

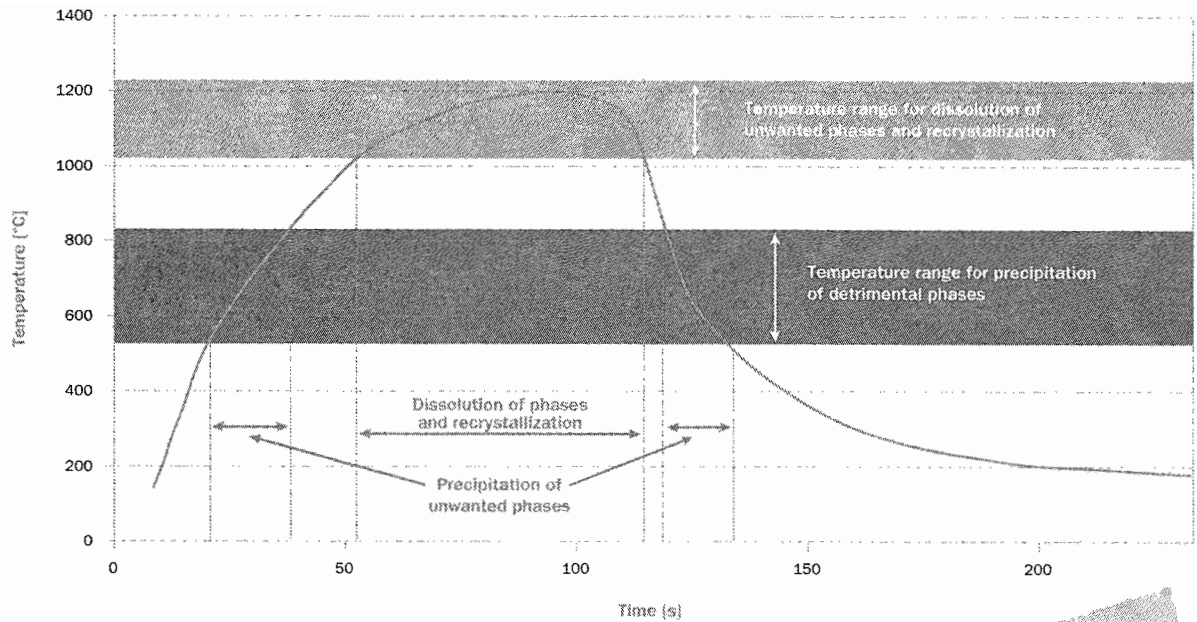


Figure 11.8. Example of a solution annealing cycle. The critical temperature ranges are strongly dependent on the steel grade.

cations where extreme cleanliness is important, for example in the pharmaceutical, semiconductor and dairy industries.

Heat treatment

Heat treatment is not without risk, as the material properties can easily deteriorate if it is done in an incorrect and uncontrolled way. The wrong combination of temperature/time/cooling rate can cause precipitation of detrimental phases, such as carbides, nitrides and sigma-phase. These may impair the mechanical properties, impact toughness and the corrosion resistance. In most cases, it is therefore usually safer to completely avoid heat treatment, but there are certain situations when it is justified.

The need of heat treatment is often driven by code or application requirements. The main reasons are restoration of microstructure to improve properties, relaxation of residual stresses to reduce risks of fatigue and stress corrosion cracking and improvement of dimensional stability.

Solution annealing

Solution annealing, Figures 11.7 and 11.8, softens material after cold working and dissolves secondary phases that can precipitate during hot working or welding. The term "full anneal" often means that the material is in its optimum metallurgical condition, with secondary phases completely dissolved and homogenized. This condition produces the best corrosion resistance and ductility. Because it is conducted at high temperatures, annealing in air produces a surface oxide scale that must be removed by descaling and pickling to restore the surface corrosion resistance.

The temperature is normally between 750 to 1200 °C depending on steel grade and the purpose of the annealing. Further details are given in the chapter 3, Physical metallurgy. The cooling should normally be as fast as possible; air cooling is normally fast enough but water quenching can be necessary for certain grades. Recom-

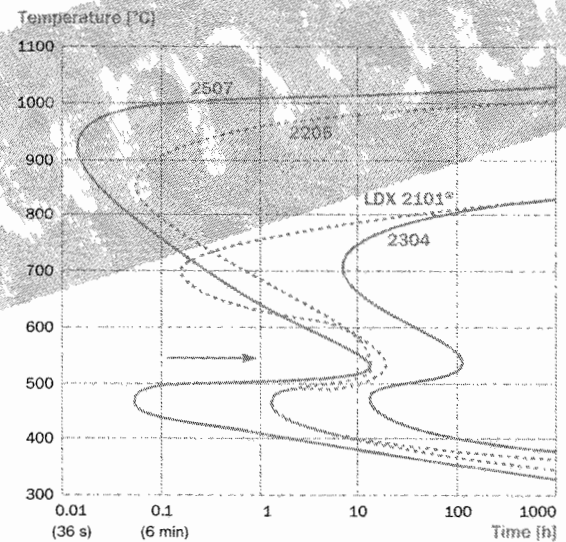


Figure 11.9. TTT (Time Temperature Transition) curves showing the narrow temperature range in which it is possible to carry out stress relieving of duplex stainless steel grades.

mended solution annealing temperatures and cooling practice for individual grades are given in Outokumpu data sheets.

Stress relieving

Stress relief treatments reduce residual stresses that may develop during forming and welding, and lower the risk of distortion or stress corrosion cracking. Stress relief is performed at temperatures below those used for solution annealing, and may not always require the descaling and pickling needed after full annealing. There are several procedures (temperature/time intervals) to perform stress relieving, each with its pros and cons.

When selecting heat treatment, the steel grade's susceptibility to precipitation of detrimental phases has to be considered, Figure

11:9. Furthermore, the shape of the work piece has to be taken into account, as large differences in thicknesses can give rise to new residual stresses during rapid cooling from high temperatures.

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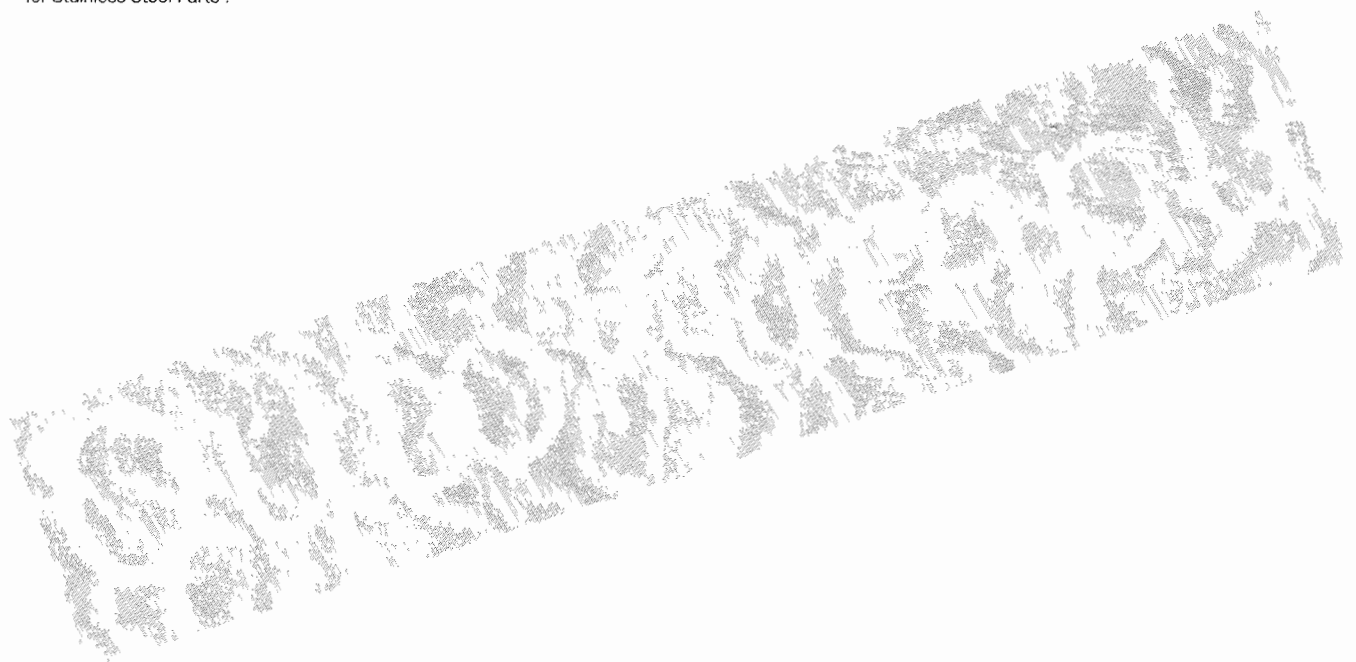
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ASTM A967, "Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts".



Handling and storage of stainless steel

Stainless steel products should be handled and stored in such a way that they are not damaged. The level of the demands depends both on the product and the intended future use. If the material is to undergo a fabrication sequence that includes both heat treatment and pickling, slight surface damage may be tolerated. On the other hand, if the stainless steel product will be directly installed, the demands of storage and handling are much more stringent.

A high standard of cleanliness, good order, and common sense regarding how various operations impact on the material, is usually enough to achieve appropriate handling conditions.

A clean, smooth and white surface provides the best corrosion resistance

As it is the surface which gives the material its corrosion resistance, one must always remember to protect the stainless steel surface. This includes taking care to avoid any mechanical damage. Scratches or other damage introduced in the fabrication shops are a common cause of passive film deterioration.

All kind of contamination should be avoided. Different types of contamination have different effects on the stainless steel. Carbon steel particles give rise to rust stain, Figures 12:1 and 12:2, paint, grease and oil can give rise to intergranular attack after welding or a heat treatment operation. Low melting metals such as copper, zinc, lead, aluminium and brass can give rise to cracks in weld or heat treated areas, so-called LME (Liquid Metal Embrittlement). The easiest way to avoid contamination is to keep stainless steel products separated from carbon steel and other metals.

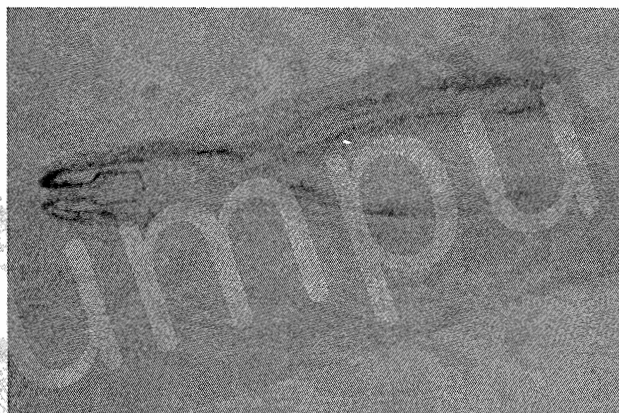


Figure 12:1. Staining caused by a pair of tongs left on a stainless steel plate.

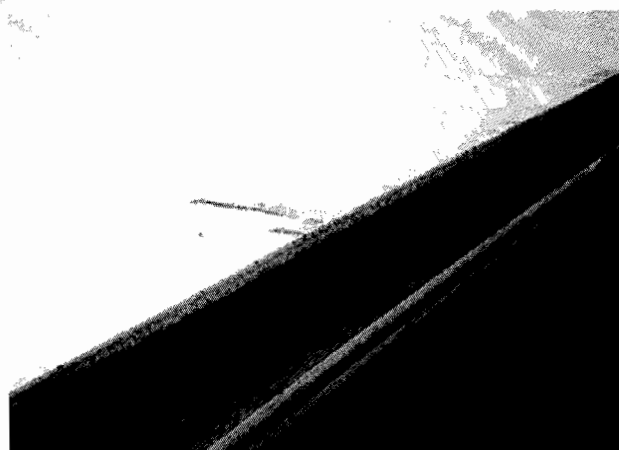


Figure 12:2. Staining caused by iron contamination from truck forks.

Store stainless steel indoors if possible

Storing indoors helps to protect the steel from external pollution. If indoor storage is not possible, the stainless steel should be covered. This is especially important if a wrapping which might absorb water and stain the surface, such as cardboard, has been used.

Use the packaging

The packaging should not be broken unnecessarily, it usually provides a good protection. It is often possible to save a lot of trouble and expense by taking advantage of the packaging, especially if the stainless steel surface is susceptible to damage e.g. a polished or ground surface.

The use of strippable plastic film coatings on the stainless steels can help to avoid surface contamination. If the stainless steel has a protective film cover, it should be left on as long as practically possible and removed just before handover. Special packaging measures may be needed for protecting stainless steel components in transit in order to protect the surface. For example, care is needed when components are being secured to pallets or vehicles for transport to avoid damage to surfaces from straps or strapping. Suitable protective materials, such as wood, should be placed between the stainless steel and the securing straps. If carbon steel strapping is to be used to secure items to pallets or in bundles, some form of wrapping or padding is required to prevent the strapping from damaging the edges or surface of the stainless steel components.

Store flat or in racks

To maintain flatness and avoid permanent deformation, sheet should be stored in wooden boxes and should be covered to prevent airborne contamination, Figure 12:3 and 12:4. Plate should be stored vertically on racks in a covered dry location, to minimise contamination and avoid the possibility of footprints. Racks of carbon steel should be protected by wooden, rubber or plastic battens or sheaths to avoid carbon steel contamination of the stainless steel.

Extra precautions for pipes

The rules for storage of tubes and pipes are the same as for storage of sheet and plate but one should remember that it is much more difficult to clean the inside of a pipe than an open plate or sheet surface. Extra precautions are therefore needed to avoid inside contamination, especially for thin pipes with small diameter. One effective way to protect the pipe inside is to use end-plugs.

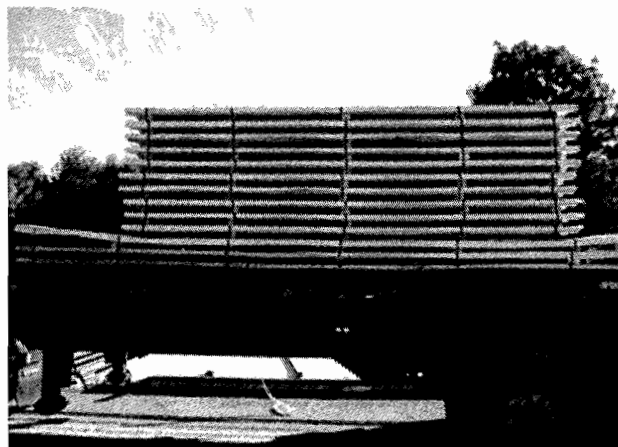


Figure 12:3. Example of careless loading. The bottom plates have lost their flatness.

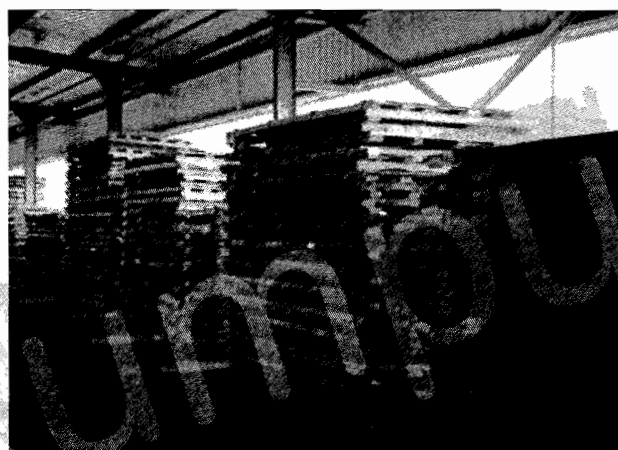


Figure 12:4. Flat storage in wooden boxes.

Maintenance of stainless steel

Cleaning/Restoration

Stainless steel does not remain stainless in all circumstances. Stainless steel products need to be cleaned to maintain a pristine appearance and preserve corrosion resistance. Stainless steel will not corrode under normal atmospheric conditions provided the correct grade has been selected and appropriate fabrication procedures and post treatment are followed. However, lack of cleaning can lead to accumulation of corrosive substances that surpass the corrosion resistance of the stainless steel grade selected. This may lead to staining and, in more severe cases, initiation of corrosion.

Advice is often sought concerning the frequency of cleaning of products made of stainless steel, and the answer is quite simple, clean the stainless steel surface when it is dirty in order to restore its original appearance. This may vary from one to four times per year for external applications or it may be once a day for an item in hygienic or aggressive applications.

Corrosion

Usually, discolorations is the first indication of incipient corrosion. In this case, it is no longer sufficient to remove visible stains by means of usual cleaners. In the tiny pits, which may hardly be perceptible to the unaided eye, corrosive media or corrosion products may be trapped, which will cause new stains to form. In such cases, it is advisable to use a cleaning agent which has a pickling and/or passivating effect. These kind of cleaning agents are often very aggressive and consequently health, safety and environmental precautions have to be taken. If the corrosion attack is more severe with deep pits or cracks, grinding and weld repair might be needed.

Weld repair

Repair welding may be necessary for filling pits or other defects which are too deep to just remove by grinding. Repair welding deserves as much or even more attention than the original structural welds.

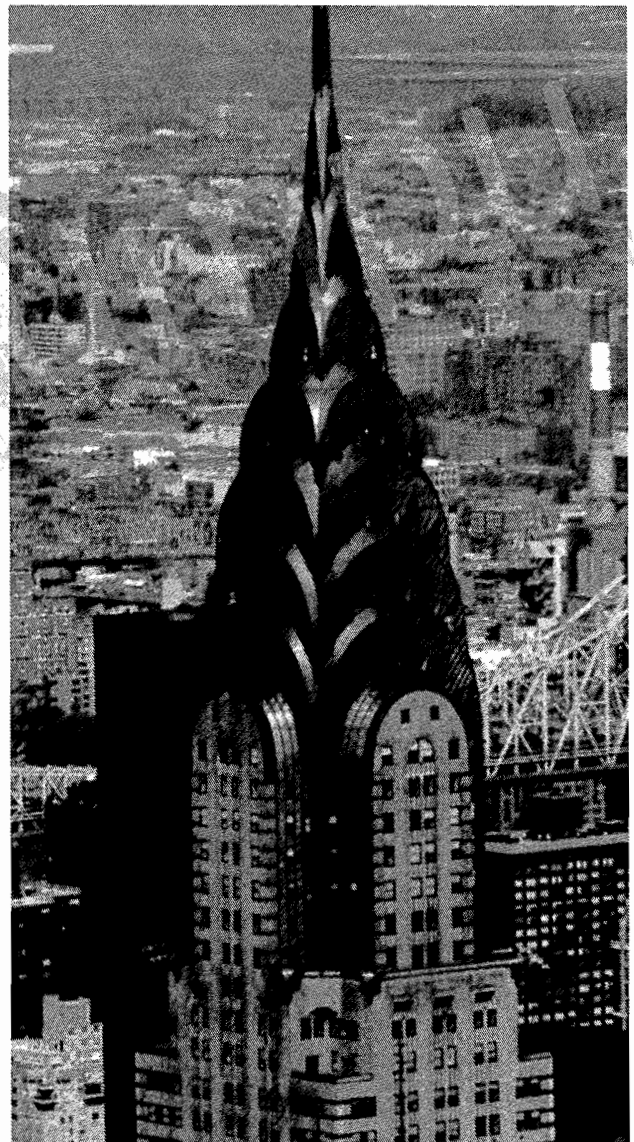
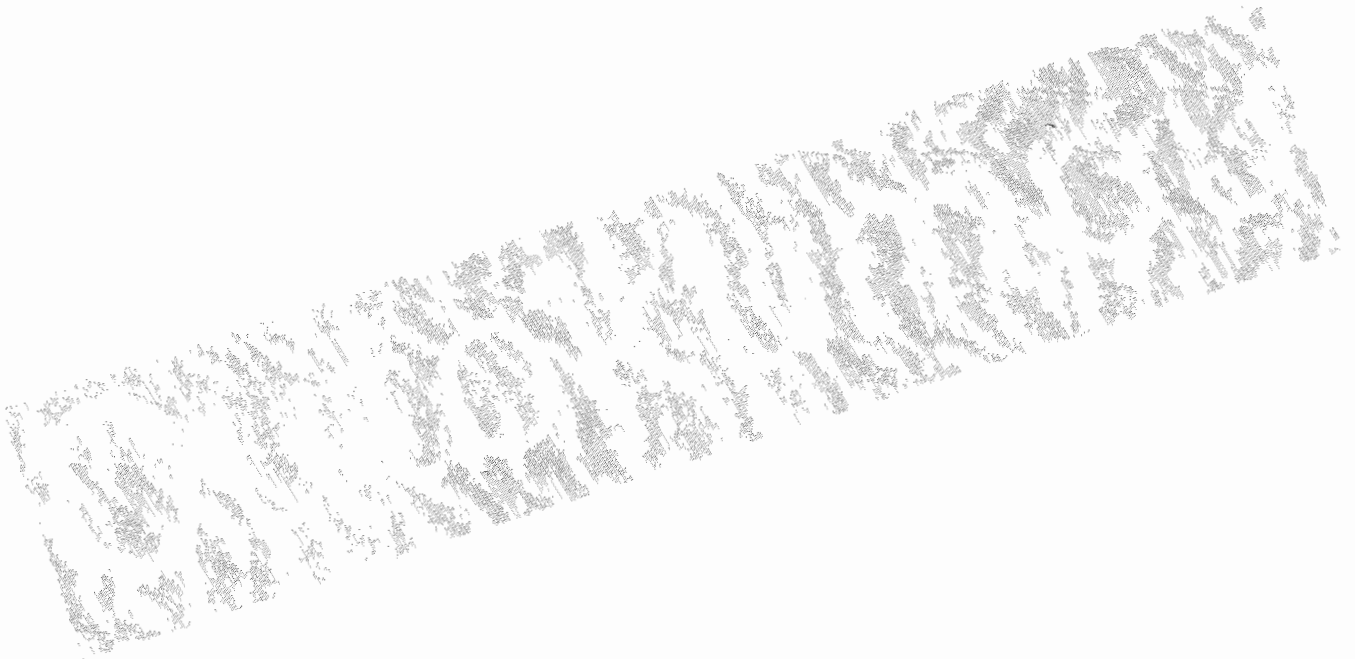


Figure 13.1. Chrysler building in New York erected 1930. During the years, it has only been cleaned twice, with considerable surface deposits accumulation between the cleanings. During its second cleaning in 1995 a few panels near heating exhausts showed some pitting and had to be replaced otherwise in perfect condition.

All types of contamination have to be removed from the surface prior to weld repair. This can be done either by grinding to clean metal appears, or chemically with an appropriate cleaning agent. Cracks must be totally gouged out or removed and weld repairs can be carried out from both sides, if access is possible. Deep pits or localized corrosion can be welded with filler to restore the original thickness. If there is a larger area, which cannot be welded by build-up, it might be replaced with patch.

However, there is a clear risk that new stresses are introduced during weld repair, with subsequent failure as a consequence. Extra precautions are needed for stainless steel grades which are susceptible to form precipitates due to the heating cycle. A high heat input or too low cooling rate can result in degradation of both HAZ and weld deposit, so only one re-weld operation is advisable, even that with extreme care and control. The general recommendation for the most vulnerable materials is that any form of re-welding should preferably be avoided.



Sustainable stainless

Sustainability is about much more than just the environment. It takes into consideration the impact on environment, society, and economy (planet - people - profit).

Environment (Planet)

Stainless steel is the most recycled material in the world and 82% of the stainless steel in use is estimated to be recycled into new steel. When recycled, the stainless steel is not downgraded; the remelted recycled steel has just as good quality and properties as the original steel. Due to the attractiveness and high value of stainless steel scrap no subsidies are needed to uphold a working scrap market.

In principle, stainless steel can be recycled an infinite number of times. However, the 6% annual increase in stainless steel production together with the durability of stainless steel products means that there is a scarcity of stainless steel scrap. This in turn means that although today's production is based mainly on recycled steel, virgin material in the form of alloying elements is still needed. Today approximately 60% of the raw material used to make new stainless steel is recycled steel and for Outokumpu the recycled steel content is between 85 and 90%.

Steel making, especially for alloyed steel, is undisputedly very energy consuming. However, the stainless steel industry has worked systematically on energy efficiency for many years and Outokumpu has decreased its direct CO₂ emission per ton of produced steel by 20% the last 10 years. Also, since remelting scrap is more energy efficient than making steel out of virgin raw materials, the scrap input ratio of 60% worldwide means a 33% reduction of CO₂ emissions compared to producing the same amount of steel from virgin raw materials. This corresponds to more than 42 M tons of CO₂ annually.

The inert nature of stainless steel products offers many advantages during use. From an environmental point of view the passive layer that prevents metals release from the surface is of special interest. It means that stainless steel can be used in applications like roofing and water piping without risking metal leaching and contaminating the environment, e.g. the ground water.

Society (People)

Stainless steel has a long history of use in applications where cleanliness and high hygienic requirements are important, like medical equipment and food processing. Stainless steel does not affect the taste of food and drink and the surface is easy to clean and to disinfect. Stainless steel surfaces do not release metals or organic substances that could affect the indoor air quality in buildings negatively.

The reason behind the inert behaviour of stainless steel is the passive layer that also prevents the material from corroding. This means also that stainless steel does not behave like its alloying components. For example, nickel on its own can cause skin sensitization (allergy), while numerous tests have shown that nickel-containing stainless steel does not cause such allergic reactions.

The benefits to society by using stainless steel are numerous. Stainless steels have, for example, helped to make the process of desalination (i.e. producing potable water from seawater) economically viable. Thus many arid areas of the world can now enjoy the benefits that come from the availability of fresh water. Stainless steel is important for the development of new energy sources like solar power and the production of bioenergy, also for conventional energy sources e.g. in desulphurisation plants to reduce noxious emissions from fossil fuels.

Economy (Profit)

Choosing the right stainless steel grade for an application ensures that it will have low maintenance costs, a long life and be easily recycled at the end of that life. This makes stainless an economical choice in many applications from washing machines to process applications. The fire and corrosion resistance of stainless steel makes it a good choice in transportation, building or public works such as railways, subways, tunnels and bridges. These properties, together with stainless steels' mechanical behaviour, are of prime importance in these applications to ensure human beings are protected and maintenance costs are kept low.

High strength stainless steels provide extra benefits both in terms of economy and resource use, since less material can be used in constructions. High strength steels may absorb more energy in the case of collisions, which improves safety in vehicles and many other structural components and systems.

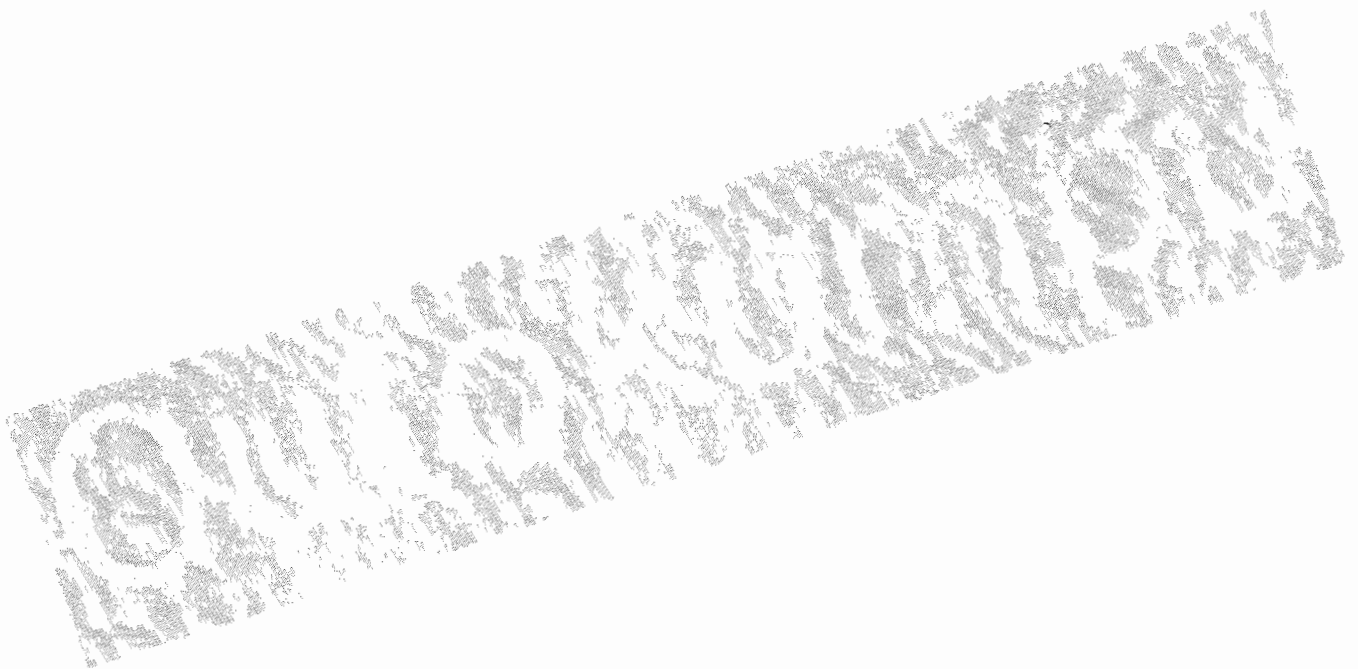
Stainless steel is durable which has a positive effect on the life cycle cost over the full lifetime.

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Stainless steel and CO₂. Facts and scientific observations (International Stainless Steel Forum)

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Glossary

Below are explanations to some words used in this handbook and reference to in what chapter you can read more.
(C4) = chapter 4.

1D surface finish

Surface finish designation according to EN 10088-2 of material that is hot rolled, heat treated, pickled, and free of scale. (C4, C5)

22Cr duplex

The duplex grade 2205 is sometimes referred to as 22Cr duplex as the chromium content is close to 22 %. (C2)

25Cr superduplex

The duplex grades 2507 and 4501 are sometimes referred to as 25Cr superduplex grades as the chromium content is close to 25 % in these grades. (C2)

2B surface finish

Surface finish designation according to EN 10088-2 and ASTM A480 of material that is cold rolled, heat treated, pickled and skin passed, where skin passing may be done by tension levelling. (C4, C5)

2BB surface finish

The Outokumpu designation of material that is cold rolled, heat treated, bright pickled and skin passed. (C5)

2D surface finish

Surface finish designation according to ASTM A480 of material that is cold rolled, heat treated pickled or descaled. (C4, C5)

2E surface finish

Surface finish designation according to EN 10088-2 of material that is cold rolled, heat treated and mechanically descaled. (C4, C5)

2H surface finish

Surface finish designation according to EN 10088-2 of cold rolled material that is work hardened to certain tensile levels. (C5)

2R surface finish

Surface finish designation according to EN 10088-2 of cold rolled material that is bright annealed, i.e. heat treated under inert gas atmosphere. (C4, C5)

6Mo superaustenitic

The austenitic grades 254 SMO® and 4529 are sometimes referred to as 6Mo superaustenitic grades as the Mo content is around 6 % in these grades. (C2)

7Mo superaustenitic

The austenitic grade 654 SMO® is sometimes referred to as 7Mo superaustenitic grade as the Mo content is around 7 %. (C2)

Activation

The changing of a passive surface of a metal to a chemically active state. (C6)

Active

(1) A state of a metal that is corroding without significant influence of reaction product. (C6)

(2) A lower or more negative electrode potential. (C6)

Anion

A negatively charged ion. An anion will migrate through the electrolyte toward the anode under the influence of a potential gradient. (C6)

Anisotropy, r-value

Determined as the ratio between thickness and width strain in the tensile test. (C7)

Annealing

Heat treatment that alters the microstructure of a material causing changes in properties such as strength, hardness, and ductility. (C5)

Anode

The electrode of an electrochemical cell at which oxidation occurs. (C6)

AOD

Argon Oxygen Decarburisation. A method to reduce the carbon content in the stainless steel melt. (C1, C4)

AP line

Annealing and Pickling line. (C4)

Atmospheric corrosion

Corrosion of a metal by contact with substances present in the atmosphere, such as water, carbon dioxide, water vapor, and sulphur and chloride compounds. (C 6)

Austenite

One of the two major metallic phases in stainless steel, with a face-centred cubic structure. Austenite is promoted by higher levels of elements favoring austenite such as nickel and nitrogen. See also FCC. (C3)

Austenitic stainless steel

The austenitic grades are the largest group of stainless steels. They have good to excellent corrosion resistance, good formability and weldability. Their good impact strength at low temperatures is

often exploited in cryogenic applications. Cold working increases their strength. The austenitic microstructure makes the steel non-magnetic in the solution annealed condition. (C2)

Autogenous welding

Welding without adding filler metal. (C10)

BA surface finish

Surface finish designation according to ASTM A480 of material that is bright annealed, i.e. heat treated under inert gas atmosphere. (C4, C5)

BA-line

Bright Annealing line. Annealing line using hydrogen or hydrogen/nitrogen atmosphere to avoid oxidation during heat treatment. (C4)

Bar

Products supplied in straight lengths, never in coils, thus differentiating them from rod. Bars can be supplied in hot-rolled, and cold worked condition and have different geometries such as rounds, squares, hexagons and octagonal shape. (C5)

BCC

A Body-Centred Cubic structure, in which there is a central atom between the corner positions in the unit cell, Figure 3:6. (C3)

BCT

A Body-Centred Tetragonal structure with the same type of atomic positions as BCC but a unit cell in which only two of the lattice parameters are equal, Figure 3:6. (C3)

Billet

A semi-finished steel product with a square cross section up to 200 mm × 200 mm. (C5)

Blank

The starting sheet intended for forming. (C10)

Bloom

A cast semi-finished steel product with a smaller cross section than slabs, often rectangular, typically larger than 200 mm × 200 mm. (C5)

Bright annealing

Heat treatment of cold rolled stainless steel in an inert gas atmosphere often hydrogen or hydrogen/nitrogen which protects the steel from getting oxidised. (C4)

BWR

Nuclear Boiling Water Reactor. (C6)

C700

To write C700 is a way to describe that the material is work hardened (temper rolled) to a tensile strength of 700 MPa. (C5)

CAPL

Continuous Annealing and Pickling Line. (C4)

Carburization

A type of high temperature corrosion, in which the stainless steel reacts with e.g. CO or CO/CO₂ gas present in the environment. (C6)

Catastrophic oxidation

Catastrophic oxidation generally occurs in the temperature range 640-950 °C in the presence of elements whose oxides either melt or form eutectics with the chromium oxide (Cr₂O₃) scale. For this reason molybdenum, which forms low-melting-point oxides and oxide-oxide eutectics, should be avoided in materials for service at temperatures above 750 °C. (C6)

Cathode

The electrode of an electrochemical cell at which reduction occurs. (C6)

Cathodic protection (CP)

A technique used to prevent the corrosion of metal by making it the cathode of an electrochemical cell. This can be achieved by

connecting the metal to be protected to a less noble metal, i.e. a galvanic anode, which corrodes instead of the protected metal. Alternatively, imposed electrochemical polarization can be achieved by using an external DC power source. (C6)

Cation

A positively charged ion. A cation will migrate through the electrolyte toward the cathode under the influence of a potential gradient. (C6)

CCT

Critical Crevice corrosion Temperature. (C6)

Chi phase

A brittle intermetallic phase with a cubic structure. Chi phase occurs in the ternary Fe-Cr-Mo phase diagram. (C3)

Clearance

The distance between the punch and the die during e.g. punching. (C10)

Coil

Coil is a continuously hot or cold rolled sheet that is rolled to a ring shape (coil). (C5)

Cold rolling

Rolling of the stainless steel is done at room temperature. (C4)

Cold working

Cold working, also known as strain hardening or work hardening, is the strengthening of a metal by plastic deformation. (C5)

Corrosion

Corrosion is the gradual destruction of material by chemical reaction with its surrounding environment. (C6)

Corrosion fatigue

Fatigue under the combined action of mechanical loading and corrosive environment. (C6, C7)

Corrosion potential

The potential of a corroding surface in an electrolyte relative to a reference electrode under open-circuit conditions (also known as open-circuit potential). (C6)

Cottrell atmosphere

Cottrell atmosphere occur in body-centered cubic (BCC) materials and explains how dislocations are pinned in some metals by carbon or nitrogen interstitials. (C4)

CPP

Continuously Produced Plate. (C4, C5)

CPT

Critical Pitting corrosion Temperature. (C6)

Creep

The time dependent slow plastic deformation of metals under a constant stress. (C7)

Creep rupture strength, R_{mT}

The stress level that leads to rupture after a specific time in the creep region. (C7)

Crevice corrosion

Localized corrosion of a metal surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity of the metal to the surface of another material. (C6)

Critical Crevice corrosion Temperature (CCT)

Lowest temperature at which stable propagating crevice corrosion occurs under specified test conditions. (C6)

Critical Pitting corrosion Temperature (CPT)

Lowest temperature at which stable propagating pitting corrosion occurs under specified test conditions. (C6)

Cr-steel

Ferritic stainless steels are sometimes referred to as Cr-steels due to the main alloying element chromium. (C2)

CTL-line

Cut-To-Length line. (C4)

CVC

Continual Varying Crown. (C4)

Delta ferrite

A non-magnetic form of ferrite, stable between 1403 °C and 1535 °C which is the melting temperature. (C10)

Density

The density of a stainless steel grade is its mass per unit volume, e.g. g/cm³ or kg/dm³. (C8)

Desulphurisation

Desulphurisation is a way to remove sulphur compounds from exhaust gases that otherwise could form acidic compounds when released from the stack.

DFT

Density Functional Theory. DFT is a quantum mechanical method used to investigate the electronic structure of condensed phases by solving the Schrödinger equation. (C1)

DualDuplex™

A concept used in multi stage flash (MFS) chambers in desalination industry, where a higher alloyed duplex grade are used in the lower section and a lower alloyed duplex grade is used for the upper part where the environment is less aggressive. (C9)

Duplex stainless steel

A stainless steel with a ferritic-austenitic microstructure. The phase balance is approximately 50 % ferrite and 50 % austenite. The grades are magnetic due to the ferrite content. Due to their high strength, duplex grades can give cost effective solutions when thinner gauges can be used. Less material also gives more light-weight constructions. (C2)

EAF

Electric Arc Furnace. (C4)

Elastic modulus

The elastic modulus, or Young's modulus, is a measure of the stiffness of a stainless steel. (C7, C8)

Elastic/plastic deformation

In the elastic region an imposed strain is fully recovered upon unloading, while in the plastic region, only the elastic part of the strain is recovered. (C7)

Electric resistivity

The electrical resistivity quantifies how strong a stainless steel grade opposes the flow of electric current. (C8)

Electrolyte

A chemical substance containing free ions that makes it electrically conductive. (C6)

Engineering stress strain/true stress strain

The engineering stress strain curve is based on the original cross section area of the specimen, while the true stress strain curve compensates for the continuous decrease of the specimen cross section area during deformation. (C7)

Environmentally Assisted Cracking (EAC)

Brittle fracture of a normally ductile material in which the corrosive effect of the environment is a contributing factor. (C6)

Equiaxed microstructure

A structure in which the grains have approximately the same dimension in all directions. (C4)

Eutectic

Mixture of two or more compounds with a lower melting point than any of the compounds themselves. (C6)

Fatigue

The progressive and localized structural damage that occurs when a material is subjected to cyclic loading. (C7)

Fatigue life

The number of cycles to fracture in cyclic loading. (C7)

FCC

A Face-Centred Cubic structure in which there is an atom in the centre of face of the unit cell, Figure 3:6. (C3)

Ferrite

One of the two major metallic phases in stainless steel, with a body centred cubic structure. Ferrite is promoted by higher levels of elements favoring ferrite such as chromium and molybdenum. See also BCC. (C3)

Ferritic stainless steel

A stainless steel with a ferritic microstructure that makes the steel magnetic. These steels contain no or very small amounts of Ni which makes these steels more price stable compared to grades with high Ni content as Ni often demonstrates high price volatility. (C2)

Ferrochrome, FeCr

Important alloying element for stainless steel production. (C4)

Ferromagnetism

Ferromagnetism is the basic mechanism by which certain materials (such as stainless steels) form permanent magnets, or are attracted to magnets. (C8)

Free-machining grades

Grades with increased amount of sulphur or selenium to facilitate chip breaking. (C10)

Galvanic corrosion

Also denoted bimetallic corrosion or dissimilar metal corrosion. Refers to corrosion when two dissimilar materials with a conductive contact are connected in a corrosive electrolyte. (C6)

Hardness

A measure of how resistant a material is to a permanent shape change when a force is applied normal to the surface. (C7)

HAZ

Heat Affected Zone. The area around the weld bead that is unavoidably heated during welding. (C10, C13)

Heat capacity

The heat capacity specifies the amount of heat required to change the temperature of specific mass of stainless steel by a given amount. (C8)

Heat input

The amount of heat added when welding, expressed as KJ/mm. (C10)

HIC

Hydrogen Induced Cracking. (C10)

High temperature mechanical properties

The mechanical properties at temperatures above which creep is dominating. (C7)

HISC

Hydrogen Induced Stress Cracking. (C6)

Hot cracking

Cracks formed in the weld during solidification. (C10)

Hot rolling

Rolling of the stainless steel is done at a temperature above the recrystallization temperature of the material. (C4)

Hydrogen embrittlement

A loss of ductility of a metal resulting from absorption of hydrogen. Hydrogen penetrates into e.g. the grain boundaries and cause cracking. (C6, C10)

Hydrogen induced cracking, HIC

Hydrogen penetrates into e.g. the grain boundaries and cause cracking. (C10)

Hydrogen induced stress cracking, HISC

Cracking that results from the presence of hydrogen, eg. from cathodic protection, in a metal in combination with tensile stress. (C6)

Ingot

A semi-finished steel product obtained by casting the melt into fixed size moulds. (C5)

Intergranular corrosion

Preferential corrosion attack along the grain boundaries, or immediately adjacent to grain boundaries, while the bulk of the grains remain largely unaffected. (C6)

Interpass temperature

The recommended temperature of the material between the weld passes. Can be specified as a minimum or maximum temperature. (C10)

KTH

The Royal Institute of Technology, Stockholm, Sweden. (C1)

Laves phase

A brittle intermetallic phase with a hexagonal structure. It exists in the Fe-Mo phase diagram with a nominal composition Fe_2Mo , and also occurs in higher systems. (C3)

LCC

Life Cycle Cost. (C9)

Lean duplex

The duplex grades LDX 2101® and 2304 are sometimes referred to as lean duplex grades due to their "lean" chemical composition. (C2)

Life Cycle Cost, LCC

The life cycle cost is the total cost of an application during its entire life, including material cost, fabrication cost, operating and maintenance cost, including the value of the material when scrapped. (C9)

Liquidus

The temperature below which a solid phase starts to form from the melt. (C3)

LME

Liquid Metal Embrittlement. (C12)

LNG

Liquid Natural Gas. (C9)

Localized corrosion

Corrosion, such pitting and crevice corrosion, which results in attack at specific sites while other parts of the metal may remain totally unaffected. (C6)

Lüders band

Lüders bands, also known as "slip bands" or "stretcher-strain marks," are localized bands of plastic deformation in metals experiencing tensile stresses, common to low-carbon steels and ferritic stainless steels. (C4, C5)

Martensite

A body-centred tetragonal metallic structure which can be formed from unstable austenite on quenching. See also BCT. (C3)

Martensitic stainless steel

A stainless steel with a martensitic microstructure that makes the steel magnetic and contributes to high strength. (C2)

Maximum strain to fracture, A_f

The fracture strain measured with initial measuring length x . (C7)

M_{500}

The temperature at which 30% deformation (strictly speaking a true strain of 0.3) causes the formation of 50% martensite from an austenitic structure. (C3, C7)

Metal dusting

A special form of carburization, also called catastrophic carburization. (C 6)

Metal leaching

In this handbook metal leaching is defined as metal ions from the construction material leaching and contaminating the environment. (C14)

Microstructure

The microstructure of stainless steel is either ferritic, martensitic, ferritic-austenitic or austenitic. Ferritic grades have a body-centred cubic structure while martensitic grades have a body-centred tetragonal structure and austenitic grades have a face centred cubic structure. See also BCC, BCT and FCC. (C2)

Mixed acid

Pickling bath often containing a mixture of nitric acid (HNO_3) and hydrofluoric acid (HF). (C4)

Mother plate

The original plate from which several smaller plates are cut. (C4)

M_s

The temperature below which the transformation from austenite to martensite starts. (C3)

Nitridation

A type of high temperature corrosion, in which the stainless steel reacts with nitrogen compounds in the environment. (C6)

No.1 surface finish

Surface finish designation according to ASTM A480 of material that is hot rolled, heat treated, pickled, and free of scale. (C4, C5)

Noble

A higher or more positive electrode potential. Noble metals include gold and platinum. (C6)

Oxidation

- (1) Loss of electrons in a chemical reaction.
- (2) Corrosion of a metal that is exposed to an oxidizing gas at elevated temperatures. The stainless steel reacts with O_2 , H_2O , CO_2 and forms an oxide on the stainless steel surface. (C6)

Passivation

(1) A reduction of the anodic reaction rate of an electrode involved in corrosion e.g. due to the presence of a passive film. (C6)

(2) Chemical treatment to improve the passive layer on stainless steel. Normally not needed if the steel has been properly pickled. (C11)

Passive

A state of a metal in which a surface reaction product causes a marked decrease in the corrosion rate relative to that in the absence of the product. A passive metal usually exhibits a higher electrode potential than one which is undergoing active dissolution. (C6)

Passive layer

The chromium oxide layer on the stainless steel surface that protects the steel from being attacked by corrosion. (C14)

pH

pH is a measure of the acidity of a solution. Pure water has a pH close to 7. Solutions with a lower pH than 7 are said to be acidic, and solutions with a higher pH are said to be alkaline. (C6)

Pickling

Removal of surface oxides by chemical treatment in a pickling bath often consisting of a mixed-acid bath containing nitric (HNO_3) and hydrofluoric acid (HF). (C4, C5, C11)

Pitting (corrosion)

Localized corrosion of a metal surface that is confined to a small area and takes the form of cavities called pits. (C6)

Pitting potential

The potential above which pits are initiated and start to grow. A high value of the pitting potential usually means a higher local corrosion resistance. (C11)

Pitting Resistance Equivalent (PRE, PREN)

Number developed to reflect and predict the pitting corrosion resistance of stainless steels based on chemical composition. Several formulas exist, but we use:

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

(C6)

Plastic/elastic deformation

In the elastic region an imposed strain is fully recovered upon unloading, while in the plastic region, only the elastic part of the strain is recovered. (C7)

Plate

Flat product thicker than 3 mm (EN 10079) or 4.76 mm (ASTM A480). (C5)

ppm (parts per million)

For water solutions $1 \text{ ppm} = 1 \text{ mg/l} = 0.0001\%$ (C6)

PRE/PREN

Pitting Resistance Equivalent. (C6)

Precipitation hardening

Hardening by a special mechanism involving the formation of precipitates within the microstructure. (C2)

PRODEC®

PRODEC® (PRODUCTION Economy) is Outokumpu's trademark for some grades with improved machinability. (C2, C9, C10)

Proof strength, $R_{p0.2}$

The engineering stress level that gives 0.2% permanent engineering strain after loading up to $R_{p0.2}$. This is defined as the start of plastic deformation for stainless steel. The proof strength at 1% ($R_{p1.0}$) is also commonly used for the austenitic grades. (C7)

Quarto plate

Plate produced in a reversing hot rolling mill is generally known as "quarto plate". (C4, C5)

RAP-line

Rolling, Annealing and Pickling line. (C4)

Recrystallization

Heat treatment to soften the steel, previously hardened by cold work, and to control the grain structure in the final product. (C5)

Reduction

Gain of electrons in a chemical reaction. (C6)

REM

Rare Earth Metal. Important alloying addition in Outokumpu's heat resisting MA-grades. (C6)

Ridging

The phenomenon known as ridging and roping is observed as raised ridge-like or rope-like features running parallel to the rolling direction on the surface of low alloyed ferritic stainless steel sheet after e.g. deep drawing. Ridging and roping will primarily lead to aesthetic rather than functional effects.

Rod

Hot rolled long product having a nominal size generally 5 mm or above and wound into irregular coils. (C5)

Roping

The phenomenon known as roping or ridging is observed as raised rope-like or ridge-like features running parallel to the rolling direction on the surface of low alloyed ferritic stainless steel sheet after e.g. deep drawing. Roping and ridging will primarily lead to aesthetic rather than functional effects.

Roughing mill

A rolling mill where the slab is rolled to reduce its thickness to prepare the slab for further rolling in the Steckel mill. (C4)

RSJ

Rolled Steel Joists used in building construction projects. (C5)

SAF

Submerged Arc Furnace. (C4)

Sand blasting

Sand blasting is a process to remove surface deposits by applying fine sand particles to the surface at a high pressure. (C11)

Scale

When thick oxide layer formed in e.g. furnace atmospheres, breaks down and spalls off due to growth stresses, the material "scales". (C1)

SCC

Stress Corrosion Cracking. (C6)

SEN

Submerged Entry Nozzle. (C4)

Sheet

Flat product with a thickness of maximum 3 mm (EN 10079) or 4.76 mm (ASTM A480). (C5)

Shot peening

Shot peening is a cold working process used to produce a compressive residual stress layer and modify mechanical properties of metals. It entails impacting a surface with shot (round metallic, glass or ceramic particles) with force sufficient to create plastic deformation.

SHRP

Steckel Hot Rolled Plate. (C5)

Sigma phase

A hard, brittle, nonmagnetic intermetallic phase with a tetragonal structure. Sigma phase exists in the Fe-Cr and Fe-Mo binary phase diagrams and in higher systems. (C1, C3)

Skin-pass

Rolling operation to smoothen the surface, improve the flatness and to increase the yield strength. Skin-passing gives a 2B surface. (C5)

Slab

A semi-finished steel product obtained by rolling or forging ingots or by casting a melt in a continuous caster and cut the strand into suitable lengths. (C5)

Sitting

A way to cut a coil into several narrow coils suitable for the end-users following production steps. (C4)

Slug

The left over scrap after cutting. (C10)

Solidus

The temperature below which there is no molten phase present. (C3)

Sour service

Environment with natural gas and crude oil containing considerable amounts of hydrogen sulphide (H_2S). (C6)

Spallation

Spallation is a state where the oxide formed on the stainless steel surface breaks and spalls off. (C6)

SPM

Skin Pass Mill. (C4)

SSC

Sulphide Stress Cracking. (C6, C9)

Stabilisation

Alloying with strong carbide-formers such as titanium and niobium to bind carbon and suppress the risk of forming chromium carbides, which can seriously degrade stainless steel properties. (C3)

Stainless steel

An iron-base alloy with at least 10.5% chromium that forms a corrosion resistant passive layer on the steel surface. See e.g. ASTM A941 "Standard Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys". (C2)

Steckel mill

Steckel rolling is a hot rolling operation where the strip is rolled back and forth between two coiler furnaces and the strip is reduced in thickness in each pass between the coilers. (C4)

Strain hardening

Strain hardening, also known as work hardening or cold working, is the strengthening of a metal by plastic deformation. (C5)

Stress Corrosion Cracking (SCC)

Cracking of a material produced by the combined action of corrosion and tensile stress (residual or applied). (C6)

Strip

Cold or hot rolled flat product often delivered as a coil. (C5)

Sulphidation

A type of high temperature corrosion, in which the stainless steel reacts with sulphur compounds in the environment. (C6)

Sulphide Stress Cracking (SSC)

Cracking of metal involving corrosion and tensile stress (residual or applied) in the presence of water and hydrogen sulphide (H_2S). (C6, C9)

Surface roughness

The surface roughness is often expressed by the Ra value (μm). A low Ra value indicates a smooth surface. (C9)

Temper rolling

Rolling operation to cold work the steel for increased strength. (C5)

Tension levelling

A rolling operation to straighten the sheet and smoothen the surface. (C5)

Thermal conductivity

The thermal conductivity is the property of a material to conduct heat. (C8)

Thermal expansion

Thermal expansion is the tendency of the stainless steel to change in length in response to a change in temperature. (C8)

ThermoCalc

Thermodynamic database system used in development of stainless steel for calculating phase equilibria. (C1, C3)

Toughness

The ability to absorb energy in the plastic range. (C7)

TR surface finish

Surface finish designation according to ASTM A480 of cold rolled (Temper Rolled) material that is work hardened to certain tensile levels. (C5)

True stress strain/engineering stress strain

The engineering stress strain curve is based on the original cross section area of the specimen, while the true stress strain curve compensates for the continuous decrease of the specimen cross section area during deformation. (C7)

TTT curve

Time Temperature Transformation curve shows the kinetics of precipitation or other phase transformations as a function of temperature. (C3, C11)

Ultimate tensile strength, R_m

The largest stress on the tensile testing curve characterizing the maximum obtainable engineering stress and is associated with the uniform elongation A_g . (C7)

Uniform corrosion

Also termed general corrosion. Uniform corrosion is characterized by corrosive attack proceeding evenly over the entire surface area, or a large fraction of the total area, with general thinning of the material as a result. (C6)

Uniform elongation, A_g

The limit of uniform elongation where necking starts. (C7)

Wet corrosion

Also designated aqueous corrosion. Corrosion in liquids, usually water based, or moist environments. (C6)

Wire

Product of constant full cross section along its length, obtained by cold drawing rod through a reducing die or passing under pressure between rollers and rewinding the drawn product. (C5)

Widmanstätten austenite

Elongated lamellae of austenite formed within ferrite grains; seen particularly in duplex stainless steel welds. (C3)

VOD

Vacuum Oxygen Decarburization. A method to reduce the carbon content in the stainless steel melt. (C4)

Work hardening

Strengthening of the steel by plastic deformation. (C2, C5)

Work hardening, n

The increase of stress with strain in the plastic region of the stress strain curve. (C7)

Young's modulus of elasticity, E

The Young's modulus, or elastic modulus, is a measure of the stiffness of a stainless steel. It is the slope of the stress strain curve in the elastic region. (C7, C8)

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