SUMITOMO METALS

DP28W™

Duplex Stainless Steel for Urea Plant

Introduction

A new super duplex (ferrite-austenite) stainless steel **DP28W™** has been developed by Sumitomo Metal Industries, Ltd. and Toyo Engineering Corporation (TEC), specifically for use in urea plants. **DP28W™** has an excellent corrosion resistance in urea-carbamate solutions, and high resistance to stress corrosion cracking in the chloride containing environments. Its properties are characterized as follows;

- ✓ Excellent resistance to general corrosion in urea-carbamate solutions
- ✓ High resistance to stress corrosion cracking
- ✓ Very high mechanical strength
- ✓ Good weldability
- ✓ Good formability

Standard

DP28W™ has been already registered as ASTM, UNS Design S32808 and ASME Code Case2496.

Chemical composition

Table 1 shows the chemical requirement for **DP28W™**. Excellent corrosion resistance is achieved by an optimum alloying design such as high chromium content, addition of tungsten and optimum balance of ferrite-austenite structure. Especially addition of tungsten improves corrosion resistance of heat-affected zone during welding thermal cycle, and the phase stability, preventing from precipitation of sigma phase.

Table 1 Chemical requirement (mass%)

	C	Si	Mn	P	S	Ni	Cr	Mo	N	W
DP28W™	max. 0.030	max. 0.50	max. 1.10	max. 0.030	max. 0.030	max. 8.20	27.00 -27.90	0.80 -1.20	0.30 -0.40	2.10 -2.50

Physical properties

Density 7.86 g/cm³

Coefficient of thermal expansion

(x10⁻⁶/°C)

Temperature °C	30-100	30-150	30-200	30-250	30-300	30-350	30-400
DP28W™	13.6	13.9	14.1	14.3	14.5	14.7	14.8

Thermal conductivity and specific heat

Temperature °C	Thermal conductivity (W/m·K)	Specific heat (J/kg·K)
20	12.4	458
100	15.0	519
150	16.1	547
200	17.2	570
250	18.2	586
300	19.2	607
350	20.2	627
400	21.7	651

Modulus of elasticity

Temperature °C	RT	100	150	200	250	300	350	400
DP28W™	191	186	183	180	176	172	168	164

Mechanical property

DP28W™ has remarkable mechanical property. Tensile requirement at room temperature is shown in Table 2 and example of tensile test result in comparison with other stainless steels is shown in Table 3. It is indicated that **DP28W™** has a high mechanical strength compared with austenitic stainless steels such as 25Cr-22Ni-2Mo and 316L. It provides great advantage for mechanical design of equipment.

Table 2 Tensile requirement

Tensile Strength (MPa)	0.2% Proof Stress (MPa)	Elongation (%)
min.800	min.550	min.15

Table 3 Mechanical properties

Grade	Tensile Strength (MPa)	0.2% Proof Stress (MPa)	Elongation (%)	Hardness (Hv)
DP28W™	934	647	42	281
DP12	822	610	42	251
25-22-2(S31050)	676	352	50	173
316L	518	234	52	144

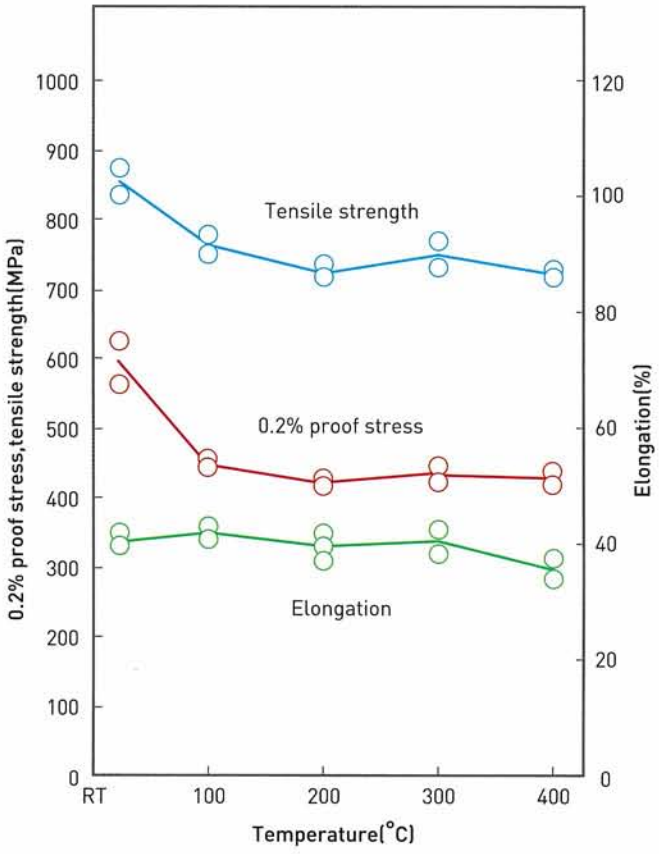

Fig. 1 Tensile properties at high temperature

Fig. 1 shows typical tensile properties at high temperature. **DP28W™** has good impact properties both at room temperature and at low temperature. Fig. 2 shows a typical impact energy curve. The ductile-brittle transition temperature of **DP28W™** is estimated below –100deg.C.

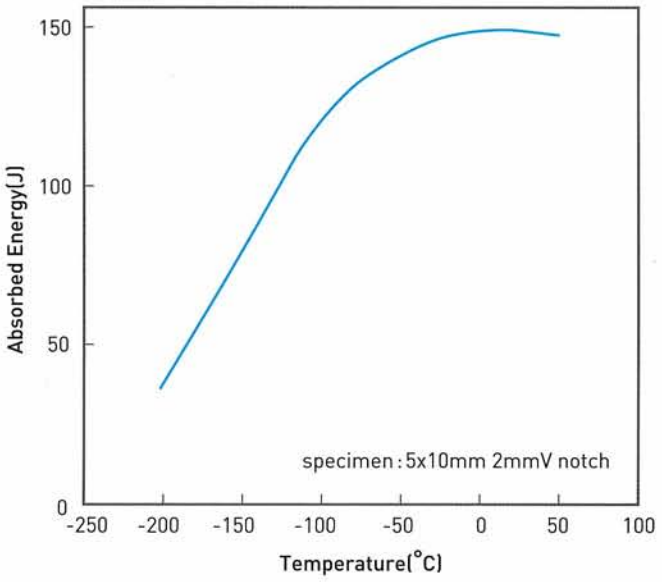

Fig. 2 Typical impact energy curve

Microstructure

Typical microstructure of **DP28W™** is shown in Fig. 3. **DP28W™** has a fine two phases (ferrite-austenite) structure to improve both corrosion resistance and mechanical properties.

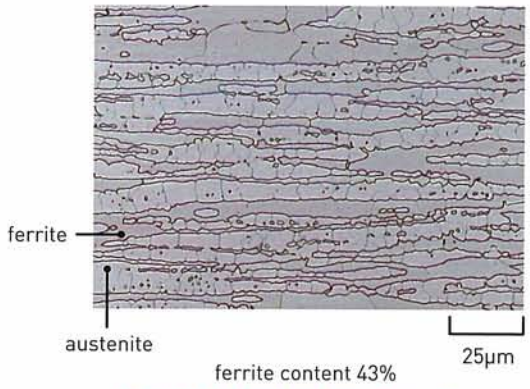

Fig. 3 Typical microstructure

Corrosion resistance

Corrosion resistance to corrosion in boiling nitric acid <Huey test>

Huey test is commonly used to evaluate corrosion resistance of materials applied to urea plants. Fig. 4 show results from huey tests of **DP28W™** and DP12 (S31260). Duplex stainless steel accelerated corrosion in weld and HAZ sometimes causes serious trouble. This accelerate corrosion is caused by unbalanced ferrite/austenite phase proportion and/or precipitations of carbides/intermetallic compounds. **DP28W™** has overcome this problem by optimizing chemical composition of base metal and by developing special welding material.

Appropriate ferrite/austenite balance is kept even in HAZ under the favorable addition of austenite formers. Optimized addition of molybdenum and tungsten prevents sigma phase precipitation during thermal cycles. This gives **DP28W™** good corrosion resistance in HAZ.

Chemical composition of welding material for **DP28W™** is modified from base metal considering rapid cooling rate, which deteriorates corrosion resistance. Boiling nitric acid test (Huey test) result of all weld metal sample of **DP28W™** is shown in Fig. 5. Corrosion rate of **DP28W™** weld metal is around half of DP12 (S31260). As a result **DP28W™** is highly resistant to corrosion in boiling nitric acid, even welded **DP28W™** is also highly resistant.

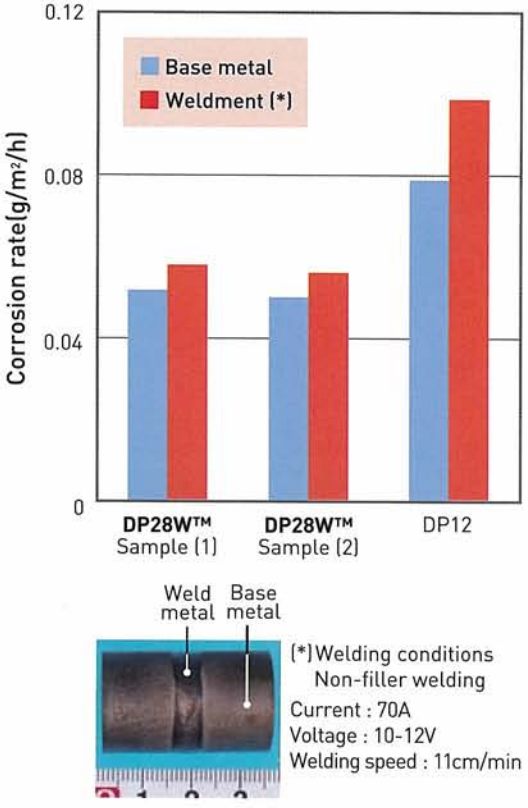

Fig. 4 Corrosion rate of DP28W™ and DP12 in boiling nitric acid

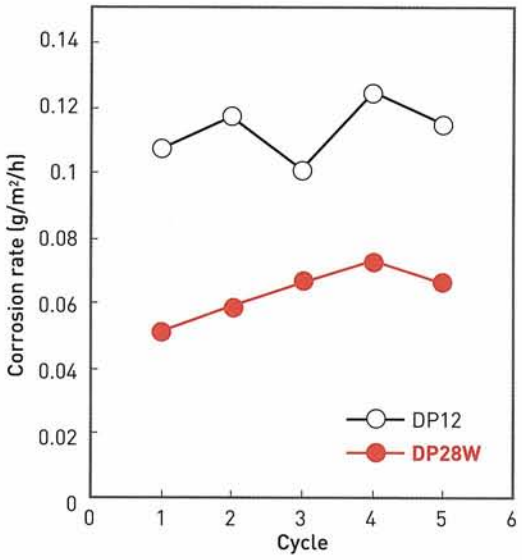

Fig. 5 Huey test result of all weld samples of DP28W™ and DP12

Corrosion resistance to urea carbamate solution

The corrosion properties in urea carbamate solution are being proved both in a pilot plant and commercial plants. Practical experience in this type of environment has shown that **DP28W™** has highly corrosion resistance.

Fig. 6 shows a result of an immersion test in a pilot plant. 316L-UG corrodes very high because it cannot keep passivation film due to sever corrosiveness in the pilot plant. Even in this situation, **DP28W™** shows excellent corrosion resistance, which provides 10-20% lower corrosion rate than DP12 (S31260). These excellent corrosion resistance results in long service life of components in the plant.

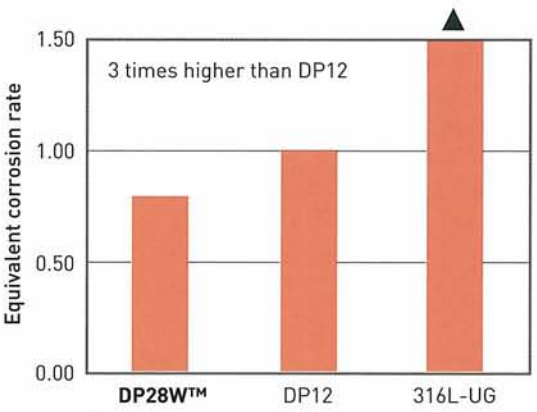

Fig. 6 Result of corrosion test in urea carbamate solution

Re-passivation properties in urea carbamate solution

Duplex stainless steel, in particular **DP28W™**, has a big advantage in re-passivation properties because of high chromium and lower nickel content. **DP28W™** has the ability to form the passive layer, that gives resistance to active corrosion, under the condition of very little dissolved oxygen. This excellent re-passivation property contributes to minimize the risk of active corrosion.

Weldability

DP28W™ has good weldability. Chemical composition of **DP28W™** has been designed to prevent sigma phase precipitation during thermal cycles and to exhibit excellent corrosion resistance in both the base metal and its weldment. Preheating or post weld heat treatment is not necessary. Interpass temperature shall be controlled below 150deg.C. Matching filler metals have been developed for gas tungsten arc welding(GTAW) and electro slag welding(GESW).

Appearance of weld overlay by ESW is shown in Photo 1. ESW is the most widely used for fabrication of urea high pressure equipment. Slag exfoliation of ESW is good. No undercut is observed at the boundary of beads. Well-matched combination of strip and flux gives optimum chemical composition and excellent corrosion resistance in weld metal.

Photo 1 Apperance of weld overlay by ESW

Formability

DP28W™ has good formability. Appearance of bended U tube after dye-penetrant test is shown in Photo 2. Result of flaring and flattening tests according to ASTM standard is satisfactory as well.

Photo 2 Appearance of bended U tube of DP28W™

ADVANTAGES OF DP28W™ THROUGH PLANT LIFECYCLE

The expected corrosion rate of **DP28W™** is lower than current materials in use. The corrosion resistance in HAZ and weld metal is greatly improved compared to conventional duplex stainless steel. These positive features provide the following advantages through the plant lifecycle;

✓Extend life of components exposed to urea-carbamate solution
✓Decrease frequency of maintenance
✓Reduce the risk of unexpected trouble due to active corrosion

PRODUCTION EXPERIENCE

DP28W™ has been applied mainly as internal parts of TEC's urea plants since 2002. In 2004, **DP28W™** was nominated as one of the candidate materials of synthesis Reactor of total recycle plant in Japan which had been considered to be replaced. The owner had strong intention to operate a new reactor under the same operating condition as an existing reactor, which was fabricated with titanium. But for the materials to be nominated, the operating condition seemed to be very severe because titanium requires little amount of passivation air even at high temperature. After one year immersion test into the reactor, **DP28W™** was selected because it showed the best result among candidate materials. The corrosion rate is far lower than titanium. The reactor that is fabricated with **DP28W™** has started into operation successfully since 2006 under the same operating conditions as the case for titanium.

Notes

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