Stainless Steel

Material General Review

SUS: The first “S” stands for Steel, U stands for “Special Use,” and the last “S” represents Stainless.
Stainless Steel can resist oxidization because of its surface is covered by a tough film of Chromium Oxide. If the Cr content is less than 12%, its effect is reduced due to lack of compact protection film. In addition, when the C content increases, the risk of oxidization is augmented because C easily bond with Cr to form Carbonate Chromium precipitation; which results in lower Cr and hence inferior oxidization resistance. So the typical Stainless Steel, C content is limited under 0.1%, even under 0.03%.
Stainless steel applications can be categorized according to its usages such as corrosion resistance, elevated temperature strength decreasing resistance, low temperature toughness decreasing resistance, and etc.

Going by element contents and metallographic, the common stainless steels can be divided into the following three categories:
13 Cr Stainless Steel, martensite type, represented by model SUS410, SUS420.
18 Cr Stainless Steel, ferrite type, represented by model SUS430
18-8 Stainless Steel, austenite type, represented by model SUS304

If we examine the oxidization resistance property, austenite stainless steel > ferrite stainless steel > martensite stainless steel.

If we go by its strength level, then martensite stainless steel > ferrite stainless steel > austenite stainless steel.

Category	quenching property	oxidization resistance property	elevated temperature strength	low temperature toughness	weld-ability	magnetic induc-tance
austenite stainless steel	none	superior	superior	superior	superior	none
ferrite stainless steel	none	superior	inferior	inferior	inferior	yes
martensite stainless steel	yes	inferior	Good	inferior	inferior	yes

- 18-8 series is most popular stainless steel. It has excellent corrosion resistance property, because it contains 18% Cr and 8% Ni. The lattice between Ni and Fe is very close and enhance an adhesiveness of Cr oxide film on to the matrix. If the lattice between Ni and Fe is space out, this result in poor adhesiveness of Cr oxide.
- When the Ni content reaches 8%, the microstructure will become oxidation resisting austenite structure. The reason is that austenite has single phase multi-angular grain structure; thus its grain boundary is impervious to porosity and lead to good oxidation resistance.
- Austenite structure will form when it is heated to phase transformation temperature or above; however, adding element Ni allows the microstructure to maintain face centered cubic austenite structure in room temperature.

The Correlation between Weldability and Microstructure

Martensite Stainless Steel

- SUS410 or SUS 420 types of Martensite Stainless Steel contains about 11~13.5% Cr, which is similar to Low Carbon Steel with magnetic inductance characteristic. During welding process, there is concern of arc blow. It is with higher electrical resistance and lower thermal conductivity coefficient than the normal carbon steel; The brittle structure will be formed by quick cooling.
- To prevent HAZ (Heat Affect Zone) to form hard and brittle structure, which means susceptibility to shrinkage stress and hydrogen inclusion, pre-heating and inter pass temperature must be controlled according to the base metal's carbon content along with the consideration of the size of weldment, the restriction level, and the filler metal chemical composition.
- The average weldment needs the treatment of 200~400°C of preheat and sustain inter-pass temperature at this level, and 700~800°C of post heat so as to allow a more gradual cooling rate for the weld metal and HAZ which result in less shrinkage stress while allowing more atomic hydrogen to escape in order to achieve better elongation of weld metal.

Ferrite Stainless Steel

- SUS 430 Ferrite stainless steel contains about 15~18% Cr, which is much more than Maternsitic Stainless Steel, and its C content is usually limited under 0.12%. If the C content exceeds 0.20%, it is then classified as AISI 431 Matensite Stainless Steel.
- The positive characters of Ferrite Stainless Steel is its soft texture, good elongation, good machining-ability and corrosion resistance, no hardening occurrence due to processing or welding. Besides the similarity with carbon steel and Martensite Stainless steel, there are concerns of the magnetic inductance and arc blow.
- When HAZ (Heat Affected Zone) is heated to melting point around, that will result in grain coarsening which leads to embrittle ; thus, 150°C of preheat is necessary before welding. During the welding process, never stay at the range of embrittlement temperature 400~565°C, especially 475°C, and the weldment should not be overheated also.
- No microstructure transformation for Ferrite Stainless Steel due to its composition, so it is impossible to process fine grain treatment. When it is heated over 930°C, the ferrite will suffer grain coarsening, and embrittlement because of losing its elongation and toughness.
- Ferrite Stainless Steel has few matching standard welding consumables with emphasis mostly on corrosion resistance property and linear expansion coefficient which means the selection of 309, 310, 312 and other austenite stainless steel for welding.

Austenite Stainless Steel

- Austenite Stainless Steel contains many beneficial traits such as high corrosion resistance, machinability, and weldability, which makes it widely popular. 300 series dominates the usage (with minor demand for 200 series). This stainless steel elemental content contains about 15~32% of Cr, Ni 8~37%, and dominates the overall stainless steel demand with over 90% usage. SUS 304 (18Cr – 8Ni steel) is one of the most common type.
- Austenite Stainless Steel can retain proper strength and corrosion resistibility regardless of low or high temperature with weldment usage in as welded condition.
- Austenite Stainless Steel does not suffer from magnetic inductance and arc blow during welding process. Series 310, 320 and 330 are full austenite structure which means complete immunity to magnetic inductance; 312 weld metal contains approximately 25% ferrite with obvious magnetic inductance; 304 (L), 309 (L), 347 and likes contain low amount of ferrite which means low but some magnetic inductance. Austenite Stainless Steel with lower alloy content, which suffers from full anneling, such as 304 steel, could have magnetism from cold working.
- Compare to the average carbon steel, low alloy steel or 400 series stainless steel, Austenite Stainless Steel has lower melting point, higher electrical resistance and lower heat conduction coefficient (about 1/3 of average carbon steel); which mean high heat concentration in the welding zone, but with heat expansion coefficient 50% over average; thus is more susceptible to deform due to welding heat and hence requires low heat input welding.
- It has the best weldability because lack of quenching hardening issue. However if the temperature remains between 550 ~ 800°C, the weldment will lose its oxidation resistance due to carbonate chromium precipitation. Choosing low carbon content filler metal when welding in combination of low heat input welding can significantly lower carbonate chromium precipitation.
  In addition to the above described three types, there are precipitation hardened type and duplex phases type stainless steel.

* Precipitation hardened type stainless steel: Major elements are Cr and Ni (Cr accounted for 17%; Ni is 4%) under the category of 600 series stainless steel (like SUS 630).
Duplex phases type stainless steel: Main elemental components are Cr, Ni, and Mo (22% of Cr, 9% of Ni, and 3 % of Mo). Since its microstructure contains ferrite and austenite, hence the name duplex phases type stainless steel (such as Alloy 2205).

Welding Consumables Selection (similar base metal)

Base metal	Classification (major element composition) %	Covered Electrode	MIG / TIG	Flux Cored Wire	SAW – Submerged arc welding wire
304	18Cr-8Ni	G308 G308M	GM308 GT308	GMX308L GMX308L-O	GS308 GS308L
304L	18Cr-8Ni-low carbon content	G308L NT308L	GM308L GT308L	GMX308L GMX308L-O	GS308L
309S	23Cr-12Ni	G309 G309L	GM309 GT309	GMX309L GMX309L-O	GS309 GS309L
310S	25Cr-20Ni	G310	GM310 GT310		
312	30Cr-9.5Ni	G312	GM312 GT312		
316	18Cr-8Ni-2.5Mo	G316	GM316 GT316	GMX316L GMX316L-O	GS316 GS316L
316L	18Cr-8Ni-2.5Mo-low carbon content	G316L	GM316L GT316L	GMX316L GMX316L-O	GS316L
317	18Cr-13Ni-3.5Mo	G317	GM317 GT317		
347	18Cr-8Ni-Nb	G347	GM347 GT347		
321	18Cr-8Ni-Ti	G347	GM347 GT347		
410	13Cr	G410	GM410 GT410		
430	18Cr	G430	GM430 GT430		

Note : G307 and G307M listed on catalog are mainly used on dissimilar metals between Mn steel and cast steel or steel forging welding, not available for welding on stainless steel.

Welding Consumables Selection (dissimilar base metal)

Base metal	201 202	304 304L	309 309S	310 310S	317 316	317L 316L 316Ti	321 347	409 430 446	410 420	Carbon Steels and Low Alloy Steels
201 202	347 308L	347 308L	347 309LMo	347 310 309LMo	318 347	308L 316L 347	347	347 309LMo	309LMo 309L	309LMo
304 304L		347 308L	347 309LMo 308L 309L	347 310 308L	347 318 308L	347 318 308L	347 308L	309LMo 309L	309MoL	309LMo 309L
309 309S			309LMo 309L	309LMo 309L 310	309LMo 318 316 309L	309L 316L 318	347 309LMo	309LMo 309L	309LMo 309L	309LMo 309L
310 310S				310	316L 318 310	316L 318 310	347 310	309LMo 309L 316L	309LMo 309L 310	309LMo 309L 310
317 316					318 316L	316L 318	347 316L	309LMo 309L	309LMo 309L	309LMo 309L
317L 316L 316Ti						316L 318	347 316L	309LMo 309L	309LMo 309L	309LMo 309L
321 347							347	309LMo 309L	309LMo 309L	309LMo 309L
409 430 446								309L 309LMo	309LMo 309L	309LMo 309L
410 420									410 309LMo 309L	309LMo 309