For Stainless Steel

A guide for selecting welding consumables

Steel type	Key note for application	SMAW	FCAW	GMAW	GTAW	SAW
304	▪General	**NC-38**	**DW-308** **DW-308LP**	**MGS-308**	**TGS-308**	**PFS-1／US-308**
304L	▪Cryogenic temperatures	**NC-38LT**	**DW-308LT**		**TGS-308L**	**PFS-1LT／US-308L**
	▪Low carbon 0.04% max.	**NC-38L**	**DW-308L** **DW-308LP**	**MGS-308LS**	**TGS-308L** **TGX-308L**	**PFS-1／US308L**
	▪High temperature service and solution treatment	**NC-38, NC-38L**	**DW-308LH**			
304H	▪High temperatures	**NC-38H**	**DW-308H**			
304N2	▪General		**DW-308N2**			
-	▪Dissimilar-metal joints	**NC-39** **NC-39L** **NC-39MoL**	**DW-309** **DW-309L** **DW-309MoL** **DW-309LP** **DW-309MoLP**	**MGS-309** **MGS-309LS**	**TGS-309** **TGS-309L** **TGX-309L**	**PFS-1／US-309** **PFS-1／US-309L**
	▪High temperature service and solution treatment		**DW-309LH**			
316	▪General	**NC-36**	**DW-316** **DW-316LP**		**TGS-316**	**PFS-1M／US-316** (single pass) **PFS-1／US-316** (multi-pass)
316L	▪Cryogenic temperatures	**NC-36LT**	**DW-316LT**		**TGS-316L**	
	▪Low carbon (0.04% max.)	**NC-36L**	**DW-316L** **DW-316LP**	**MGS-316LS**	**TGS-316L** **TGX-316L**	**PFS-1M／US-316L** (single pass) **PFS-1／US-316L** (multi-pass)
	▪High temperature service and solution treatment	**NC-36, NC-36L**	**DW-316LH**			
316LN	▪Low carbon (0.04% max.)		**DW-317L**			
316H	▪High temperatures		**DW-316H**			
-	▪Urea	**NC-316MF**			**N04051** **TGS-310MF**	
317L	▪Low carbon (0.04% max.)	**NC-317L**	**DW-317L**		**TGS-317L**	**PFS-1／US-317L**
347	▪General	**NC-37**	**DW-347**		**TGS-347** **TGX-347**	**PFS-1／US-347**
	▪Low carbon	**NC-37L**		**MGS-347S**		
	▪High temperatures	**NC-37**	**DW-347H**			
321	▪General	**NC-37**	**DW-347**			**PFS-1／US-347**
	▪High temperatures		**DW-347H**			
310S	▪General	**NC-30**	**DW-310**		**TGS-310**	
312	▪General	**NC-32**	**DW-312**			
-	▪Duplex stainless	**NC-329M**	**DW-329A** **DW-329AP**		**TGS-329E**	
410	▪General	**CR-40**		**MGS-410**	**TGS-410**	**PFS-4M／US-410**
405, 409	▪Overlaying in cladding	**CR-40Cb**	**DW-410Cb**		**TGS-410Cb**	
	▪Underlaying in cladding	**CR-43Cb** **CR-43CbS**	**DW-430CbS**			
-	▪Low carbon martensite		**MXA-135N** **MXA-410NM**			
409, 430, 436 410L	▪Car exhaust system		**MXA-430M**	**MGS-430M**		

Tips for better welding results for individual welding processes

SMAW

(1) Use proper welding currents because the use of an excessive current causes overheating electrodes and thereby welding usability and weld metal mechanical properties can be deteriorated.
(2) Keep the arc as short as possible.
(3) Control the weaving width of electrode within two and a half times the diameter of the electrode.

FCAW

1. Features:

(1) DW stainless flux-cored wires are cost-effective wires because of high welding efficiency with the deposition rate 2-4 times as high as those of stick electrodes as shown in Fig. 1 and deposition efficiency of about 90%.
(2) DW stainless wires offer a wider range of current and voltage in comparison with solid wire as shown in Fig. 2, which facilitates easier application for both semi-automatic and automatic welding.
(3) DW stainless series has excellent usability and weldability with stable arc, low spatter, good slag removal, smooth bead appearance, and high X-ray soundness.

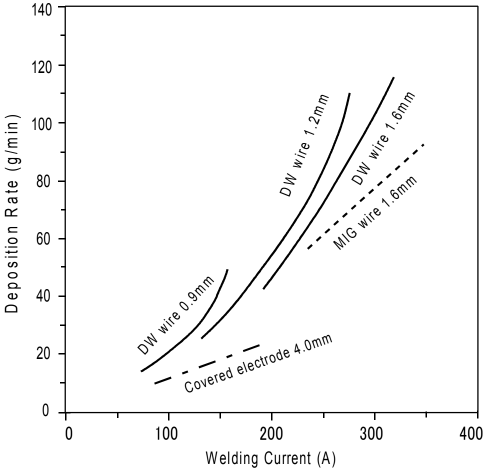


Fig. 1 Deposition rate as a function of welding current

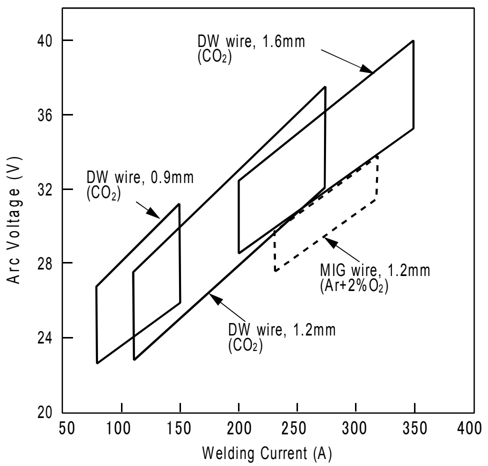


Fig. 2 Proper ranges of welding current and arc voltage

2. Notes on usage

(1) Welding power source:
Use a DC power source with constant voltage and the polarity DC-EP. Inverter-type welding power sources can also be used. When the use of a certain pulsed arc power source causes much spatter, use the wire with ordinary currents, turning off the pulse switch.

(2) Shielding gas:
Use CO_2 for shielding gas for general applications. Ar-CO_2 mixtures with 20-50% CO_2 can also be used, but compared with CO_2, porosity (pit and blowhole) is apt to occur. The proper flow rate of shielding gas is 20-25 litter/min.

(3) Wire extension:
Keep the wire extension at about 15 mm for 0.9-mm wire and 15-20 mm for 1.2- and 1.6-mm wire. The use of a shorter wire extension may cause pit and worm-tracking porosity. The wire extension in welding with an Ar-CO_2 mixture should be 5 mm longer than in use of CO_2.

(4) Protection against wind:
When wind velocity at the vicinity of an arc is more than 1 m/sec., blowhole is apt to occur, and dissolution of nitrogen into the weld metal may deteriorate slag removal and decrease the ferrite content of the weld metal, thereby causing hot cracking. To prevent these problems, use an adequate shielding gas flow rate and a windscreen.

(5) Welding fumes:
Flux-cored wires generate much more welding fumes in terms of the amount of fumes at unit time in comparison with that of covered electrodes. To protect welders from harmful welding fumes, be sure to use a local ventilator and an appropriate respirator.

(6) Storage of wire:
Once a DW stainless wire picked up moisture, it cannot be dried at high temperatures, unlike covered electrodes. If a DW wire was left in a wire feeder in a high-temperature high-humidity atmosphere in summer season, a wet environment in rainy season or a dewfall environment at night in winter season, the use of it may cause pit and worm-tracking porosity due to moisture pick up. Once a wire was unpacked, the wire should be kept in an area of low humidity, taking appropriate preventive measures against dewfall water and dust.

3. Applications

(1) Butt welding:

Applicable plate thicknesses are 2 mm or larger with a 1.2mm wire and 5 mm or larger with a 1.6mm wire in flat position. P-series wires enable to weld thin plates with 3-4 mm thickness in vertical position. One-side welding can be applied for similar-shape grooves in flat, horizontal and vertical positions by using a backing material of FBB-3 (T size). In this case, the root opening should be about 3-4 mm to obtain good reverse beads.

(2) Horizontal fillet welding:

Proper welding speeds are approximately 30-70 cm/min in horizontal fillet welding. With a 309 type wire, dissimilar-metal welding of stainless steel to carbon steel can be done in the same welding condition as used for welding stainless steels. However to secure the ferrite content of weld metal, welding currents should be 200A or lower and welding speeds should be 40 cm/mm or slower with a 1.2mm wire.

(3) Overlaying and joining of clad steels:

The 1st layer of overlaying onto carbon steel should be welded with a 309 (or 309MoL) type wire by the half lapping method. In case where the dilution by the base metal is excessive, the ferrite content of the weld metal decreases and thereby hot cracking may occur. Therefore, it is important to use appropriate welding conditions to control the dilution particularly for the first layer. In order to obtain the proper dilution ratio, welding currents should be 200A or lower and welding speeds should be 20-40 cm/min with a 1.2mm wire. With a 1.6mm wire, use welding currents in the 200-250 range and welding speeds in the 20-30 cm/min range. Refer to Fig. 3.

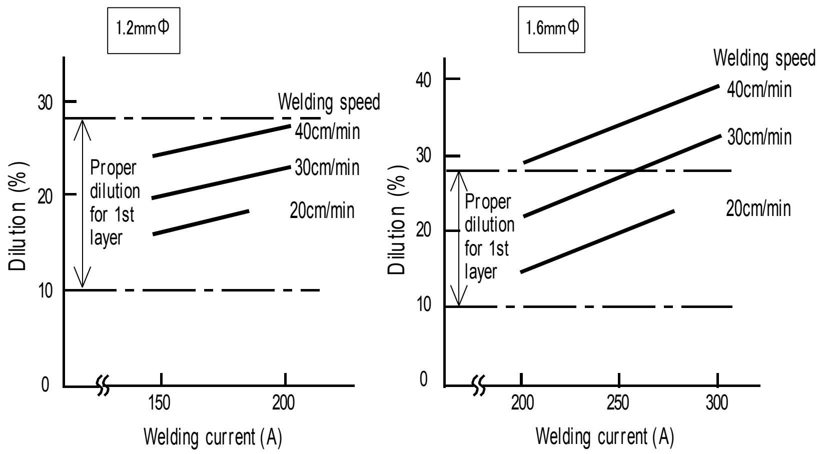


Fig. 3 Dilution ratios as a function of welding currents

GMAW

(1) Polarity:

DC-EP is suitable.

(2) Shielding gas:

98% Ar-2%O_2 mixture is recommended for general applications. Proper gas flow rates range in 20-25 l/min. Ar-CO_2 mixture is not suitable for low carbon stainless steel (Type 304L) because the carbon content of deposited metal increases.

(3) Arc length:

GMAW of stainless steel generally uses the spray arc transfer mode due to lower spatter generation. Adjust arc voltage so that arc length becomes 4-6 mm. When arc length is excessively short, blowholes are apt to occur. Inversely, when arc length is excessively long, the wetting of deposited metal on the base metal becomes poor.

(4) Protection against wind:

GMAW is likely to be influenced by wind and thereby blowholes may occur. Use a windscreen to protect the arcing area against wind when the wind velocity near the arc is 0.5m/sec or more.

(5) Pulsed arc welding:

In pulsed arc welding, a stable spray arc can be obtained even with low welding currents. Pulsed arc is suitable for overlaying, welding of thin plates and vertical welding.

GTAW

(1) Polarity:

DC-EN is suitable.

(2) Shielding gas:

Argon gas is mainly used for shielding. Suitable flow rates of shielding gas are in the range of 7-15 l/min. at 100-200A of welding current and 12-20 l/min. at 200-300A in manual GTAW.

(3) Torch:

Two types of GTAW torches are available. One has a gas lens, another has no gas lens. A torch with a gas lens provides better shielding effect preventing the weld bead from oxidation since the gas lens can provide a regular gas flow.

(4) Tungsten electrode extension:

Proper tungsten electrode extensions are generally in the range of 4-5 mm. In the case where shielding effect tends to be lower as in welding corner joint, tungsten extension is recommended to be 2-3 mm. In welding of deep groove joints, tungsten extension should be longer as 5-6 mm.

(5) Arc length:

Proper arc lengths are in the range of 1-3 mm. When it is excessively long, the shielding effect becomes poor.

(6) One-side welding without backing materials:

In the case of one-side welding without backing materials, adopt back shielding in order to prevent oxidization of the penetration bead. However, with a flux-cored filler rod for GTAW, sound penetration bead can be obtained without back shielding.

(7) Fully austenitic type filler wires:

With a fully austenitic type filler wire (e.g., TGS-310, TGS-310MF), use lower welding currents and welding speeds to prevent hot cracking.

Ferrite content measuring methods for austenitic stainless steel weld metal

Method	Principle of measuring ferrite content
Ferrite Indicator:	Comparing the magnetic attraction between a standard ferrite percent insert and a test specimen
Ferrite Scope:	Measuring a change of magnetic induction affected by the ferrite content of a test specimen
Magne Gage:	Measuring the pull off force necessary to detach a standard permanent magnet from a test specimen
Structure Diagram:	Calculating Ni equivalent and Cr equivalent of the chemical composition of a test specimen and reading the crossing point of the two equivalents in a structure diagram. Three structure diagrams are available: Schaeffler diagram, Delong diagram and WRC diagram. See Figs. 1, 2 and 3.
Point Counting:	Calculating the area percentage of ferrite in the microstructure of a test specimen, by using a optical microscope

Fig. 1 Schaeffler Diagram

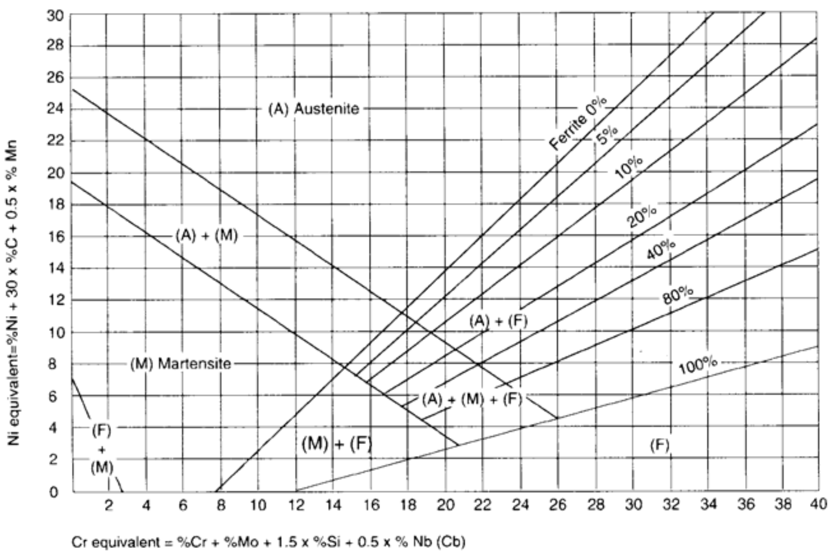


Fig. 2 Delong Diagram

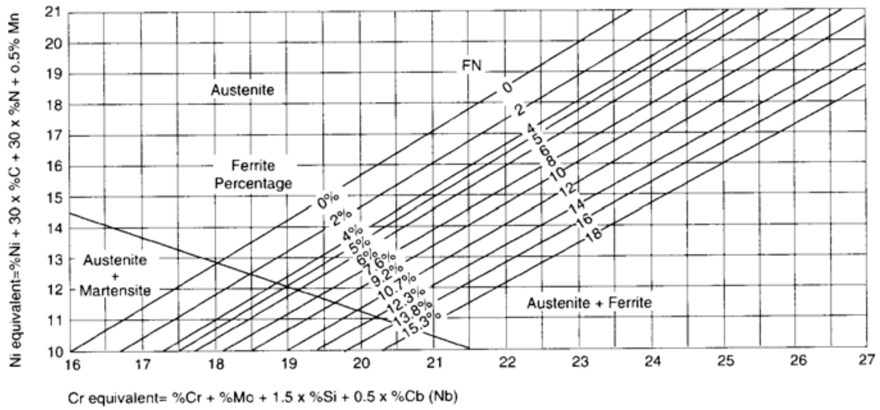
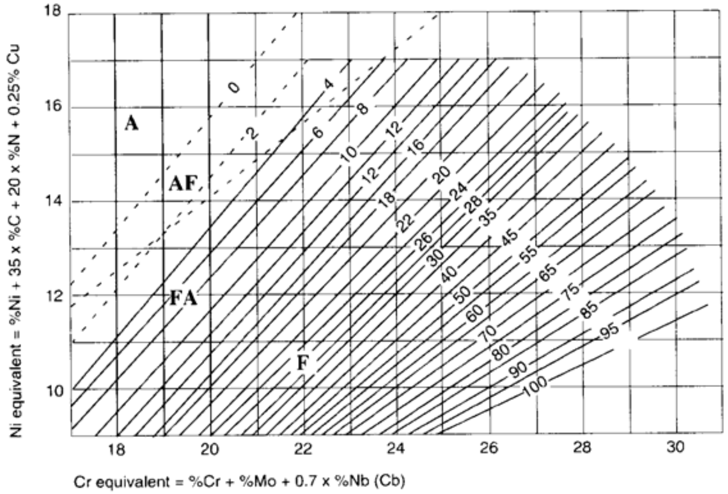


Fig. 3 WRC Diagram



A, AF, FA,F stand for solidification modes
A : Austenitic single phase (r)
AF : Primary phase (r) + Eutectic Ferrite (δ)
FA : Primary phase (δ) + Peritectic / Eutectic phase (r)
F : δ Single phase Solidification