Doc.No. 032013-N116

Flux cored filler rod for Normal Duplex Stainless Steel

TG-X2209

KOBE STEEL, LTD.

WELDING BUSINESS

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Flux cored filler rod for Normal Duplex Stainless Steel ; TG-X2209

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TG-X2209 is flux cored filler rod designed for root pass welding of 22Cr type duplex stainless steels such as S31803 and S32205.

TG-X2209 can eliminate gas purging for back shielding root pass weld in one-side TIG pipe welding.

1 General instruction

1.1 Product specification

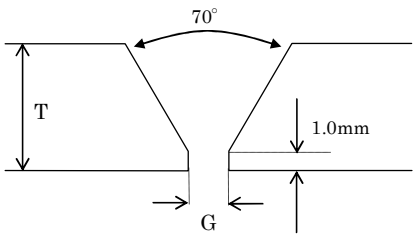
Table 1-1 Product specification

Product name	*Product size (Diameter×Length)*	*Classification*
TG-X2209	2.2mmφ×1000mm	None

1.2 Characteristics on Usage

Usability of TG-X2209 is almost same as conventional TG-X series. In order to get good bead shape of root pass, root gap has to be wider by 0.5~1.0mm compared to conventional TG-X series.

Table 1-2 Proper groove condition

Groove Preparation			
Plate thickness (T)	4mm	6mm	≧10mm
Root gap (G)	2.5mm	3.0mm	3.5mm

Shielding gas : 100%Ar

Back shielding gas: Not needed

Slag composition : Composite oxide. Ti, Ca, and Si etc.

2 Properties of all-weld metal

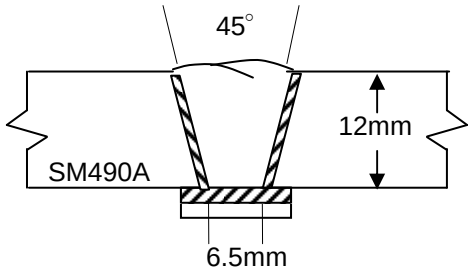
All-weld metal was produced, and its chemical composition, mechanical properties and corrosion resistance were evaluated.

2.1 Welding conditions

Welding conditions in producing all-weld metal are shown in Table 2-1.

Table 2-1 Welding conditions for all-weld metal

Welding wire	*TG-X2209, 2.2mm ϕ*
Polarity	DCEN
Welding position	Flat
Welding current	200A
Arc voltage	14V
Welding speed	12-14cm/min
Heat input	12-14kJ
Shielding gas	100%Ar 15L/min
Preheat	RT
Inter-Pass temperature	<150℃
Pass sequence	8layers-16 passes



Beveled surface is buttered by TG-X2209.

2.2 Chemical compositions of all-weld metal

Chemical compositions of all-weld metal are presented in Table 2-2.

Table 2-2 Chemical composition (%), PRE and ferrite content of all-weld metal

	C	*Si*	*Mn*	*P*	*S*	*Cu*	*Ni*	*Cr*
TG-X2209	0.015	0.64	0.87	0.015	0.003	0.03	9.48	23.06

	Mo	*Nb*	*N*	*PRE*	*FNW*	*FF*
TG-X2209	3.34	0.018	0.15	36.5	47	41

PRE: Cr+3.3Mo +16N
FNW: Ferrite Number (FN) by WRC1992 Diagram
FF: Ferrite Number (FN) by Ferrite Scope (*Fischer Ferrite Scope MP-30*)
(Average value among 10 measurements)

2.3 Tensile properties of all-weld metal

Tensile test result conducted at ambient temperature 20℃ is presented in Table 2-3.

Table 2-3 Tensile properties of all-weld metal

	0.2% P.S. *(MPa)*	*T.S.* *(MPa)*	*EL* *(%)*
TG-X2209	603	811	32

(Diameter: 6.0mm, G.L.: 24.0mm)

2.4 Charpy impact properties of all-weld metal

Charpy impact tests (10 x 10mm, 2mm.-V notch) were conducted at -50℃. Absorbed energy is presented in Table 2-4.

Table 2-4 Absorbed Energy at Charpy impact test

	Test temp at -50℃
TG-X2209	139, 135, 139 Avg. 138J

2.5 Pitting Corrosion Test of all-weld metal -ASTM G48 Practice E-

Critical Pitting Temperature (CPT) was determined as 25℃ by ASTM G48 Practice E *"Critical pitting temperature test for stainless steels".*

Table 2-5 Pitting Corrosion Test result by G48 E

Size of Specimen	*Test Solution*	*Time of exposure*	*CPT*
3 x 10 x 75mm	6%$FeCl_3$ + 1%HCl solution aq.	24 hrs	25℃

3 Properties of butt weld joint

V-groove butt weld joint of Normal duplex stainless steels were produced by TG-X2209 and filler solid wire TG-S2209 (AWS A5.9/5.9M ER2209) at flat position. TG-X2209 was used for root pass welding and TG-S2209 was used for the other passes.

3.1 Base metal and TIG Wire

Table 3-1 Chemical compositions (%) of base metal and TIG wire

	C	*Si*	*Mn*	*P*	*S*	*Cu*	*Ni*	*Cr*
Base metal S31803	0.011	0.59	1.80	0.024	<0.0005	0.15	5.79	22.70
TG-S2209	0.015	0.39	1.69	0.017	0.0014	0.10	8.66	22.57

	Mo	*Nb*	*N*	*PRE*	*FNW*
Base metal S31803	3.07	0.012	0.17	35.6	-
TG-S2209	3.07	<0.005	0.17	35.4	44

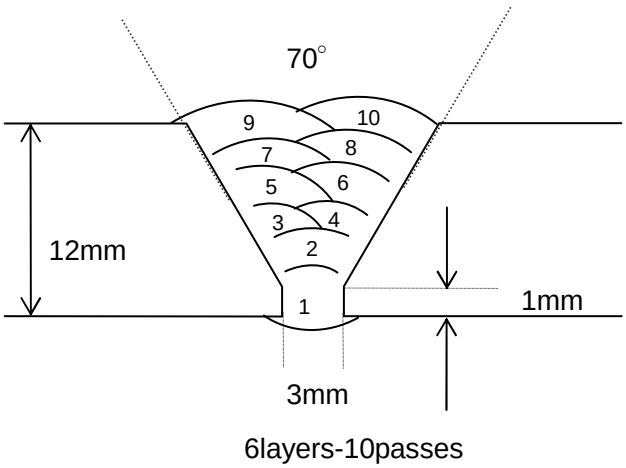
PRE: Cr+3.3Mo +16N FNW: Ferrite Number (FN) by WRC1992 Diagram

3.2 Welding conditions

Table 3-2 Welding condition

Layer	*1st*	*2nd~6th*
Welding wire	TG-X2209 2.2mm ϕ	TG-S2209 2.4mm ϕ
Welding current	100A	150A
Arc voltage	11V	12V
Welding speed	4cpm	7-10cpm
Heat input	17kJ/cm	10-16kJ/cm
Shielding gas	100%Ar 15L/min	
Back Shielding gas	**None**	
Polarity	DCEN	
Welding position	Flat	
Preheat	RT	
Inter-Pass temperature	<150℃	

Groove configuration



6layers-10passes

3.3 Appearance and cross sectional view of weld joint

Weld bead appearance and macro structure of cross section of weld joint are presented in Table 3-3. Ferrite number (FN) measured by Ferrite Scope is also shown in Table 3-4. Average value among 10 measurements is reported.

Table 3-3 Weld bead appearance and macrostructure

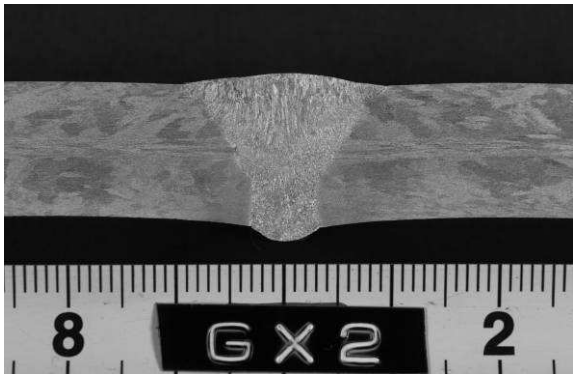
Weld bead (Cap pass)	
Weld bead (Root pass)	
Macro structure	

Table 3-4 Ferrite Number measured by Ferrite Scope (FN)

Cap pass	*52*
Root pass	31

3.4 Radiographic test of weld joint

Weld joint was subject to radiographic test to evaluate the soundness of the weld metal. Both ends were exempt and 250mm length of the center of the weld bead was evaluated.

Table 3-5 Radiographic test

Liner indication	*Round indication*
None	<1.0mm×2

3.5 Side-bend test of weld joint

Side-bend test was conducted in accordance with AWS B4.0/4.0M with the test piece thickness, t=9.5mm as bending radius is equal to 2t. Test piece was bended 180 degrees. The results are shown in Table 3-6.

Table 3-6 Side bend test result

Bended specimen	*Defect*	*Result*
	None	Satisfactory

3.6 Transversal tensile test of weld joint

Transverse tensile test was conducted.

Table 3-7 Transverse tensile test result

Size	*Tensile stress (MPa)*	*Fractured location*	*Appearance of test specimen*
12.7mm x 38mm (t x w)	816	Base metal	

3.7 Pitting Corrosion Test of weld joint

The test was according to ASTM G48 Practice E *"Critical pitting temperature test for stainless steels"*

Two test specimens were sampled from the area including weld metal, HAZ, and base metal.

Test result is shown in Table 3-8.

Test Solution	*Time of exposure*	*Test temperature*
6%FeCl3 + 1%HCl solution aq.	24 hrs	22℃

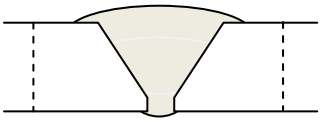
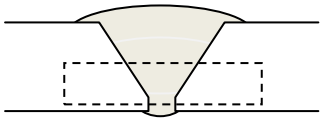
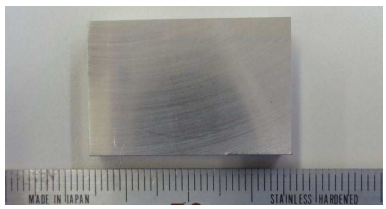
Type of specimen	I	II
Location of specimen	 Size: 12 x 20 x 30mm	 Size: 5 x 20 x 30mm
Appearance of specimen		

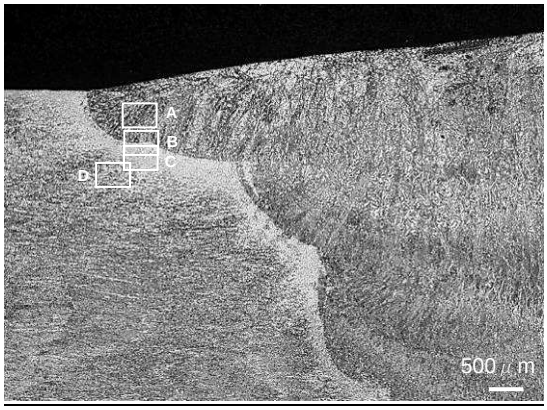
Table 3-8 Pitting Corrosion Test result by G48

Type of specimen	*Corrosion rate* (mdd)	(g/m^2・h)
I	35.8	0.149
II	1.7	0.007

Corrosion rate (m**dd**)=weight loss (**mg**) / [specimen area (**dm^2**) x time (**day**)].

3.8 Microstructure of weld joint

Microstructures of weld joint are shown in Fig.3-1 and 3-2.



Location of observation

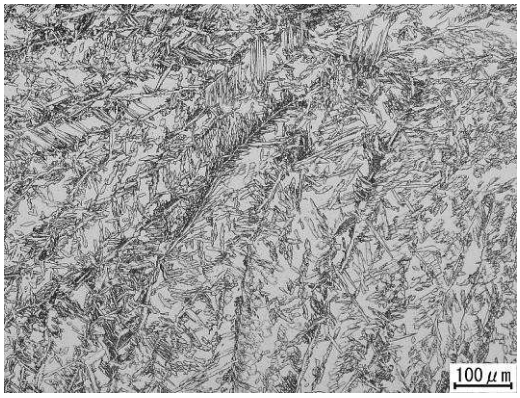
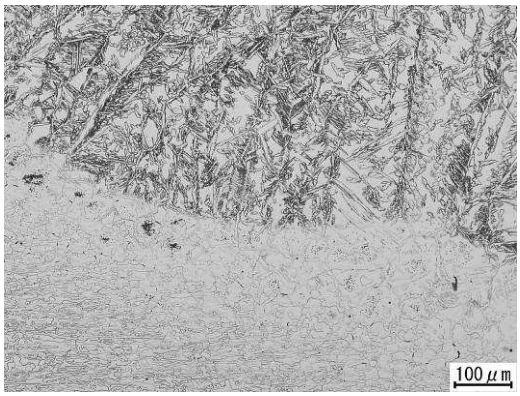
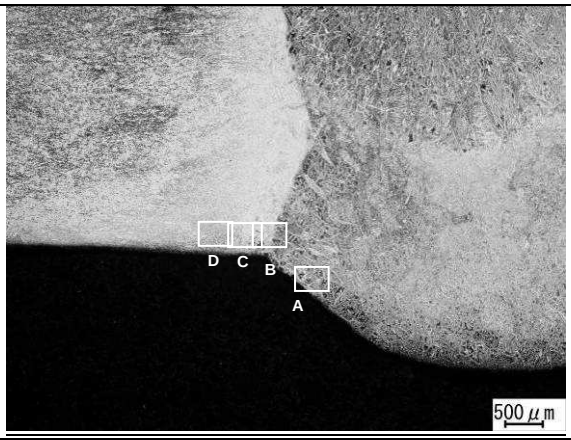
A:Weld Metal	B:Bond
	
C:HAZ	D:Base metal
	

Fig.3-1 Microstructure of weld joint (Cap pass)



Location of observation

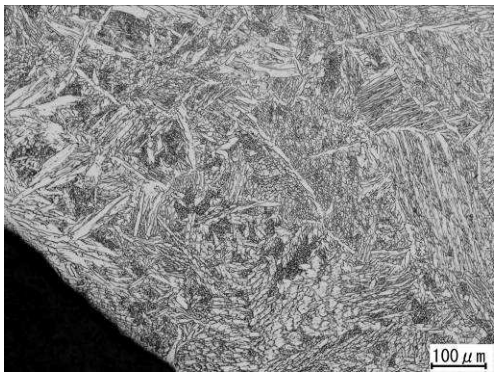
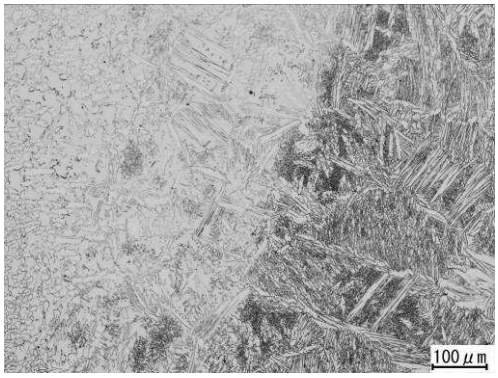
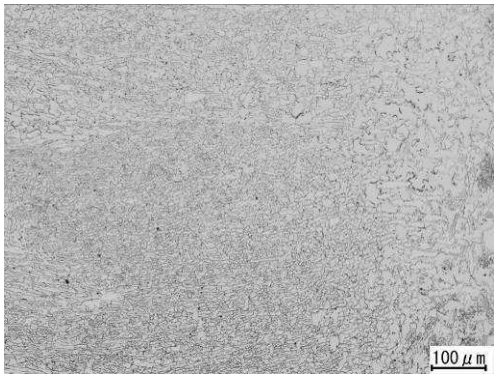
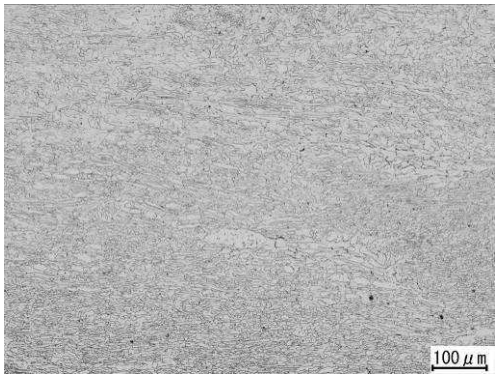
A:Weld Metal	B:Bond
	
C:HAZ	D:Base metal
	

Fig.3-2 Microstructure of weld joint (Root pass)

4 Properties of butt weld joint pipe

V-groove butt weld joint of Normal duplex stainless steels pipe were produced by TG-X2209 and TG-S2209 at all position. TG-X2209 was used for root pass welding and TG-S2209 was used for the other passes.

4.1 Base metal and TIG Wire

Table 4-1 Chemical compositions(%) of base metal and TIG wire

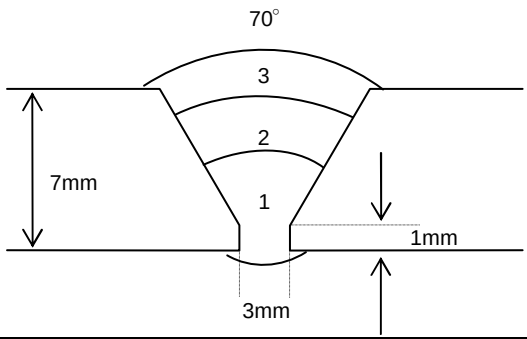
	C	*Si*	*Mn*	*P*	*S*	*Cu*	*Ni*	*Cr*
Base metal S31803	0.023	0.59	1.72	0.025	<0.0005	0.10	5.24	22.50
TG-S2209	0.015	0.39	1.69	0.017	0.0014	0.10	8.66	22.57

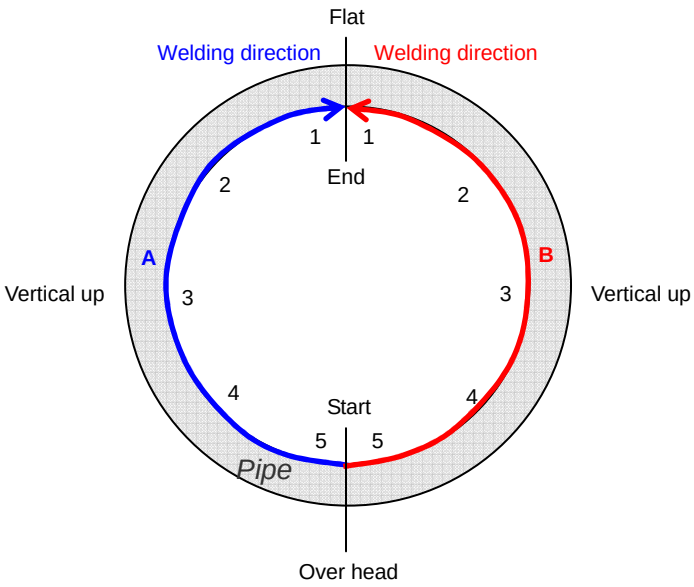
	Mo	*Nb*	*N*	*PRE*	*FNW*
Base metal S31803	3.29	<0.005	0.15	35.8	-
TG-S2209	3.07	<0.005	0.17	35.4	44

PRE: Cr+3.3Mo +16N FNW: Ferrite Number (FN) by WRC1992 Diagram

4.2 Welding condition

Table 4-2 Welding conditions

Layer	*1st*	*2nd*	*3rd*
Welding wire	**TG-X2209 2.2mm ϕ**	**TG-S2209 2.4mm ϕ**	**TG-S2209 2.4mm ϕ**
Welding current	90A	110A	130A
Arc voltage	11V	11V	11V
Welding speed	5cpm	4cpm	4cpm
Heat input	12kJ/cm	18kJ/cm	22kJ/cm
Shileding gas	100%Ar 15L/min		
Back shielding gas	**None**		
Polarity	DCEN		
Welding position	All position		
Preheat	RT		
Inter-Pass temperature	<150℃		
Groove configuration			

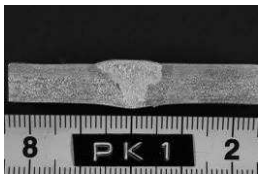
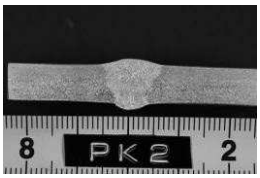
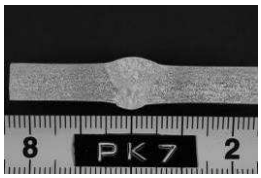
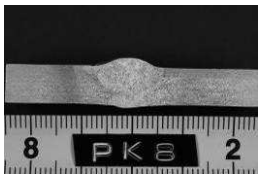
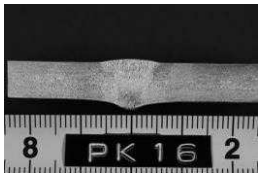
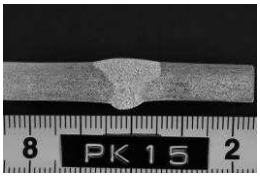
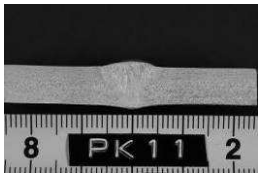
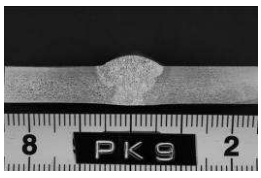


4.3 Appearance and cross sectional view of weld joint pipe

Appearance and macro structures of cross sections of weld joint pipe are presented in Figure 4-1 and Table 4-3.

Figure 4-1 Appearance of weld joint pipe

Table 4-3 Cross sectional macro structure

	1 Flat	*2*	*3 Vertical up*	*4*	*5 Over head*
A					
	1 Flat	*2*	*3 Vertical up*	*4*	*5 Over head*
B					

4.4 Ferrite number (FN) measured by Ferrite Scope

Ferrite number measured by Ferrite Scope are also shown in Table 4-4. Average values among 10 measurements are reported.

Table 4-4 Ferrite Number by Ferrite scope (FN)

Measured position	*1 Flat*	*2*	*3 Vertical up*	*4*	*5 Over head*
Cap pass	40	37	38	40	39
Root pass	28	30	31	28	31

5 Summary

1) TG-X2209 is flux cored filler rod designed for root pass welding of 22Cr type duplex stainless steels such as S31803 and S32205.
2) The outstanding feature of this product is to eliminate gas purging for back shielding root pass weld in one-side TIG pipe welding.
3) The usability of TG-X2209 is almost same as conventional TG-X series, and TG-X2209 can be applied to pipe welding at all positions.
4) By using Argon shielding gas, all-weld metal has sufficient tensile strength and practical resistance to pitting corrosion.

(Complete)