ISSF
INTERNATIONAL STAINLESS STEEL FORUM

Non-Corrosion Properties of Stainless Steels

Stainless Steels: it is not only the corrosion resistance that matters

Stainless steels are often rightly associated
with corrosion resistance ...
but they can do much more!

The following examples illustrate
the usefulness of other properties
of stainless steel long products.

Background on stainless steel long products processing routes and products

Stainless steel long products cover all stainless steels obtained from the hot rolling of semis, bars and wire.

Semis, also called billets, have a square cross-section with round edges, and are almost entirely used for either hot forging (valve bodies for instance) or hot re-rolling by independent re-rollers.

Bars above 20 mm are usually produced directly by hot rolling. They are then heat treated, descaled, straightened and usually machined/ground to achieve the required tolerance (H9 to K13 usually) and surface finish.

Bars having a diameter between 20 mm down to 5 mm are usually obtained by straightening of hot rolled, annealed and pickled wire rod (see below). Drawing benches allow direct conversion of wire rod to bright drawn bars, tolerance H9. Tolerances H8 or lower require a further grinding operation. Bars below 5 mm require a further cold-drawing operation (see below) before bar conversion. Most of the bars are machined into a very wide variety of parts, some of them very complex with tight tolerances.

Hot rolled wire rod in irregular wound coils is heat treated, then pickled in acid baths to remove the black oxide layer. Hot rolled wire rod diameter ranges from 5 to 32 mm approximately. Broadly speaking there are three main applications for wire rod:

Cold or warm heading for the production of fasteners or cutlery (for the latter, some of the stainless grades require hot forging). In a typical fastener production, say a bolt with an hexagonal head, the cold leading machine performs successive operations of calibration, cutting, cold heading in 2 to 3 blows, cutting the hexagonal shape, delivering thus a fastener which needs only the final thread-rolling to be finished.

Bar conversion (see above)

Drawn wire, obtained by drawing coil-to-coil on single or multi-pass machines (up to 14 passes) followed by annealing as required, results in a wire of the desired diameter and mechanical properties. For fine wire (roughly below 0.8 mm) more multi-pass drawing and annealing cycles are necessary to achieve the required wire properties. Ultra-fine wire, down to about 0.015 mm can thus be obtained (using appropriate re-melted stainless steel grades). The main areas of use of drawn wire are:

- **Forming wire**: bent and formed parts for household, building and miscellaneous applications
- **Spring wire**: used for the manufacture of high performance springs
- **Welding wire**: used for MIG, TIG or electrode welding of steels (mostly stainless)
- **Fine wire**: used for mesh (decorative and filtration applications) or braids (for flexible hoses)
- **Profiled wire**: used for oil, water, coil, food and beverage filtration, as well as for decorative purposes
- **Wire for machining**: either converted to bars down to about 2 mm on small drawing benches (see bars above) or for machining from coils on the “Escomatic” machines. Such a wide variety of applications and processing routes call for over 200 stainless grades, a complexity inherent to long products.

Physical Properties

Electrical appliances

Direct acting Solenoid Valve

In this type of valve, the valve shaft is put into motion when current flows through the surrounding coil. The stainless steel which is used must be “soft” magnetic (i.e. must possess a low coercitive field Hc). This generally requires special heat treatments to be carried out. Solenoids of this type are used extensively to control electrical appliances.

Grade: EN 1.4105 +Si or AISI 430FR, EN 1.4106
Proprietary grades

Why Stainless Steel?

Soft magnetic

Physical Properties

Medical

Magnetic Resonance Imaging

During a MRI scan, a strong magnetic field aligns the nuclear magnetisation of (usually) hydrogen atoms in water in the body. The use of non-magnetic materials in the equipment is therefore mandatory. A computer interprets the data, and creates images that display the different resonance characteristics of different tissue types. Trained medical staff can examine the resulting image and use the information to diagnose many different types of medical conditions within the human body.

Magnetic Resonance Imaging (MRI) is a powerful medical imaging technique. MRI is based on the physical and chemical principles of nuclear magnetic resonance (NMR), a technique used to gain information about the nature of molecules.

Grades: Austenitic stainless steels

Why Stainless Steel?

Non magnetic

Non-Corrosion Properties of Stainless Steels

Physical Properties

Oil and gas

Non Magnetic Drill Collars

Drill collars are heavy walled tubes, up to 300 mm in diameter and having a length of about 10 m. They provide weight on the drill bit and house sensitive electronic equipment. These collars are non magnetic so that they do not interfere with the electronic devices used to monitor the position of the drill bit (such as Measurement While Drilling equipment). This electronic equipment uses the earth's magnetic field as a positioning guide and any magnetic steels in the vicinity of this measuring equipment would obscure the reading.

NMDC

Grades: 16Cr 20Mn 2Mo 0,4N proprietary analyses

Why Stainless Steel?

- Non magnetic
- Good mechanical properties

Physical Properties

Energy

Generator End Rings

The diameter of the end ring of a turbo generator can be between 0.5 and 1.6 meters. The end ring must pass stringent tests to ensure it can operate without deformation at speeds ranging from 3,000 to 3,600 revolutions per minute. A 20 % overspeed test is also conducted before the end-rings are passed for use.

Non-magnetic stainless steel reduced the losses in the ring that are caused by eddy currents and thermal stresses. The steel also possesses a high yield strength in order to avoid plastic deformation due to the high stresses produced by the shrink-fit and centrifugal forces.

Grade: DIN: 1.3816

Why Stainless Steel?

- Non magnetic
- Good mechanical properties

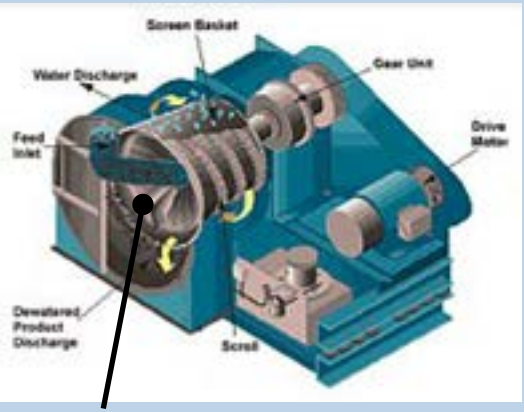
Physical Properties

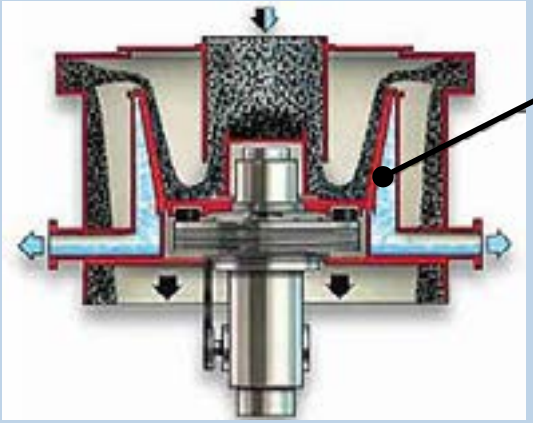
Energy

Coal Filtration Baskets

The run-of-mine from a coal mine requires the separation of coal (density about 1.4) from the stones (density about 2.2), which is usually done by gravity in "heavy media" (a slurry of water and magnetite, adjusted to a density of about 1.6).

The coal is then de-watered, (i.e. separated from the remaining water and magnetite), usually in centrifuges (vertical or horizontal) that use rotating slotted baskets. These baskets are made of amagnetic stainless steel to avoid "sticking" of magnetite on the surface.





Basket

Grades: EN1.430, AISI: 304, AISI: 202 modified

Why Stainless Steel?

- Non magnetic
- Abrasion resistance

Physical Properties

Coefficient of Thermal Expansion

Glass-to Metal seals

They provide a way to hermetically pass an electrical conductor from one environment to another. The glass, as well as providing the seal, acts as an insulator between the pins and the housing. These conductor feeds can thus be used for many applications such as: vacuum components, sensor or transducer housings, in harsh environments and in medical implantable devices.

Grades: EN1.4762, AISI 446

Why Stainless Steel?

- Coefficient of Expansion similar to that of glass
- Electrical conductivity

Physical Properties

Domestic Appliances

Heating elements

Ferritic-chromium-aluminium stainless steels combine a controlled electrical resistivity with outstanding oxidation resistance. The oxidation resistance is a result of the high chromium and aluminium content in the stainless.
The heating elements are used in many domestic applications such as toasters and hair dryers.

They also have industrial uses in fan heaters and industrial furnaces.
For more demanding applications, and particularly at higher temperatures, nickel-chromium alloys or ceramics are used (for example, SiC, MoSi2).

Fabrication process: Hot rolled wire rod is drawn and annealed in successive steps into small diameter wire. This is then wound to form heating elements for electrical appliances.

Grades: Fe - Cr - Al stainless steels

Why Stainless Steel?

- Electrical conductivity
- Oxidation resistance

Low-Temperature Properties

Oil and gas

Cryonic valve

This valve operates at cryonic temperatures, in harsh weather conditions.

Dimensional stability is required during cycles ranging from ambient temperature to liquid natural gas temperatures (usually -196°C) to avoid leakage. Perfect reliability is essential.

107 cm (42 inch) valve

Tapped valve after testing in liquid nitrogen

Valve at the LNG terminal in Bilbao, Spain

Grades:

Body and disk: EN1.4307 (ASTM: A351 CF3M)

Stem: EN1.4401 (ASTM: A182 F316)

Why Stainless Steel?

- Good mechanical properties at cryonic temperatures
- Dimensional stability during thermal cycling

Low-Temperature Properties

Biology

Fittings and valves for cryonic equipment

Stainless steel fittings, valves and ancillary equipment are routinely used in biology for cryonic storage of liquid gas in Dewar vessels.

Grades: Austenitic stainless steels

Why Stainless Steel?

- Mechanical properties at cryonic temperatures
- Cleanability

Low-Temperature Properties

White goods

Ice auger

Refrigerators with crushed ice dispensers are equipped with a cooling/heating unit which produces ice shells and then released them into a tray. They are then crushed by an helical-shaped ice auger to supply the ice for water and other drinks.

Grades: EN1.4016, AISI 430

Why Stainless Steel?

- Mechanical properties at low temperatures
- Perfect for contact with food and beverages

High-Temperature Properties

Energy

Steam Turbine Blades

Coal, gas and nuclear power plants produce electricity by heating water to create steam. The steam is driven through turbine blades at very high pressure. The blades drive the turbine which generates electricity.

The typical operating temperature of the steam is around 600° C. The blades must be tough and resistant to creep, stress, corrosion and cracking.

The super-martensitic stainless steels used in these blades are perfect for use in this application.

Fabrication process: Large blades are forged from billets, machined, then heat-treated. Small blades are heat-treated and machined from flat bars.

Grades: Proprietary 0.2C 13Cr Nb V super martensitic stainless steels

Why Stainless Steel?

- Good mechanical properties at elevated temperatures

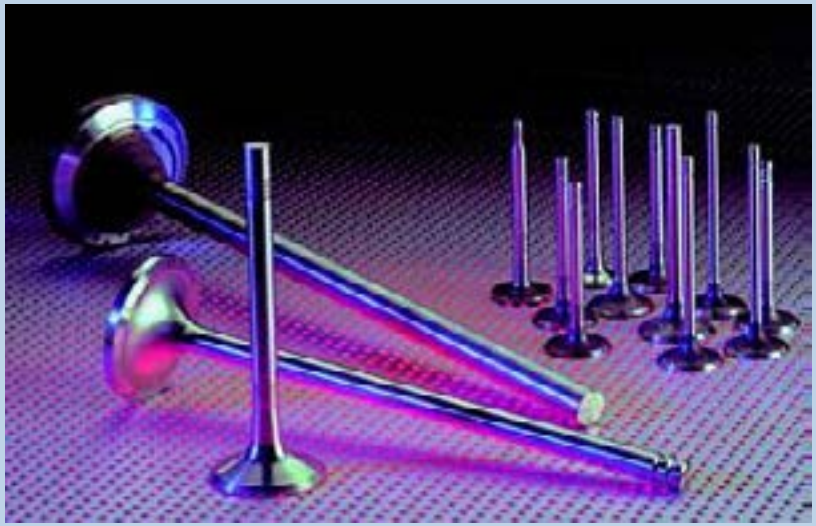
High-Temperature Properties

Automotive:

Intake and Exhaust Valves

Exhaust valves in combustion engines operate at high temperatures. However, the gas temperature of intake valves is much lower.

This dictates the use of different stainless grades for the intake and exhaust valves. Stainless steel provides optimum performance at the lowest cost.



Grades:Exhaust: Austenitic grades such as EN1.4882 and 1.4871
Intake and shaft: Martensitic grades such as EN1.4718

Why Stainless Steel?

- Good mechanical properties at elevated temperatures

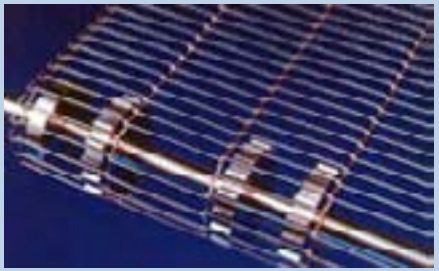
High-Temperature Properties

Furnace Equipment

Conveyor belts

Widely used for continuous baking or cooking of food.
Very frequently used also in all industries wherever baking, firing, annealing, etc. is needed.

The stainless belt undergoes repeated thermal cycling.



Grades: EN1.4845; AISI 310
EN1.4841; AISI 314
EN1.4886; AISI 330

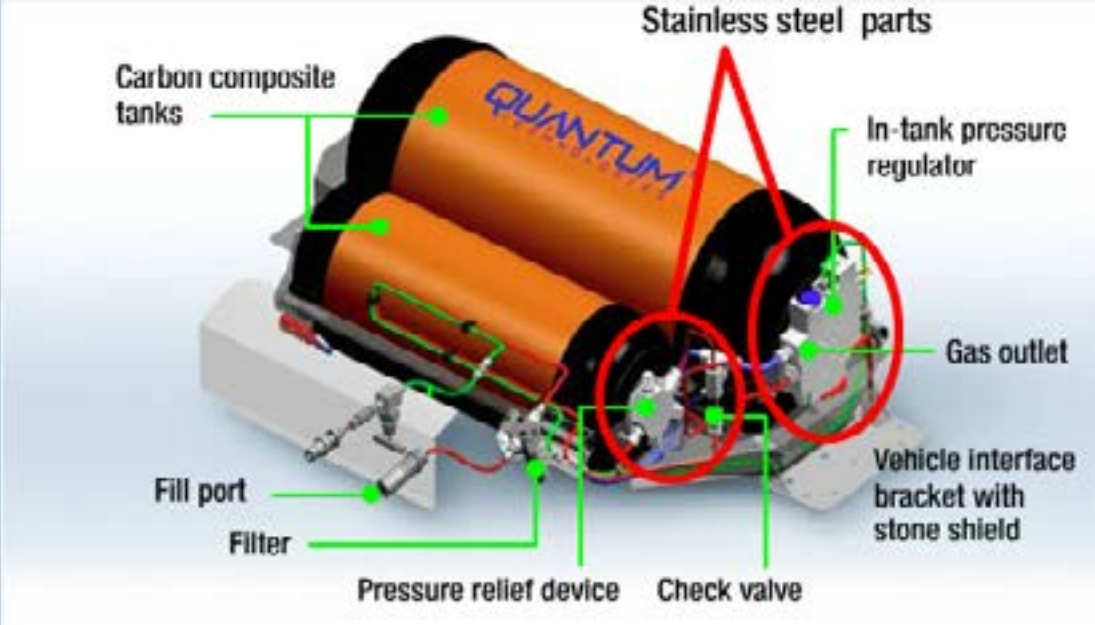
Why Stainless Steel?

- Good mechanical properties at elevated temperatures

Strength and Toughness

Automotive

High Pressure Hydrogen Equalizer Component



Hydrogen powered cars will require high pressure (+700 bar) hydrogen tanks. The tanks must be reliable under all conditions and at temperatures ranging between -60 and +60° C.

One of the major challenges is to find materials that can resist the effect of hydrogen which can make them brittle. Special austenitic stainless steels meet this requirement and have the high strength required for this application.

Grades: EN1.4435; AISI 316L

Why Stainless Steel?

- Does not become brittle after long exposure to hydrogen
- Durability

Strength and Toughness

Aerospace

Landing Gear Components

Aircraft landing gear components are subject to extreme stress during both take-off and landing.

Re-melted martensitic stainless steels are preferred over engineering steels for parts of the landing gear of commercial aircrafts. The re-melted martensitic stainless provides good mechanical properties, while avoiding the need of cadmium-plating, which is now banned because of its toxicity.

Grades: EN1.4548; AISI 630 ESR melted
EN1.4545; AMS 5659; ASTM 564

Why Stainless Steel?

- Good mechanical properties
- No coatings required

Strength and Toughness

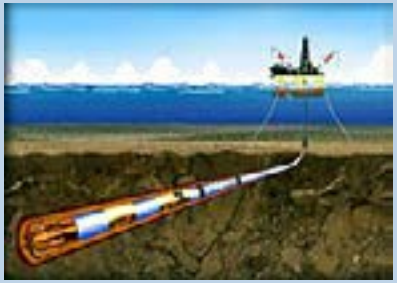
Oil and Gas

Rotor shaft

Directional drilling, a major advance in oil technology, allows the drilling of curved holes, usually to the horizontal into the oil-rich formation.

A key element is the hollow helical shaped rotor shaft, which is driven by high pressure water injected from the surface. The resultant twisting forces drive the drill bit in a rotational motion.

MWD (Measurement while Drilling) electronic equipment allows the positioning, and steering of the drill bit.
Rotor OD ranges from about 100 to 160 mm.



Grades: EN1.4542; AISI 630

Why Stainless Steel?

- Good mechanical properties

Strength and Toughness

Medical

Implants

Stainless steel, together with titanium and cobaltbased alloys, is widely used for surgical implants such as hip and knee joints, fasteners and plates.

These implants may either be temporary or permanent.

The stainless is re-melted to ensure a high level of purity for optimum biocompatibility and mechanical properties. Stainless steel is also the preferred material for all surgical, dental and medical tools and equipment.

Grades: EN1.4441 (ISO-5832-1) and
EN1.4472 (ISO-5832-9)

Why Stainless Steel?

- Biocompatibility
- Good mechanical properties

Strength and Toughness

Recreational

Bicyle Wheel Spokes

Bicycle spokes are usually made of drawn stainless steel wire for high strength (UTS > 1200MPa) while maintaining sufficient ductility for the forming and threading of the spoke ends.

Grades: EN1.4301; AISI 304

Why Stainless Steel?

- Good mechanical properties
- Aesthetics

Strength and Toughness

Recreational

Bicyle Brake Cables

Stainless brake cables are widely used in bicycles for their mechanical resistance and are obviously critical safety components.

They are also used for gear change systems.

Grades: EN1.4310; AISI 302

Why Stainless Steel?

- Good mechanical properties
- Safety component
- Aesthetics

Strength and Toughness

Building

Glass Facade «Spiders»

The glass panels on the façade are held in place by strength "spiders" which carry the weight of the glass.
Although their primary function is mechanical, their appearance does not detract from the overall elegance of the structure. They are expected to last as long as the building itself without any risk of damage or collapse.

Grades: EN1.4542; AISI 630
EN1.4462; ASTM F51

Why Stainless Steel?

- Good mechanical properties
- Low maintenance
- Aesthetics

Strength and Toughness

Construction

Post-Tensioning Tie Rods

The great Roman theatre, the symbol of Verona, dates back to the first half of the 1st Century AD. It was once one of the most important open air opera theatres in the Roman Empire.

Recent restoration work involved the construction of new covering for the central orchestra pit, an underground room and the underground sewage tunnels.

The new covering slab is structurally supported by a system of roof struts and post-tension tie rods. These minimise strains and deformation from loads placed on top. The post tension system used, comprising stainless steel bars, guarantees structural safety, quality and durability.

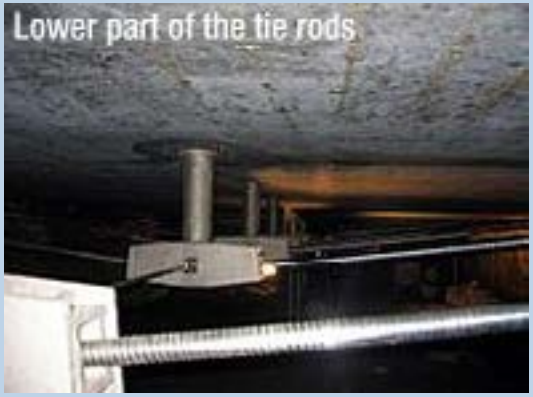
Grades: EN1.4057; AISI431, EN1.4301; AISI304
EN1.4401; AISI316

Why Stainless Steel?

- Good mechanical properties
- Durability

Upper part of the tie rods

Detail of the head



Lower part of the tie rods

Strength and Toughness

Construction

Tensegrity® Glass Beams

A new type of glass panel beam has been developed at the University of Pisa, Italy. The basic concept involves preventing and guiding glass fracture by breaking it into triangular modular elements. The elements are connected to each other by applying a pre-stress in the form of pre-tensioned stainless steel cables or bars. The glass is predominantly subject to compression. The final collapse of the structure depends on the ductility of the steel.

The structure relies on the principle of tensile integrity or Tensegrity as it is better known. Tensegrity refers to the integrity of structures as being based in a synergy between balanced tension and compression components.

All ancillary are made of stainless steel. This is for both aesthetic and durability reasons.

Grades: EN1.4401; AISI316

Why Stainless Steel?

- Aesthetics
- Good mechanical properties

Strength and Toughness

Construction

Nedujinja Shrine Bridge

In the reconstruction of the bridge at the Nedujinja Shrine, grade 410 stainless steel rebar was chosen for its durability as a reinforcement material in concrete structures.

A ferritic grade was selected over an austenitic grade because of its low thermal expansion properties and low cost. About 1.2 tons of stainless steel was used in the bridge.

Grades: EN1.4005; AISI410L

Why Stainless Steel?

- Good mechanical properties
- Durability

Aesthetics

Building

Outdoor Parking Mesh

The carpark at Winnipeg International Airport is wrapped in metal fabric, dramatically differentiating the exterior of the newly constructed garage. This was the first airport project in Canada, and one of the first in North America to target Leadership in Energy and Environmental Design (LEED) Certification.

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System was developed by the United States Green Building Council (USGBC) in 1998. It provides a suite of standards for environmentally sustainable construction.

Grades: EN1.4401; AISI316

Why Stainless Steel?

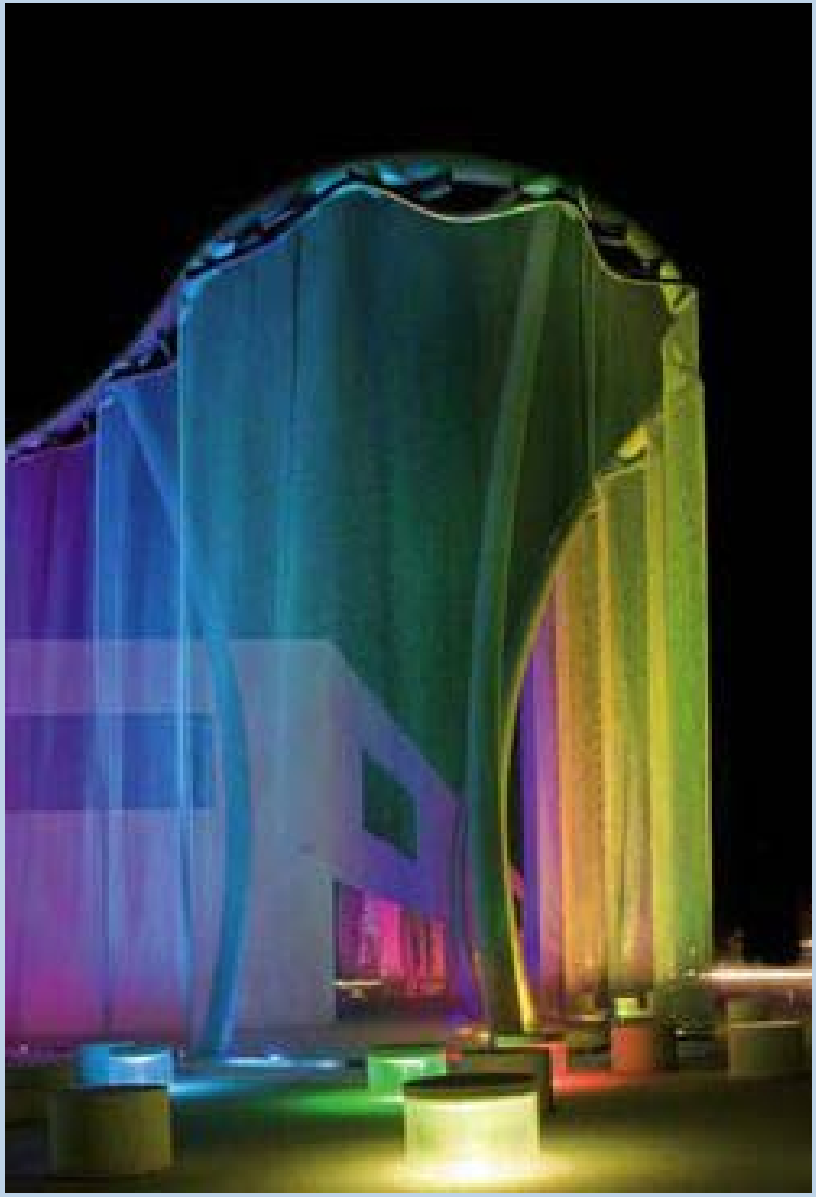
- Aesthetics
- Resistant to harsh weather
- Maintenance-free

Aesthetics

Building

Decorative Mesh

The architect chose stainless steel for the cladding of this building because of its aesthetic qualities, both by day and by night.



Grades: EN1.4401; AISI316

Why Stainless Steel?

- Aesthetics
- Suitability for harsh weather conditions
- Low maintenance

Aesthetics

Building

Handrail Cable

Initially used on yachts, these guard rail cables have found new uses in buildings and other public spaces.
They enable elegant designs and still admit the maximum amount of light.

Grades: EN1.4401; AISI316

Why Stainless Steel?

- Aesthetics
- Good mechanical properties

Aesthetics

Building

Door Handle

Along with their elegant look, these stainless steel door handles provide a smooth touch and feeling of sturdiness.

Grades: EN1.4301; AISI304

Why Stainless Steel?

- Aesthetics
- Smooth touch
- Feeling of «sturdiness»

Aesthetics

Consumer goods

Watches

The best-known luxury watch brands offer high quality stainless steel models. Elegant design, superb finish, sturdy and lasting, these watches deserve their well-earned reputation. Most watch casings are manufactured from a high-quality stainless steel piece by hot forging, precision machining and careful surface finishing.

Grades: EN1.4404; AISI316L
EN1.4435; AISI316LMo
EN1.4439; AISI 904L

Why Stainless Steel?

- Aesthetics
- Smooth touch
- Feeling of «sturdiness»

Environment

Building

Thermal Insulation Inserts

The connector is a structural component used to join external concrete balconies to internal concrete floor slabs. Stainless steel reinforcement bars provide the load transfer and have a long service life. Rigid chlorofluorocarbon-free polystyrene insulation offers improved thermal protection. The connectors are easy to handle and to install.

Stainless steel provides the required strength, corrosion resistance and maintenance-free life in all weather conditions.

This system improves the thermal insulation of buildings by avoiding cold bridging, thereby reducing heat losses and improving comfort inside.

Grades: EN1.4462 (ASTM F51)
EN1.4362

Why Stainless Steel?

- Durable
- Good mechanical properties

Balcony connectors in place before concrete is poured

Connectors awaiting installation of the balcony

Environment

Automotive

Steel Wool

Silencer wool is used in automotive exhausts to reduce noise emissions from the vehicle.

Stainless competes with glass and direct-cast metallic fibres in this application.

Grades: EN1.4113; AISI434

Why Stainless Steel?

- Oxidation resistance (hot gases)

Fire Resistance

Construction

Anchors of the tunnel cladding

The Mont Blanc tunnel between Italy and France was the scene of a terrible fire in March 1999 which claimed many lives. The tunnel re-opened following three years of extensive work to repair the damage caused by the blaze.

Safety precautions in the tunnel are now extremely tight. Particular attention is paid to the fire resistance in all components in the tunnel.

The Italian National Roads Authority has published a circular which contains directives for the construction of tunnels. Stainless steel, thanks to its characteritic stability and resistance to high temperatures, is cited as the material of choice for the fabrication tunnel components such as smoke extraction fans and lighting systems.

The system used to anchor the fibre cement cladding panels that line the Mont Blanc tunnel is now composed of 16 mm stainless anchors. The anchors have been tested to ensure they maintain their support function for at least two hours at 1,000° C.

Grades: EN1.4404; AISI316L

Why Stainless Steel?

- Fire resistance

Fire Resistance

Construction

Anchoring Heads

Anchoring heads of cables in the Pirelli building.

In April 2002, a light aircraft hit the Pirelli skyscraper in Milan, Italy. At least five people were killed in the accident and more than 30 injured.

The top floors of the 30-storey building caught fire. In particular, serious damage was caused to the 26th and 27th floors. The planking of the 26th floor took on a concave shape, bending more than 25 cm, while the floor of the upper story took a slightly convex shape.

Restoration of the structure involved inserting a group of post-stretched cables. The anchoring of the heads of the active-reinforcement cables (or noses) against the core of the beam in reinforced concrete was done by means of 28 mm threaded stainless steel bars with a yield stress of >800 Mpa.

Grades: EN1.4301; AISI 304

Why Stainless Steel?

- Fire resistance
- Good mechanical properties

ISSF Members producing stainless steel long products

Aichi Steel Corporation http://www.aichi-steel.co.jp	Japan
Baoshan Iron and Steel Co. http://www.shno1steel.com	China
Böllinghaus http://www.boellinghaus.de	Germany
Cogne Acciai Speciali http://www.cogne.com	Italy
Daido Steel Co. Ltd. http://www.daido.co.jp	Japan
Deutsche Edelstahlwerke GmbH http://www.dew-stahl.com	Germany
Nippon Steel and Sumikin Stainless Steel Corporation http://www.ns-sc.co.jp	Japan
North American Stainless (NAS) http://www.northamericanstainless.com	USA
Outokumpu Oyj http://www.outokumpu.com	Finland
Roldan S.A. http://www.acerinox.com	Spain
SeaH Changwon Integrated Special Steel Corp. http://www.seahss.co.kr	Korea
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