NIPPON STEEL

www.nipponsteel.com

NIPPON STEEL CORPORATION
2-6-1 Marunouchi, Chiyoda-ku,Tokyo 100-8071 Japan
Tel: +81-3-6867-4111

Quality Characteristics of SuperDyma™
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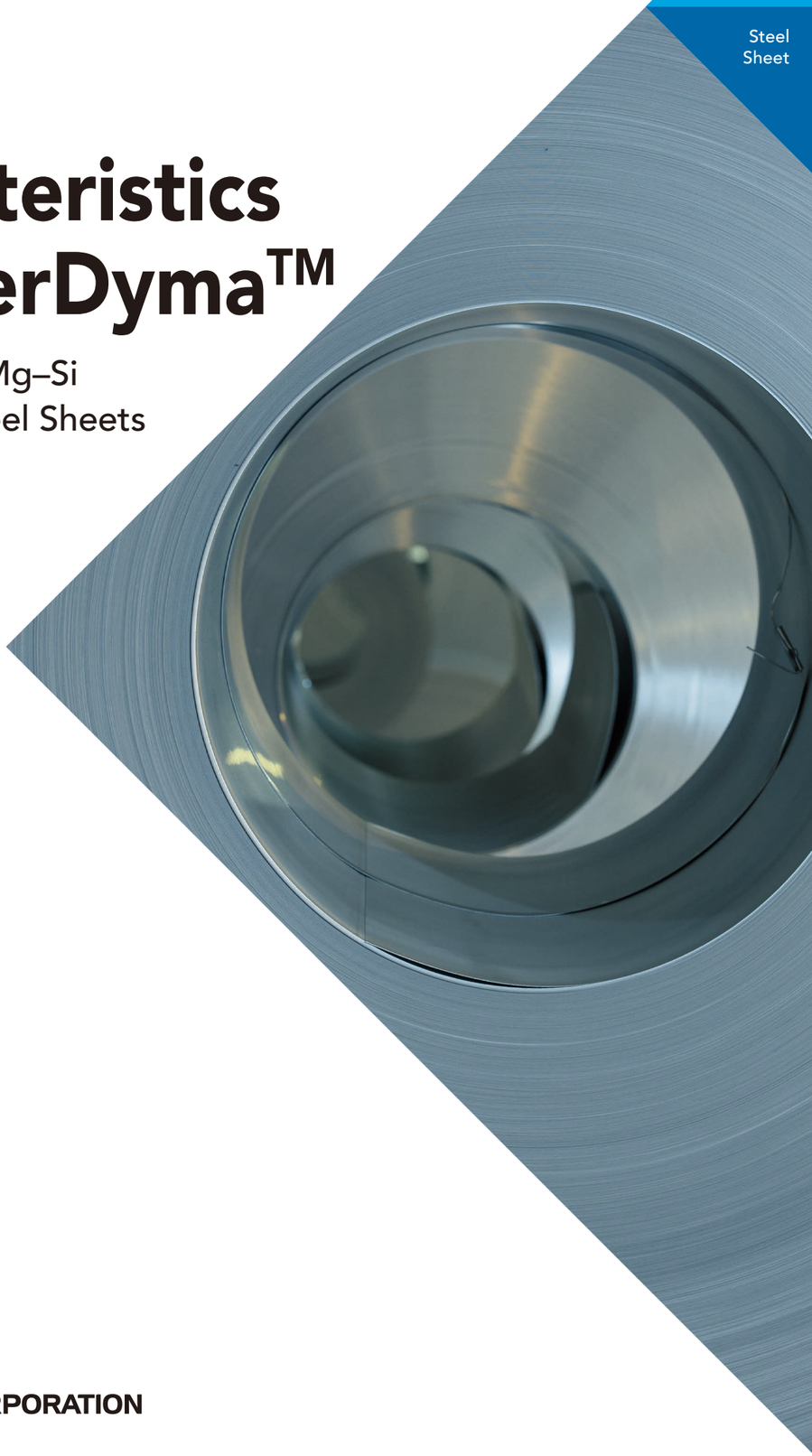
NIPPON STEEL

Steel Sheet

Quality Characteristics of SuperDyma™

Hot–dip Zn–Al–Mg–Si
Alloy Coated Steel Sheets



NIPPON STEEL CORPORATION

Contents

Spot Weldability

1. Test Specimens

Table 1 shows the test specimens applied. The plate thickness is 0.8 mm, the coating mass/side of SUPERDYMA is 90 g/m^2, and the chromium coating mass/side is 20 mg/m^2. ALSHEET™ (aluminum-coated sheet of NIPPON STEEL) was used as the comparison material.

Table 1 ***Test Specimens***

Product	Thickness (mm)	Coating mass/side (g/m^2)	Chromium coating mass/side (mg/m^2)	Remarks
SUPERDYMA	**0.8t**	**90**	**20**	**Proto-type product manufactured at commercial line**
ALSHEET	0.8t	60	14	Product manufactured at commercial line

2. Test Methods

Table 2 ***Welding Conditions***

Welding pressure	Squeeze	Up slope	Welding time	Hold	Cooling water
190 kgf	30 cycles	3 cycles	7 cycles	25 cycles	2ℓ/min

Electrode applied: Obara DHOM type; **Pre-dots:** 20 dots
Nugget diameter: The button diameter measured through peeling-off was assessed as the nugget diameter. In the case of irregular nugget diameters, the average of the long and short diameters was used.

Table 3 ***Test Conditions for Appropriate Welding Current***

Minimum welding current	3.8 mm or more in average nugget diameters
Expulsion-generation welding current	Of N=2, welding current for which at least 1 expulsion is generated
Maximum welding current	Of N=2, welding current for which at least 1 expulsion and strong deposition between electrode and steel sheet are generated

Table 4 ***Test Conditions for Continuous Dotting Property***

Welding current for continuous dotting	(Minimum welding current + Maximum welding current)/2
Judgment of continuous dotting numbers	End in 3.8 mm or under in average nugget diameters

3. Test Results

Fig. 1 shows the test for appropriate welding currents. The range of appropriate welding currents for SUPERDYMA is relatively high compared to that of ALSHEET.

The welding current used in the continuous dotting test was set at (minimum welding current + maximum welding current)/2. The welding current applied in the test was 13.0 kA for SUPERDYMA and 11.4 kA for ALSHEET.

Fig. 2 shows the continuous dotting test results. The continuous dotting number was 400 dots for SUPERDYMA and 300 dots for ALSHEET.

Fig. 1 ***Range of Appropriate Welding Currents***

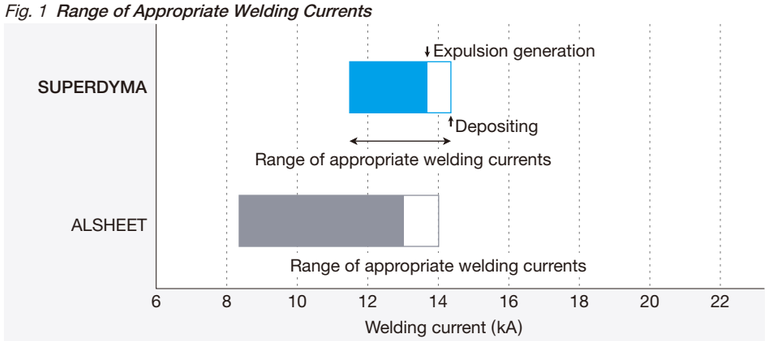
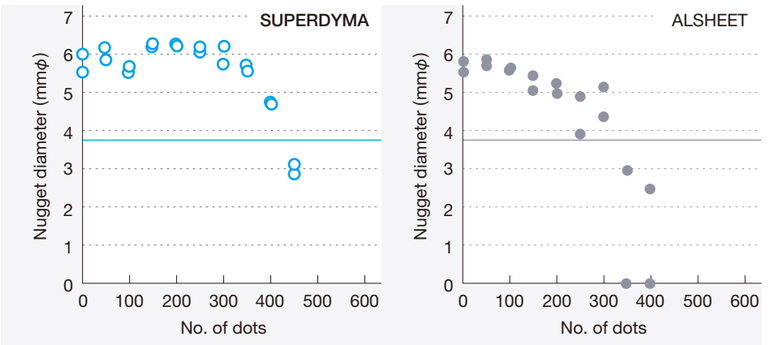


Fig. 2 ***Continuous Dotting Tests***



Corrosion Resistance of Spot Welds

1. Test Specimens

Table 5 shows the test specimens applied.

Table 5 ***Details of Test Specimens***

Product	Thickness (mm)	Coating mass/side (g/m²)	Post-treatment	Remarks
SUPERDYMA	**0.8t**	**90**	**Y treatment**	**Proto-type product manufactured at commercial line**
ALSHEET	0.8t	60	Y treatment	Product manufactured at commercial line
DURGRIP (Galvannealed)*	0.8t	55	No treatment	Product manufactured at commercial line
WELCOTE**(*)	0.8t	30	Organic film coated	Product manufactured at commercial line
Hot-dip Zn-5%Aℓ alloy coated sheet	0.8t	90	Y treatment	Product manufactured at commercial line

*Hot-dip Zn-Fe alloy coated sheet ** Organic composite coated sheet (*) WELCOTE is a product sold and registered trade mark in Japan.

2. Test Methods

Steel sheets of 100×50C were spot-welded at two points to sheets of 150×70C to prepare the test specimens. Table 6 shows the welding conditions. After spot welding, tape sealing was provided on the rear of the specimens and cut-end surface; these specimens were then used for corrosion resistance tests. For the surface of WELCOTE, an organic composite coating was provided.

Then a cyclic corrosion test was conducted; one cycle consisted of ❶ salt spraying [SST (5%NaCℓ, 35ºC, 4 hours)], ❷ drying [DRY (60ºC, 30% RH, 2 hours)] and ❸ wetting [WET (50ºC, 98% RH, 2 hours)].

Table 6 ***Welding Conditions***

Welding pressure	Squeeze	Up slope	Welding time	Hold	Cooling water	Welding current
190 kgf	30 cycles	3 cycles	7 cycles	25 cycles	2ℓ/min	13 kA

Electrode applied: Obara DHOM type; **Pre-dots:** 20 dots

3. Test Results

Photo 1 shows the results of the cyclic corrosion tests (up to 9 cycles). The occurrence of red rust was observed on every coated sheet subjected to 3 cycles. SUPERDYMA and Hot-dip Zn-5%Aℓ alloy coated sheet developed a protective film over the welds as the number of cycles increased, thereby inhibiting further generation of red rust. ALSHEET continued to show red rust at the welds as the number of cycles increased. The entire surface of DURGRIP (Galvannealed) showed red rust. While red rust occurred at the welds of WELCOTE, it occurred only slightly on their periphery.

Photo 1 ***Corrosion Resistance of Welds***

	SUPERDYMA	ALSHEET	DURGRIP-Galvannealed	WELCOTE	Hot-dip Zn-5%Aℓ alloy coated sheet
3 cycles					
6 cycles					
9 cycles					

Corrosion Resistance of Repaired Welds by Spraying

1. Test Specimens

Table 7 ***Test Specimens***

Product	Coating composition	Thickness (mm)	Coating mass (g/m²)	Surface treatment
SUPERDYMA	**Zn–11%Aℓ–3%Mg–0.2%Si**	**2.3**	**160**	**Special chromate treatment**
Hot-dip Zn-5%Aℓ alloy coated sheet	Zn–5%Aℓ	2.3	169	Special chromate treatment

2. Test Methods

Fig. 3 ***Butt Welding***

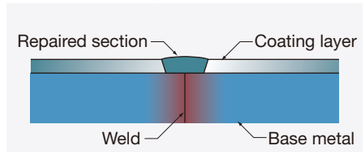


Table 9 ***Neutral Salt Spray Cyclic Test Method***

Condition	Temperature (ºC)	Humidity (%)	Salt concentration (%)	Time	Remarks
❶ Salt spray	35±1	100	5±0.5	2 hours	8 hours/cycle
❷ Drying	60±1	20~30	—	4 hours	
❸ Wetting	50±1	95≦	—	2 hours	

(1) Welding and Weld Repair

① Butt electric-resistance welding was conducted, and the weld was repaired using zinc-rich paint (refer to Fig. 3).

② Table 8 shows the thickness of the paint film used for repair painting.

Table 8 ***Results of Zn-rich Paint Repairing***

Product	Thickness of repair painting (μm)	
	Salt spraying test	Neutral salt cyclic test
SUPERDYMA	**18.6**	**20.8**
Hot-dip Zn-5%Aℓ alloy coated sheet	17.6	19.8

(2) Corrosion Resistance Tests

The corrosion resistance of the repaired welds and base metal was assessed by a salt spray test and a neutral salt cyclic test (JIS H 8502: Table 9, Conventional JASO Tests)

3. Test Results

① The corrosion resistance of welds on SUPERDYMA that were repaired with zinc-rich paint proved remarkably high compared to Hot-dip Zn-5%Aℓ alloy coated sheet (refer to Figs. 4 and 5).

② This high corrosion resistance appears to be attributable to the fact that the resistance to corrosion provided by the protective film, an inherent property of SUPERDYMA, also worked on the repaired welds.

Fig. 4 ***Corrosion Resistance Assessment Results for Repaired Welds*** *(Salt Spray Test)*

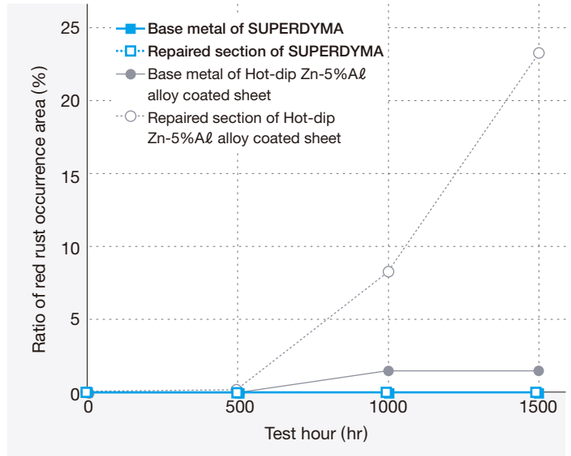
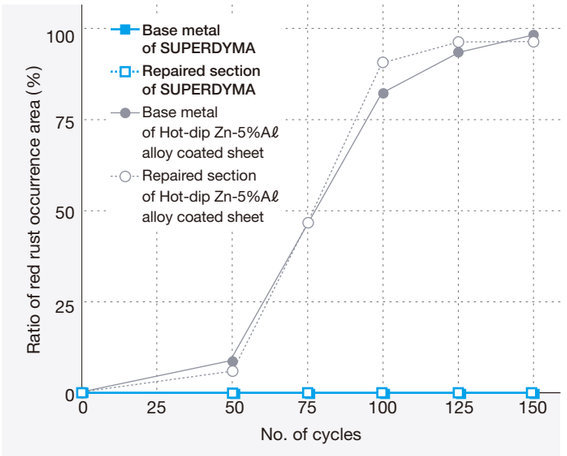


Fig. 5 ***Corrosion Resistance Assessment Results for Repaired Welds*** *(Neutral Salt Cyclic Test)*



Corrosion Resistance of Cylindrically-drawn Sections

1. Test Specimens

Table 10 shows the test specimens applied. The plate thickness was 1.0 mm, the coating mass/side of SUPERDYMA was 95 g/m^2, and the chromium coating mass/side was 40 mg/m^2. Hot-dip galvanized steel sheets were used as the comparison material.

Table 10 ***Test Specimens***

Product	Thickness (mm)	Mechanical properties				Coating mass/side (g/m^2)	Chromate coating mass/side (mg/m^2)	Remarks
		YP–L (MPa)	TS–L (MPa)	El–L (%)	R			
SUPERDYMA	**1.0t**	**149**	**308**	**47**	**1.5**	**95**	**40**	**Proto-type product manufactured at commercial line**
Hot-dip galvanized sheet	1.0t	149	296	49	1.5	130	15	Product manufactured at commercial line

2. Test Methods

Table 11 shows the deep-drawing test conditions. The drawing ratio was set at 2.0. After paint sealing the lower end of the test specimen following deep drawing, a cyclic corrosion test was conducted under the conditions shown in Table 12.

Table 11 ***Deep-drawing Test Conditions***

Punch diameter	50ϕ
Die shoulder	R10
Punch shoulder	R10
Drawing ratio	2.0
Blank holder pressure	0.5 ton

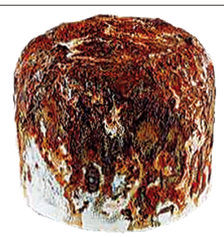
Table 12 ***Cyclic Corrosion Test Conditions***

❶ Salt spray (5% NaCl, 35°C, 4 hours)
❷ Drying (60°C, 30% RH, 2 hours)
❸ Wetting (50°C, 98% RH, 2 hours)

3. Test Results

Photo 2 shows the surface appearance before and after corrosion tests. Red rust was not observed on the surface of SUPERDYMA even after applying 60 cycles of cyclic corrosion tests.

Photo 2 ***Surface Appearance before and after Cyclic Corrosion Tests***

	SUPERDYMA	Hot-dip galvanized sheet
Before test		
After 30 cycles		
After 60 cycles		

Corrosion Potential (Corrosion due to Contact with Dissimilar Metals)

1. Test Specimens

① Cold-rolled steel sheet
② Hot-dip galvanized steel sheet
③ Hot-dip Zn-5%Al alloy coated steel sheet
④ SUPERDYMA

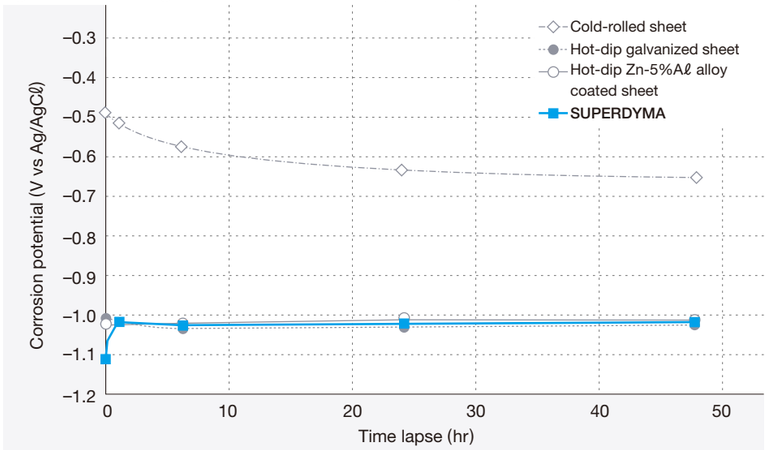
2. Measurement Methods

① Measurement was made of the corrosion potential of specimens immersed in 5%NaCl at room temperature employing an Ag/AgCl reference electrode.
② Surface exposure of the specimens was adjusted to 1 cm^2 by means of tape sealing.

3. Results and Considerations

① While SUPERDYMA containing Mg showed a base corrosion potential that was attributable to $MgZn_2$ just after immersion, the corrosion potential simulated that of other Zn-type coated sheets after the lapse of 1 hour (refer to Fig. 6). This phenomenon seems to be attributable to the suppression of anodic dissolution of the coating affected by the hydration film containing Mg that was formed at the initial stage of corrosion.
② According to the above, it is considered that when SUPERDYMA makes contact with a dissimilar metal, the phenomenon of corrosion due to contact with dissimilar metals, attributable to corrosion potential, closely simulates that of common Zn-type coated sheets.

Fig. 6 ***Secular Changes of Corrosion Potentials*** *(5% NaCl, room temperature)*



Acid and Alkali Resistance

SUPERDYMA shows exceptionally good alkali resistance.

Fig. 7 ***Acid and Alkali Resistance of Various Coated Sheets*** *(24 hours)*

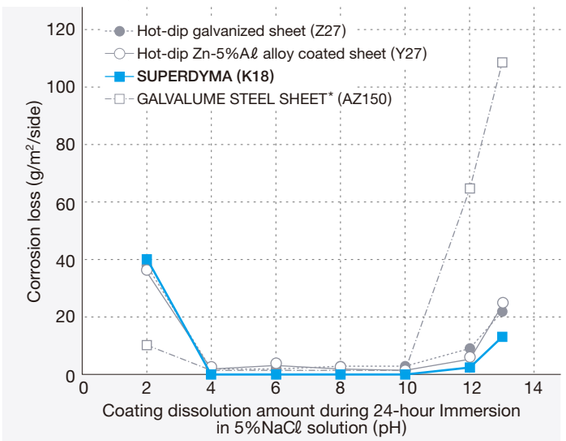
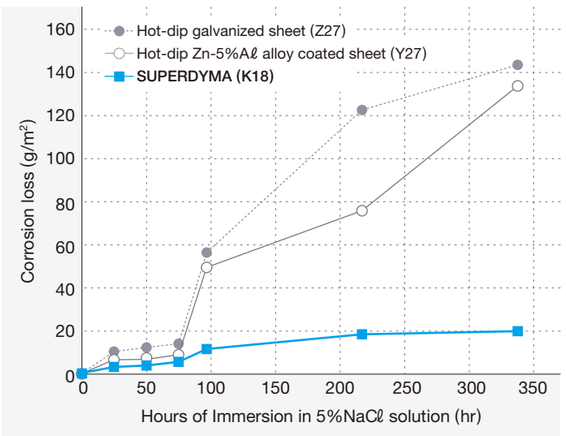


Fig. 8 ***Corrosion Resistance of Various Coated Sheets under Strong Alkali Environment*** *(pH=12.5, 340 hours)*



*: "GALVALUME" is the regisgterd trade name of BIEC International Inc.

Ammonia Resistance

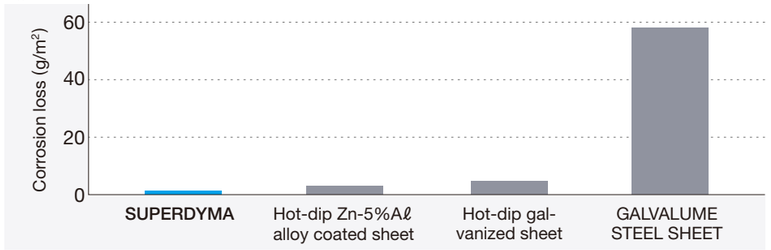
1. Test Methods

Ammonia water ranging in solutions from 5% to 25% was used for tests. The ammonia resistance of SuperDyma was assessed in terms of corrosion loss after immersion for 24 hours at 40℃.

2. Test Results

SUPERDYMA showed better ammonia resistance than Hot-dip Zn-5%Aℓ alloy coated sheet.

Fig. 9 ***Ammonia Resistance of Various Coated Sheets***



Protective Film Formed at the Cut-end Surface

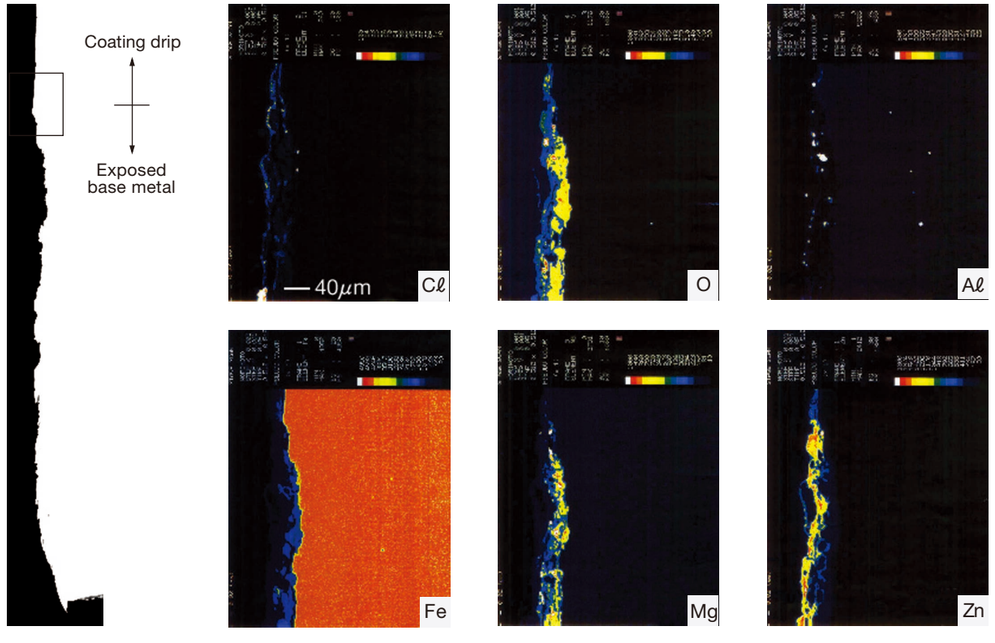
1. Test Methods

① Test specimen: SUPERDYMA with thickness of 3.2 mm; coating: K22 equivalent of products manufactured at commercial lines (no treatment)
② Exposure period: 6 months from September 2000
③ Exposure site: Compound of R&E Center of NIPPON STEEL (coastal environment at Futtsu, Chiba Prefecture)

2. Observations

The exposed base metal on the cut end of the specimen was covered with corrosion products containing Zn and Mg.

Photo 3 ***Observation Results***



Corrosion-protection Treatment of Cut-end Surface

1. Test Specimens

Table 13 ***Test Specimens***

Product	Thickness	Coating mass	Surface treatment
SUPERDYMA	3.2mm	K18	Special chromate treatment (Y treatment)

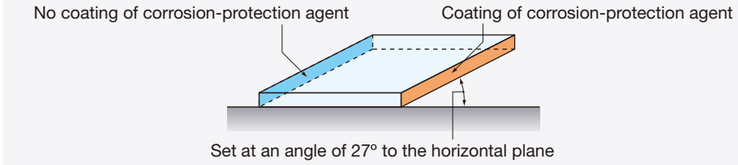
2. Corrosion-protection Agent

Breton R143-C (manufactured by Sugimura Chemical Industry)

3. Test Methods

① The surface of one cut end of the specimen was coated with the corrosion-protection agent and exposed outdoors (refer to Fig. 10).
② Exposure period: From August 8, 2001
③ Exposure site: Ichikawa, Chiba Prefecture (rural environment)

Fig. 10 ***Test Method***



4. Test Results

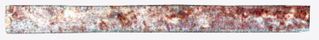
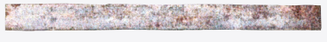
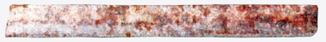
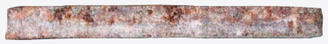
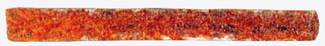
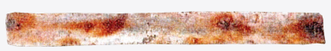
Photo 4 ***Corrosion-protection Treatment of Cut-end Surfaces*** *(Results of Outdoor Exposure Tests)*

Exposure time	Coating of corrosion-protection agent	No coating of corrosion-protection agent
1 week		
1 month		
2 months		
3 months		

Results of Exposure Test on Cut-end Surface

① SUPERDYMA possesses excellent corrosion resistance at cut-end surfaces.
② In the initial stage of outdoor exposure to the environment, the surface of the cut end of the specimen generated a small amount of red rust. However, the surface was soon covered by a stable protective film that almost completely inhibited further development of corrosion for long time.

Photo 5 ***Corrosion-protection Treatment of Cut-end Surfaces (Results of Outdoor Exposure Tests)***

Product	Exposure time	
	8 months	20 months
Hot-dip galvanized sheet Coating mass: 100 g/m²/side		
Hot-dip Zn-5%Aℓ alloy coated sheet Coating mass: 90 g/m²/side		
SUPERDYMA **Coating mass: 90 g/m²/side**		
GALUVALUME STEEL SHEET (laboratory-prepared sample) Coating mass: 90 g/m²/side		

Sample conditions: Thickness (3.2 mm), surface treatment (no treatment)
Exposure site: Futtsu weathering site, NIPPON STEEL (Cut-end surface was set sideways; photos at left: down side)

Chemical Conversion Treatment Property

1. Test Specimens

Table 14 shows the test specimens applied.

Table 14 ***Product***

Product	Coating composition	Thickness (mm)	Coating mass (g/m^2)
SUPERDYMA	**Zn–11%Aℓ–3%Mg–0.2%Si**	**0.8**	**90**
Hot-dip galvanized sheet	Zn	0.8	135
Hot-dip Zn-5%Aℓ alloy coated sheet	Zn–5%Aℓ	0.8	90

2. Phosphate Treatment Methods

Table 15 shows the phosphate treatment method.

Table 15 ***Phosphate Treatment Method***

Step	Treatment	Chemicals applied	Treatment time (sec)
1	Degreasing	FC–L4480	120
2	Rinsing	—	20
3	Surface adjustment	PL–ZTH+PL–ZN	20
4	Chemical conversion treatment	PB–L3081	120
5	Rinsing	—	20
6	Rinsing (pure water)	—	10

3. Assessment Methods

The mass of phosphorus deposits on the chemical conversion coating was measured by the fluorescent X-ray method, and its appearance was observed by means of SEM.

4. Assessment Results

① The mass of phosphorus deposits on the chemical conversion coating of SUPERDYMA was very similar to that of hot-dip galvanized steel sheet or Hot-dip Zn-5%Aℓ alloy coated sheet (refer to Fig. 11).
② It was confirmed that the configuration of the phosphate crystals, as shown in Photo 6, was of regular needle crystals, as in the case of hot-dip galvanized sheet and Hot-dip Zn-5%Aℓ alloy coated sheet.
③ From the above, it can be judged that SUPERDYMA possesses favorable chemical conversion treatment properties similar to those of hot-dip galvanized sheet and Hot-dip Zn-5%Aℓ alloy coated sheet.

Fig.11 ***Measurement Results for Phosphorus Deposit Mass in Chemical Conversion Coating***

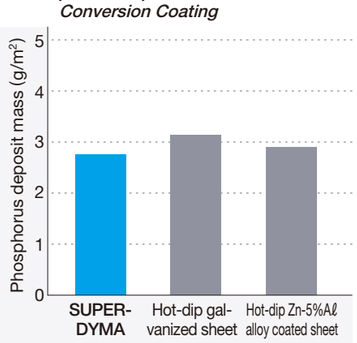
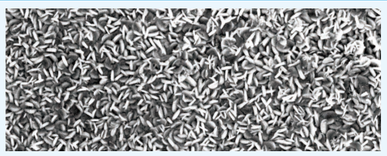
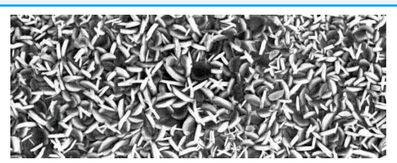
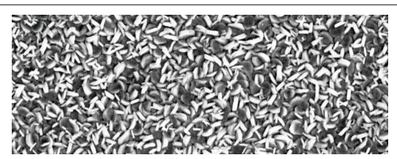


Photo 6 ***SEM Observation Results for Chemical Conversion Coating (×1,000)***

Product	SEM observation photo
SUPERDYMA	
Hot-dip galvanized sheet	
Hot-dip Zn-5%Aℓ alloy coated sheet	

Comparison of Corrosion Resistance with Stainless Steel

1. Test Specimens

Table 16 ***Test Specimens***

No.	Product	Standards	Configuration
1	**SUPERDYMA (SD)**	**NSDHC–Y–K18**	Flat sheet sample (with edge sealing)
2	Stainless steel (SUS)	SUS 304	

2. Test Conditions

Table 17 ***Test Conditions***

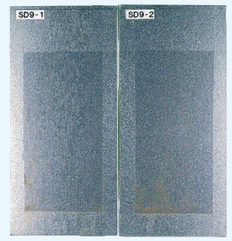
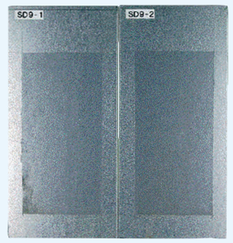
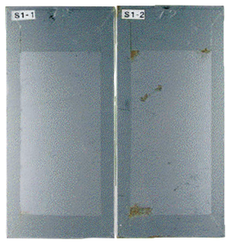
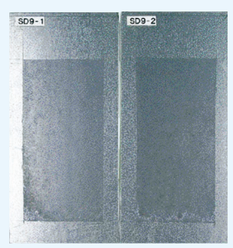
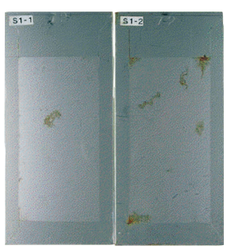
Test method	Test conditions	Test time
Cyclic corrosion test JASO M609	❶ Salt spray (5% NaCℓ, 35°C, 2 hours)	30, 60 and 90 cycles
	❷ Drying (60°C, 30% RH, 4 hours)	
	❸ Wetting (50°C, 95% RH, 2 hours)	

Cyclic corrosion test with one cycle composed of ❶ to ❸ (8 hours/cycle)

3. Test Results

Photo 7 shows the data at 30, 60 and 90 cycles of cyclic corrosion tests. White rust was observed for SUPERDYMA, but no red rust was seen even at 90 cycles. On the other hand, red rust was observed after only 30 cycles for stainless steel and continued to develop as the number of cycles increased.

Photo 7 ***Assessment Test Results for Corrosion Resistance*** *(Cyclic Corrosion Test: JASO M609 Method)*

	SUPERDYMA (Y-K18)	Stainless steel (SUS 304)
30 cycles		
60 cycles		
90 cycles		

4. Assessment

As demonstrated above, SUPERDYMA showed better resistance to red rust than stainless steel.