Specialty steels

- Maraging steels are low-carbon, high-nickel steels strengthened by precipitation hardening rather than carbon martensite. They undergo aging treatments that form intermetallic compounds, leading to exceptional toughness and strength. Used in aerospace, tooling, and high-performance components.
- Spring Steels: Medium- to high-carbon steels with Si and Mn, providing high yield strength and fatigue resistance.
- HSLA (High-Strength Low-Alloy) Steels: Designed for strength and toughness with small additions of Nb, Ti, or V. They are weldable and used in structural applications.

Applications and Summary

Specialty steels are essential in tools, dies, aerospace, structural, and wear-resistant applications. Their properties are tailored through careful alloying and heat treatment.

Stainless Steels

Introduction to Stainless Steels

Stainless steels are corrosion-resistant alloys primarily composed of iron and at least 10.5% chromium. They form a passive oxide film on the surface that provides corrosion resistance. Other elements like Ni, Mo, and N are added to enhance properties.

Classification of Stainless Steels

• Ferritic: BCC, magnetic, not hardenable by heat treatment, e.g., Type 430.

• Martensitic: BCT, magnetic, hardenable by quenching, e.g., Type 410.

• Austenitic: FCC, non-magnetic, not hardenable by heat treatment, e.g., Type 304/316.

• Duplex: Mixed ferrite and austenite, good strength and corrosion resistance.

• Precipitation-Hardening (PH): Martensitic or semi-austenitic, strengthened by solution treatment + aging, e.g., 17-4PH.

Heat Treatment of Stainless Steels

• Ferritic: Annealed to relieve stress and refine grain size.

• Martensitic: Austenitized, quenched, and tempered.

• Austenitic: Solution annealed at ~1050°C, rapidly cooled to prevent carbide precipitation.

•Duplex: Solution treated to balance ferrite and austenite phases; cooled to avoid intermetallic phases.

• Precipitation-Hardening (PH): Solution treated followed by aging to form strengthening precipitates (e.g., 17-4PH, 15-5PH).

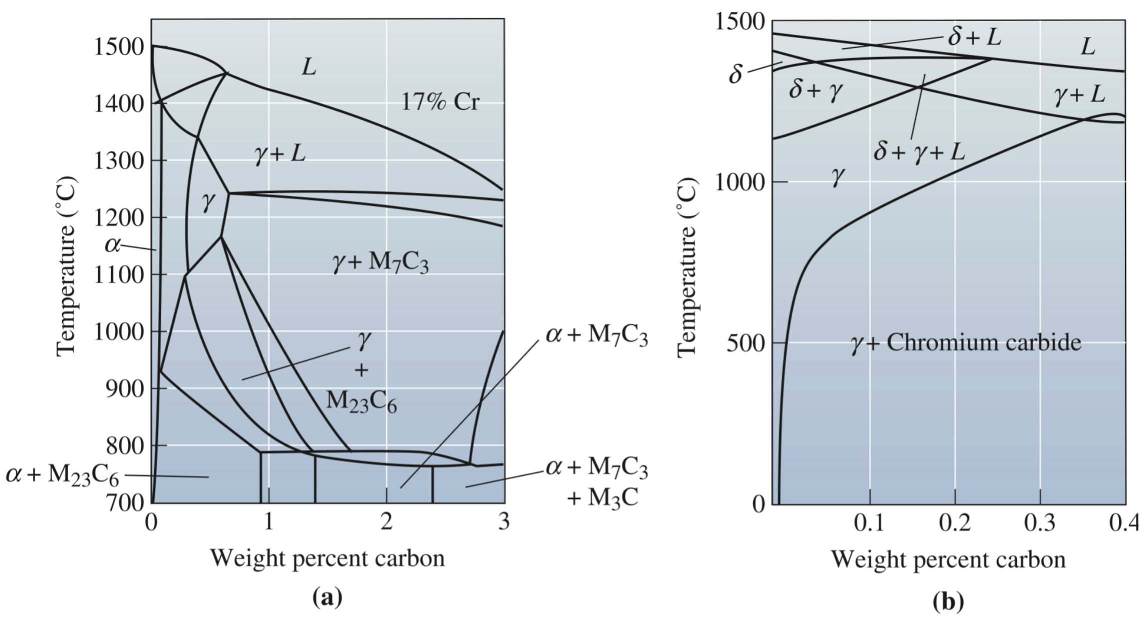

Figure 1 (a) The effect of 17% chromium on the iron-carbon phase diagram. At low carbon contents, ferrite is stable at all temperatures. Note that "M" stands for "metal" such as Cr and Fe or other alloying additions. (b) A section of the iron-chromium-nickel-carbon phase diagram at a constant 18% Cr-18% Ni. At low carbon contents, austenite is stable at room temperature.

Table 1 Typical compositions and properties of stainless steels

Steel	% C	% Cr	% Ni	Others	Tensile Strength (psi)	Yield Strength (psi)	% Elongation	Condition
Austenitic								
201	0.15	17	5	6.5% Mn	95,000	45,000	40	Annealed
304	0.08	19	10		75,000	30,000	30	Annealed
					185,000	140,000	9	Cold-worked
304L	0.03	19	10		75,000	30,000	30	Annealed
316	0.08	17	12	2.5% Mo	75,000	30,000	30	Annealed
321	0.08	18	10	0.4% Ti	85,000	35,000	55	Annealed
347	0.08	18	11	0.8% Nb	90,000	35,000	50	Annealed
Ferritic								
430	0.12	17			65,000	30,000	22	Annealed
442	0.12	20			75,000	40,000	20	Annealed
Martensitic								
416	0.15	13		0.6% Mo	180,000	140,000	18	Quenched and tempered
431	0.20	16	2		200,000	150,000	16	Quenched and tempered
440C	1.10	17		0.7% Mo	285,000	275,000	2	Quenched and tempered
Precipitation hardening								
17-4	0.07	17	4	0.4% Nb	190,000	170,000	10	Age-hardened
17-7	0.09	17	7	1.0% Al	240,000	230,000	6	Age-hardened

Sensitization and Stabilization

• Sensitization occurs when austenitic stainless steels are held at 450–850°C, forming chromium carbides at grain boundaries.

• This depletes chromium locally, reducing corrosion resistance.

• Stabilization involves adding Ti or Nb to form more stable carbides, preventing chromium depletion.

Example ***Design of a Stainless Steel Weldment***

A piping system used to transport a corrosive liquid is fabricated from 304 stainless steel. Welding of the pipes is required to assemble the system. Unfortunately, corrosion occurs, and the corrosive liquid leaks from the pipes near the weld. Identify the problem and design a system to prevent corrosion in the future.

SOLUTION

Table 13-4 shows that 304 stainless steel contains 0.08% C, causing the steel to be sensitized if it is improperly heated or cooled during welding. Figure 23-15 shows the maximum temperatures reached in the fusion and heat-affected zones during welding. A portion of the pipe in the HAZ heats into the sensitization temperature

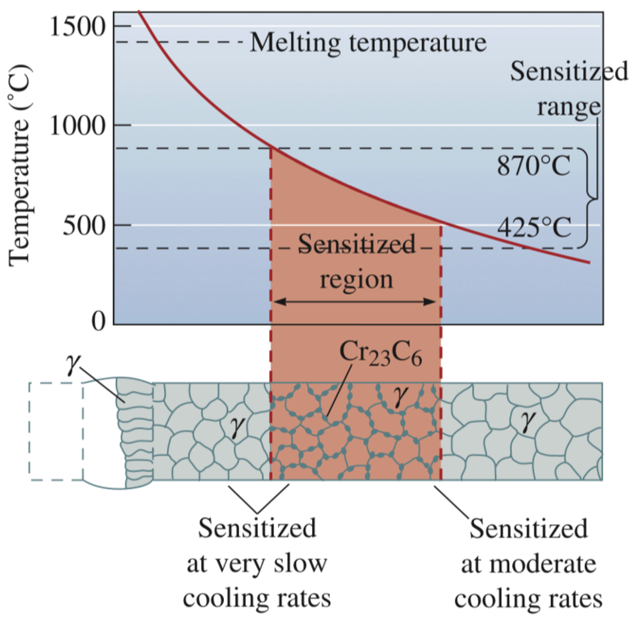

Figure 5

The peak temperature surrounding a stainless steel weld and the sensitized structure produced when the weld slowly cools (for Example 23-10).

range, permitting chromium carbides to precipitate. If the cooling rate of the weld is very slow, the fusion zone and other areas of the heat-affected zone may also be affected. Sensitization of the weld area, therefore, is the likely reason for corrosion of the pipe.

Several solutions to the problem may be considered. We might use a welding process that provides very rapid rates of heat input, causing the weld to heat and cool very quickly. If the steel is exposed to the sensitization temperature range for only a brief time, chromium carbides may not precipitate. Joining processes such as laser welding or electron-beam welding are high-rate-of-heat-input processes, but they are expensive. In addition, electron beam welding requires the use of a vacuum, and it may not be feasible to assemble the piping system in a vacuum chamber.

We might heat treat the assembly after the weld is made. By performing a quench anneal, any precipitated carbides are re-dissolved during the anneal and do not reform during quenching; however, it may be impossible to perform this treatment on a large assembly.

We might check the original welding procedure to determine if the pipe was preheated before joining in order to minimize the development of stresses due to the welding process. If the pipe were preheated, sensitization would be more likely to occur. We would recommend that any preheat procedure be suspended.

Perhaps our best design is to use a stainless steel that is not subject to sensitization. For example, carbides do not precipitate in a 304L stainless steel, which contains less than 0.03% C. The low-carbon stainless steels are more expensive than the normal 304 steel; however, the extra cost does prevent corrosion and still permits us to use conventional joining techniques.

Corrosion Resistance and Applications

- Chromium oxide film provides passivation.
- Mo improves resistance to pitting and crevice corrosion.
- Applications: medical devices, food processing, aerospace, power plants.

Industrial Case Study: Intergranular corrosion in stainless steel

Case: Stainless steel pipes corroded along grain boundaries.

Cause: Sensitization due to improper heat treatment.

Lesson: Heat treatment of stainless steels must consider carbide precipitation