

Duplex stainless steels are a specific group of engineering stainless steel materials consisting of the austenitic and ferritic phase in roughly equal proportions in the microstructure. They are widely popular because of their good corrosion resistance along with high strength and ease of fabrication. Compared to traditional austenitic stainless steel and ferritic stainless steel grades; Duplex Stainless Steels provide a range of benefits like:

- **Improved Strength:** Roughly two-times stronger than normal stainless-steel grades.
- High Toughness and Ductility
- High Corrosion Resistance
- **Cost-Effectiveness:** High strength of DSS material required less pipe thickness reducing pipe weight. Also, lower levels of nickel reduce cost.

Applications of Duplex Stainless Steel

Excellent corrosion resistance with increased strength and affordable pricing makes duplex stainless steels (DSS) a popular choice for a variety of industries. Their wide uses are found in:

- Chemical and liquid processing
- Offshore (flowlines, risers) and other industrial operations
- Naval parts and components
- Pulp and paper production
- Pollution control equipment
- Water Treatment/Desalination plants
- Construction, Infrastructure, Architecture
- Hot water and brewing tanks
- Food and Drink Storage
- Boilers, Heat exchangers, pressure vessels

- Marine Tanks
- Renewable Energy
- Nuclear Industry

Duplex Stainless Steel Grades

Duplex stainless steels have a higher chromium content, 20–28%; higher molybdenum, up to 5%; lower nickel, up to 9% and 0.05–0.50% nitrogen as compared to austenitic stainless steels. For resistance against pitting corrosion, DSS material is an ideal selection. The resistance against pitting corrosion is characterized by the pitting resistance equivalence number, or PREN Number defined as follows:

$$\text{PREN} = \% \text{Cr} + 3.3 \% \text{Mo} + 16 \% \text{N}$$

Depending on the PREN Number values, Duplex Stainless Steel are categorized into four grades.

- **Lean duplex grades (PREN range: 22–27):** No deliberate Molybdenum addition. mainly used in building and construction industry for bridges, pressure vessels or tie bars. Example: S32001, S32101, S32304, S32202.
- **Standard duplex (PREN range: 28–38):** The most widely used (More than 80%) duplex stainless steel material with mid-range properties. Example: S32003, S31803, S32205
- **Super duplex (PREN range: 38-45):** Higher contents of Cr, Ni, Mo, N and even W. Specifically designed for highly corrosive oil&gas and chemical industries. Example, S32750, S32760, S32950, S32808.
- **Hyper duplex (PREN >45):** These are highly alloyed duplex stainless steels. Example S32707, S33207

Naming Convention for Duplex Stainless Steels

Various naming conventions are followed for duplex stainless steels such as:

- **Composition based Names:** For DSS 2205 or 2305; 22 or 23 denotes %Cr and 5 denotes %Ni in that specific DSS material.
- **UNS Designation:** Unified Numbering System or UNS designation of DSS materials are the most popular and listed on ASTM specifications.
- **AISI Designation:** Only one DSS material type 329 has AISI designation.

Duplex Stainless Steel properties

As informed earlier the duplex name has arrived from the co-existence of both austenitic (FCC Structure) and ferritic (BCC Structure) in approximately equal proportions (Fig. 1). The major alloying elements are Chromium, Silicon, Molybdenum, Carbon, Nickel, Nitrogen, Manganese, Copper, Tungsten.

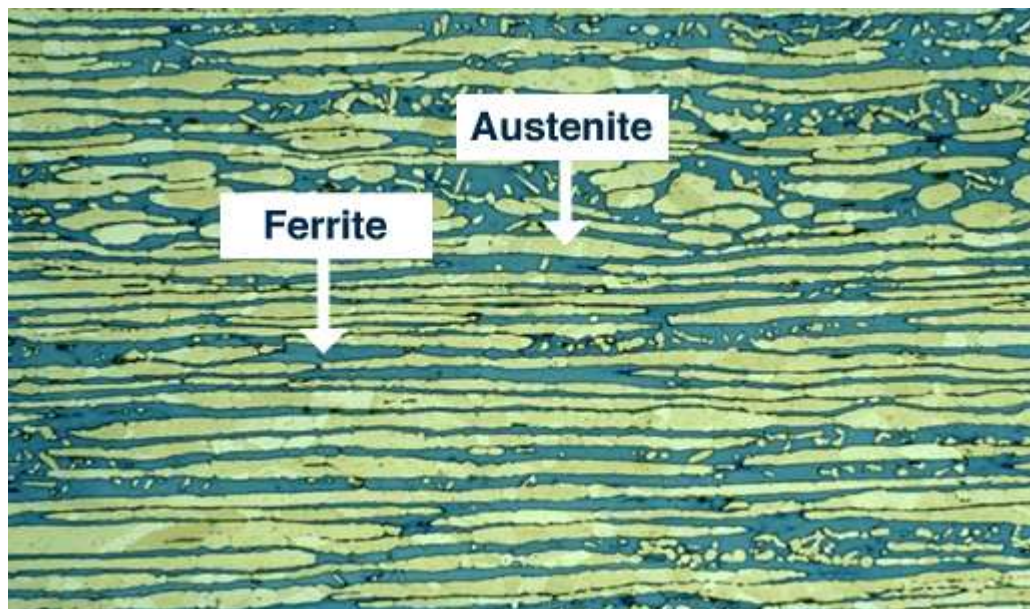


Fig. 1: Duplex Stainless Steel Microstructure

Typical duplex stainless steel exhibits a higher strength value as compared to stainless steel. But, the working temperature range of DSS is normally narrow as at around 300°C undesirable intermetallic phases (α' -alpha prime phase)

start to precipitate which decreases the mechanical properties and corrosion resistance by embrittlement phenomenon. The following table provides some selected properties of common duplex stainless steel grades.

DSS Grades	ASTM A789 Grade S32520 Heat- Treated	ASTM A790 Grade S31803 Heat- Treated	ASTM A790 Grade S32304 Heat- Treated	ASTM A815 Grade S32550 Heat- Treated	ASTM A815 Grade S32550 Heat- Treated
Elastic Modulus	200 GPa	200 GPa	200 GPa	200 GPa	200 GPa
Elongation	25 %	25 %	25 %	15 %	20 %
Tensile Strength	770 MPa	620 MPa	600 MPa	800 MPa	650 MPa
Brinell hardness	310	290	290	302	290
Yield Strength	550 MPa	450 MPa	400 MPa	550 MPa	450 MPa
Thermal expansion co-efficient	1E-5 1/K	1E-5 1/K	1E-5 1/K	1E-5 1/K	1E-5 1/K
Specific Heat capacity	440 – 502 J/(kg·K)	440 – 502 J/(kg·K)	440 – 502 J/(kg·K)	440 – 502 J/(kg·K)	440 – 502 J/(kg·K)
Thermal Conductivity	13 – 30 W/(m·K)	13 – 30 W/(m·K)	13 – 30 W/(m·K)	13 – 30 W/(m·K)	13 – 30 W/(m·K)

Table: Properties of Duplex Stainless Steel

The stress-strain curve of austenitic, ferritic, and duplex stainless steels are plotted in the following curve for reference:

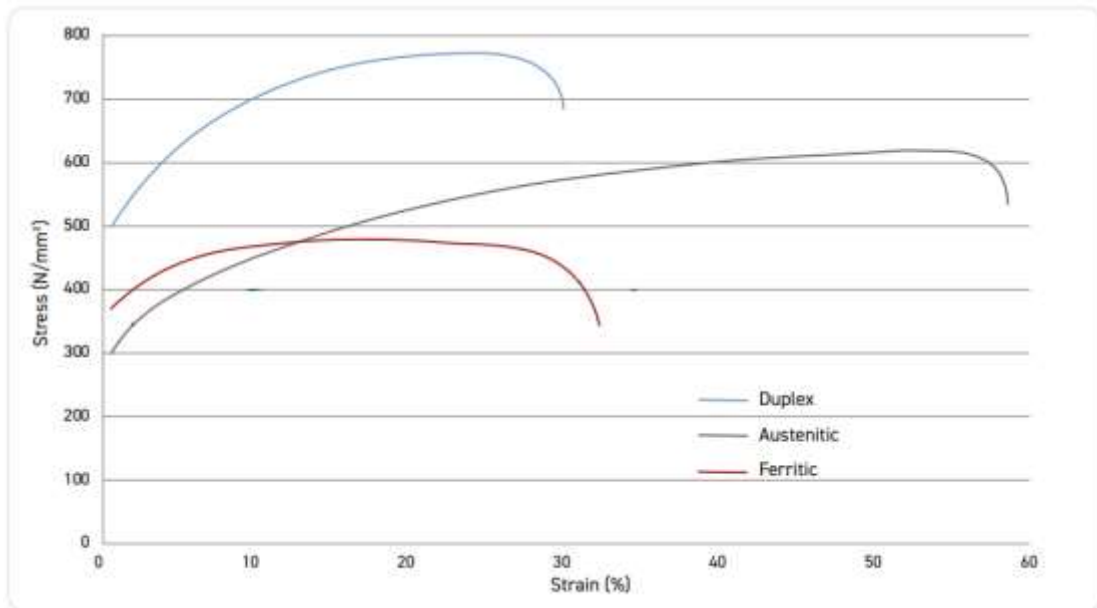


Fig. 2: Stress Strain curve comparison

for SS and DSS

Composition of Duplex Stainless Steel

The following table in Fig. 3 provides the chemical compositions in %wt for common DSS materials.

Grade	UNS No.	EN No.	C	Cr	Ni	Mo	N	Mn	Cu	W
Wrought duplex stainless steels										
First-generation duplex grades										
329	S32900	1.4460	0.08	23.0–28.0	2.5–5.0	1.0–2.0	–	1.00	–	–
**	S31500	1.4424	0.03	18.0–19.0	4.3–5.2	2.5–3.0	0.05–0.1	–	–	–
	S32404		0.04	20.5–22.5	5.5–8.5	2.0–3.0	0.20	2.00	1.0–2.0	–
Second-generation duplex grades										
Lean										
	S32001	1.4482	0.03	19.5–21.5	1.0–3.0	0.6	0.05–0.17	4.0–6.0	1.0	–
	S32101	1.4162	0.04	21.0–22.0	1.35–1.7	0.1–0.8	0.20–0.25	4.0–6.0	0.1–0.8	–
	S32202	1.4062	0.03	21.5–24.0	1.0–2.8	0.45	0.18–0.26	2.00	–	–
	S82011		0.03	20.5–23.5	1.0–2.0	0.1–1.0	0.15–0.27	2.0–3.0	0.5	–
2304	S32304	1.4362	0.03	21.5–24.5	3.0–5.5	0.05–0.6	0.05–0.20	2.50	0.05–0.60	–
		1.4655	0.03	22.0–24.0	3.5–5.5	0.1–0.6	0.05–0.20	2.00	1.0–3.0	–
Standard										
	S32003		0.03	19.5–22.5	3.0–4.0	1.5–2.0	0.14–0.20	2.00	–	–
2205	S31803	1.4462	0.03	21.0–23.0	4.5–6.5	2.5–3.5	0.08–0.20	2.00	–	–
2205	S32205	1.4462	0.03	22.0–23.0	4.5–6.5	3.0–3.5	0.14–0.20	2.00	–	–
25 Cr										
	S31200		0.03	24.0–26.0	5.5–6.5	1.2–2.0	0.14–0.20	2.00	–	–
	S31260		0.03	24.0–26.0	5.5–7.5	2.5–3.5	0.10–0.30	1.00	0.2–0.8	0.1–0.5
	S32506		0.03	24.0–26.0	5.5–7.2	3.0–3.5	0.08–0.20	1.00	–	0.05–0.30
	S32520	1.4507	0.03	24.0–26.0	5.5–8.0	3.0–4.0	0.20–0.35	1.50	0.5–2.0	–
255	S32550	1.4507	0.04	24.0–27.0	4.5–6.5	2.9–3.9	0.10–0.25	1.50	1.5–2.5	–

Grade	UNS No.	EN No.	C	Cr	Ni	Mo	N	Mn	Cu	W
Super duplex										
2507	S32750	1.4410	0.03	24.0–26.0	6.0–8.0	3.0–5.0	0.24–0.32	1.20	0.5	–
	S32760	1.4501	0.03	24.0–26.0	6.0–8.0	3.0–4.0	0.20–0.30	1.00	0.5–1.0	0.5–1.0
	S32808		0.03	27.0–27.9	7.0–8.2	0.8–1.2	0.30–0.40	1.10	–	2.1–2.5
	S32906		0.03	28.0–30.0	5.8–7.5	1.5–2.6	0.30–0.40	0.80–1.5	0.8	–
	S32950		0.03	26.0–29.0	3.5–5.2	1.0–2.5	0.15–0.35	2.00	–	–
	S39274		0.03	24.0–26.0	6.8–8.0	2.5–3.5	0.24–0.32	1.0	0.2–0.8	1.5–2.5
	S39277		0.025	24.0–26.0	6.5–8.0	3.0–4.0	0.23–0.33	0.80	1.2–2.0	0.8–1.2
		1.4477	0.03	28.0–30.0	5.8–7.5	1.5–2.6	0.30–0.40	0.80–1.50	≤0.8	–
Hyper duplex										
	S32707		0.03	26.0–29.0	5.5–9.5	4.0–5.0	0.30–0.50	1.50	1.0	–
	S33207		0.03	29.0–33.0	6.0–9.0	3.0–5.0	0.40–0.60	1.50	1.0	–

Fig. 3: Typical Chemical Composition of Duplex Stainless Steel

Corrosion Resistance of Duplex Stainless Steel

Due to the presence of a relatively high % of chromium, molybdenum, and nitrogen, Duplex Stainless Steels exhibit a high level of corrosion resistance capability in a variety of environments. DSS materials are specifically selected for oxidizing, acidic, and hot alkaline environments. To fight against pitting corrosion, DSS is the ideal material choice. The PREN Number defined above describes the resistance of DSS against localized pitting corrosion. An increase in PREN Number increases the resistance against pitting corrosion that is quantified using Critical Pitting Temperature. Materials with higher CPT are more resistant to pitting corrosion.

Duplex stainless steels possess better Stress Corrosion Cracking resistance than austenitic stainless steels.

Fabrication of Duplex Stainless Steel

Duplex Stainless steel is supplied in a pipe, plate, sheet, tube, fittings, or bar form. Depending on the requirement they must be fabricated. Special tools are required for the fabrication of duplex stainless steel materials. They have very good weldability and hot forming capability. However, DSS materials are normally difficult for machining purposes.