SHEng
SMART HEALTHCARE ENGINEERING
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STAINLESS STEEL IN HEALTHCARE FACILITIES

Part 2

Class content material

This document is part of a training materials collection developed within the Erasmus+ project “Smart healthcare engineering”, SHEng, project No. 2023-1-RO01-KA220-HED-000159985.

The collection is intended for engineering students and professionals working in the healthcare sector. It covers technical subjects relevant to hospital infrastructure, equipment, materials and support services, helping readers understand how engineering contributes to safe patient care and the reliable operation of healthcare facilities.

These materials support classroom teaching and independent study. They should be used alongside the project handbook and the presentations, courses and other learning resources available on the project website. Each document addresses a specific subject, while the collection provides a broader understanding of the responsibilities and practical challenges of healthcare engineering.

The content is educational. Its application in practice requires consideration of the conditions of each healthcare facility, the applicable standards and the instructions provided by equipment manufacturers.

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Designation and classification of stainless steels

1. Designation of stainless steels

European designation of stainless steels and other alloy steels (excepting high-speed steels) where the average content by weight of at least one alloying element is ≥ 5% (EN 10027-1:2016 [T1]):

Principal symbols							Additional symbols for steels	Additional symbols for steels products
G	X	n	n	n	a..	n-n..	an	+an +an .....
PM	X	n	n	n	a..	n-n..		

Principal symbols represent:

- G = steel casting (where necessary);
- PM = powder metallurgy (where necessary for tool steel);
- X = the average content of at least one alloying element ≥ 5%;
- nnn = 100 × specified average carbon percentage content;
- a = chemical symbols indicating alloying elements that characterize the steel;
- n-n = numbers, separated by hyphens, representing respectively the average percentage of the elements rounded to the nearest integer.

Additional symbols contain:

- a = chemical symbol, separated by a hyphen, indicating an alloying element that characterizes the steel and whose content is in the range 0.20...1.0 %;

- n = 10 × specified average content for the alloying element.

Group 3 may contain various symbols for steel products, indicating:

- special requirements (Table 16 from EN 10027-1:2016);
- heat treatment (Table 18 from EN 10027-1:2016).

For example:

- X6Cr17 EN 10088-2:2024 is an austenitic stainless steel with C≤ 0.08 %, Cr= 16 to 18 %,
- X2CrNiMo17-12-2 EN 10088-2:2024 is an austenitic stainless steel with C≤ 0.03 %, Cr= 16.5 to 18.5 %, Ni= 11 to 13 %, Mo= 2 to 2.5 %.

EN 10027-2:2015 specifies a standardized numerical system (steel numbers) used to designate steel grades, complementing the symbolic steel names defined in EN 10027-1 There are several designations for stainless steels [1]:

Number = 1.40XX Stainless steel with Ni < 2.5 % without Mo, Nb and Ti

Number = 1.41XX Stainless steel with Ni < 2.5 % and Mo but without Nb and Ti

Number = 1.43XX Stainless steel with Ni >= 2.5 % without Mo, Nb and Ti

Number = 1.44XX Stainless steel with Ni > = 2.5 % with Mo but without Nb and Ti

Number = 1.45XX Stainless steels with special additions

Number = 1.46XX Chemical resistant and high temp Ni alloys

Number = 1.47XX Heat resistant steels with Ni < 2.5 %

Number = 1.48XX Heat resistant steels with Ni > = 2.5 %

Number = 1.49XX Materials with elevated temperature properties.

In the United States, the designation of stainless steels is based on two primary systems: the traditional AISI (American Iron and Steel Institute) numbering system and the modern UNS (Unified Numbering System). Although AISI designations remain widely used in commercial communication, UNS codes predominate in official standards, material certificates, and technical

specifications. The following detailed comparison presents all essential correlations in the form of structured tables, for greater clarity and ease of reference [2].

Differences between the AISI and UNS systems [2]:

Aspect	AISI System	UNS System
Full Name	American Iron and Steel Institute	Unified Numbering System
Developed By	American Iron and Steel Institute	ASTM International + SAE International
Introduction Period	Mid-20th century	1970s onward
Primary Purpose	Practical commercial identification	Precise, standardized identification of all alloys
Current Status	Still used in daily communication	Preferred in modern standards (ASTM, ASME, etc.)
Number Format	3-digit number + optional suffix	Letter + 5 digits (Sxxxxx for stainless)
Expandability	Limited (no longer actively updated)	Highly expandable
Ambiguity Level	Higher (same number can cover slight variants)	Very low (unique designation for each grade)
Typical Example	304, 316L, 410	S30400, S31603, S41000

Comparative structure of AISI and UNS designations [2]:

Feature	AISI	UNS
Series Indication	First digit (2xx, 3xx, 4xx)	Letter prefix (S = stainless)

Feature	AISI	UNS
Carbon Level Indication	Suffix letters (L = low, H = high)	Last digits of the number
Special Additions	Suffix (Ti, N, Se, Cu, etc.)	Incorporated into the unique 5-digit number
Coverage of New Alloys	Poor	Excellent
Formal Standards Adoption	Secondary	Primary

The equivalence of various stainless steel grades, their chemical composition, and their mechanical properties can be found in [3].

2. Stainless steels classification

Solid solutions α, having Body-Centered Cubic (BCC) structure, and γ, having Face-Centered Cubic (FCC) structure, comprising alloying elements in interstitial position (C and N) or substitution position (Cr, Ni, Ti) are the matrix of stainless steels. Interstitial and intermetallic phases and inclusions comprise minor constituents:

- interstitial phases:
  - the most common types of carbides are M23C6,
  - Cr23(B,C)6, Cr23C6 and Cr23C6 that can dissolve elements like Mo, Ni, V, W,
  - other chromium carbides (Cr7C3, Cr6C) and nitrides (CrN, Cr2N),
  - the presence of Ti, Nb or Zr generates the formation of MX-type carbides, nitrides, or carbonitrides with FCC structure,
- intermetallic phases:
  - the sigma phase (σ) having complex crystal network with chemical composition B4A or BA4,
  - the AB2 type phase and the Laves (n) phase, when molybdenum (Fe2Mo), niobium, titanium, tungsten etc. are present,

- the intermetallic phase having electronic character (Hume-Rothery type) such as the χ phase, with an isomorphous crystallographic network.

Stainless steels can be classified based on their chemical composition or crystal structure (Figure 1).

Ferritic stainless steels (400 series according to AISI) are usually chromium-containing alloys with BCC crystal structures. They have a Cr content of 13…17% and a C percentage of < 0.07%. Some grades may contain aluminum, molybdenum, niobium, silicon and titanium to obtain specific characteristics. Selenium or sulfur can be added to improve machinability.

The ferritic stainless steels are ferromagnetic. Because of BCC structure they have good ductility and formability, and their high-temperature strengths are not as good as those of the austenitic grades. In heavy sections and at low temperatures, toughness may be somewhat restricted. These steels are neither heat treatable, nor hardenable since their structure cannot be changed by heat treatment. They have a propensity for grain growth during heat treatment and welding, which causes cold brittleness in large cross-sections.

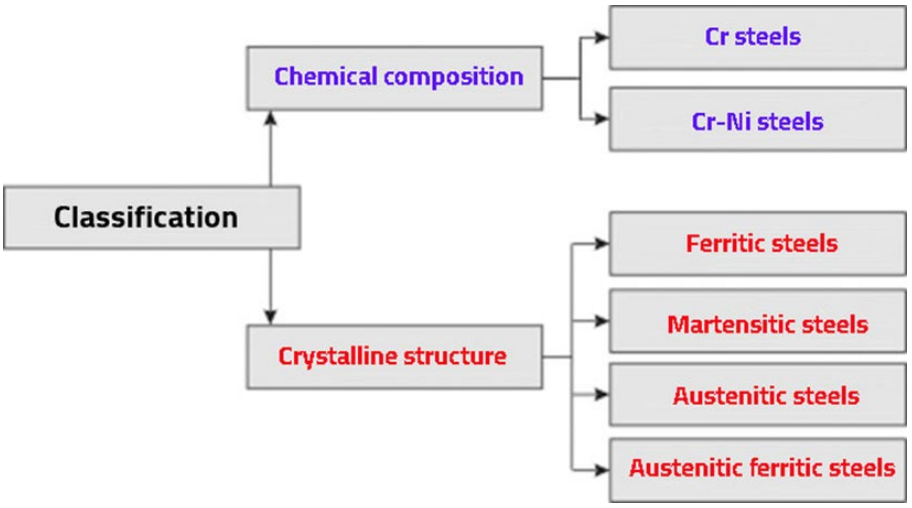

Fig. 1. Classification of stainless steels

Properties of ferritic stainless steels:

- good corrosion resistance,
- resistant to stress crack corrosion,
- only thin cross-sections can be welded,
- good warm and cold formability,

- magnetic,
- cannot be hardened by heat treatment,
- low coefficient of thermal expansion,
- high thermal conductivity,
- more economical than austenitic steels.

Next table contains main alloying elements of the ferritic stainless steels grades [4]:

Group	Steel designation according to EN 10088 (AISI)	EN Number	Composition (in mass %)			
			Cr	Mo	C max.	Others
Ferritic	X6Cr17 (430)	1.4016	16.0-18.0		0.08	
	X2CrTiNb18 (441)	1.4509	17.5-18.5		0.03	[3xC+0.30] to 1.0 Nb / 0.1-0.6 Ti
	X3CrTi17 (439)	1.4510	16.0-18.0		0.05	[4x(C+N)+0.15] to 0.80 Ti*
	X2CrMoTi18-2 (444)	1.4521	17.0-20.0	1.80-2.50	0.025	[4x(C+N)+0.15] up to 0.80 Ti*

Martensitic stainless steels (400 series according to AISI) are iron-chromium-carbon alloys with a Body-Centered Tetragonal (BCT) crystal structure in the hardened state. This martensitic structure is obtained when carbon-doped ferritic steels are rapidly cooled. This material has to be tempered after quenching to make it machinable and storable because martensitic steel is brittle and prone to stress cracking. Although martensitic steels have high hardness and are resistant to corrosion; however, they have only a low level of toughness at low temperatures.

Martensitic stainless steels are ferromagnetic. The percentage of chromium is between 10.5 and 18%, and the carbon content may be higher than 1.2%. To guarantee a martensitic structure following hardening, the amounts of carbon and chromium are balanced. In the case of cutting edges, excess carbides may be present to preserve knife blades or to boost wear resistance. To change the tempering response after hardening, elements like niobium, silicon, tungsten and vanadium can be added. In certain media, small amounts of nickel can be added to improve toughness and corrosion resistance. To make some grades more machinable, sulfur or selenium is added.

Properties of martensitic stainless steels:

- good corrosion resistance,
- not susceptible to stress crack corrosion,
- can only be welded conditionally,

- moderate hot and cold formability,
- magnetic,
- can be hardened by heat treating,
- low coefficient of thermal expansion,
- high thermal conductivity,
- more economical than austenitic steels,
- lends itself to machining.

Next table contains main alloying elements of the martensitic stainless steels grades [4]:

Group	Steel designation according to EN 10088 (AISI)	EN Number	Composition (in mass %)			
			Cr	Mo	C	Others
Marten-sitic	X20Cr13 (420)	1.4021	12.0-14.0		0.16-0.25	
	X17CrNi16-2 (431)	1.4057	15.0-17.0		0.12-0.22	1.5-2.5 Ni
	X39CrMo17-1	1.4122	15.5-17.5	0.8-1.3	0.33-0.45	≤ 1.0 Ni

Austenitic stainless steels have FCC structure. This structure is obtained due to the alloying content of austenitizing elements such as nickel, manganese and nitrogen. According to AISI designation, chromium-manganese austenitic steels belong to 200 series and chromium-nickel austenitic steels belong to 300 series.

Austenitic stainless steels can only be hardened by cold working and are virtually nonmagnetic when annealed. They usually have good resistance to high temperatures and remarkable cryogenic qualities. The typical range for chromium content is 16…26%, nickel is up to approx. 35%, and manganese is up to 15%. The 2xx series steels have up to 7% Ni, 4 to 15.5% Mn, and nitrogen. The 3xx types have up to 2% Mn and higher nickel concentrations. It is possible to add aluminum, copper, molybdenum, niobium silicon and titanium to give specific properties like oxidation resistance or resistance to halides. To make some grades more machinable, sulfur or selenium may be added.

Properties of austenitic stainless steels:

- very good corrosion resistance, but susceptible to stress crack corrosion,
- easy to weld,
- very good hot and cold formability,

- non-magnetic,
- cannot be hardened by heat treatment,
- greater coefficient of thermal expansion,
- low thermal conductivity,
- great toughness even at low temperatures.

Next table contains main alloying elements of the austenitic stainless steels grades [4]:

Group	Steel designation according to EN 10088 (AISI)	EN Number	Composition (in mass %)				
			Cr	Ni	Mo	C max.	Others
Austenitic (CrNi)	X5CrNi18-10 (304)	1.4301	17.5-19.5	8.0-10.5		0.07	max. 0.11 N
	X2CrNi18-9 (304L)	1.4307				0.03	
	X2CrNi19-11 (304L)	1.4306	18.0-20.0	10.0-12.0			
	X6CrNiTi18-10 (321)	1.4541	17.0-19.0	9.0-12.0		0.08	5xC-0.7 Ti
Austenitic (CrNiMo)	X5CrNiMo17-12-2 (316)	1.4401	16.5-18.5	10.0-13.0	2.0-2.5	0.07	max. 0.11 N
	X2CrNiMo17-12-2 (316L)	1.4404				0.03	
	X6CrNiMoTi17-12-2 (316Ti)	1.4571		10.5-13.5		0.08	5xC-0.7 Ti
Austenitic (CrMn)	X12CrMnNiN17-7-5 (201)	1.4372	16.0-18.0	3.5-5.5		0.15	5.5-7.5 Mn / 0.05-0.25 N
	X9CrMnNiCu17-8-5-2 [a] (201Cu)	1.4618 [a]	16.5-18.5	4.5-5.5		0.10	5.5-9.5 Mn/1.0-2.0 Cu max. 0.15 N

The structure of **duplex stainless steels** (austenitic ferritic) is a combination of FCC austenite and BCC ferrite. Chemical composition and heat treatment determine the precise amount of each phase. Most alloys are made to have roughly equal amounts of each phase when they are annealed. Although chromium and nickel are the main alloying elements, copper, molybdenum, nitrogen, silicon, and tungsten can be added to regulate structural balance and impart specific corrosion-resistance properties.

Duplex stainless steels have the same corrosion resistance as austenitic stainless steels with similar alloying content. Duplex stainless steels, on the other hand, have higher tensile and yield strengths and are more resistant to stress-corrosion cracking than austenitic steels. Duplex stainless steels have a toughness that falls somewhere between austenitic and ferritic.

Properties of duplex stainless steels:

- very good corrosion resistance,
- not susceptible to stress crack corrosion,

- easy to weld,
- moderate hot and cold formability,
- 50:50 ferrite/austenite structure,
- cannot be hardened by heat treatment,
- moderate coefficient of thermal expansion,
- moderate thermal conductivity,
- magnetic due to ferrite content,
- resistant to chlorides.

Next table contains main alloying elements of the austenitic ferritic stainless steels grades [4]:

Group	Steel designation according to EN 10088	EN Number	Composition (in mass %)				
			Cr	Ni	Mo	C max.	Others
Duplex	X2CrNiN23-4*	1.4362	22.0-24.0	3.5-5.5	0.1-0.6	0.03	0.10-0.60 Cu 0.05-0.20 N
	X2CrNiMoN22-5-3**	1.4462	21.0-23.0	4.5-6.5	2.5-3.5		0.10-0.22 N
Super-duplex	X2CrNiMoN25-7-4***	1.4410	24.0-26.0	6.0-8.0	3.0-4.5		0.24-0.35 N

3. Review questions and suggested answers

Questions for independent study

1. What does X2 mean as a prime symbol in the designation of stainless steels?

2. In what systems is stainless steel designated in the United States?

3. Which chemical elements are found in the structure of stainless steel in interstitial positions?

4. Which stainless steel is non-magnetic?

5. What is the structure of duplex stainless steels?

6. How can austenitic stainless steels be hardened?

Answers

1. Carbon content 0.02%.

2. In the United States a stainless steel is designated according to the AISI (American Iron and Steel Institute) or the UNS (Unified Numbering System).

3. C and N are found in the structure of stainless steel in interstitial positions.

4. Austenitic stainless steel is non-magnetic.

5. The structure of duplex stainless steels is austenitic-ferritic.

6. Austenitic stainless steels can only be hardened by cold working.

References

[1] https://www.steelnumber.com/en/number_en10027_eu.php) (Accessed in May 27 2026)

[2] https://www.steelspecs.com/aisi-vs-uns-stainless-steel/ (Accessed in May 27 2026)

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[4] Werdohl, U.H. (2009) Stainless Steel - When Health Comes First, Environment and human health series, Euro Inox, Brussels, ISBN 978-2-87997-307-4.

https://worldstainless.org/wp-content/uploads/2025/02/WhenHealthComesFirst_DE.pdf

Standards and technical reading

[T1] EN 10027-1:2016 Designation systems for steels - Part 1: Steel names

Acknowledgments

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