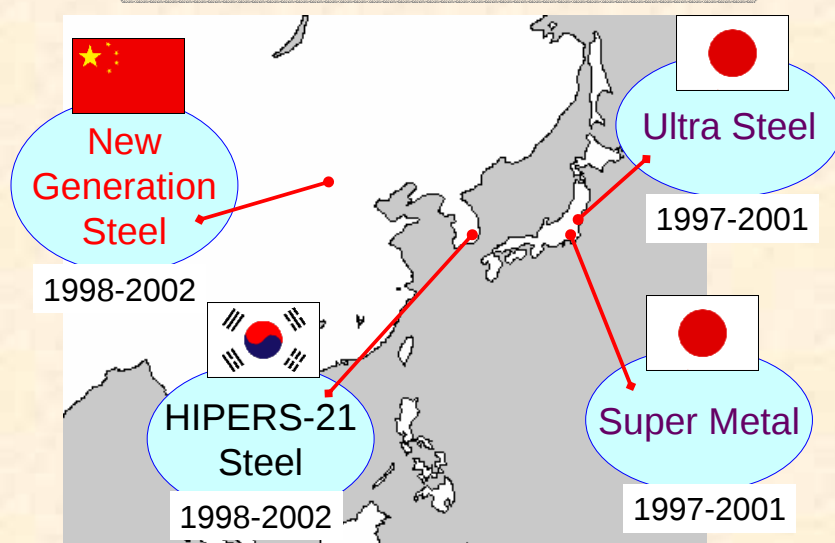


Ultrafine-grained steels: Basic researches and attempts for application



Kotobu Nagai
Steel Research Center
NIMS

Steel Projects in Asia



Common Issues in Steel Projects

Meaningful Jump in Steel Performance



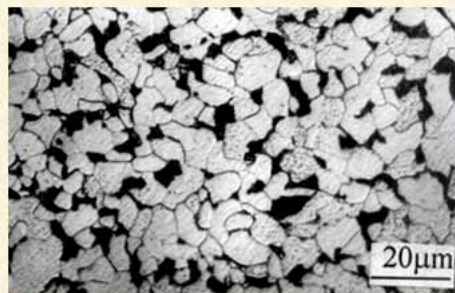
*Ultra-refinement of ferrite grain size
In low C steels*



Efficient Reduction in Environmental Burden

China: Mill Products 400MPa grade PLC steel rebar

- Improvements in low-grade steels
- Direct application at mills



Huaiyin Iron and Steel Corporation

YS:
280MPa to 410MPa
(20 μm to 7 μm)



Korea: POSCO Attempts 600MPa grade plate steel

- Exploratory research of innovative tech
- National project first (Lab scale)

Deformation	$d\alpha$
Supercooled γ	2 μm
Duplex $\alpha + \gamma$	1 μm
α	0.6 μm



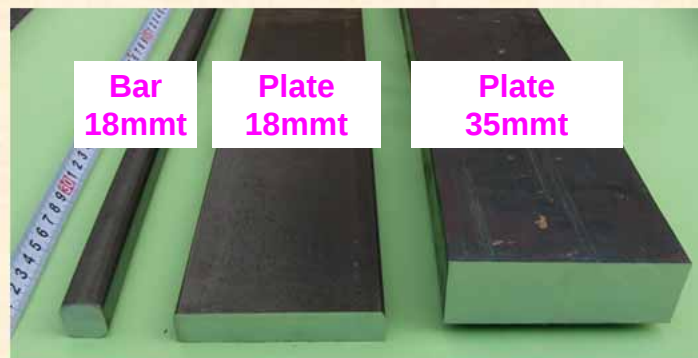
Damper-installed High Strength Type



New Structural System

Ultra Steel: NIMS Attempts 800MPa grade plate steel

- Exploratory research of innovative tech
- National project (Lab scale)



0.7-0.8 μm

Ultra Steel: NIMS Attempts Application for Mills

Wire
1.3 ϕ -3000m



0.7-0.8 μm

Osaka Seiko

Hot coil
2mmt



2 μm

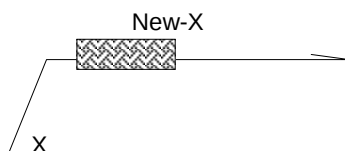
Nakayama Steel Works

Basis of Ultra-Refinement

Rex-Route

**Rebirth of
new grains (X) from
deformed structure (X)**

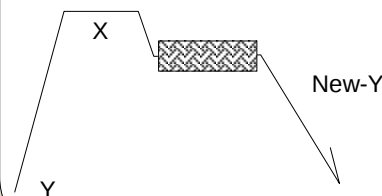
Processing Temperature: Constant



Trans-Route

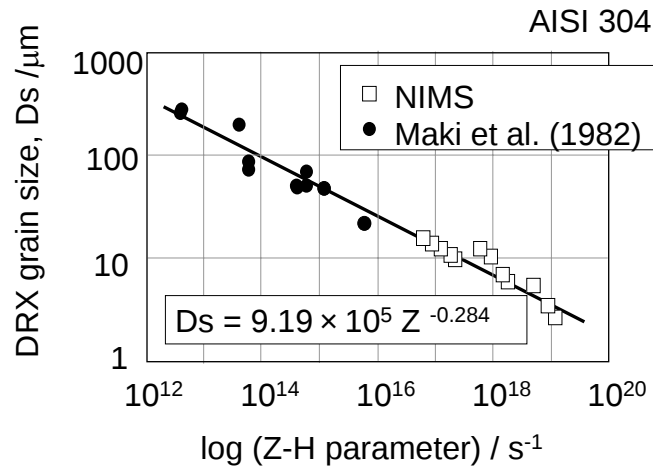
**New grains (Y)
transformed from
deformed structure (X)**

Processing Temperature: Cooling



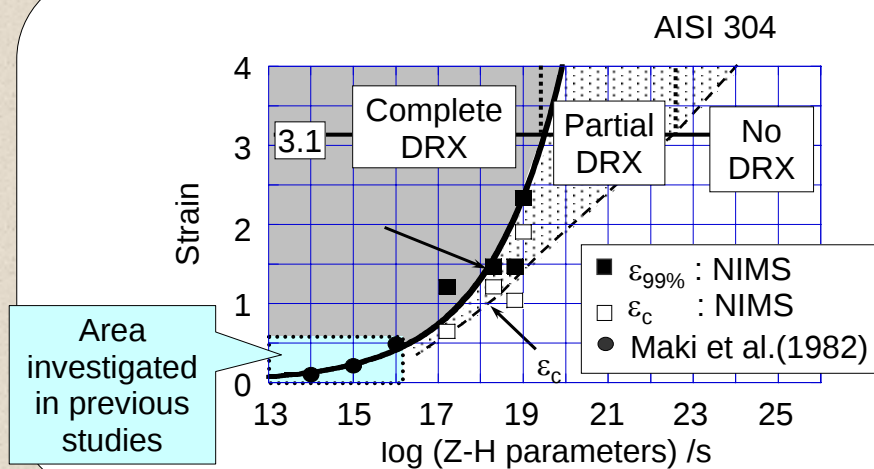
Rex-Route: Grain Size

$$Z = \dot{\epsilon} \exp (Q/RT)$$



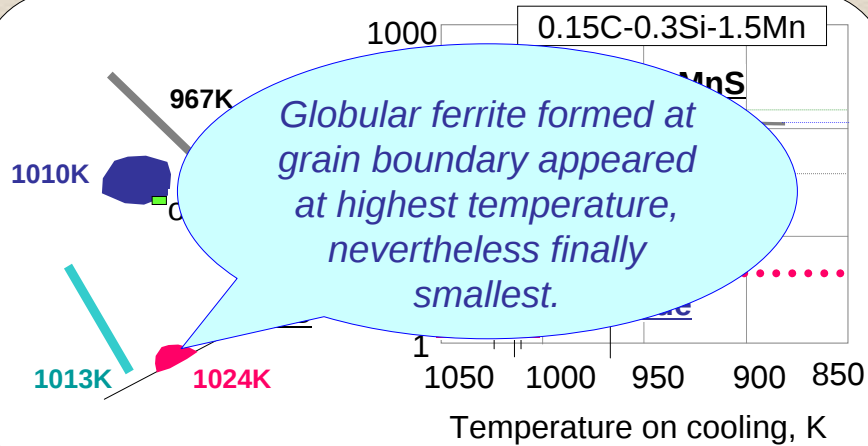
Rex-Route : Required Strain

$$\epsilon_{99\%} = 4 \times 10^{-5} Z^{0.251}$$

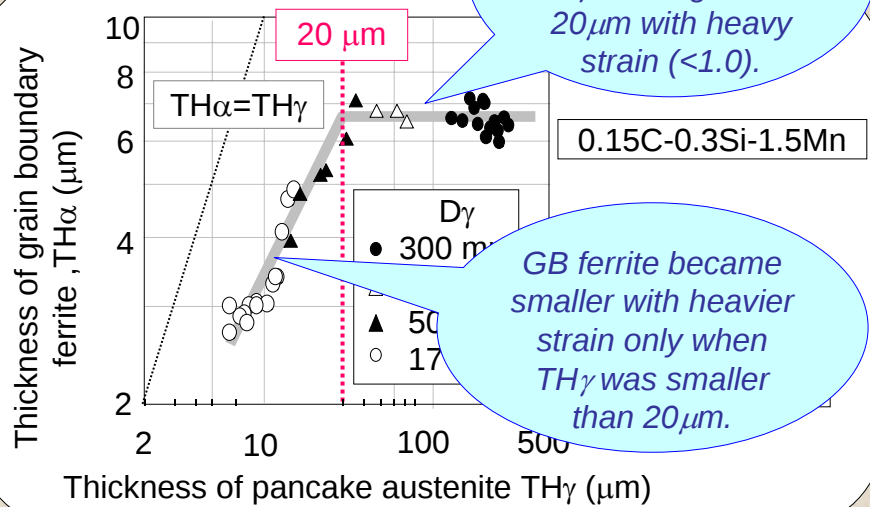


Trans-Route : NIMS Basic Understanding

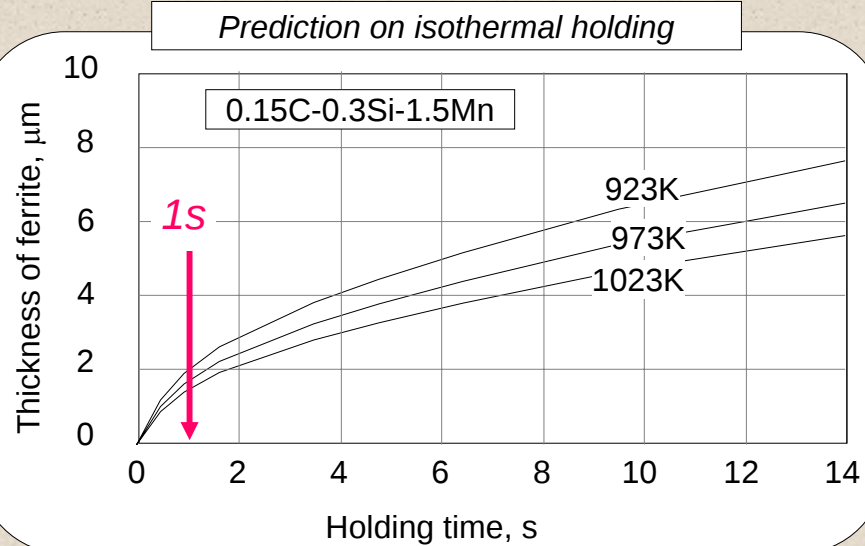
In-situ observation by Confocal Laser Scanning Microscopy



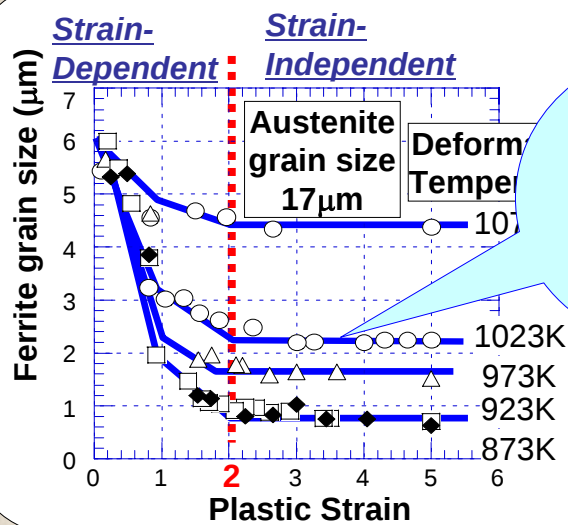
Trans-Route : NIMS Basic Understanding



Trans-Route : NIMS Basic Understanding

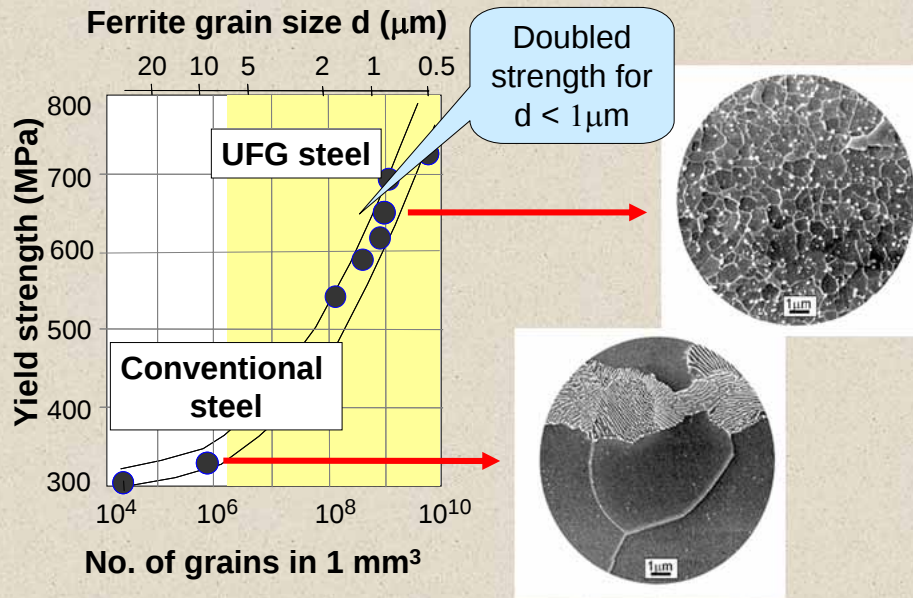


Trans-Route : NIMS Basic Understanding

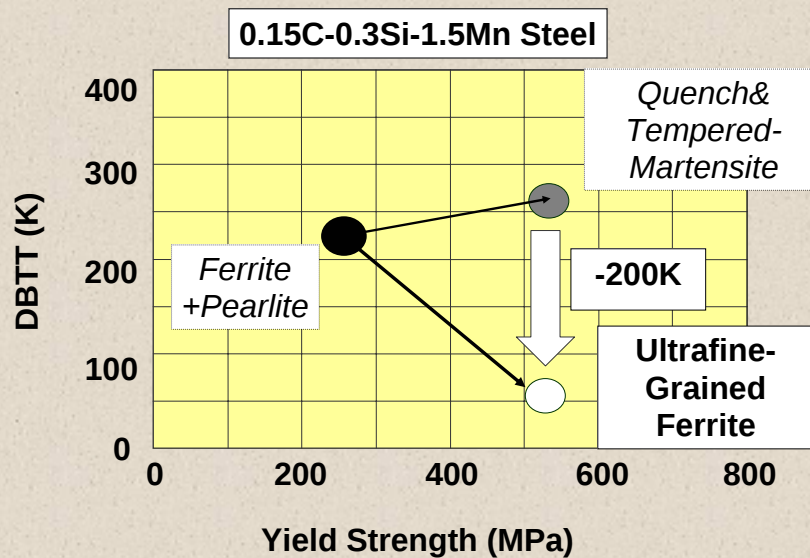


Further heavy strain larger than 2 brought about a plateau again.

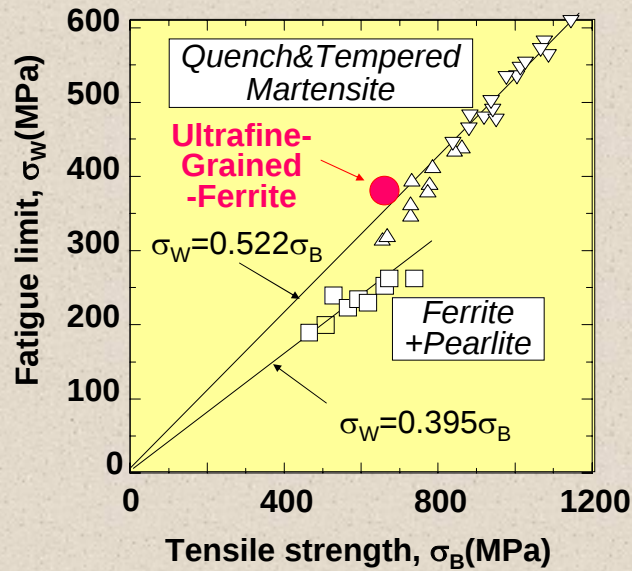
Properties of Ultrafine-grained Steel



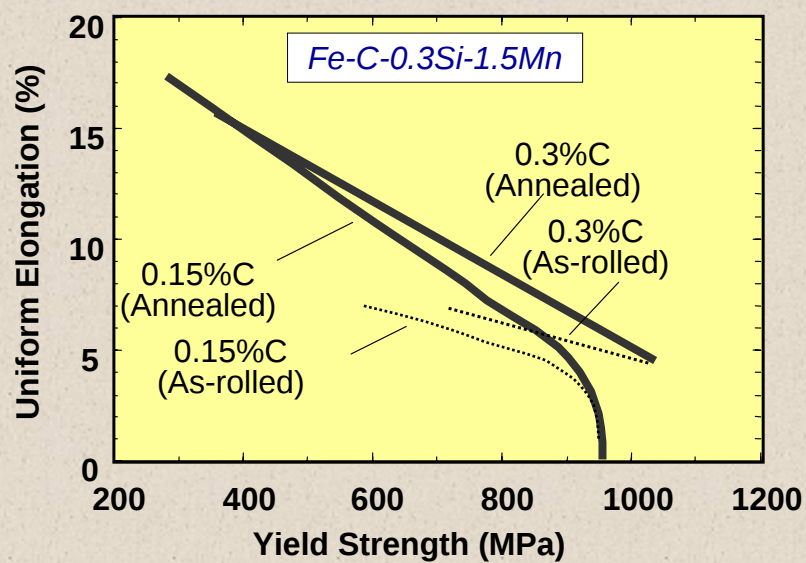
Properties of UFG Steel: toughness

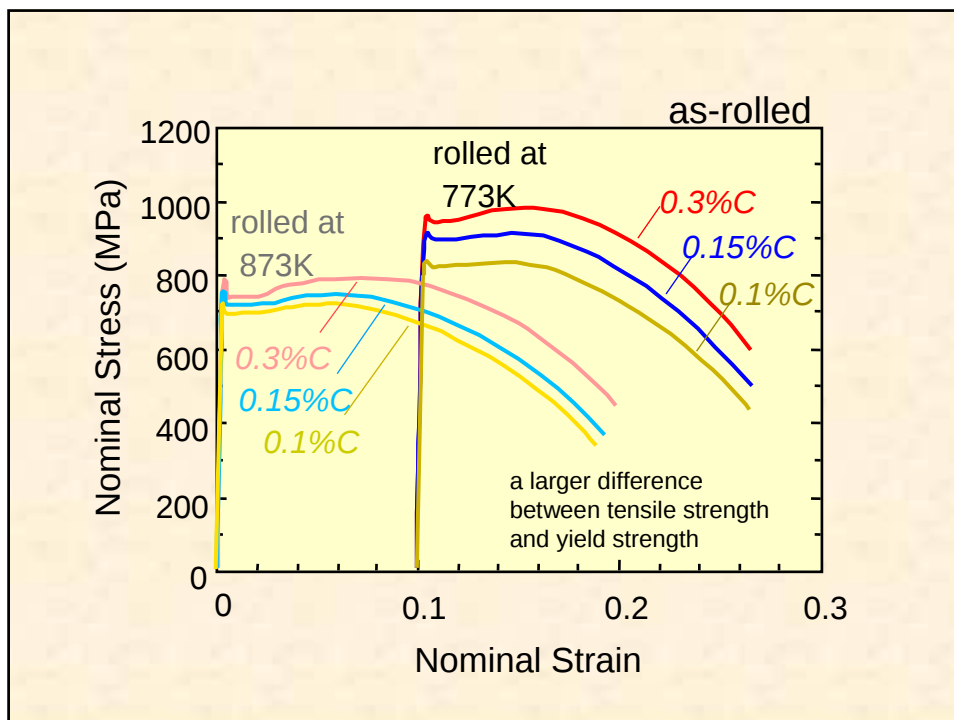
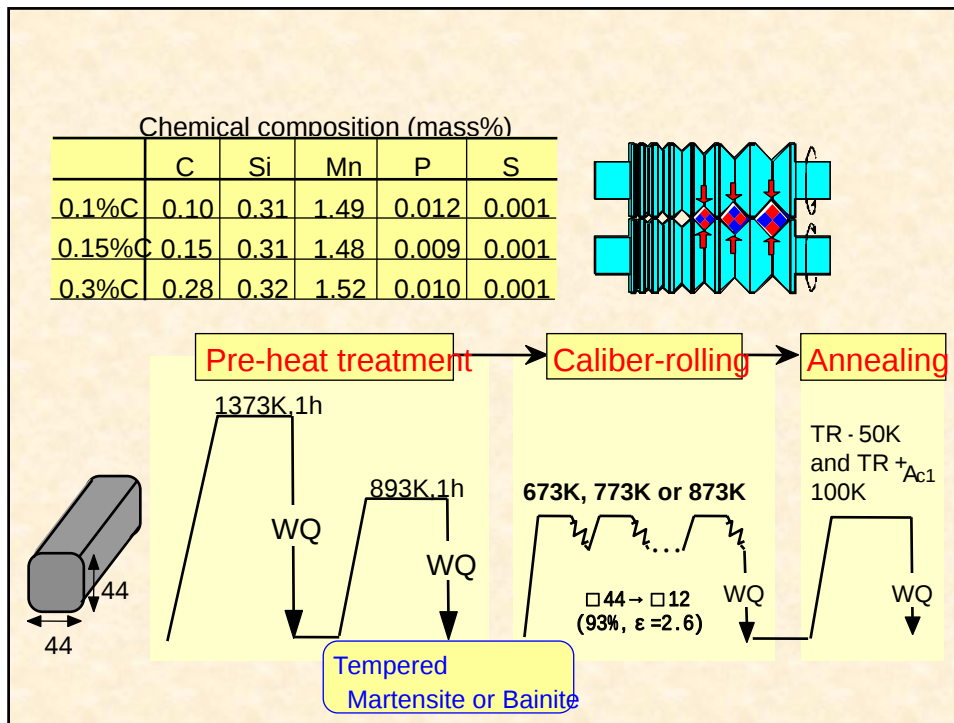


Properties of UFG Steel: fatigue

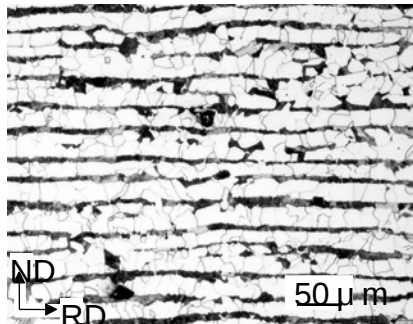


Properties of UFG Steel: ductility



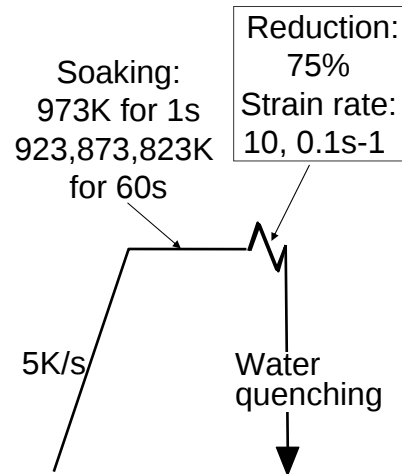


Compressive Deformation of Ferrite-Pearlite in Ferrite Region

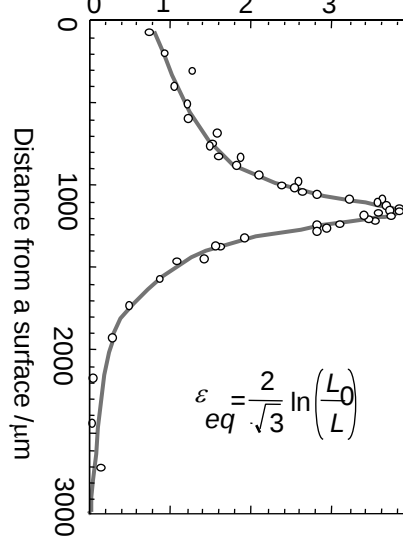


C	Si	Mn	P	S
0.16	0.41	1.43	0.014	0.004

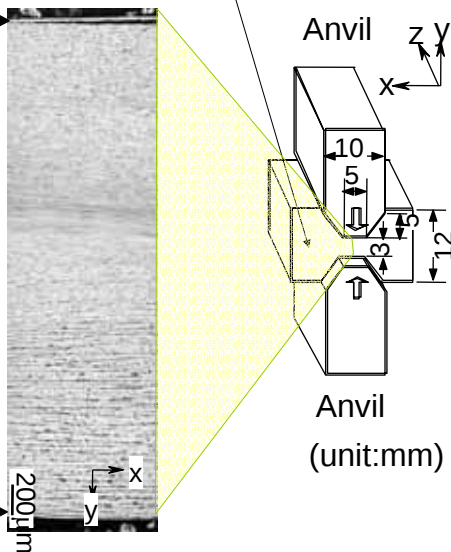
Compression axis

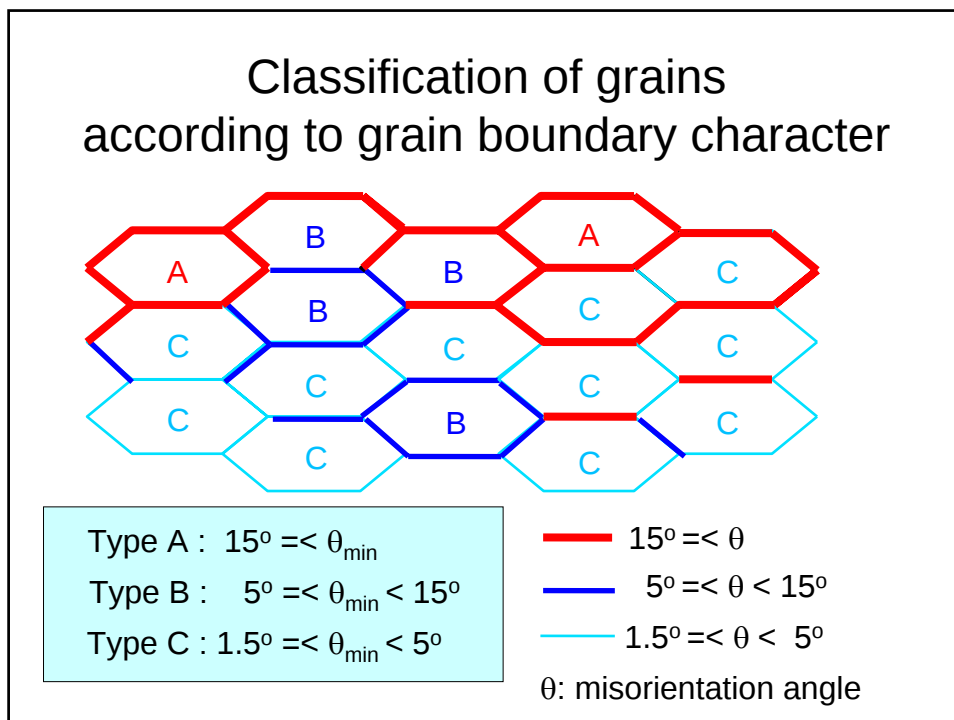
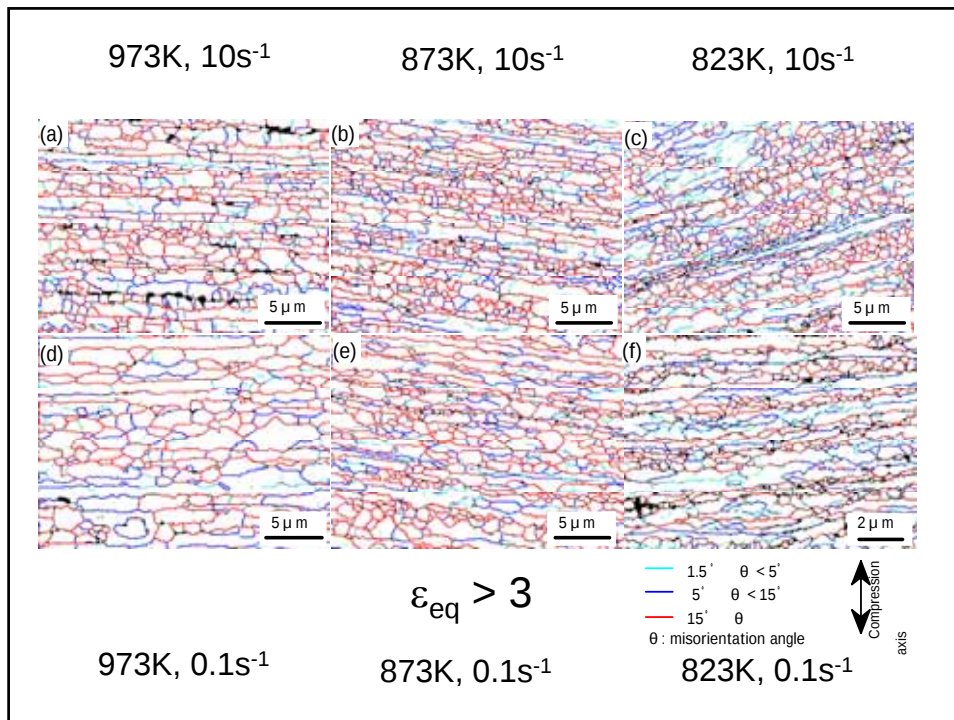


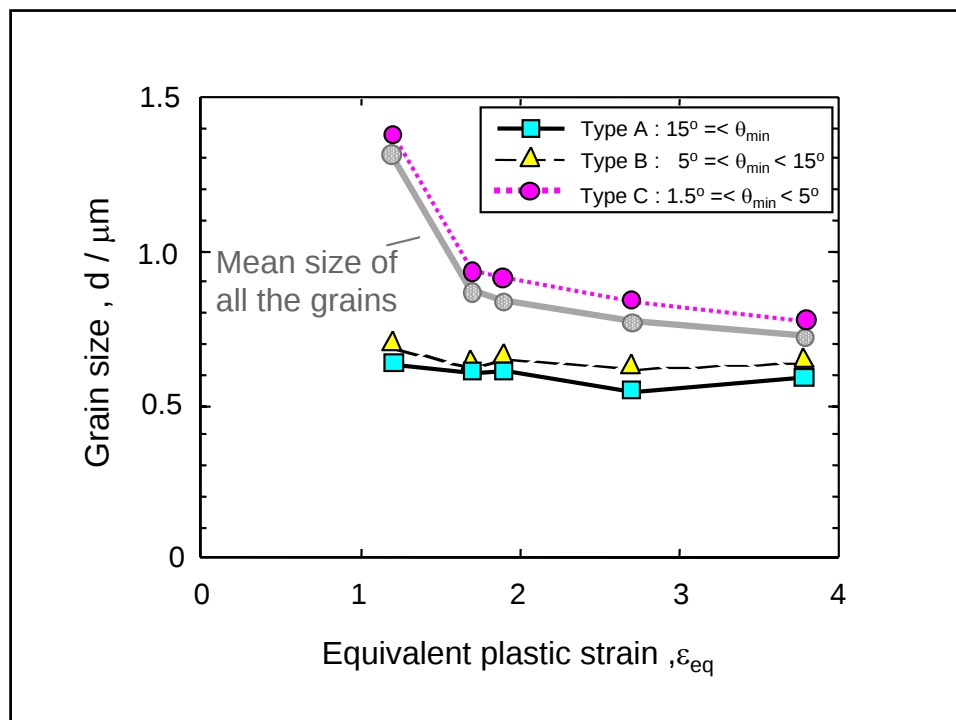
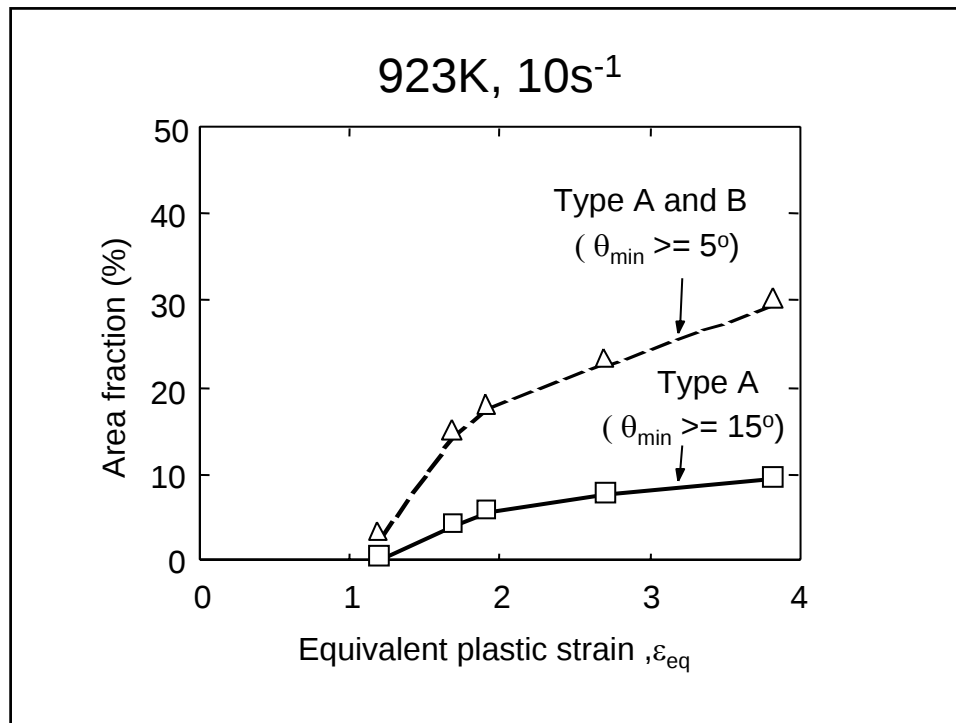
Equivalent plastic strain

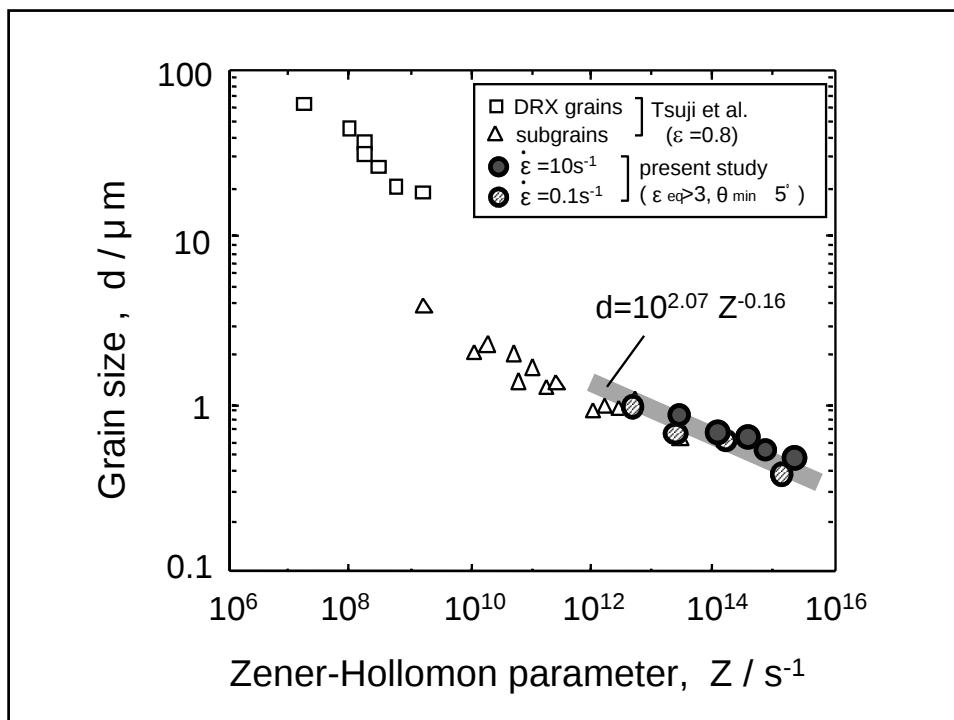
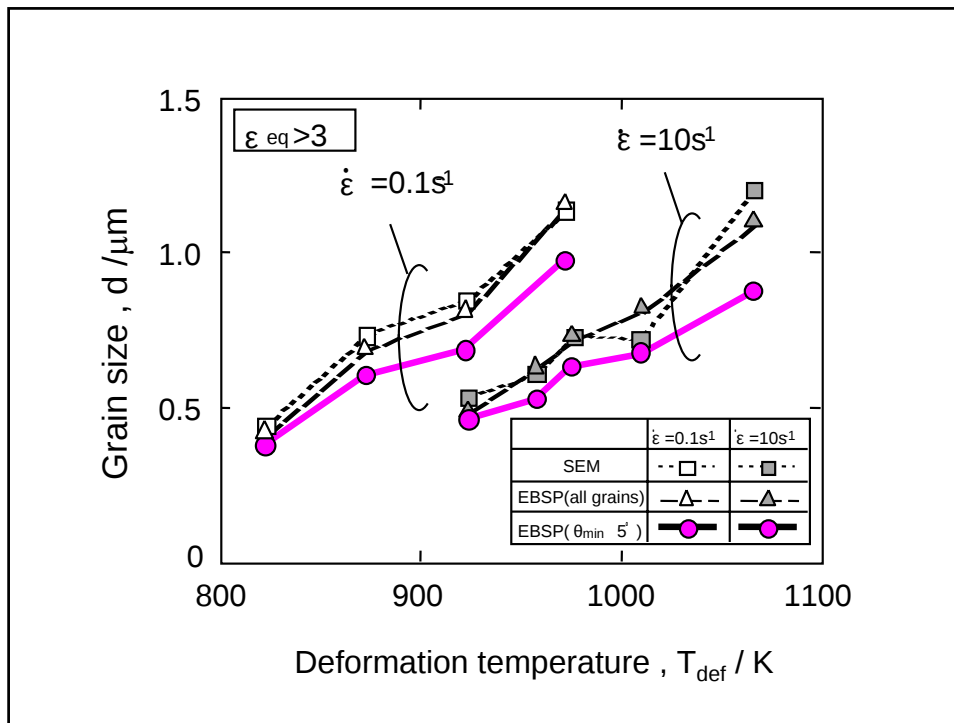


Specimen









For Application: NIMS ideas

Joint Fatigue
Strength
(Doubled)

Weathering
Steel
(>100years)

High Strength
(>800MPa)
High Toughness
(DBTT<230K)

High Strength
Bolts
(>1800MPa)

Stainless Steel
for Marine Use
(>100years)

Infrastructure -Bridge- Plate - Bolt - Welding

How can “High-Strength” be materialized?

NO enough toughness
[Joint Toughness]

NO enough fatigue
strength
[Joint Fatigue]

Unfavorable anti-corrosive
elements
[Recyclability]

Plating : Zn, Sn
Alloying : Cu, Ni

Less on-site welding
and more efficient joining
[Cost]

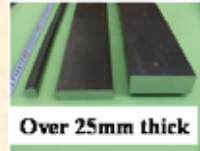
Targets



Al-Si bearing
Ultra-fine Grained
Weathering Steel

1800MPa Bolts
No Delayed Fracture

Weldments
• New methods
• Toughness • Fatigue

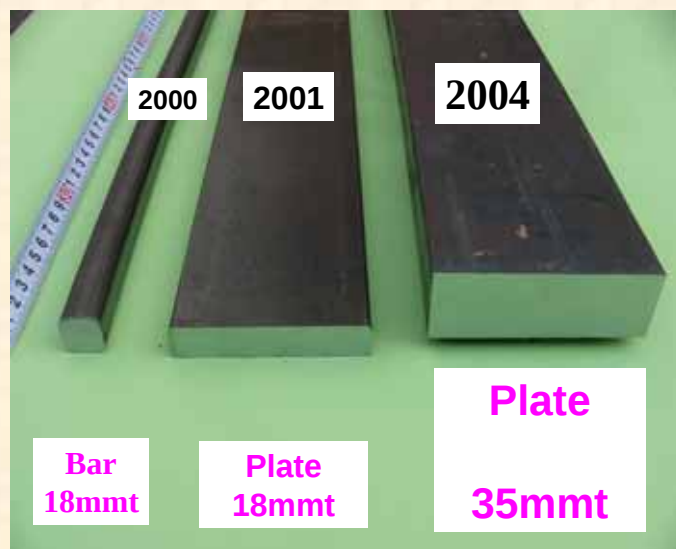


Over 25mm thick



Proto-typing together with End-user side

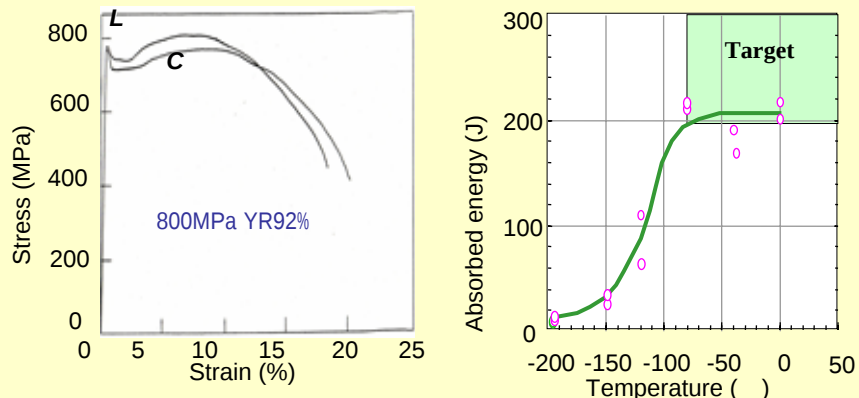
Materials Preparation



Al-Si bearing Ultra-fine Grained Weathering Steel

0.8Al-0.8Si -> Brittle -> Grain refinement

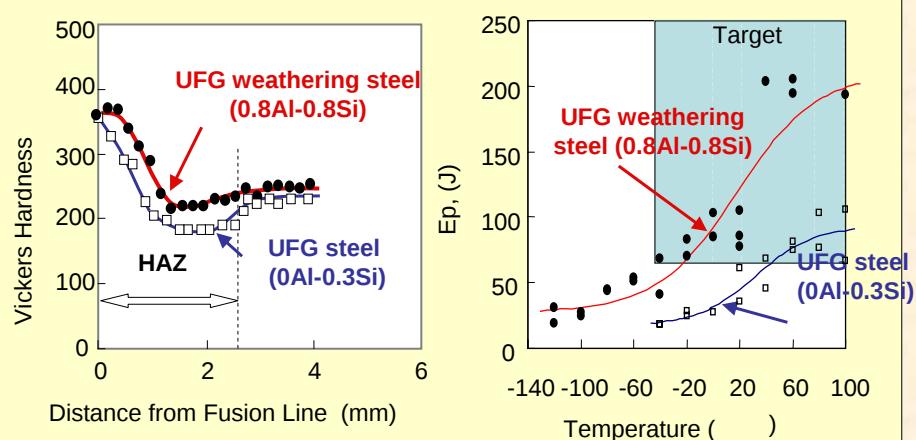
Bulk properties



Al-Si bearing Ultra-fine Grained Weathering Steel

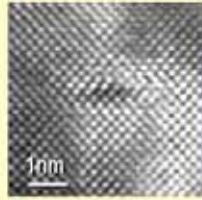
0.8Al-0.8Si -> Brittle -> Grain refinement

Joint properties



1800MPa Bolts

- No delayed fracture with 1800MPa
- Shaping of bolt



Welding

Laser



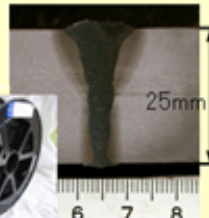
No porosity penetration for Al steel



LTT welding wire free from low temperature cracking



Arc



New Products by Ultra Steels

UFG Wire

Special Skills of Small-size Enterprise

Wire Maker



UFG Wire

Screw Maker



M1.6 Micro-screws

SRC Concepts lead the activities





*Construction and Start-up
of the NAKAYAMA Hot
Strip
and Plate Mill*

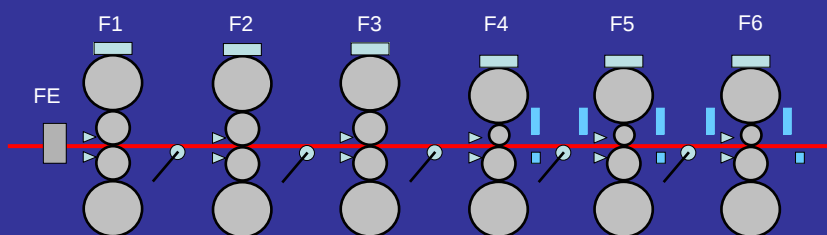




- Producing Hot coils and Plates
- 192m Compact Hot Strip Mill

Capacity	840,000 t/Y	
Slabs	170mm(t) * 600 ~ 1,600m(W)	
Products	Hot coils	Plates
Thickness	1.2 ~ 16mm	12 ~ 40mm
Width	600 ~ 1,550mm	850 ~ 1,500mm
Weight/length	Max.16ton	6 ~ 16m
Finishing	F5/F6	F3/F4

Finishing Mill

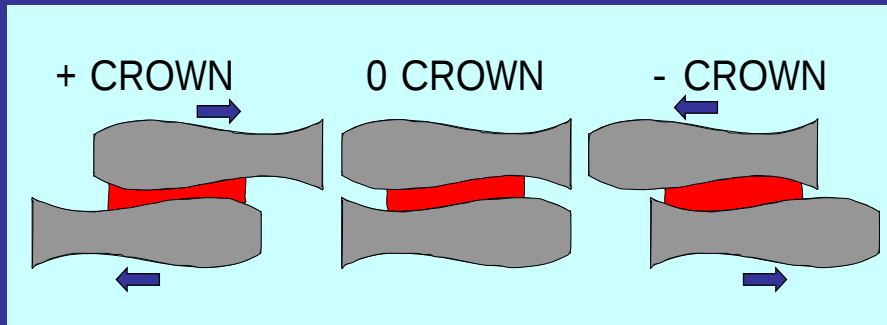


Hydraulic AGC
 Low inertia hydraulic Looper
 Roller bearing for BUR
 High rigid Mill
 CVC technology
 SRDD technology
 Roll lubrication by Grease
 Entry Edger (FE)
 Curtain Wall Cooling
 F 6 delivery Feed rollers



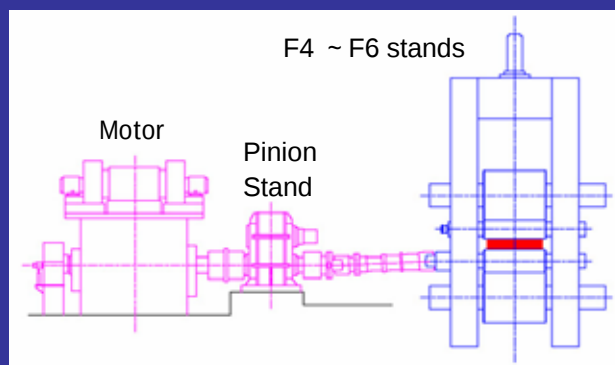
Accuracy
 Gauge
 Width
 Crown

CVC(Continuously Variable Crown)

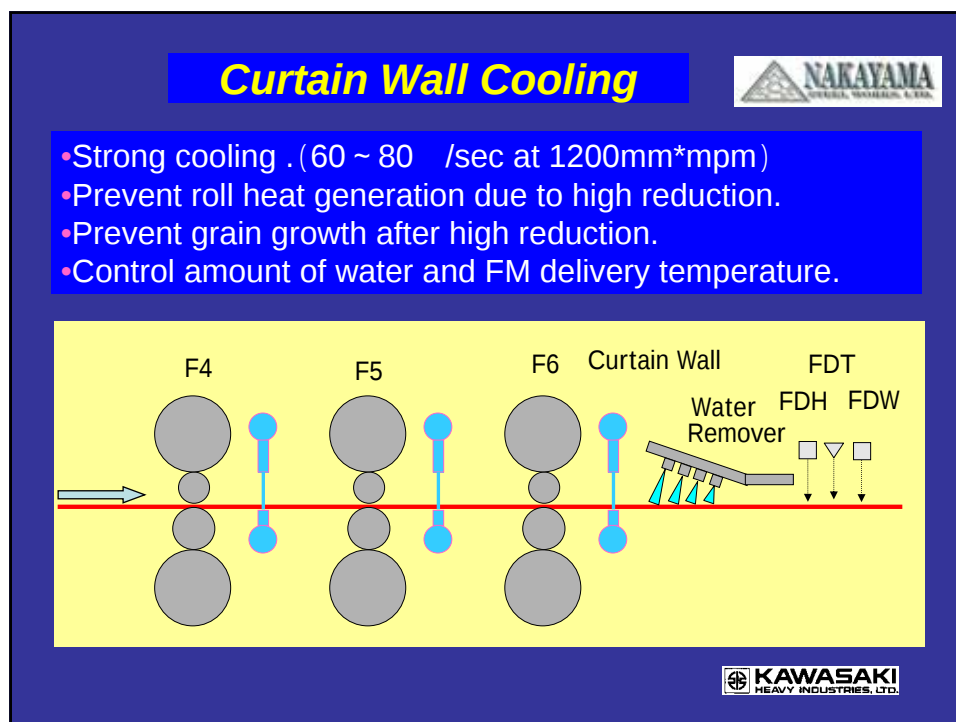
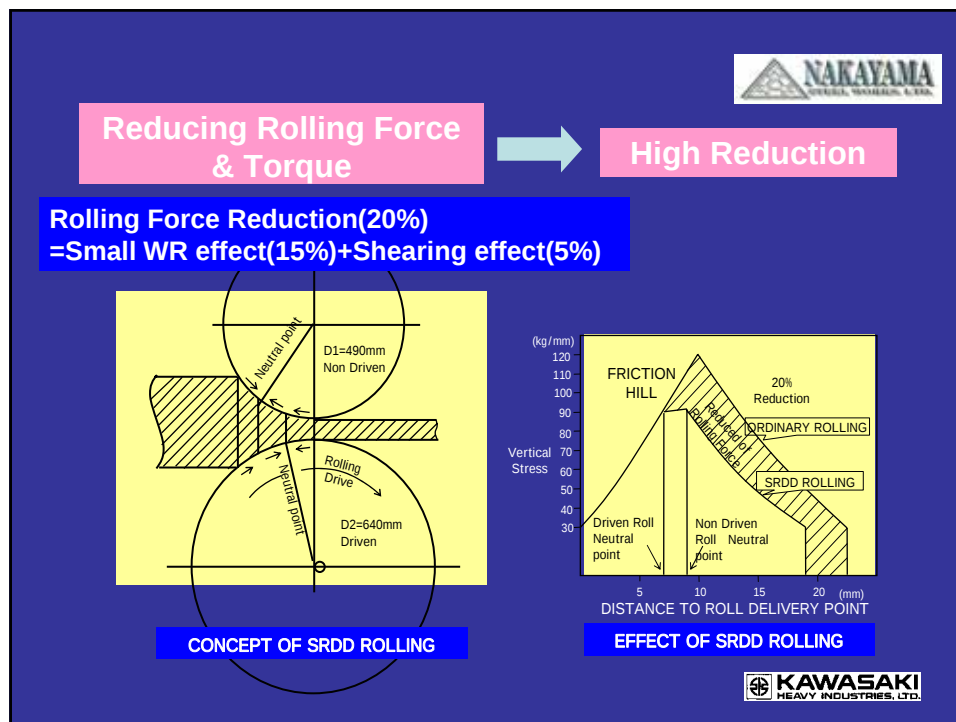


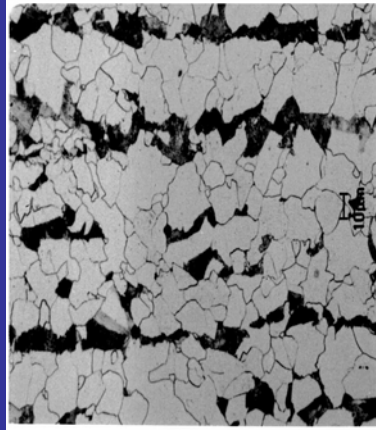
SRDD Technology

SRDD : Single Roll Drive With Different Diameter

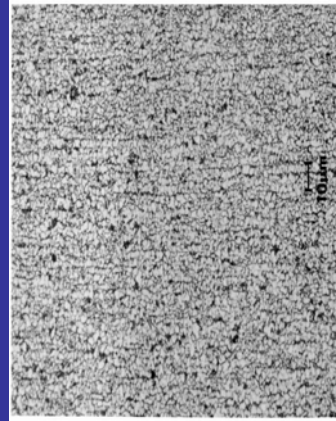


BUR
WR Φ 490/420
WR Φ 620/550
BUR



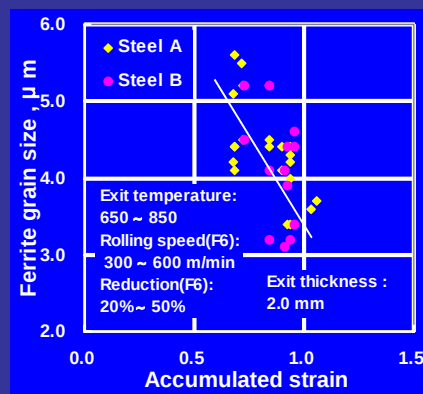
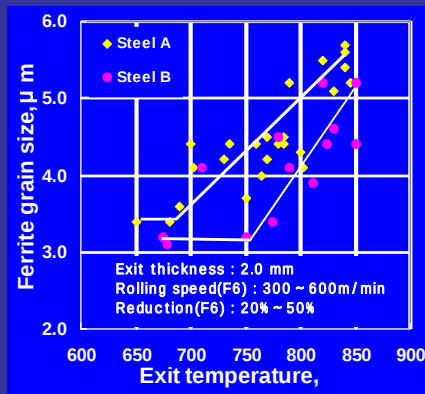


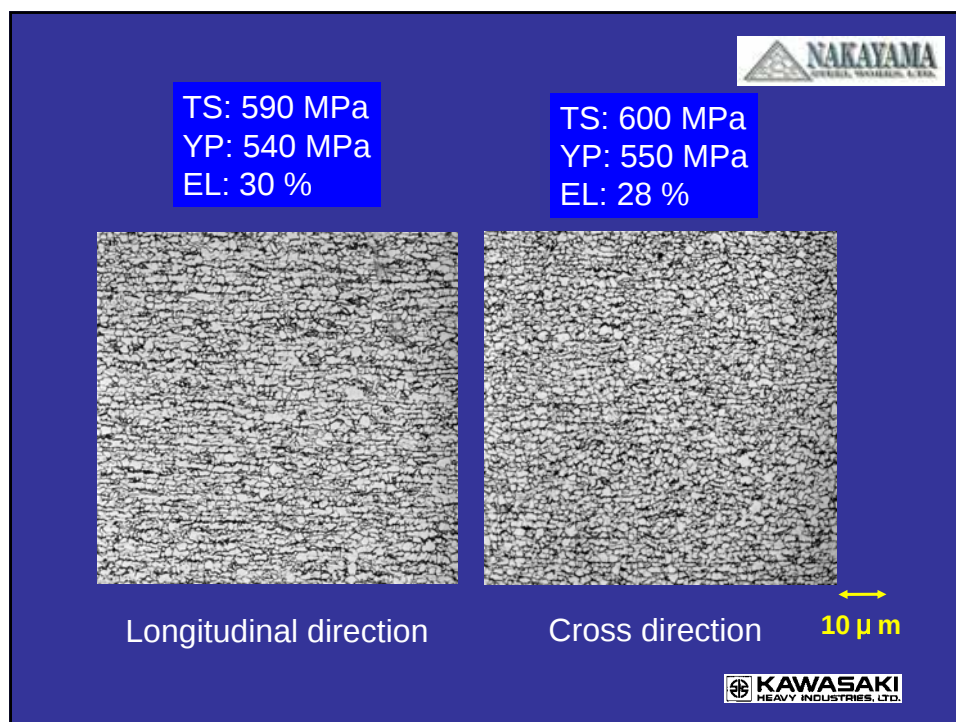
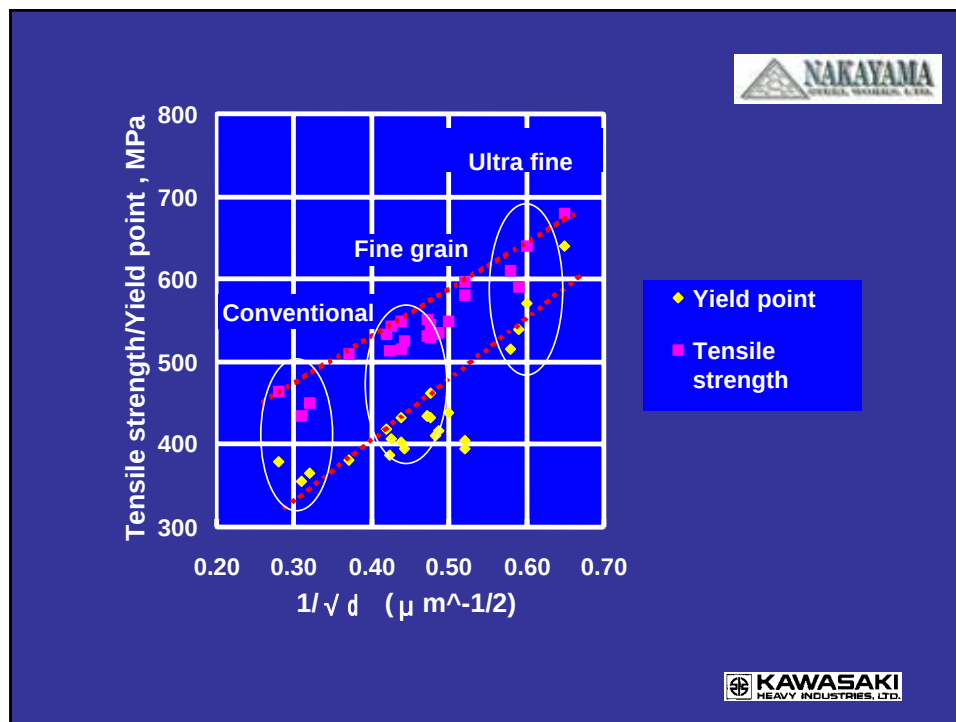
Conventional steel
Ferrite grain size : 10 ~ 20 μm



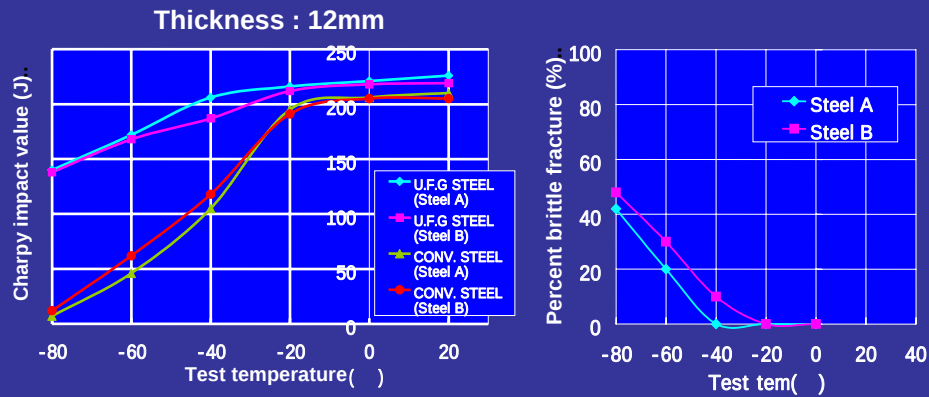
ULTRA FINE GRAIN STEEL
Ferrite grain size : 3 μm

10 μm



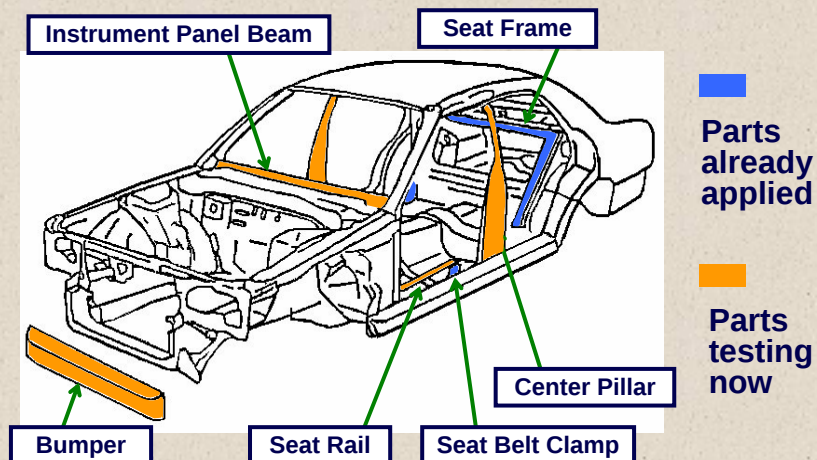


FINE GRAIN STEEL 12mm



New Products by Ultra Steels

ex) Automobile Parts
by courtesy by Nakayama



Future: Long-term Stability

ERES Initiatives

<Environment-Resources-Energy-Safety>

Steel Data Network
For Advanced Structural Steels

Network core = CISRI-NIMS

Stress-Strain
Chemical Comp.
Microstructure

Creep
Corrosion
Delayed Fracture
Fatigue

Evaluation Method
Round-robin tests

New Topics for Future

High Temperature Alloys

High-Performance Hot Coil

NO-QT Special Steels