IMPaCT

EPSRC Centre for Doctoral Training in Innovative Metal Processing (IMPaCT)

A Best Practice Guide for Welding of Newly Developed Duplex Stainless Steel (UNS S82551) Seamless Pipes

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Outline

1. Introduction

2. Material design concept
- Concept of Material Design for New Alloy Grade
- Category of newly developed UNS S82551

3. Performance of newly developed UNS S82551
- Base metal properties and weldability

4. Conclusion

5. Future plan

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1.Introduction-Background

Martensitic and duplex stainless steels have been exploited by a wide range of industrial sectors for many years because of their availability, workability, strength, toughness and corrosion resistance.

In slightly H_2S-containing environments, super martensitic stainless steel (13Cr SMSS) pipes have been used in the oil and gas industries for many years.

In early 2000's, girth welded joints in 13Cr SMSS were reported to be susceptible to SCC at HAZ in sweet conditions. **Post weld heat treatment (PWHT) is effective at preventing SCC.**

However, PWHT could have a negative impact on the efficiency of pipe laying operations in some cases.

1.Introduction-Background

Duplex stainless steels: 22Cr duplex(e.g. UNS S31803)
25Cr super duplex(e.g. UNS S39274)

- Applicable in as-welded condition (No PWHT)
- Widely used for flow line applications

However, these higher grade DSSs incur greatly increased cost

A new DSS containing 25Cr-5Ni-1Mo-2.5Cu has been developed (UNS S82551)*, which can be used in the as-welded condition in slightly sour conditions and has a lower cost than the existing DSS grades.

**D. Motoya, et.al ; Eurocorr 2012*

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2. Material design concept

Concept of Material Design for New Alloy Grade

S13Cr : Required PWHT for SCC resistance

↓

Enhancement of passive film stabilization

↓ **Add Cr**

Difficult to maintain martensitic structure

↓

Existing DSS: Contain more than 3Mo for SSC resistance

↓

Used for low amount of H_2S environment

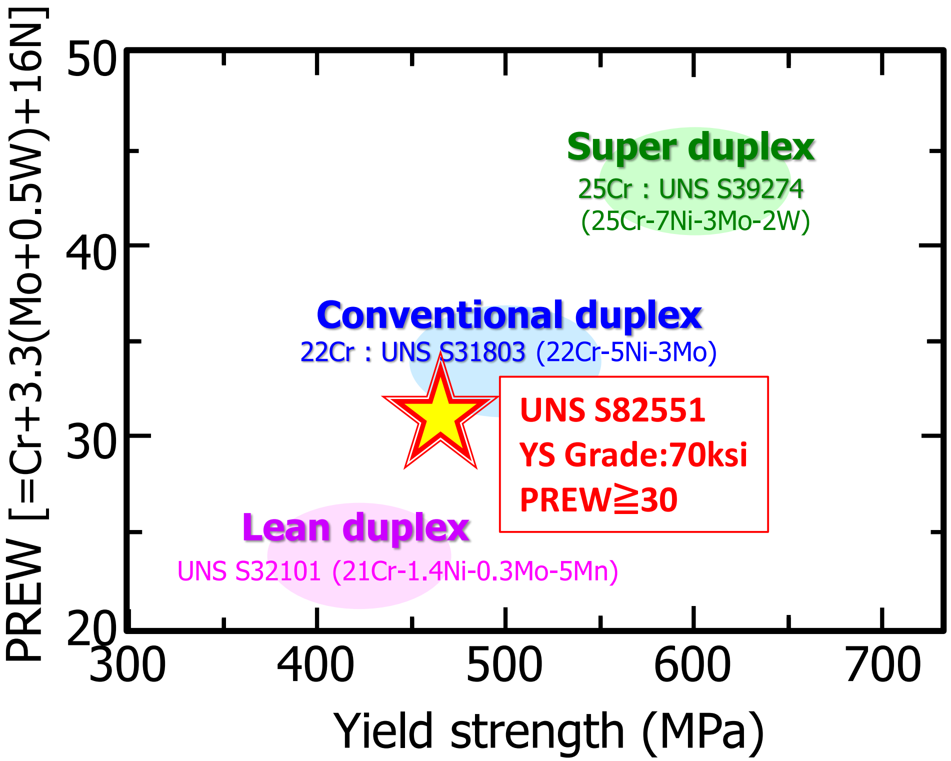
Lower cost than existing duplex stainless steel

↓ **Reduce Mo**

Material Design of SM70-2505 (UNS S82551)

2. Material design concept

Category of newly developed UNS S82551



<Chemical composition of UNS S82551>

25Cr-5Ni-1Mo-1Mn-2.5Cu-0.2N (mass%)

New material can be categorized **as "Modified" grade** from conventional duplex

<Development target>

- Superior corrosion resistance without PWHT (>13CrSMSS)
- Lower price index than existing DSS ((>22CrDSS, 25CrSDSS))

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3. Performance of newly developed UNS S82551

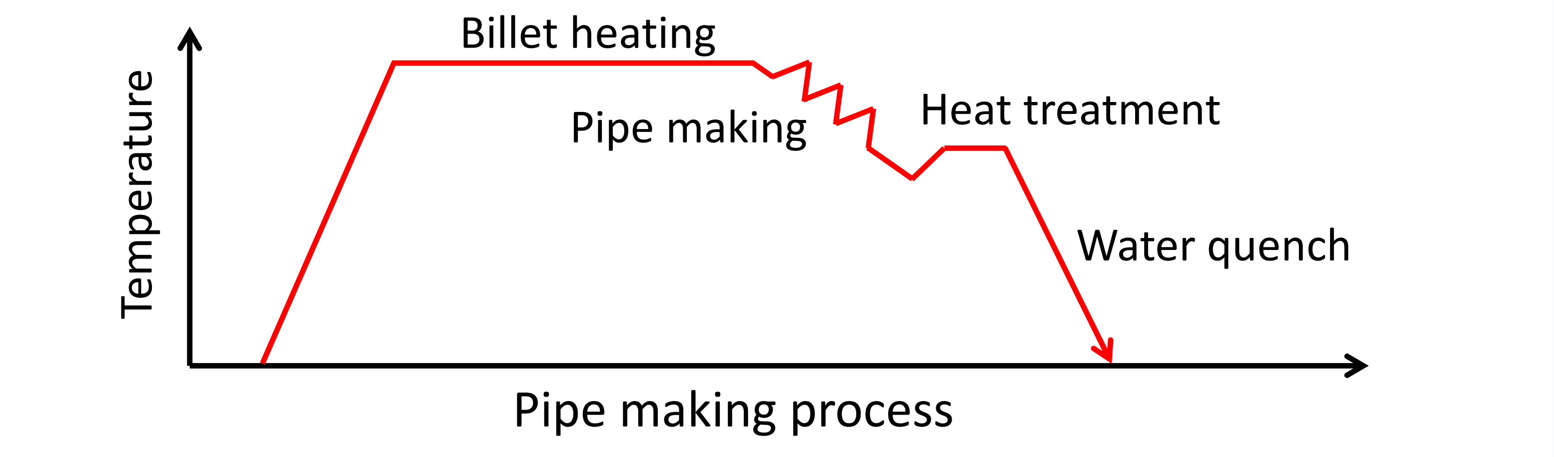
Base metal properties

- Chemical compositions of production pipe for UNS S82551

C	Mn	Cu	**Ni**	**Cr**	**Mo**	N	PREW
< 0.02	1.09	2.45	**4.96**	**24.95**	**1.09**	0.19	31.6

- Pipe making process

Pipe making : Rotary single piercing - mandrel mill process
Heat treatment : Solution heat treatment



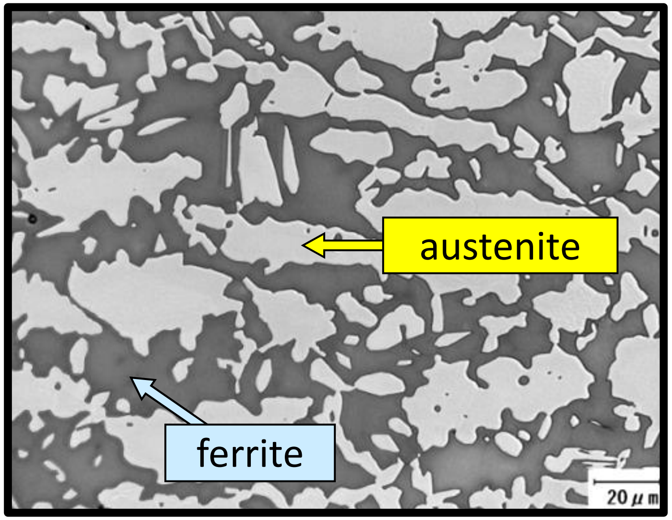
3. Performance of newly developed UNS S82551

Base metal properties

- Chemical compositions of production pipe for UNS S82551

C	Mn	Cu	Ni	Cr	Mo	N	PREW
< 0.02	1.09	2.45	**4.96**	**24.95**	**1.09**	0.19	31.6

- Microstructure



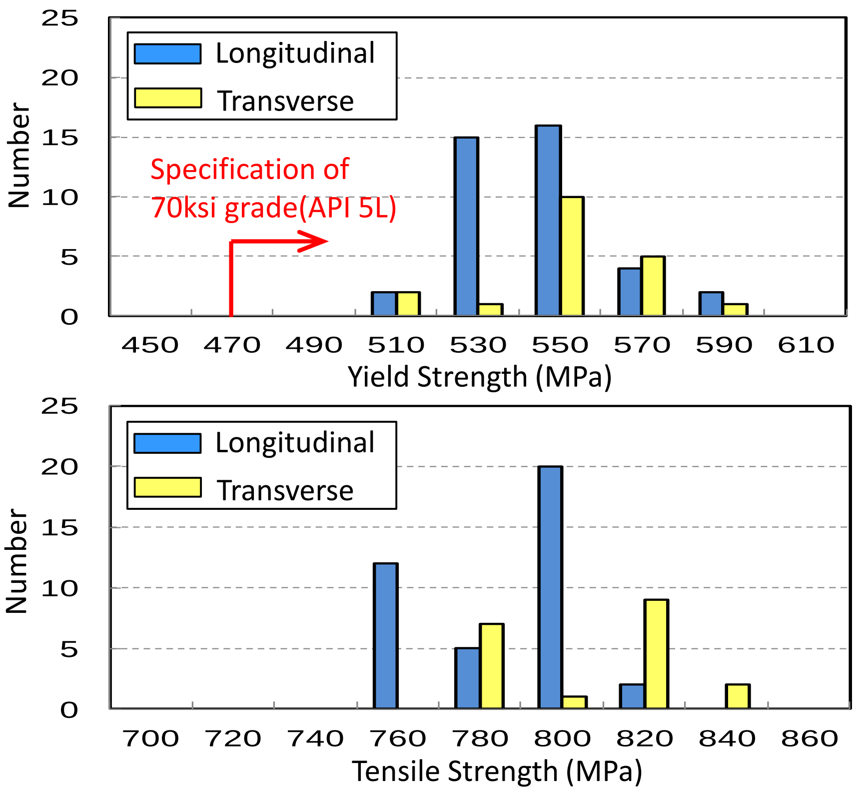
[Phase balance]
Ferrite : Austenite
approx. 50 : 50 (%)

[Sigma phase]
No Sigma phase precipitation

3. Performance of newly developed UNS S82551

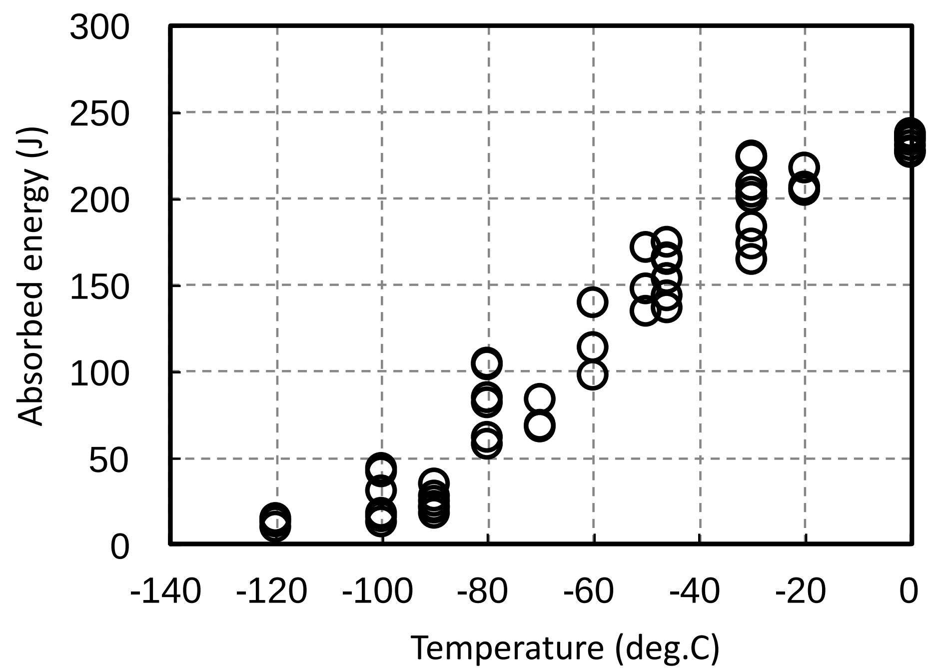
Base metal properties

[Tensile properties]



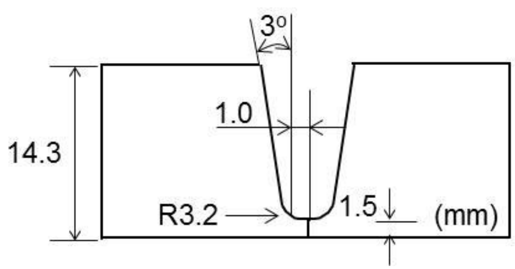
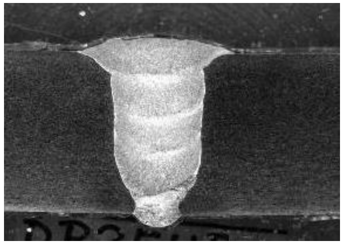
[Toughness properties]

Test Specimen : 10 x 10, 2mm V notch
Direction : Transverse



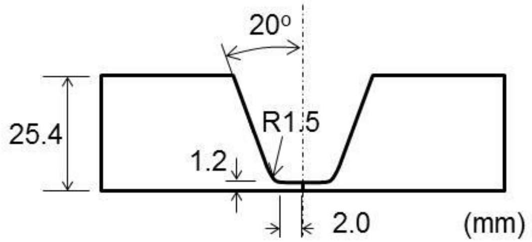
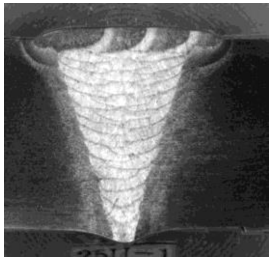
3. Performance of newly developed UNS S82551

Welding record for UNS S82551(OD273.1 x WT14.3 (mm)) by Nippon steel

Process	GMAW			Position: <ASME 1G>			
	Pass	Filler Metal	Process	Current (Amps)	Volts	Speed (cm/min)	Heat Input (kJ/mm)
	Root 1	25Cr SDSS	GMAW	148	20.6	42.8	0.43
	Fill 2-4	25Cr SDSS	PGMAW	172-185	20.4-21.2	37.4-38.5	0.57-0.59
	Cap 5	25Cr SDSS	PGMAW	119	19.9	26.0	0.55
Joint design				Macro Photo			
Preheat	None			Interpass temp.		150°C max.	
Shielding gas	69%Ar+30%He+1%CO_2(30 L/min)			Back shield gas		Ar 100% (5 L/min)	
PWHT	Not applied						

3. Performance of newly developed UNS S82551

Welding record for UNS S82551(OD273.1 x WT25.4 (mm)) by Nippon steel

Process	**GTAW**			**Position: <ASME 1G>**			
	Pass	**Filler Metal**	**Process**	**Current (Amps)**	**Volts**	**Speed (cm/min)**	**Heat Input (kJ/mm)**
	Root 1	**25Cr SDSS**	**GTAW**	**100**	**12**	**10**	**0.72**
	Fill 2-30	**25Cr SDSS**	**GTAW**	**130-170**	**12-14**	**10**	**0.94-1.43**
	Cap 31-34	**25Cr SDSS**	**GTAW**	**170**	**14**	**10**	**1.43**
Joint design				**Macro Photo**			
Preheat	**None**			**Interpass temp.**		**150°C max.**	
Shielding gas	**Ar 100% (20 L/min)**			**Back shield gas**		**Ar 100% (5 L/min)**	
PWHT	**Not applied**						

3. Performance of newly developed UNS S82551

Microstructure

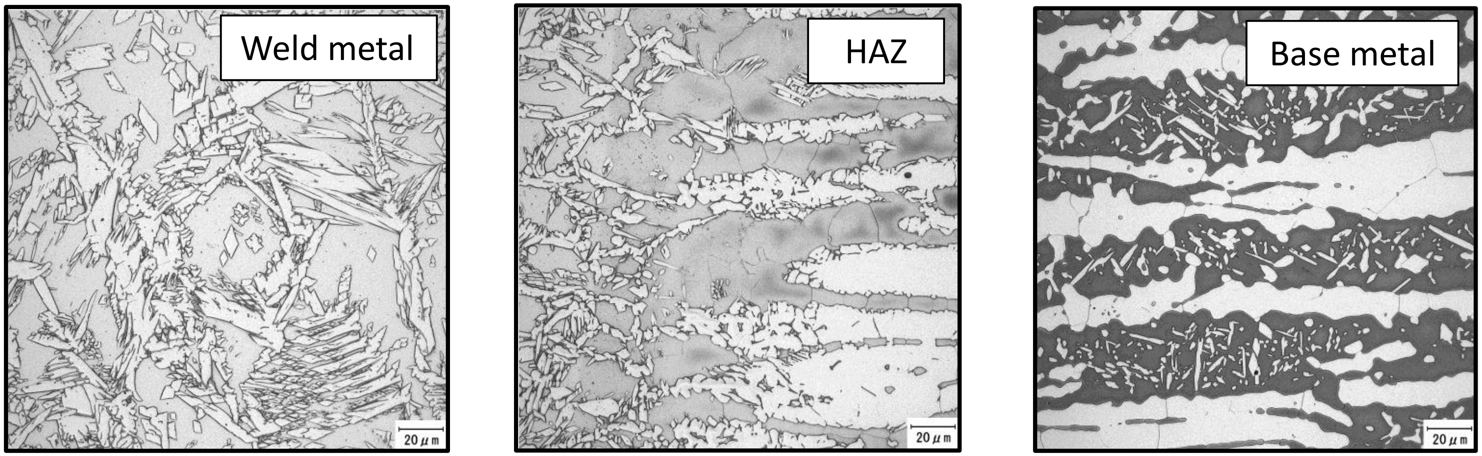


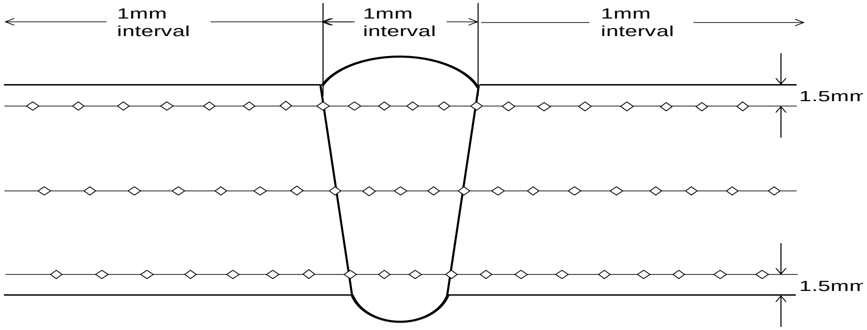
Photo. GMAW welded joint of UNS S82551 (OD273.1mm x WT14.3mm)

Pipe size	Fill		Ferrite Count		
	Process	Consumable	Position	ASTM E562	DNV OS F101 requirement
OD273.1xWT14.3	GMAW	25Cr SDSS	Weld metal	**45%**	WM/HAZ: **35～65%**
			HAZ	**62%**	
OD273.1xWT25.4	GTAW		Weld metal	**46%**	
			HAZ	**58%**	

3. Performance of newly developed UNS S82551

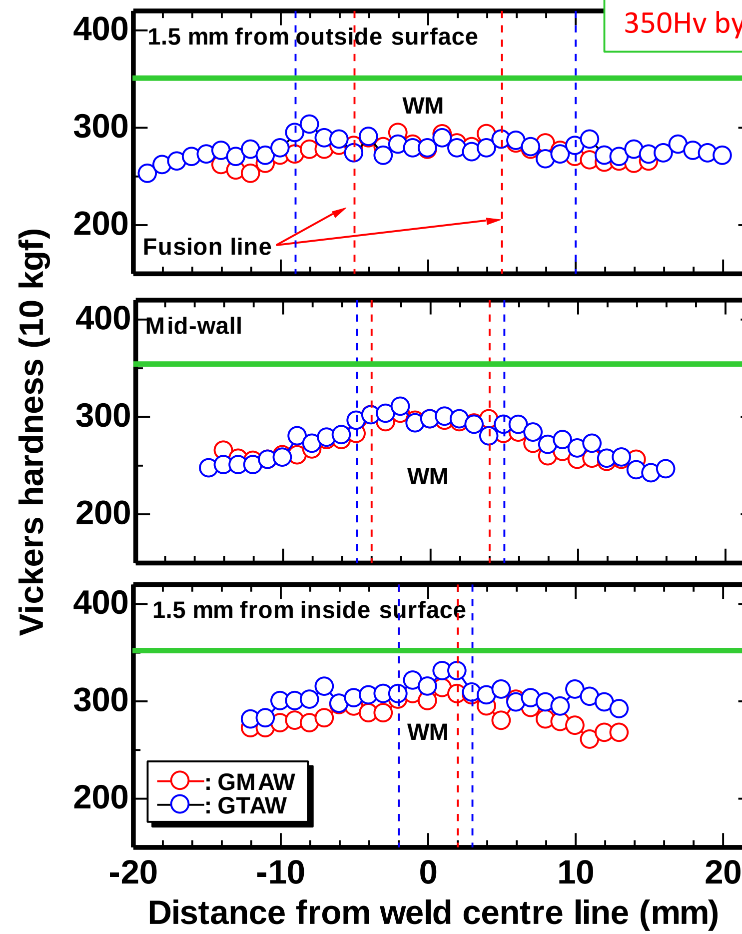
Hardness distribution

Test procedure : ASTM E384
Number of specimens : 2 specimens
Location : 1.5mm from both surfaces and 1/2 WT



Position	Maximum hardness (Hv10) (GMAW/GTAW)		
	Outside	Mid-wall	Inside
WM	294/303	303/310	313/331
HAZ	289/294	309/296	306/312
DNV OS F101 requirement	Max. 350		

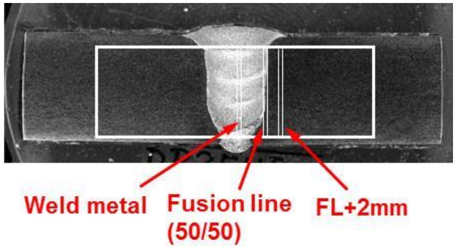
Maximum hardness 350Hv by DNV OS F101

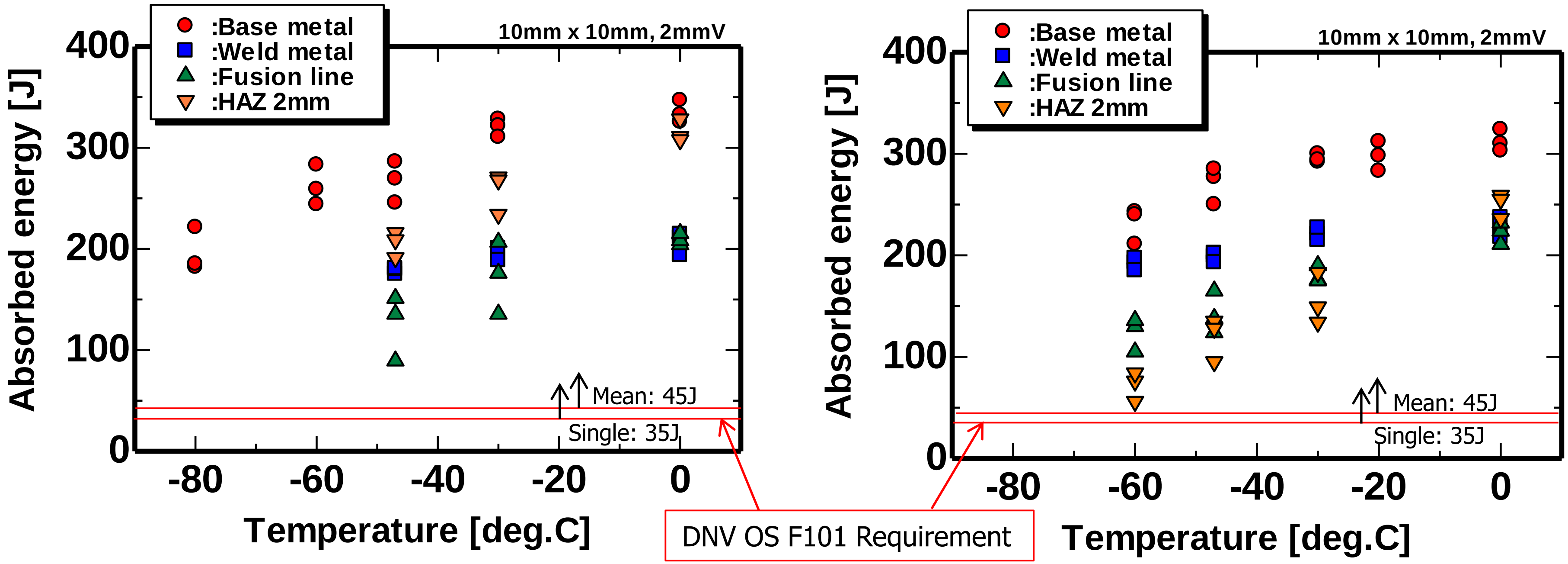


3. Performance of newly developed UNS S82551

Charpy impact properties

Test procedure: ASTM A370
Test specimen : 10 x 10mm
Direction : Longitudinal
Test temp. : 0, -30, -47, -60, -80 deg.C





(a) GMAW Joint (OD273.1xWT14.3)

(b) GTAW Joint (OD273.1xWT25.4)

3. Performance of newly developed UNS S82551

SCC and SSC resistance

Test Method : 4 point bent beam test
Specimen Size : 115^L x 15^W x 3^t (mm)
Position of Weld metal : Center of specimen
Inner surface : As intact
The other surface : 600# paper finish
Applied stress : 100% AYS
Number of specimens : Two

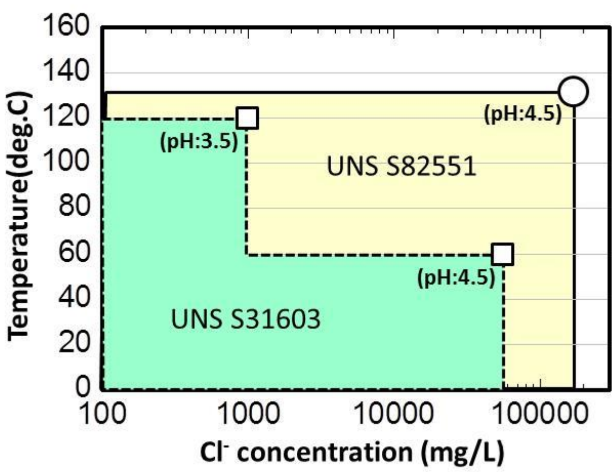
Photo: Specimen of corrosion test

Condition	Mark	Solution	pH	H_2S(MPa)	CO_2(MPa)	Temp. (deg.C)
SCC	X1	25wt%NaCl (Cl^-:180,000mg/L)	4.5	0.004	0.096	130
SSC	Y1					90
	Y2	1.6wt%NaCl (Cl^-:10,000mg/L)	4.0			
	Y3	0.17wt%NaCl (Cl^-:1,000mg/L)	3.5			

3. Performance of newly developed UNS S82551

SCC resistance

Material	Welding procedure		PWHT	Test condition		SCC results
	Method	Consumable		Cl^-[mg/L]	Temp.[^{o}C]	
UNS S82551	GMAW (1G)	25Cr SDSS	No	180,000	130	No SCC
Weldable 13Cr	GMAW (5G)	25Cr SDSS	No	180,000	110	SCC
			650^{o}Cx5min			No SCC



◯:No SCC for UNS S82551
☐:No SCC for UNS S31603*

*B.K.Holmes, et.al
Corrosion/2010, Paper No.10308

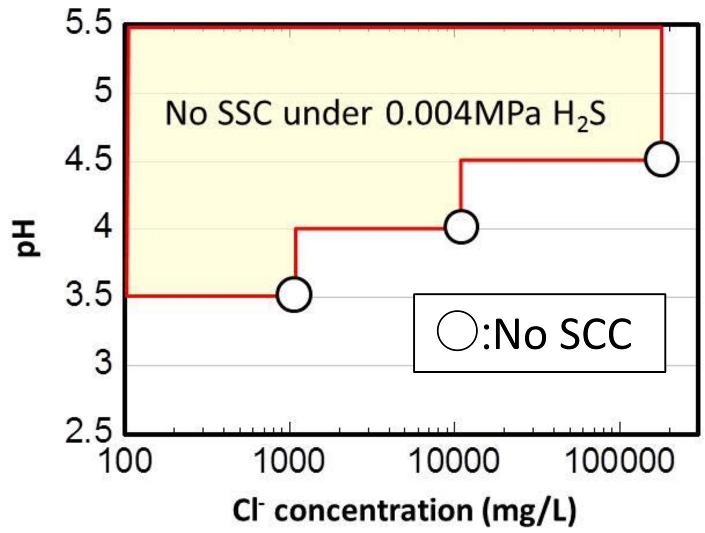
Applicable with as-welded condition

The application at wider region of temperature and Cl- than 316L can be expected.

3. Performance of newly developed UNS S82551

SSC resistance

Material.	Solution	pH	H_2S (MPa)	Temp.	Results
UNS S82551	0.17%NaCl (Cl^-:1,000mg/L)	3.5	0.004	90 deg.C	**No SSC**
	1.6%NaCl (Cl^-:10,000mg/L)	4.0			
	25%NaCl (Cl^-:180,000mg/L)	4.5			



UNS S82551 can be used in slightly sour conditions(≤0.004MPa) and has a lower cost than the existing DSS grades.

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4. **Conclusion**

5. **Future plan**

4. Conclusion

- A new duplex stainless steel containing 25mass%Cr- 5mass%Ni- 1mass%Mo-2.5mass%Cu has been developed (UNS S82551), which is intended for flowline application in slightly sour environments.
- The characteristic property of this material is **SSC resistance in slightly sour conditions despite a lower molybdenum content** than that of the existing duplex stainless steels, and **it can be used in the as-welded conditions** because it is duplex stainless steels rather than super-martensitic stainless steel.
- The as-welded joints of this material provide sufficient mechanical properties as well as corrosion resistance in slightly sour conditions, therefore this material is considered to be **the most cost effective material** depending on the corrosion resistance required.

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Nippon Steel and The Welding Institute(TWI) are collaborating on a development programme to establish best practice guide for welding of this new alloy grades.

[This presentation]

Part 1: To evaluate the feature of developed DSS (Nippon steel in-house testing)

- Alloy design
- Performance of material (Mechanical and corrosion properties)

[Future plan]

Part 2: To investigate the effect of welding condition on intermetallic precipitation, microstructure, mechanical and corrosion properties (conducted at TWI)

- The maximum heat input and interpass temperature limits for welding
- Modelling approach (Metallurgical model with welding heat transfer)

Thank you for your attention.