.51	----	----	----	0.0022	0.01	0.008

Hot stamping simulation

- Using a pilot hot stamping line with a flat die
- Hot stamping parameters of PHS1

  ---Austenitizion: 925^{o}C for 3min

  ---Temperature of die surface: 20^{o}C

  ---Press: 60t (Pressure: 10MPa)

  ---Holding time: 20s
- Hot stamping parameters of PHS2

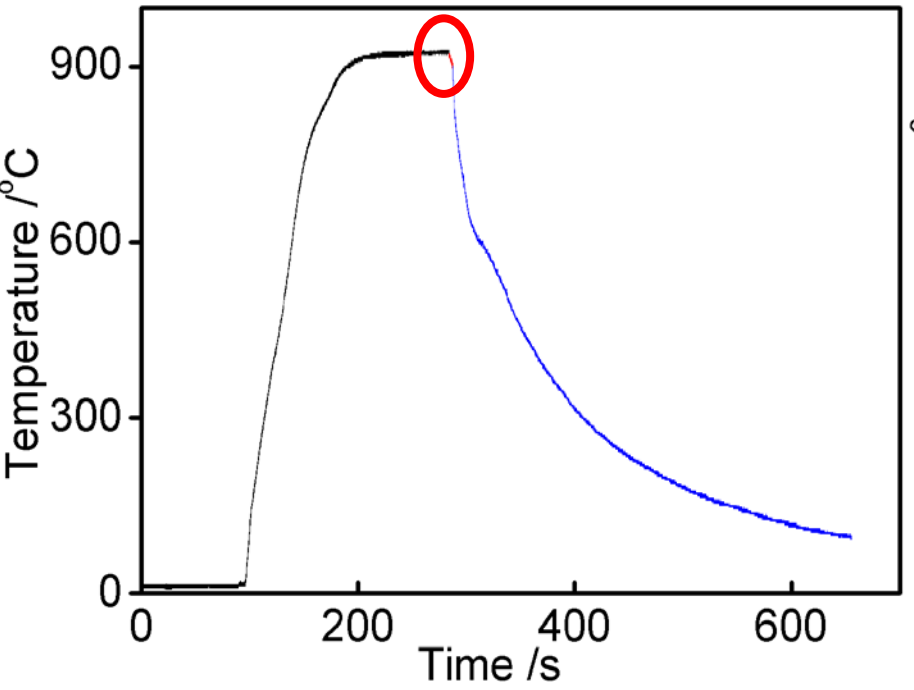
  ---Austenitizion: 930^{o}C for 5min

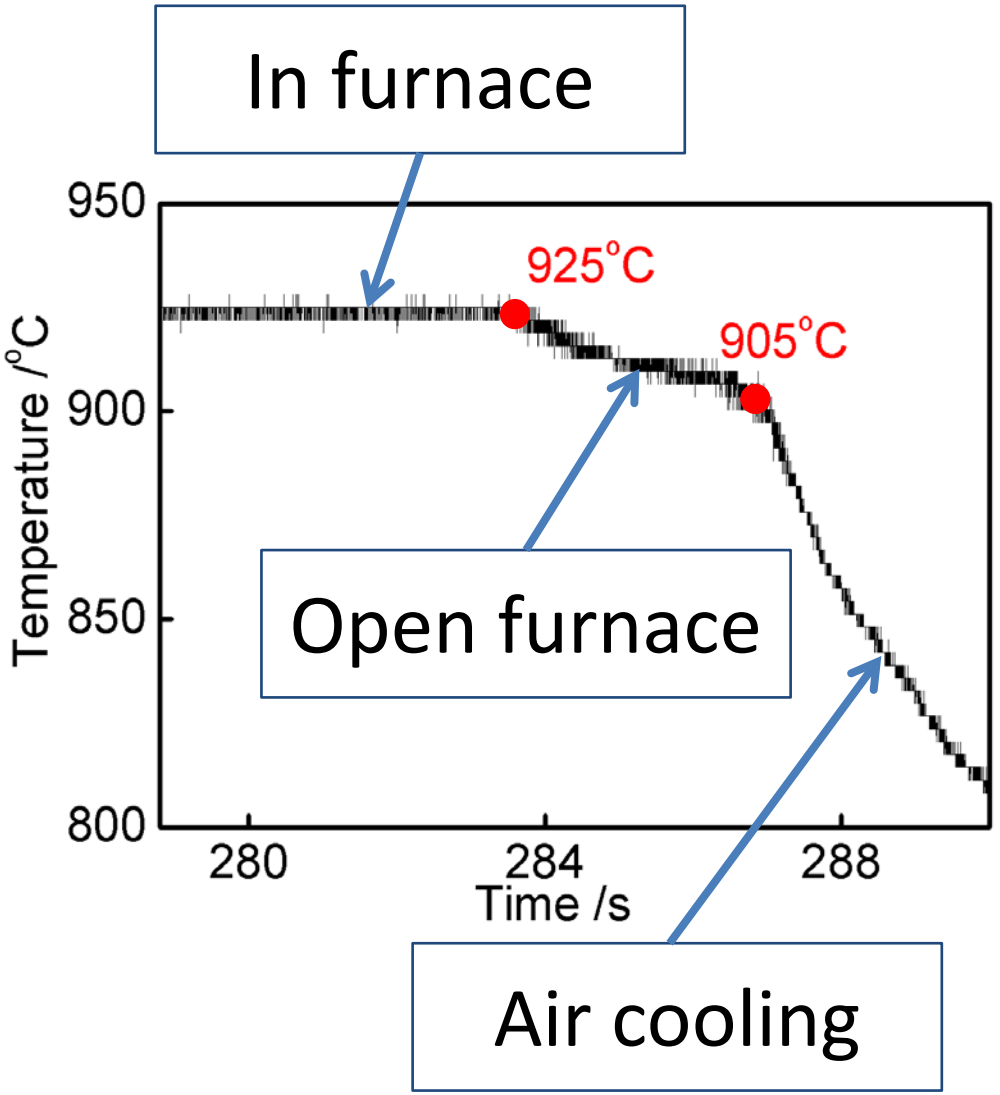
  ---Temperature of die surface: 20^{o}C

  ---Press: 120t (Pressure: 30MPa)

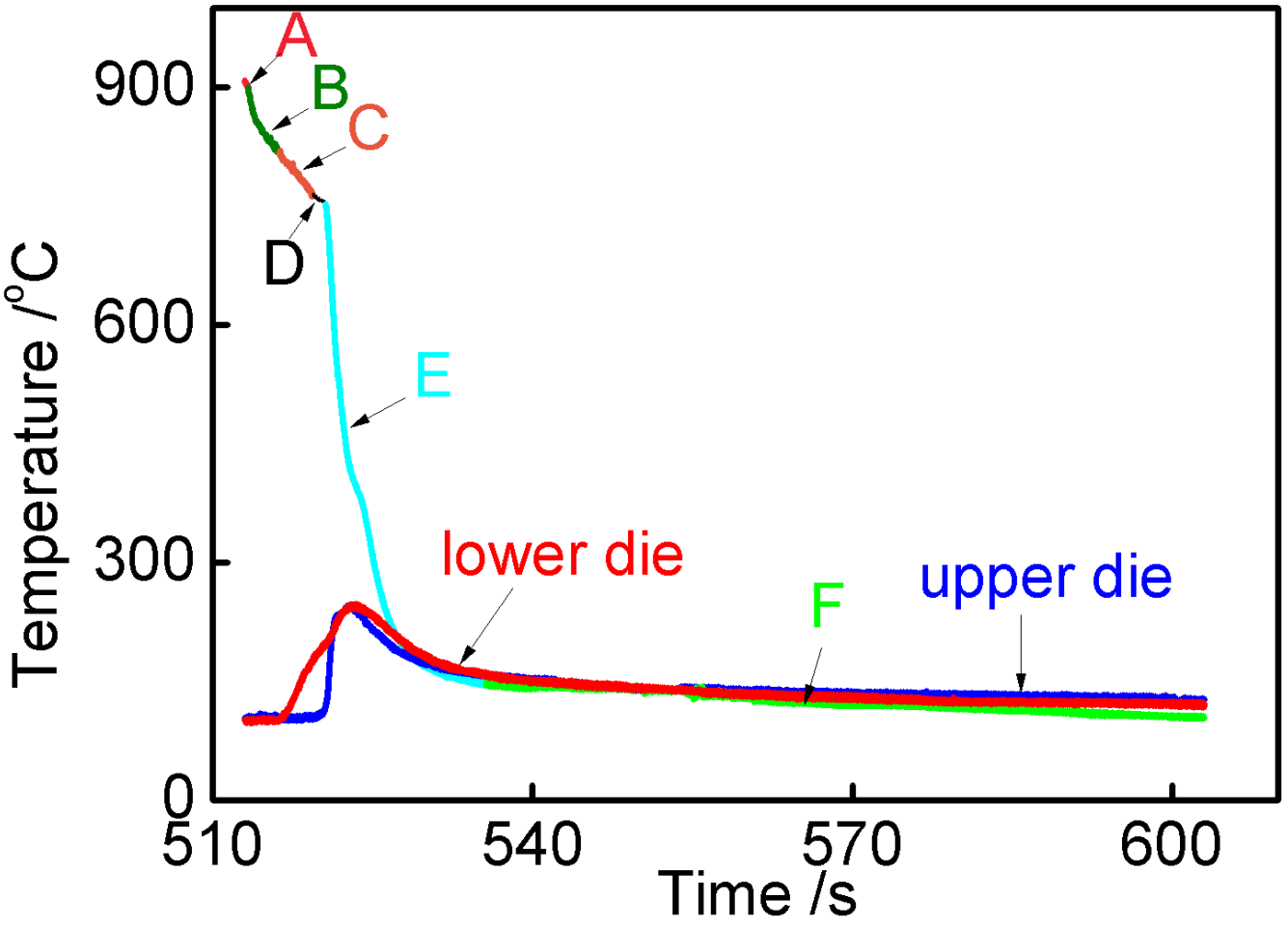
  ---Holding time: 15s

Austenitization followed by air cooling





Die quenching with pressure



A: Opening furnace

B: Air cooling

C: Contacting with lower die

D: Contacting with upper die

E: With pressure

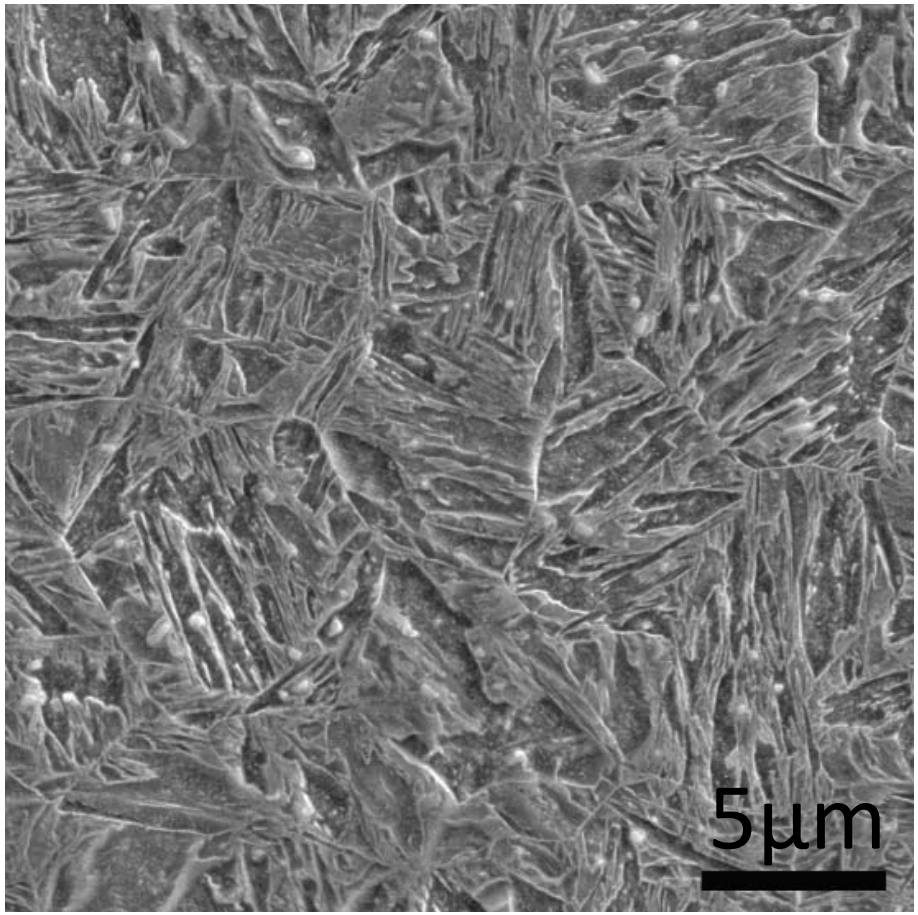
F: Air cooling

Mechanical properties of Press-hardened steels

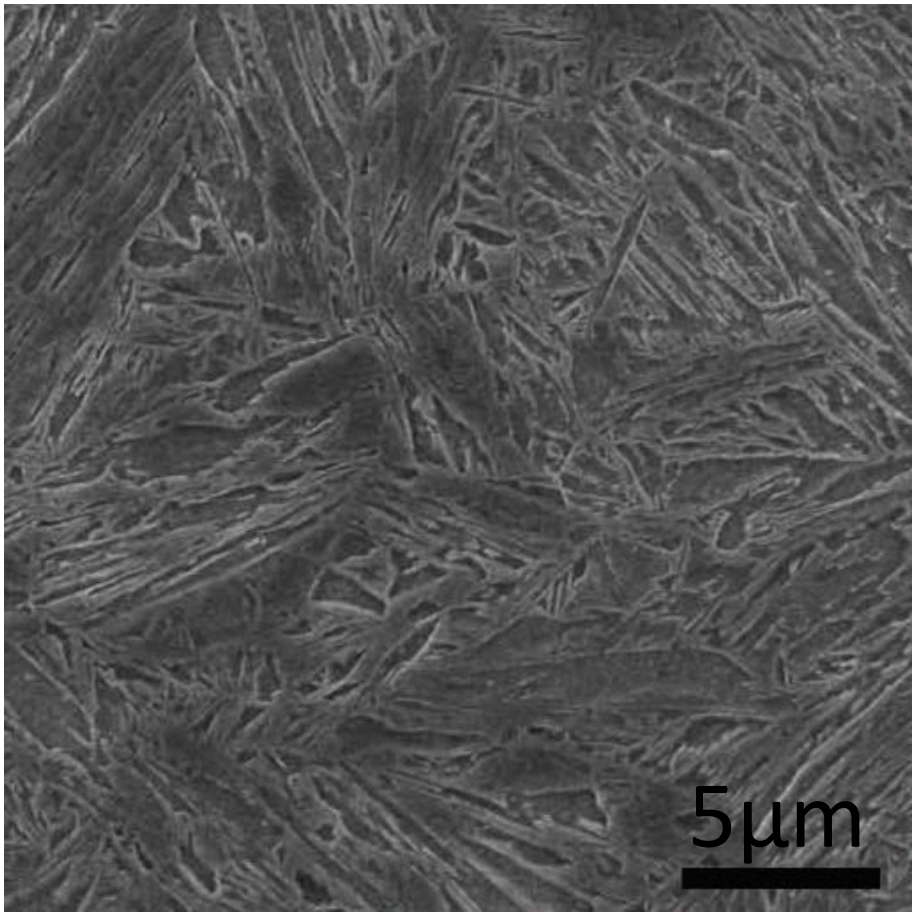
- Standard: GB/T 228-2010(Straining rate: 0.67 X 10^{-3} s^{-1})
- 50mm gauge length sub-size specimens(1.5mm thick)
- UTS, YS(0.2% offset): reported by the machine
- TEL: Measured ΔL after fracture, TEL= ΔL / L (L = 50mm)

	Die temp / °C	UTS / MPa	YS / MPa	TEL / %	Microstructure
PHS1	20	1598±4	1122	7.5±0.4	Full martensite
PHS2	20	1420±5	960	6.4±0.7	Full martensite

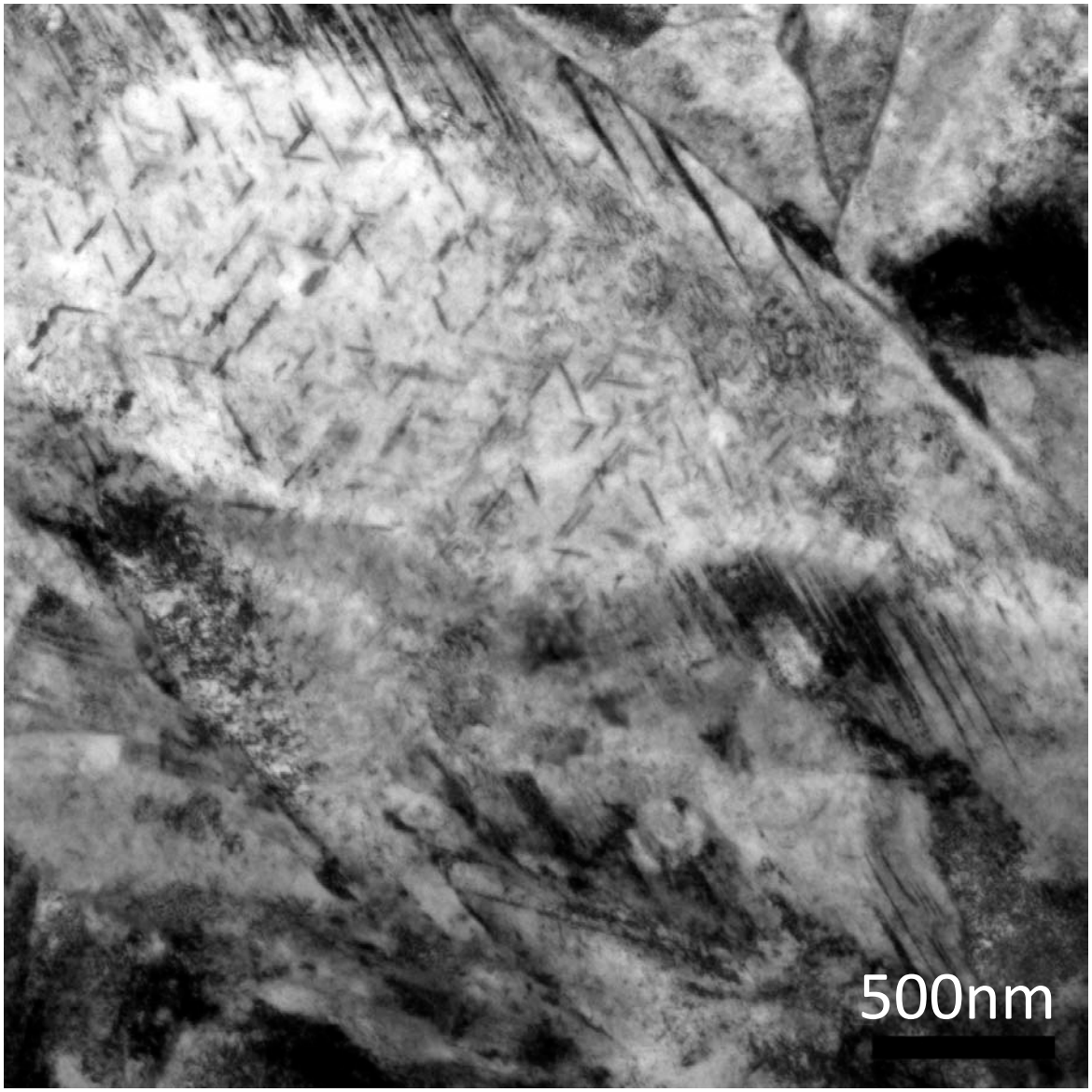
Microstructure of Press-hardened steels



PHS1

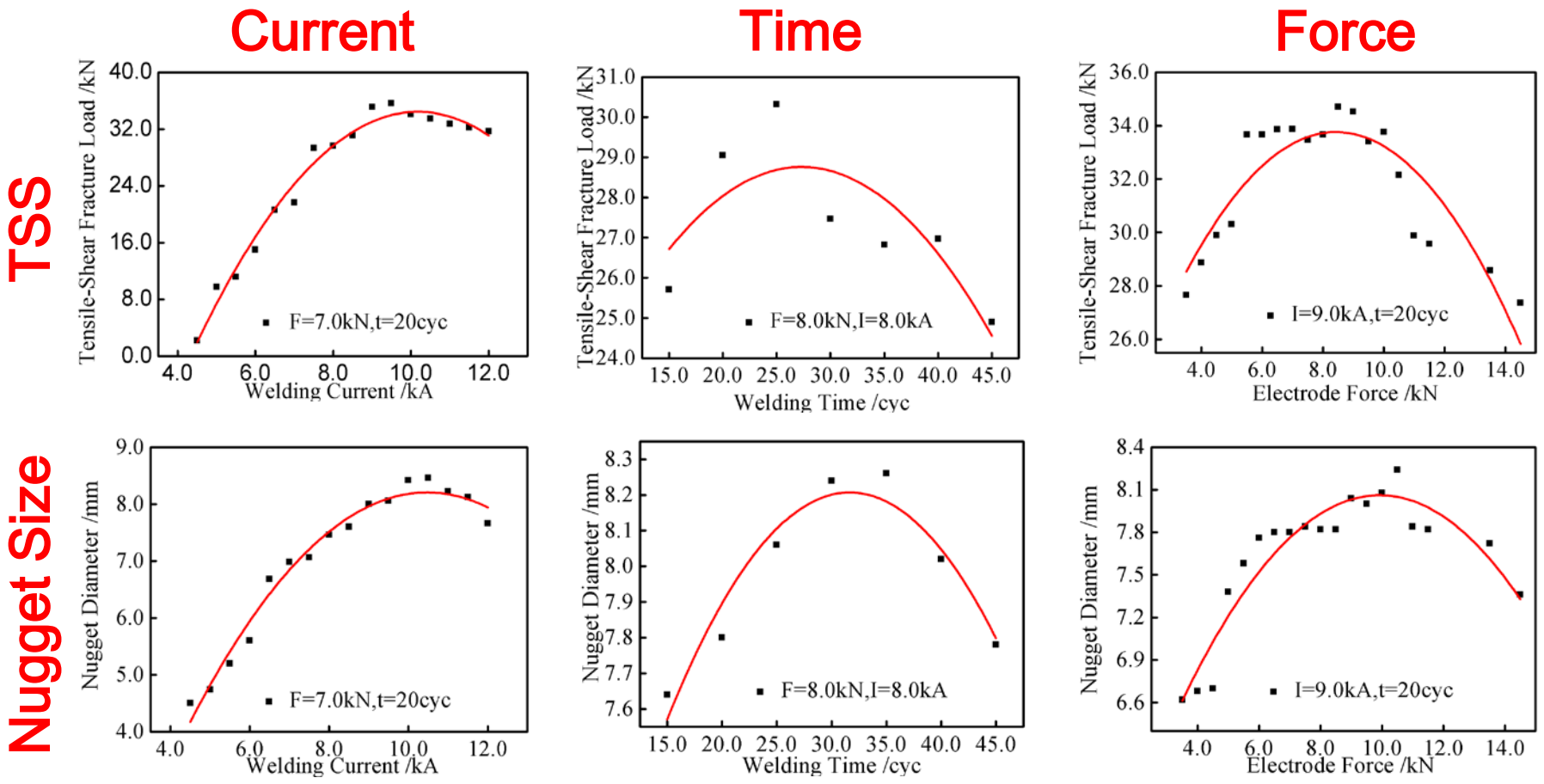


PHS2



PHS1

RSW of PHS1



Optimized welding parameters:

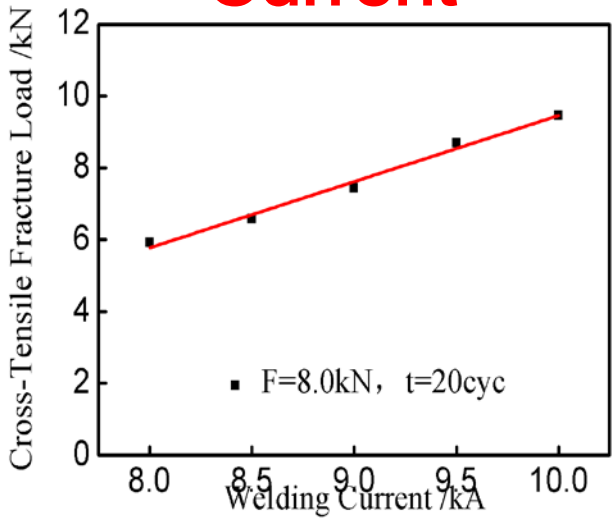
I=7.0~10.0kA, t=20~35cyc, F=6.5~10.5kN

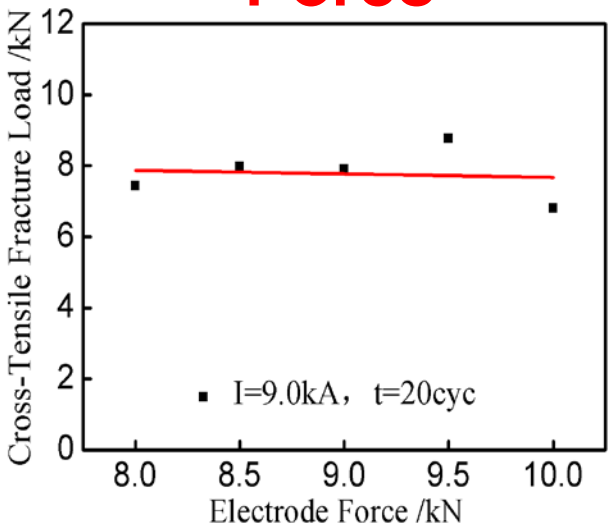
RSW of PHS1: CTS & TSS

Current

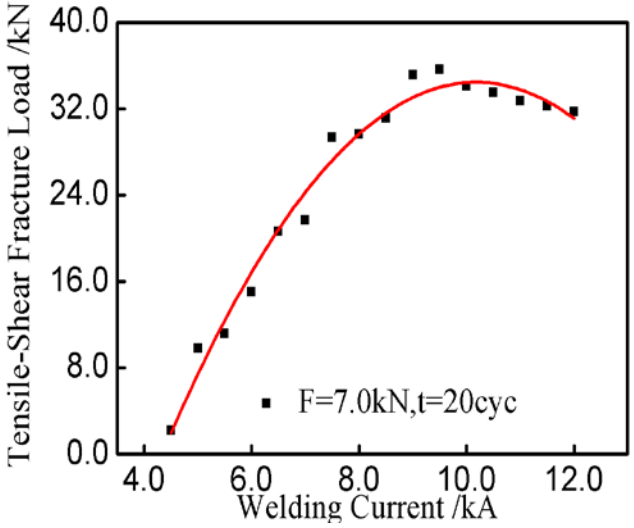
Force

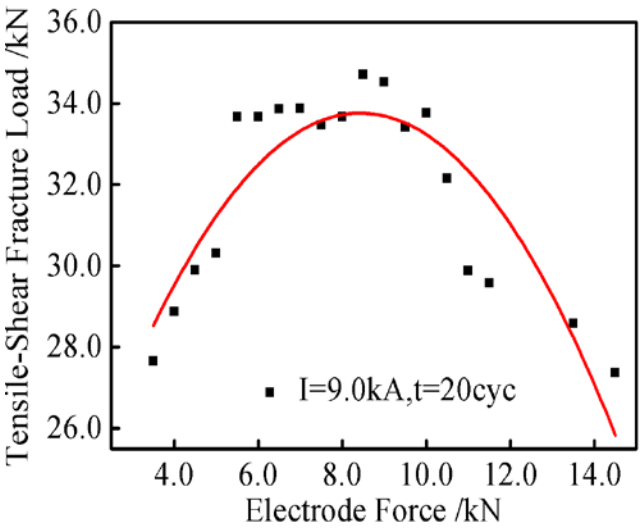
CTS





TSS





$K=F_{CTS}/F_{TSS}$

K:~0.3 , Good

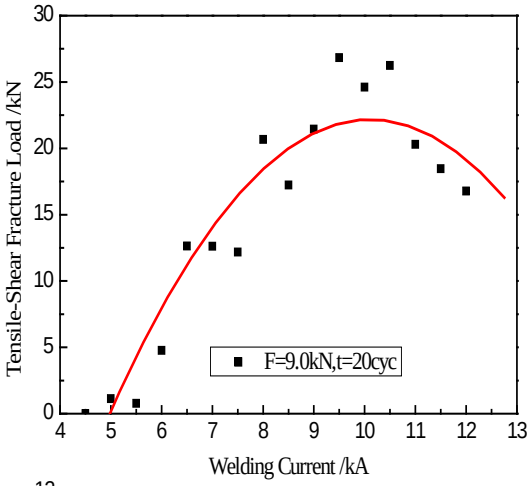
RSW of PHS2

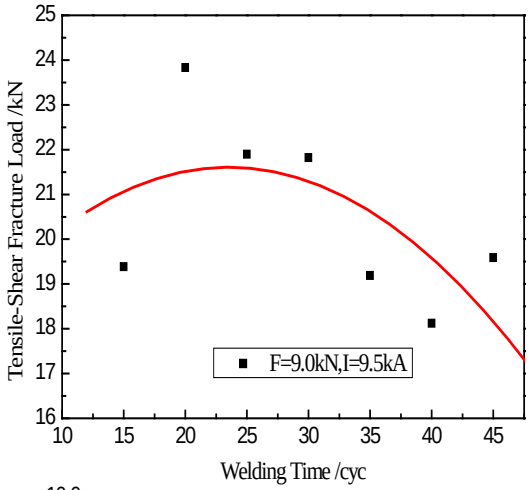
Current

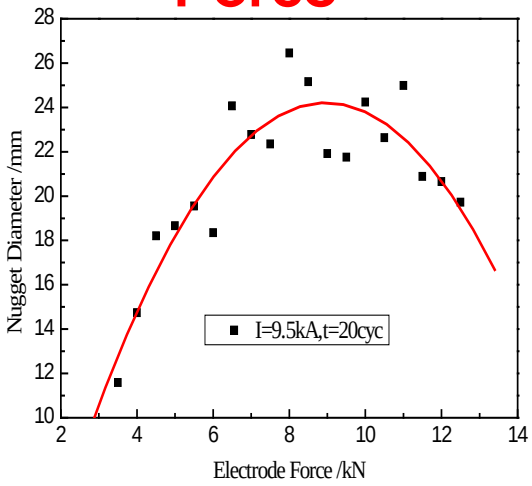
Time

Force

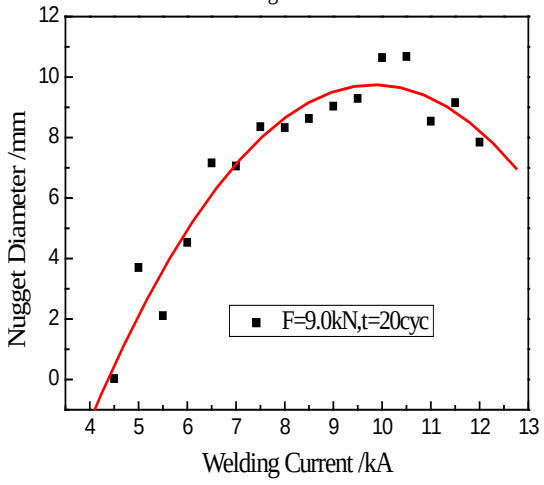
TSS

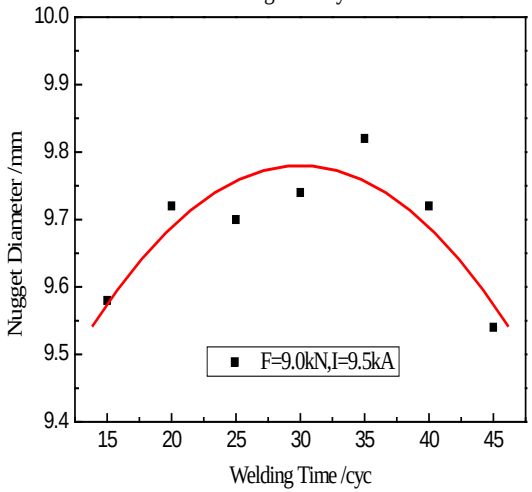


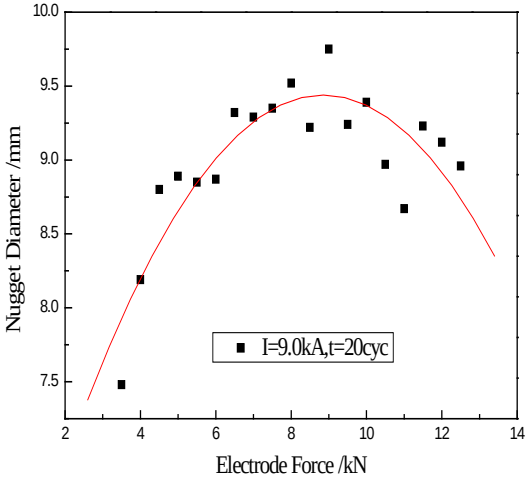




Nugget Size







Optimized welding parameters:

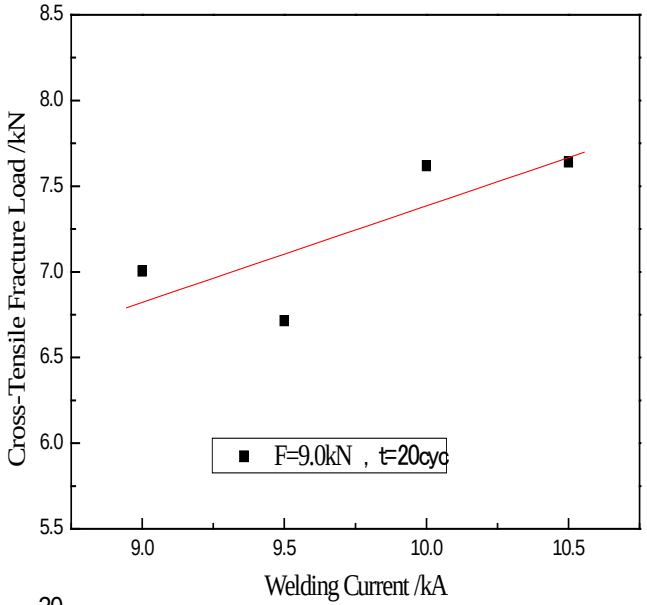
I=9.5~10.5kA, t=20~35cyc, F=8.5~9.5kN

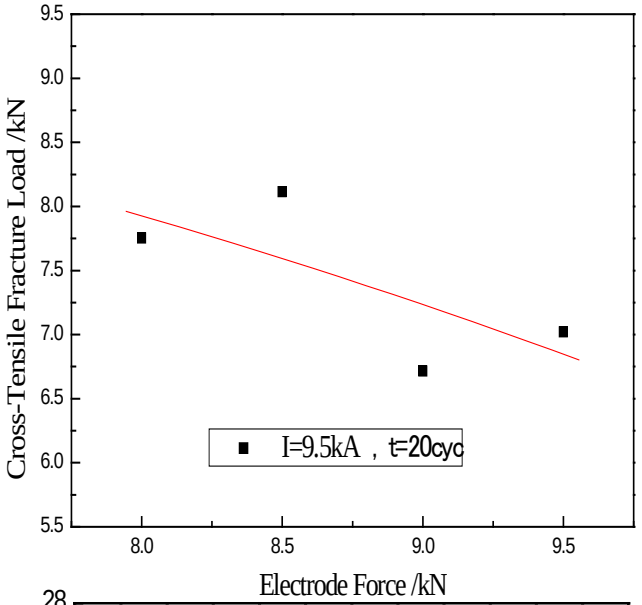
RSW of PHS2: CTS & TSS

Current

Force

CTS

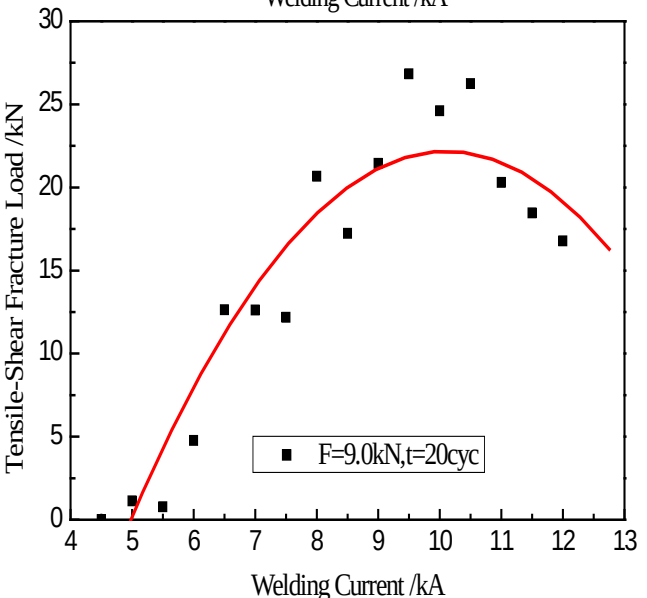


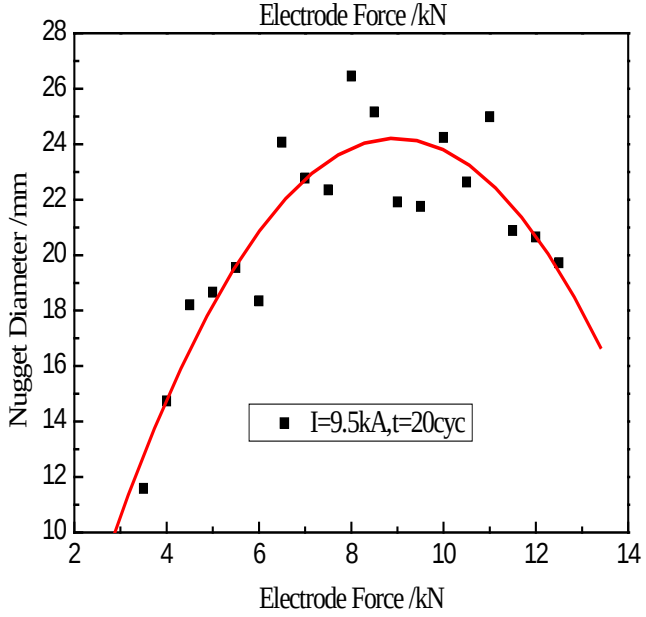


$K=F_{CTS}/F_{TSS}$

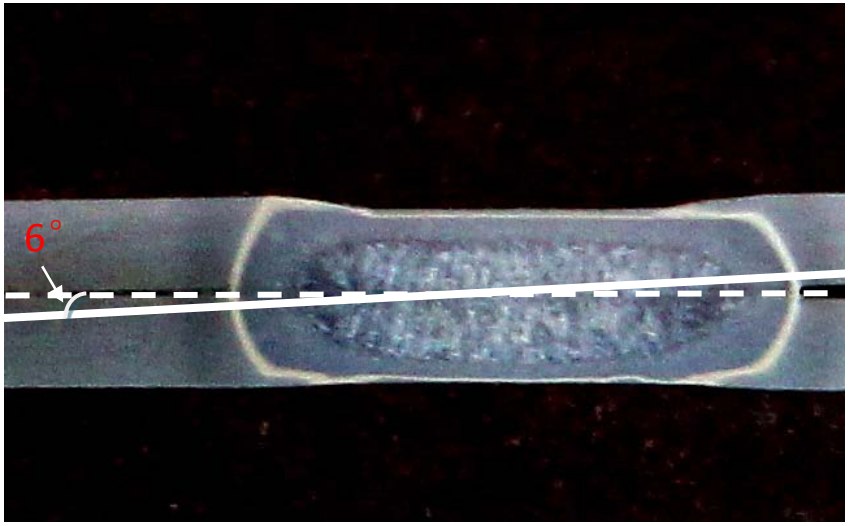
K:~0.3 , Good

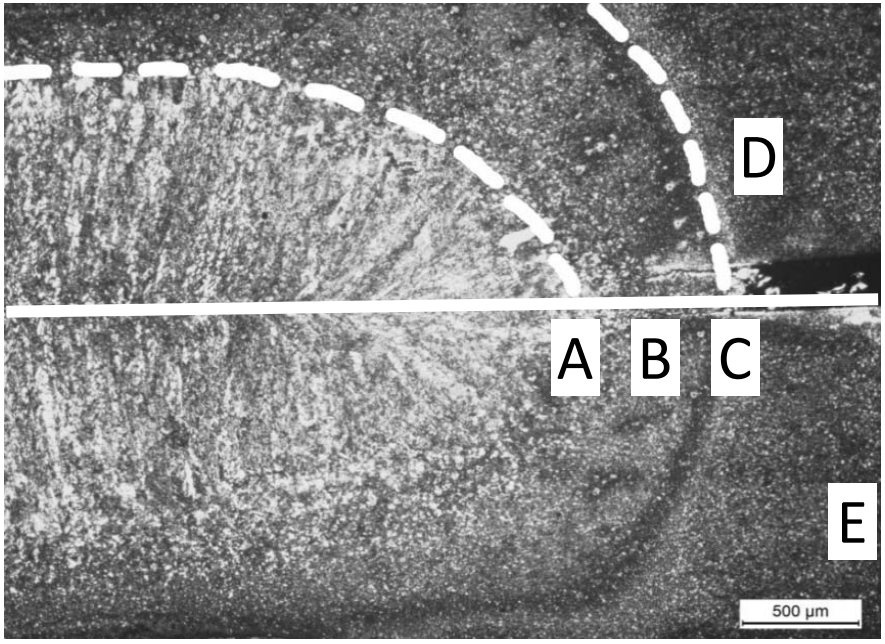
TSS

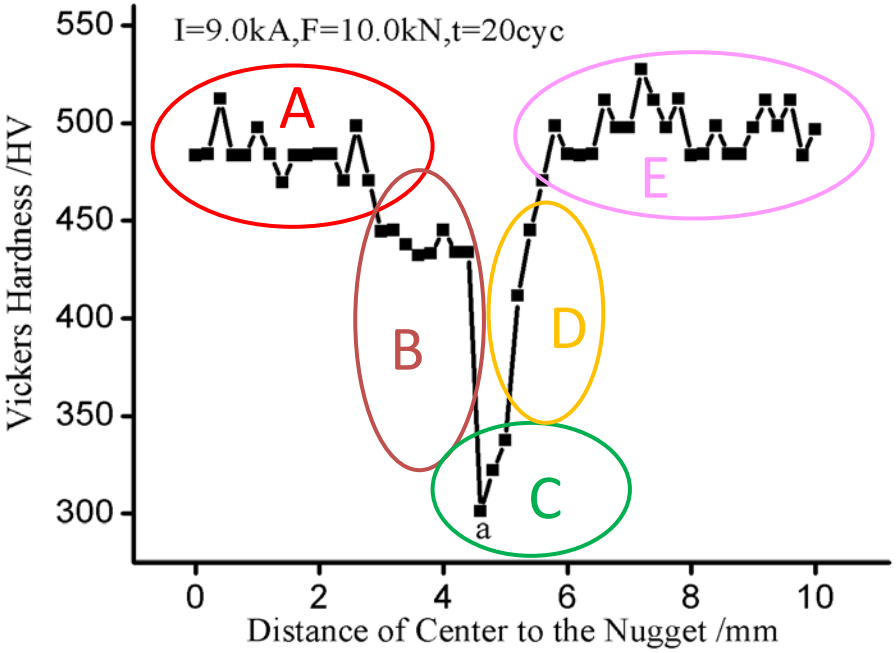




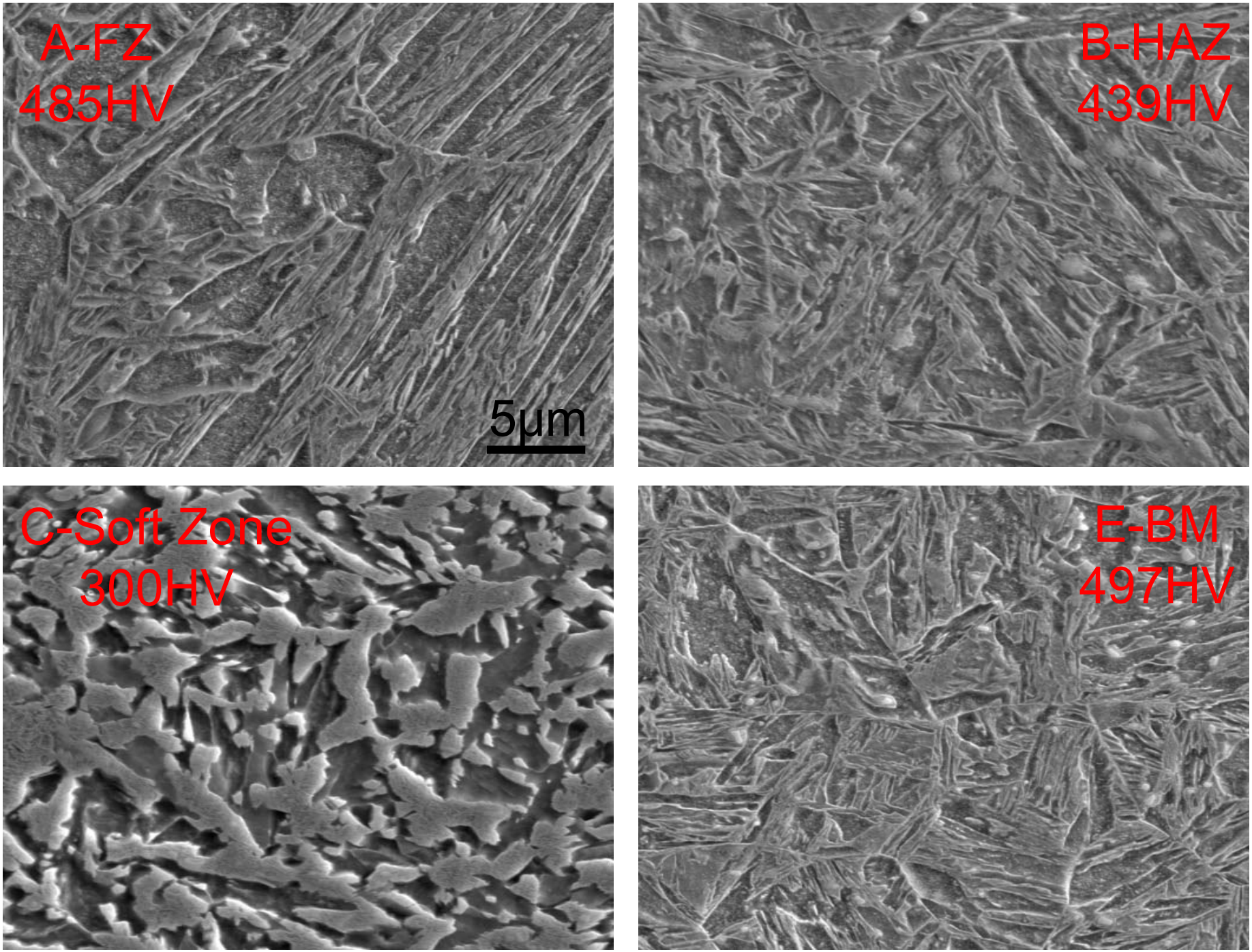
Microstructure and hardness for PHS1



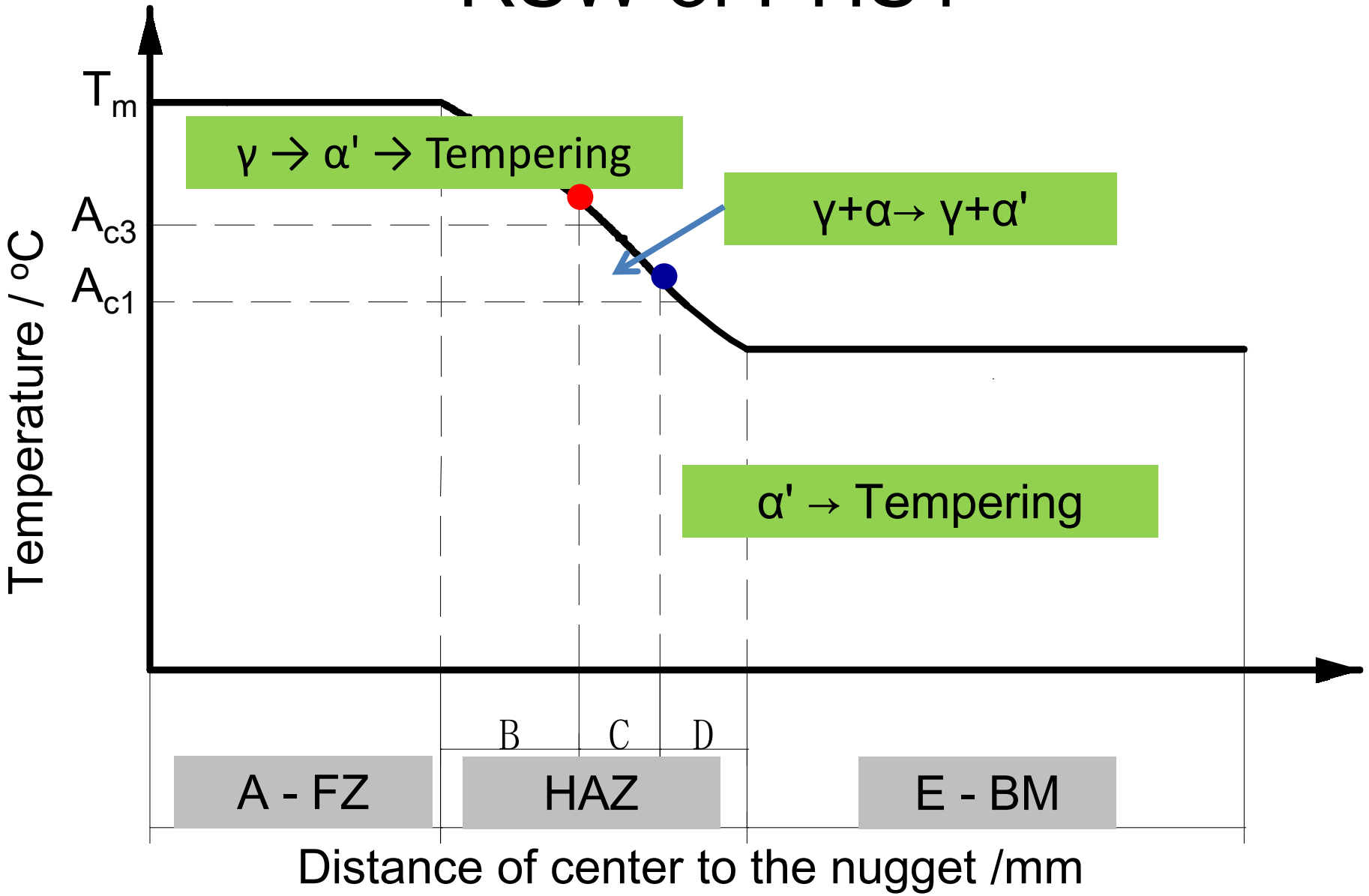




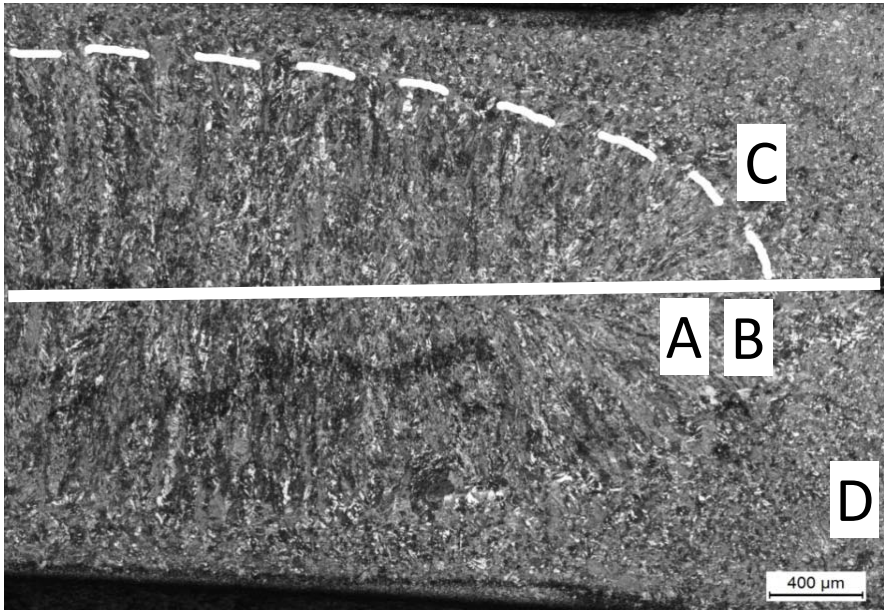
FZ	A	485HV
HAZ	B	439HV
	C	300HV(Softening zone)
	D	428HV
BM	E	497HV

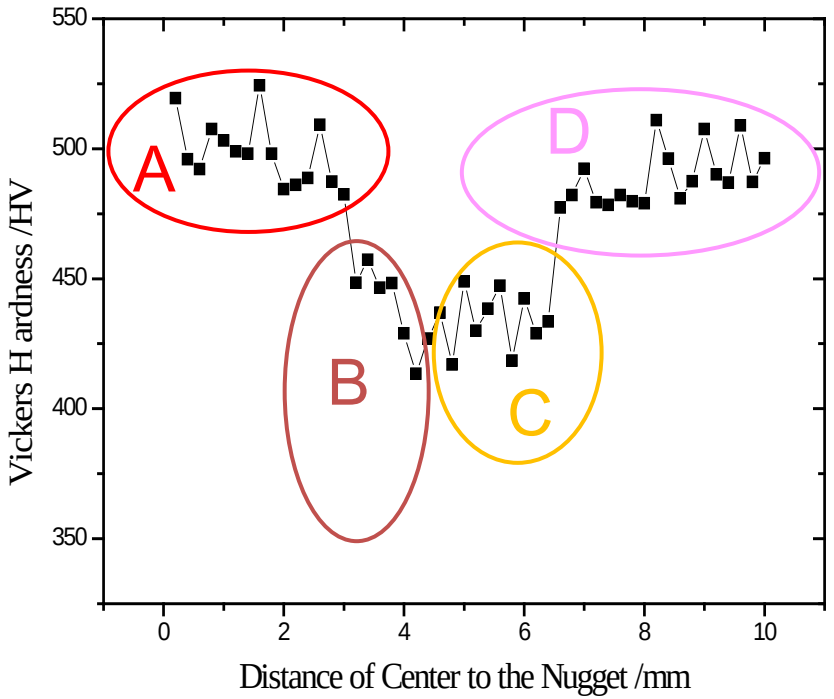

A-FZ
485HV
5μm
B-HAZ
439HV
C-Soft Zone
300HV
E-BM
497HV

Microstructural evolution during RSW of PHS1

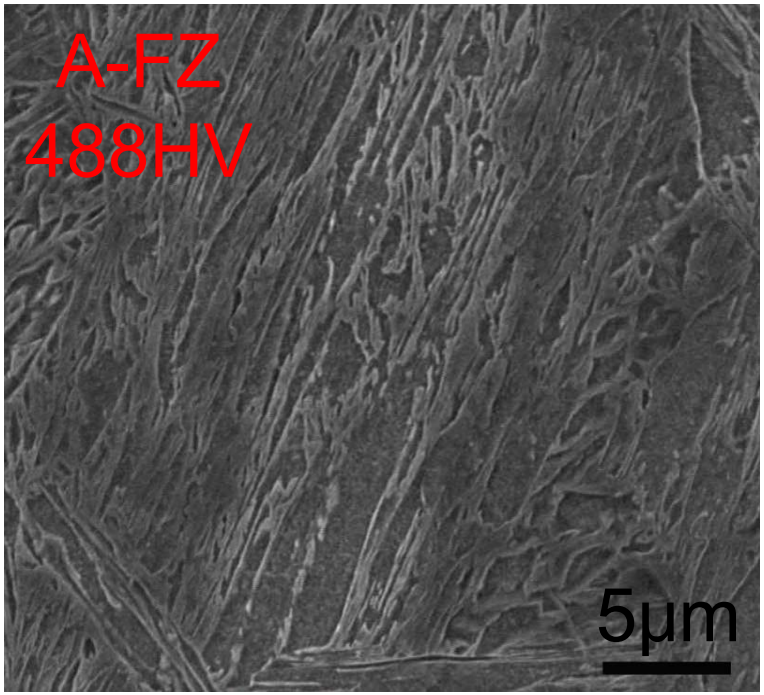


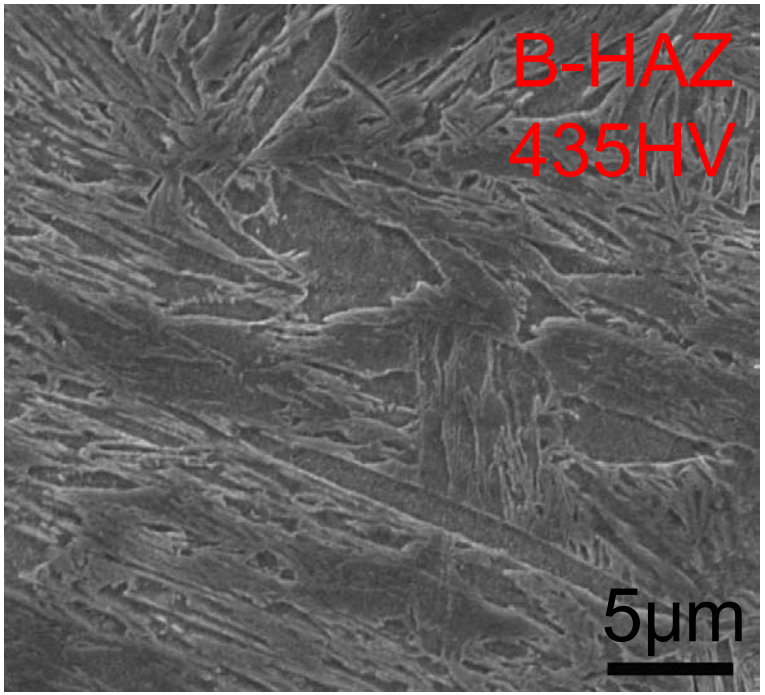
Microstructure and hardness for PHS2

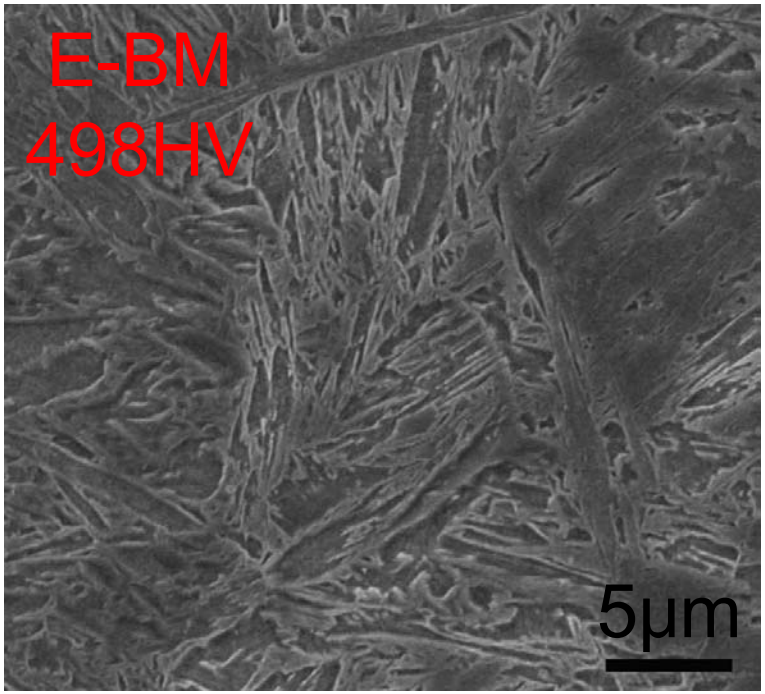




FZ	A	488HV
HAZ	B	435HV
	C	440HV
BM	D	498HV


A-FZ
488HV
5μm


B-HAZ
435HV
5μm


E-BM
498HV
5μm

Conclusions

- Excellent mechanical properties performed in spot welds of press hardened steels: both tensile shear and cross tensile
- Good toughness ($K=F_{CTS}/F_{TSS}$ ~0.3): softening zone & not so brittle in fusion zone due to autotempering
- Microstructural evolution: FZ by solidification and $\gamma \rightarrow \alpha'$ +tempering, HAZ_B by $\gamma \rightarrow \alpha'$ +tempering, HAZ_C by $\gamma+\alpha \rightarrow \gamma+\alpha'$ which dual phase softening zone formed during heating but not cooling, HAZ_D by α' tempering
- Microstructure evolution in HAZ effected by the concept of reverse hardenability?