SUSTAINABLE STAINLESS

Railcars in Stainless Steel

A Sustainable Solution for Sustainable Public Transport

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introduction

Current efforts to make our mobile lifestyle more sustainable are increasingly focused on the benefits of public transport. A shift from motor vehicles to public transport solutions, such as rail, will significantly reduce the amount of greenhouse and other noxious gases being pumped into the atmosphere. Rail in particular can provide resource saving, environmentally friendly solutions to our growing mobility needs.

Utilising stainless steel to create railcars further increases the sustainability profile of the rail industry. Its durability and minimal maintenance requirements make stainless a good choice economically. Energy saving lightweight designs, a high level of recycled content and 100% recyclability at-the-end of life are the cornerstones of stainless steel's environmental profile. Add the bright contemporary finish of stainless steel and the sustainability profile of the rail industry is further strengthened. Stainless steel in railcars is a good example of how the social, economic and environmental factors of material selection interact to make a technical solution sustainable.

Photo: Euro Inox

WHAT MAKES STAINLESS STEEL A SUSTAINABLE MATERIAL?

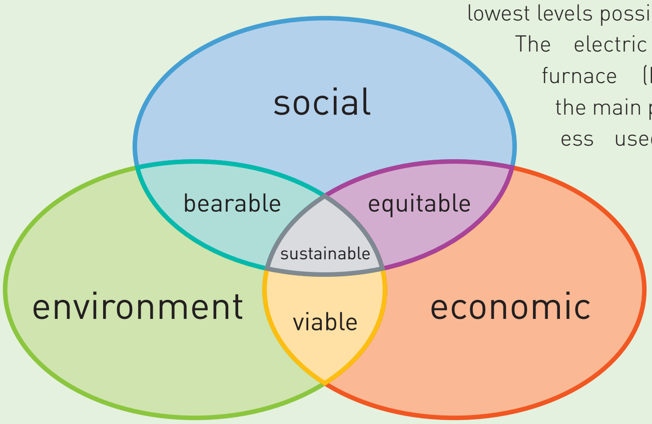
Before we can determine whether stainless steel is a sustainable material, we should first define what we mean by sustainability in relation to what is known as the triple bottom-line: People, Planet and Profit.

1. People

The material, in its use or in its production process, respects the human being, especially in terms of health and safety. A sustainable material does not harm the people working to produce it, or the people who handle it during its use, recycling and ultimate disposal.
Stainless steel is not harmful to people during either its production or use. A protective layer forms naturally on all stainless steels because of the inclusion of chromium. The passive layer protects the steel from corrosion – ensuring a long life. As long as the correct grade of stainless is selected for an application, the steel remains inert and harmless to the people who handle it and the environment. These characteristics have made stainless steel the primary material in medical, food processing, household and catering applications.

2. Planet

The emission footprints of the material, especially those related to carbon, water and air, are minimised. Reuse and recyclability are at high levels. The material has low maintenance costs and a long life, both key indicators that the impact of the material on the planet is at the lowest levels possible.
The electric arc furnace (EAF), the main process used to make stainless steels, is extremely efficient. An EAF has a low impact on the environment in terms of both CO_2 and other emissions. The EAF is also extremely efficient at processing scrap stainless, ensuring that new stainless steel has an average recycled content of more than 60%.
Stainless steels are easily recycled to produce more stainless steels and this process can be carried on indefinitely. It is estimated that about 80% of stainless steels are recycled at the end of their life. As stainless steel has a high intrinsic value, it is collected and recycled without any economic incentives from the public purse.



Source: Wikipedia

3. Profit

The industries producing the material show long-term sustainability and growth, provide excellent reliability and quality for their customers, and ensure a solid and reliable supply-chain to the end consumer.
Choosing stainless steel for an application ensures that it will have low maintenance costs, a long life and be easy to recycle at the end of that life. This makes stainless an economical choice in consumer durables (such as refrigerators and washing machines) and in capital goods applications (such as transportation, chemical and process applications).
Stainless steels also have better mechanical properties than most metals. Its fire and corrosion resistance make stainless 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. Stainless also has an aesthetically pleasing appearance, making it the material of choice in demanding architectural and design projects.
Taking into account its recyclability, reuse, long life, low maintenance and product safety, the emissions from the production and use of stainless steels are minimal when compared to any other alternative material. A detailed and precise analysis of the sustainability of stainless steel makes the choice of stainless a logical one. This might explain why, as society and governments are becoming more conscious of environmental and economic factors, the growth in the use of stainless steel has been the highest of any material in the world.

RAILCARS IN STAINLESS STEEL

Decades of Experience in Railcars

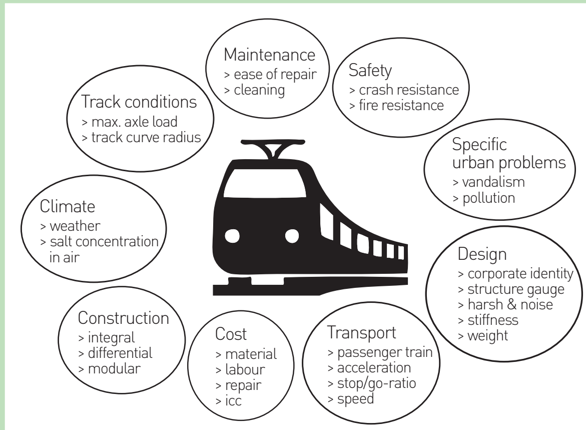
Stainless steel was first introduced in 1912. By 1932 the first railcars to utilise an all-stainless design had been put into service by the Budd Company in Canada's Rocky Mountains. The extreme temperatures and operating conditions in the Rockies enabled stainless to show off its superior technical properties and exceptional suitability for rail applications. Other rail companies soon followed suit, introducing stainless steel railcars on their routes.

Pioneer Zephyr train, USA, 1934
(Photo: Museum of Science and Industry, Chicago)

Stainless steel soon became a standard material for rail applications in the United States and Japan, a trend that has continued to the present day. New developments in stainless steel fabrication technology and the growing importance of life-cycle costs have continued to make stainless an attractive material for railcars, even in parts of the world where its use has been less common.

Why Stainless Steel?

Today stainless is used in a wide range of rail applications. Regional, commuter, metro, underground and light-rail train services all rely on stainless solutions. Each of these applications has its own profile. Material selection and design criteria are affected by the specific operating conditions the rolling stock will be exposed to during its lifetime. Many of these criteria are perfectly met by stainless steel. Stainless should be utilised whenever corrosion resistance, durability, crash resistance, fire safety, ease of cleaning, maintenance and visual attractiveness are key requirements.



Aspects of rail carriage design

Which Stainless Steel?

Although there are over two hundred stainless steel grades on the market, only a handful have become established in rail applications. As well as their superior technical performance, these grades are easily acquired and are simple to fabricate (see figure below).

Case Study 1: Let's Tango

Since December 2008 the word on the streets of Basel, Switzerland has been Tango. It's not a dance craze, but the name of Basel's new light rail.The Swiss manufacturer chose stainless steel grade EN 1.4589 for the body of the Tango. Grade EN 1.4589, with its 15% chromium, 2% nickel and 1% each of molybdenum and titanium, is an ideal solution for Basel's demanding rail network.

ASTM	EN	Type	Chem. Composition (%)	Yield Strength R_p (Mpa)	Elongation A_{80} (%)	Condition
AISI 410	1.4003	ferritic	12Cr	320	20	annealed
S420 35	1.4589	ferritic	15CR, 2Ni, Mo, Ti	420	16	annealed
AISI 301 LN	1.4318	austenitic	18Cr, 7Ni, N	350	35	annealed
AISI 304	1.4301	austenitic	18Cr, 9Ni	230	45	annealed
AISI 201	1.4372	austenitic	17Cr, 7Mn, 5Ni, N	350	45	annealed

Some grades of stainless (known as austenitic stainless steels) have a unique property: their strength increases when they are worked at ambient temperatures (called cold forming). This added strength enables manufacturers to reduce the thickness of pre-fabricated stainless steel structures for the body of a railcar, making them lighter and therefore more economic to operate. It also provides excellent crash performance. Stainless can absorb large amounts of energy in an accident, because during deformation, the material gradually increases in strength while maintaining high enough a level of ductility to prevent brittle fractures.

The unique appearance of stainless steel, which is unaffected by corrosion over the years, can be customised by applying brushed, polished or patterned finishes. The available options enable rail operators to combine the longevity and ease of maintenance of their rolling stock with characteristic and distinctive decorative features.

Stainless Railcars in Operation

Stainless steel is in use in railcar operations today. In this section we take a look at just some of the solutions that are transporting people today.

"We made a very conscious choice for this material, because it is very well established within rail vehicle construction. The Basel track conditions, with their great gradients and extremely narrow curves, place the highest demands on construction and material. Streetcars which function well here function well everywhere in the world," states Jürgen Ruess of Stadler Quality Management, the company that will build a total of 60 new Tango vehicles in the coming years for the Basel Transit Authority and Baseland Transport AG.

Tango light rail (Photo: ThyssenKrupp Nirosta)

Fabrication of Tango light rail carriages in the workshop
(Photo: ThyssenKrupp Nirosta)

"Every Tango gets a posh paint job, which reflects the colours of the respective transit company," explains Ruess. "It is important that the material of the vehicle body offers a good paint adhesion." To satisfy this requirement, the entire body is sandblasted prior to painting.

During summer 2009 the test phase of the project was finalised as the first four railcars took to the tracks. "Up to now everything has gone smoothly, both with the use of the material as well as with the completed Tango cars," says Ruess. "Once the tests are complete we expect that additional clients will then, in the most literal sense of the word, hop on the train."

Case Study 2:
Next Generation Underground in Hamburg

The next generation of trains for the metro and underground system in Hamburg, Germany will rely on a fully stainless steel design. Hamburger Hochbahn, the operator of the network, has ordered 27 of the DT 5 models for delivery between 2009 and 2013. The company has an option to purchase another 40.

Hamburger Hochbahn's new DT-5 trains will replace existing model known as the DT-3) which has been in operation on the network since the mid 1960s. Just like its predecessor DT-2, the DT-3 also utilises stainless steel in its construction. "We are happy to see that with stainless steel we unite positive long term experience on one hand with a future-oriented customer satisfaction approach on the other," said Jörg Petersen, who is responsible for the maintenance of Hamburger Hochbahn's fleet.

When they presented the mock-up of the new model to the general public in July 2008 Hamburger Hochbahn specifically highlighted responsible material selection as a key element in their approach to sustainable public transport. The company believes that the environmental product declaration for the complete vehicle design, including almost 95% recyclable materials, ensures sustainable resource saving.

Petersen knows that sustainability and cost saving are two sides of the same coin medal. "Our rolling stock is designed for a service life of 45 years. Hence durability considerations and easy maintenance are key factors of the life-cycle cost."

Hamburg, 50 km inland on the estuary of the river Elbe, is Germany's largest harbour. The elevated halide content of a coastal North Sea climate and the presence of sulphur dioxide and other corrosive exhaust gases from ships led Hamburger Hochbahn to select proven austenitic chromium nickel stainless steel for the largely unpainted skin of the railcar body. "The external surfaces in stainless steel are easy to clean and make expensive painting operation redundant," says Petersen.

"The removal of graffiti accounts for a considerable percentage of the body maintenance cost," Petersen adds. Chemically dissolving graffiti on painted surfaces degrades the coatings over time. Graffiti does not adhere well to polished and

Positive long-term experience with the DT-3 ensured Hamburger Hochbahn opted for stainless steel in its next generation of trains (Photo: Hamburger Hochbahn AG)

Mock-up of the next generation of Hamburg's metro cars
(Photo: Hamburger Hochbahn AG)

brushed stainless steel making its removal easier. The absence of a coating also means that the blank metallic surface does not undergo any colour changes due to UV-radiation. Repainting faded surfaces is a thing of the past.

The work-hardened stainless steel type AISI 301 LN (EN 1.4318) was chosen for its strength. Although the specific weight of stainless is not particularly low (7.9 kg/m^3), the wall thickness could be kept to a minimum (1.5 to 2 mm) ensuring that the fabricated components are in the same weight range as their light-metal counterparts. Superior fatigue strength makes stainless a good choice in urban public transport, where short cycles of acceleration and deceleration make operating conditions particularly demanding.

The front of the train units, where more complex forming operations are required, is fabricated from grade AISI 304 (EN 1.4301) with 18% chromium and 9% nickel content. Due to the outstanding forming potential of this stainless type the front could be made in a seamless design.

"Contact with our passengers taught us that visible stainless steel has a lasting favourable effect on our image," says Günter Elste, CEO of Hamburger Hochbahn. Stainless steel elicits a number of positive associations including hygiene, safety, durability, elegance and value. People are more willing to take public transport if the trains are comfortable and attractive. Perceived safety and cleanliness are high priorities.

Case Study 3: Stainless Steel-containing Tram Serves Alicante Coastline

Vossloh España has designed the first train-tram to be built in Spain. This new transport concept is fast, efficient, and less polluting than other modes of public transport. Developed in Alicante, the vehicle meets the needs of both train and tram travellers. New materials, such as modern stainless steels, were considered from the very first design concepts for this train-tram.

Stainless steel has been included in the production process due to its suitability for different parts of this project, particularly interiors and structural components. Few materials have the performance characteristics demanded by the railway sector. However, stainless has the mechanical characteristics, formability, and corrosion properties required. One of the main reasons Vossloh's materials engineers decided to use stainless is its great capacity to resist wear-and-tear, without losing its durability, or its aesthetic appeal.

Identifying the optimum materials mix was important to meet targets for passenger safety and low fuel consumption (and therefore low emissions). The materials selected had to be as thin and light as possible while ensuring they could fulfil their operational roles.

Train-tram station in Alicante (Photo: Vossloh España)

Train-tram stop next to Alicante beach (Photo: Vossloh España)

Because of its inherent strength, stainless steel can be thinner, and therefore lighter, than other materials while retaining its operational integrity. Vossloh España took this feature into account during the design of the train-tram.

A wide range of stainless steel grades were required for this project. Many of them have been specifically developed for use in various railroad-industry applications. Stainless steel is utilised for most of the external parts of the vehicle. Both ferritic stainless steels (such as EN 1.4003) and austenitic grades (such as EN 1.4301 [AISI 304]) are used.

The appearance, durability, mechanical properties and ease of cleaning increase the scope for stainless steel. Vossloh España has used stainless for many parts of the internal furniture, bringing modernity in terms of design, and at the same time exceptional resilience.

Stainless steel offers reductions in cost, weight and energy use. These properties are essential for the success of stainless in rail transport and to ensure the sustainable growth of the railroad industry.

Train-tram interiors (Photo: Vossloh España)

Case Study 4: Japan Rail Satisfied With Stainless Steel for Over 50 Years

Tokyu Car Corporation is the first Japanese railcar producer to use stainless steel in its products and to promote stainless in this type of application.

Stainless steel railcars were first produced in Japan in 1958 utilising SUS304 grade. Initially stainless steel was only used for the outer skin of these early models. All-stainless railcars were first introduced in 1962 (see figure below). As well as SUS304, high-tensile SUS301 grades were also used.

Today at Tokyu Car Corporation there is a distinct polarisation between the use of stainless steel and aluminium. Carbon steel is rarely used. Tokyu produces around 300-400 railcars a year, with 90% made from stainless and the remainder aluminium. Japan produces an estimated 1,000-1,200 stainless steel railcars each year.

Until the 1980s carbon steel was a popular choice for railcars due to its lower initial cost. However, extra manufacturing processes such as coating and shape-correction have increased both the initial cost and repair and maintenance charges.

Japan's first all-stainless steel railcar (Tokyu's 7000-series)
(Photo: Tokyu Car Corporation)

Recent stainless steel commuter train (JR East Japan's E233)
(Photo: Tokyu Car Corporation)

The cost of building a stainless steel railcar has been substantially lowered since the first models came into service in the 1950s. The wider use of robotics and automated processes mean that stainless railcars are often cheaper than their carbon steel counterparts.

The dominance of stainless steel over aluminium in commuter trains may be attributed to the following points:

1. Stainless steel railcars do not need coating and are easy to maintain. Aluminium railcars do normally require coating to improve their corrosion and stain resistance.

2. Aluminium railcars are often cited as being lighter in weight than their stainless steel competitors. However, this advantage is not high in railcars as aluminium trains must have a double-skin structure in order to reinforce the sides.

3. There is a growing awareness of stainless steel's superior recycling properties. Stainless railcars normally utilise 304 and 301L austenitic grades which can easily be reused. There is no deterioration in quality even when they are recycled. Series 5000, 6000 and 7000 grades are used to create aluminium railcars. These grades contain a quantity of iron to ensure rigidity. It can be time con-

suming and labour-intensive to remove them from the general aluminium waste stream. If they are recycled with other aluminium, the resulting material can only be reused for aluminium casting and similar applications.

The life of a railcar is usually estimated at between 30 and 35 years. With proper maintenance, this lifetime can be extended to 50 years in most cases. Until the 1990s it was assumed that repairing and refurbishing a railcar to extend its life for another 10 to 20 years was the most economical option. However, many years of experience have shown that:

1. Auxiliary devices, including electrical parts, become obsolete and impossible to procure after 20 years.

2. Advances in manufacturing technologies and the use of energy-saving electrical components have reduced railcar weight, enabling substantial reductions in power usage and CO_2 emissions (see table).

3. Companies have significantly reduced their maintenance workforces making maintenance more expensive.

4. Dismantling stainless steel cars was seen as a costly practice. However, it is now widely understood that this is a simple process which does not require the scrap to be separated and sorted. The stainless scrap can also be sold for a high price.

Annual CO_2 emissions and power consumption of a Tokyu 10 car train servicing the suburbs of Tokyo

	Power consumed	CO_2 emissions
OLD CARS	4.37 million kWh	1,398 tonnes
NEW CARS	2.65 million kWh	848 tonnes
DIFFERENCE	-1.72 million kWh	-550 tonnes

Source: Tokyu Corporation's Report

When these factors are taken into account, Tokyu believes that making new railcars reduces lifecycle costs more effectively than repairing and maintaining old ones. Tokyu promotes this approach in suggestions and proposals it makes to rail companies. The company also utilises a video prepared by the Japanese Stainless Steel Association (JSSA) which explains the excellent recyclability of stainless steel. Tokyu's advice and the JSSA video have proved to be very useful in educating other railcar makers and railway operators of stainless steel's advantages.

JR East, the largest railway company in Japan, undertook a Life Cycle Assessment (LCA) to compare aluminium and stainless steel. The results influenced the company to decide on stainless steel cars for its commuter trains. The current JR East fleet mostly consists of stainless steel cars for commuter trains and aluminium cars for express services and the Shinkansen trains (see figure on previous page).

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