Technical Review

Product Development on Market Trend of Stainless Steel and Its Future Prospect

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Abstract

In the 60 years since 1958, when the production of cold-rolled steel strips with wide strips began, the volume of stainless steel in Japan has been steadily increasing. This is the result of the timely development and launch of products that take advantage of the superior functions of stainless steel in response to various changes in market trends. In recent years, with the rise of Chinese mills, competition in the general-purpose field has intensified. On the other hand, the market demands for resource saving, environmental protection, maintenance-free, and next-generation technologies are increasing, and this is an opportunity to stimulate the demand for new stainless steels for the future. The following is an overview of these market trends and Nippon Steel Stainless Steel Corporation's efforts to develop new products and markets.

1. Introduction

Stainless steel is defined as "an iron-based alloy with a Cr content of 10.5% or more and a C content of 1.2% or less".[1] The Cr in the substrate combines with oxygen from outside to form an extremely thin passive film on the surface. The passive film has a self-repairing function under a general environment and exhibits high corrosion resistance for a long period of time. In addition, microalloying with Cr, Ni, Mo, and other elements and control of microstructures provide stainless steels with properties such as corrosion resistance, high temperature properties, magnetism, strength, hardness, and formability. Stainless steels have rapidly been replacing carbon steels and other materials and have been increasingly used in new applications in a wide range of fields.

In this article, we outline the progress of product development by Nippon Steel Stainless Steel Corporation in response to changes in demand for stainless steels and to expansion of markets for stainless steels. We also look at the future product development of stainless steels continuously evolving in response to diversifying and advancing needs according to changes in social situations and the growth of new technology fields.

2. Changes in Stainless Steel Production and Stainless Steel Demand Structure[2]

As shown in **Fig. 1**, the world's stainless steel production expanded to 50 million tons/year in 2018. It doubled in 10 years from 25 million tons/year in 2008 and rose at an annual rate of about 7%. When examined by region, China's stainless steel production dramatically increased and accounted for more than 50% of the total stainless steel production in the world.

Figure 2 shows the change in stainless steel production in Japan. Until 2004, it rapidly grew and peaked at 3.7 million tons/year. It then dropped after the Lehman shock, recovered to 3 million tons/year, and has remained there about.

Figure 2 also shows topics related to the demand for stainless steels. The growth of stainless steels really started with the development of mass production technology (wide cold rolling, continuous casting, refining) that dramatically improved the quality and cost of cold-rolled steel sheets and with the increase in demand with the construction rush of modern housing during the high economic growth period. Against these backgrounds, home and commercial kitchen appliances represented by sinks powerfully drove the demand for stainless steels and accelerated the diffusion of stainless steels as ordinary materials in our daily life in the 1960s. From the 1970s to the 1980s, the stainless steel demand was created for in-

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Fig. 1 World crude steel production of stainless steel

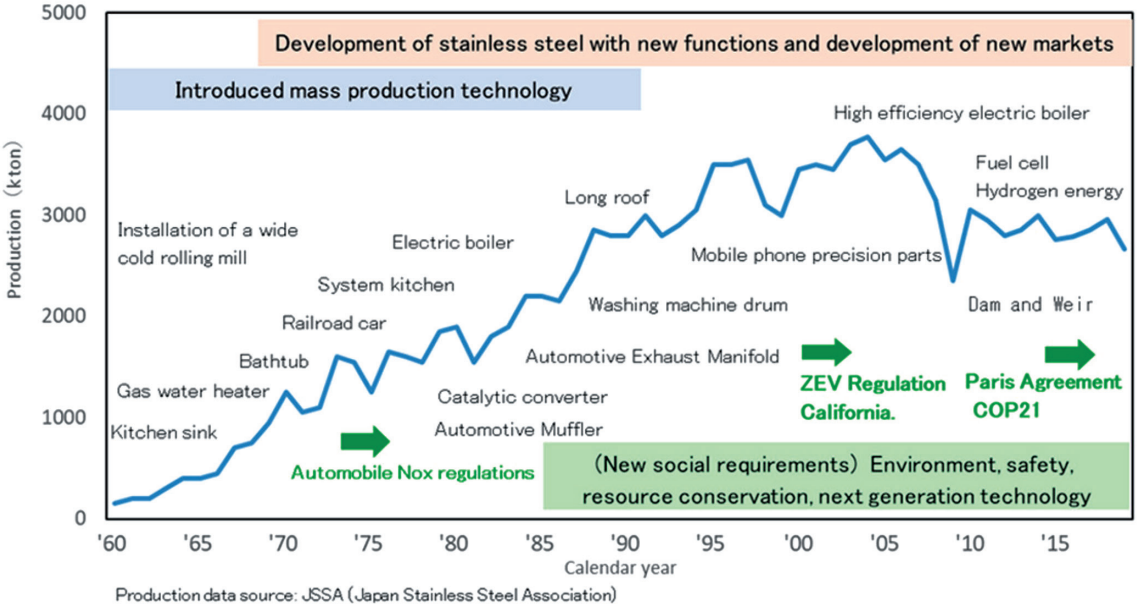


Fig. 2 Domestic stainless steel production and development history

dustrial equipment such as production equipment and plants by taking advantage of the excellent functions of stainless steels. From the 1980s, the stainless steel demand expanded for building materials, transport equipment, and electrical equipment. In the 1990s, against the background of global environmental regulations, the demand grew for transport equipment as represented by automobile exhaust gas systems.

The demand for stainless steels has expanded in various fields thanks to the development of new steel grades and the development and provision of utilization and fabrication technology in line with diversifying needs. This trend has also been encouraged by the improvement in quality and reliability and the promotion of cost reduction with the development of advanced manufacturing technology.

3. Initiatives of Nippon Steel Stainless Steel in Demand Fields by Application[2)]

3.1 Home and commercial equipment fields

Stainless steels began to spread with tableware, utensils, cutlery, office supplies, and other items extensively used in our daily lives. Kitchen sinks were a representative example. Use of stainless steel in this field began with sinks press formed from SUS304 (18Cr-8Ni) sheets. Kitchen sinks up to then were made of concrete or were tiled. The excellent corrosion resistance, formability, and cleanliness of stainless steel was widely accepted in this application. In recent years, irregular-shaped, square-shaped, and deep-drawn sinks with both design and functionality have been commercialized. Nippon Steel Stainless Steel developed the stainless steels NSSC™ 27A, 27AS (17Cr-7Ni-2Cu), NSSC 304M2, and 304M3 (16.5Cr-7Ni-1.5Si-2Cu) with better press formability and aging crack resistance than those of the SUS304. These new stainless steels are now widely used. Also, conventional wood cabinets have been increasingly replaced by all-stainless steel cabinets that are clean, maintenance-free, lightweight, and easy to install. The kitchen cabinet shown in **Photo 1** (a) is made of the stainless steel NSSC FW1 (14Cr-Sn) we developed. The alloy saving and forming features of the NSSC FW1 are put to good use in this application.

In the field of commercial kitchens, stainless steel is used in the



(a) All stainless cabinet kitchen (NSSC FW1) (b) Commercial refrigerators (SUS430)

Photo 1 Applications in field of household and commercial equipment


(a) Blending tanks for sauce production (SUS327L1) (b) Seawater desalination plant (S31803, S32304)

Photo 2 Applications in industrial equipment field

interior and exterior of refrigerators, dishwashers, and various cooking equipment. Instead of the conventional SUS430 (17Cr), the new stainless steels NSSC 430D (17Cr-Ti), NSSC FW1 (14Cr-Sn), NSSC FW2 (17Cr-Sn), and NSSC 180 (19Cr-0.3Ni-0.4Cu-Nb) with formability, weldability, corrosion resistance, and alloy saving features are now mainly used to meet diversifying requirements in the commercial kitchen field (Photo 1 (b)).

The heat resistance and high-temperature oxidation resistance of stainless steels are indispensable for the materials of gas and oil water heaters and heating combustion equipment. General-purpose heat-resistant and oxidation-resistant austenitic stainless steels have been replaced by heat-resistant ferritic stainless steels with the reduced addition of expensive alloys. Nippon Steel Stainless Steel has met the necessary requirements with the development and application of the NSSC NCA-1™ (18Cr-3Al-Ti), NSSC NCA-2™ (13Cr-1.5Si-1Al-Ti), NSSC HOM (14Cr-4.5Al), NSSC 405Si (13Cr-2Si), and NSSC FH11 (18Cr-2.5Si-Nb).

3.2 Industrial equipment fields

Stainless steel is an indispensable material in a wide range of fields that require the excellent functions of stainless steel, such as chemical plants, papermaking machines, food equipment, environmental equipment, and power generation equipment. The SUS304, SUS304L, SUS316, and SUS316L with good property balance and versatility are widely used now. In the fields of industrial equipment often used in special environments, more appropriate materials have been demanded to meet the diversification of operating environments and the increasing service life and maintenance-free requirements.

Nippon Steel Stainless Steel developed the austenitic stainless steels NSSC 170 (25Cr-13Ni-0.9Mo-0.3N), NSSC 270 (20Cr-18Ni-6Mo-0.2N), and NSSC 272 (21Cr-25Ni-6Mo-0.2N), the duplex stainless steels SUS329J4L (22Cr-5Ni-3Mo-0.13N), NSSC 2120™ (21Cr-2Ni-3Mn-1Cu-0.17N), NSSC 2351 (23Cr-5Ni-1Mo-0.17N), and SUS327L1 (25Cr-7Ni-4Mo-0.3N), and the ferritic stainless steels NSSC 190L (19Cr-2Mo-Nb), NSSC 445M2™ (22Cr-1Mo-Ti-Nb), NSSC U-20 (29Cr-3.8Mo-Nb), and NSSC 447M1 (30Cr-2Mo-Ti-Nb). High corrosion-resistant stainless steels that can withstand various harsh environments have been developed and are widely used now. Recently, lean duplex stainless steels that combine corrosion resistance with high strength have been increasing in usage. They are adopted in food tanks (**Photo 2** (a)), for example. Seawater desalination plants (Photo 2 (b)) installed increasingly to meet the economic growth in the Middle East represent another major demand for lean duplex stainless steels.

The investment in environmental equipment is increasing to meet mounting requirements for environmental protection worldwide. In the flue gas desulfurization equipment of coal-fired power plants, high corrosion resistant steel that can withstand the severe corrosion environment of the flue gas are in demand. Nippon Steel Stainless Steel's high corrosion resistant steel NSSC 270 (20Cr-18Ni-6Mo-0.2N) is becoming increasingly adopted in this application.

In the next-generation field, the investments to increase semiconductor production continue worldwide to meet the rapid progress

and spread of Internet and communication technology (ICT). The high-quality SUS304 is mainly used as an indispensable material to provide a clean environment in the vacuum chambers of semiconductor manufacturing equipment.

3.3 Building material, construction, and civil engineering fields

The use of stainless steels in these fields began with the SUS304 and SUS316 for doors, handrails, building hardware, etc. The development of technology for applying surface polishing, clear coating, metallic appearance, and various surface finishes has established stainless steels as building interior materials.

In Japan with its long coastlines and many airborne salt environments, high corrosion resistance is indispensable for exterior materials such as roofs and walls of large buildings. Materials with low thermal expansion are required for long and large roofs. To meet these requirements, we were the first to develop high-purity ferritic stainless steels. In 1989, the NSSC 220 (22Cr-0.8Mo-Nb) was applied to the roof of the Makuhari Messe. Since then, high-purity ferritic stainless steels have come to be recognized as building exterior materials. The NSSC 445M2 (22Cr-1Mo-Ti-Nb), NSSC 220M (22Cr-1.6Mo-Ti-Nb), and NSSC U-22 (22Cr-2Mo-Nb) have been widely adopted (**Photo 3** (a)). The NSSC 447M1 (30Cr-2Mo-Ti-Nb) with the highest corrosion resistance of ferritic stainless steels has been developed and adopted as exterior material to be exposed to more severe corrosive environments such as oceans and Okinawa. Recently, high-purity ferritic stainless steels with various design patterns on their surfaces are being used as the interior and exterior materials of many buildings (Photo 3 (b))[3] to the attraction of people.

In the civil engineering field, stainless steels have long been used for floodgate gate stops and various structural materials that require corrosion resistance. The method of welding sheets of the NSSC 270 (20Cr-18Ni-6Mo-0.2N) to sheath the piers of offshore structures was developed for applications where corrosion resistance is required.[4] The stainless steel sheathing method was adopted for the columns (**Photo 4** (a)) of a pier-type runway in the expansion of Haneda Airport. This method has established itself as a viable consideration.

Civil engineering structures and buildings constructed during the high-growth period are now more than 50 years old and must be repaired or reconstructed due to aging. There are mounting needs to build safe, secure, and maintenance-free infrastructure facilities. Stainless steels are being increasingly used in dams, floodgates, land lock gates, water supply reservoirs (Photo 4 (b)), piers, reinforcing bars, and other applications. The initiatives taken by Nippon Steel Stainless Steel to meet these needs with its proprietary stainless steels are described later.

3.4 Electrical equipment field

In this field, the properties of stainless steels, such as corrosion resistance, design capability, and cleanliness, have steadily prompted the switch from plastics, precoated steel sheets, and nonferrous metals to stainless steels. Surface finishing and clear coating are now applied to stainless steels.

(a) Central Japan International Airport (NSSC U-22)
Countesy of Central Japan International Airport Co., Ltd.

(b) Fukuoka Bar Association Hall (NSSC 220M, NSSC FW2)

Photo 3 Applications in field of architecture

(a) Haneda Airport stainless steel lining jacket (NSSC 270)

(b) Water supply tank in Yonago
(SUS329J4L, SUS316, SUS304)

Photo 4 Applications in civil engineering field

A typical example is the conversion of plastic washing machine drums to stainless steel drums in the 1990s (**Photo 5** (a)). The fully automatic operation of the washing machine necessitated the integration of the washing and spinning tanks into one tank and the increase of the rotating speed to ensure spinning performance. With plastic tanks, it was difficult to reduce the thickness and weight in terms of strength and to increase the spinning speed. In contrast, stainless steel can provide strength with thickness and weight reduction and ensure the spinning performance. The thickness reduction can also increase the washing capacity. Corrosion resistance, cleanliness, and recyclability also counted for stainless steel. Performance and cost favored the adoption of the ferritic stainless steels NSSC 430D and 430M2 (17Cr-Ti). Today, they are standard materials for the drums of horizontal and vertical fully automatic washing machines.

Furthermore, in this field, clear-coated products have been developed from the viewpoint of functional and design features such as stain resistance, fingerprint resistance, and antimicrobial property. Stainless steels are now used as exterior materials of home and commercial refrigerators, microwave ovens, dishwashers, rice cookers (Photo 5 (b)), electric kettles, and many other electric kitchen appliances. Nippon Steel Stainless Steel has also developed the antimicrobial stainless steel NSSC AM-1 (17Cr-1.5Cu)[5] and NSSC AM-3 (18Cr-9Ni-3.8Cu)[5], and antimicrobial clear-coated stainless steel sheets. These new products have been extensively utilized.

Water flasks, soup jars, and insulated lunch boxes for holding hot cooked rice require long-term heat or cold retention, so that they have a vacuum-insulated bottle structure. Stainless steel is the main material of vacuum bottles owing to breakage resistance upon dropping, light weight and compactness, corrosion resistance, formability, cleanliness, and cost.

In view of corrosion resistance, stress corrosion cracking (SCC) resistance, and cost, high corrosion resistant ferritic stainless steel is used as the main material for the tanks of conventional electric water heaters and of currently mainstream heat pump electric water heaters (EcoCute) that can reduce CO_2 emissions. Nippon Steel Stainless Steel developed the NSSC 445M2 (22Cr-1Mo-Nb-Ti), NSSC 220ECO (22Cr-1.2Mo-Nb-Ti), NSSC 190 (19Cr-2Mo-Nb-Ti), and cost conscious NSSC 190ECO (19Cr-1.2Mo-Nb-Ti). These grades have been widely adopted in the water heaters. Also, copper has been replaced by stainless steel to meet the corrosion resistance improvement requirements of water heater equipment piping. Nippon Steel Stainless Steel's NSSC 445M2 and NSSC 220ECO are also used in this application and expected to increase further in usage.

Moreover, a home fuel cell cogeneration system (ENE-FARM) that can generate both electricity and hot water at the same time is expected to become widespread. **Figure 3** shows the cumulative number of ENE-FARM units installed and the target number of ENE-FARM units to be installed as reported in the ENE-FARM Partners survey of 2019.[6] The cumulative number of ENE-FARM units exceeded 300 thousand at the end of October 2019 and is targeted to reach 5 300 thousand by 2030. Various stainless steels have been developed and applied to meet the required properties of not only water heater tank and piping materials, but also materials for fuel cell members such as hot modules that react fuel gas with steam and extract hydrogen. These stainless steels are expected to increase their application.

In the information technology (IT) equipment field, stainless steel is widely used in personal computers, mobile phones, and other electronic devices as well as metal masks. Non-magnetic stainless steels like the NSSC 305M1 (16Cr-12Ni-3Mn) and NSSC 130M, S (18Cr-6.5Ni-11Mn-N) are applied to applications where magnetism is objectionable. Introduction of the Internet of Things (IoT) is said to accelerate in the future. Utilization of various stainless steels is expected in the IoT field.

3.5 Transport equipment fields

3.5.1 Ship field

Stainless steel is applied to chemical tankers and LNG carriers. For chemical tankers, the SUS304L, SUS316L, and SUS316LN, and the duplex stainless steels like the NSSC DX1 are selectively used according to the type and weight of cargo. Nippon Steel Stainless Steel also supplies rolled stainless steel clad steel plates to this field.

In January 2020, international regulations[7] went into force to reduce the sulfur content in the exhaust gases of marine engines from 3.5% or less to 0.5% or less. This aims to reduce sulfur oxides (SO_x) and other air pollutants in the exhaust gases. As one measure, exhaust gas scrubbers can be installed to remove SO_x in the exhaust gases and to allow the continued use of conventional ship fuel oil. Seawater is used for cleaning in the exhaust gas scrubbers. The duplex steels SUS329J4L and SUS327L1 and the super austenitic steel NSSC 270, each with high corrosion resistance, have been widely used in exhaust gas scrubbers in recent years.

3.5.2 Automotive and motorcycle field

To improve fuel efficiency by tightening automobile exhaust gas

(a) Washing machine drum (NSSC 430D)

(b) Outer plate of cooker (NSSC 430D, SUS430 coated with transparent resin)

(c) Hot water tank for electric boiler (NSSC 190)

Photo 5 Applications in home appliance field

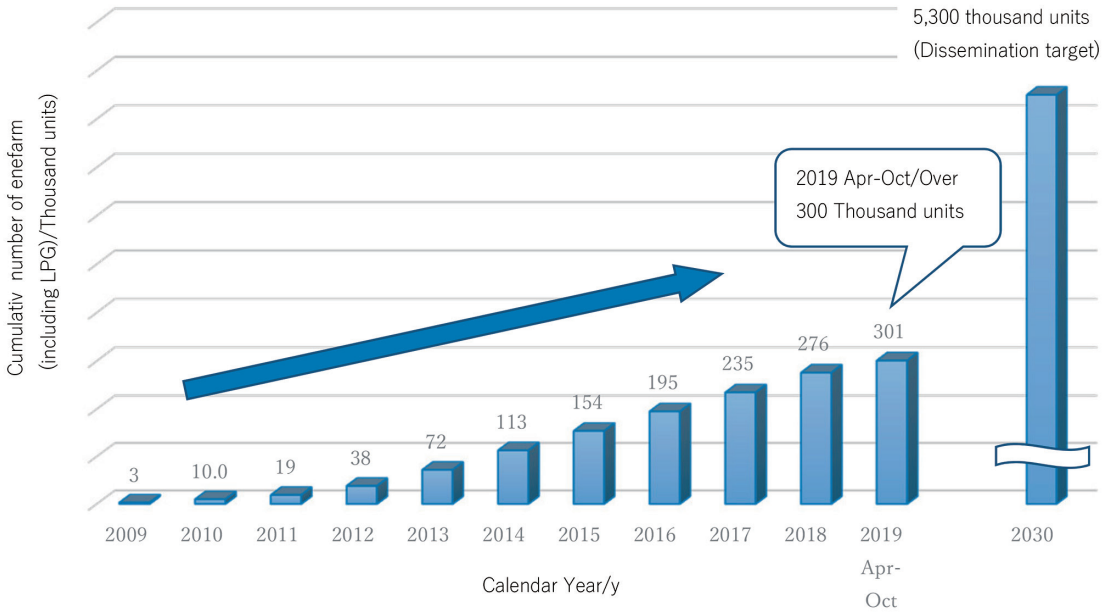


Fig. 3 Cumulative number and dissemination target of enefarm

regulations and by reducing weight, automobile exhaust systems required materials with excellent heat resistance and corrosion resistance. Previously, castings and aluminum-coated steel sheets were used in this application. Now, various high-performance stainless steels have been developed and applied to exhaust systems. High-temperature strength, thermal fatigue resistance, oxidation resistance, and high-temperature salt corrosion resistance are mainly required for exhaust system parts close to the engine (hot end). Salt corrosion resistance and condensed water corrosion resistance are mainly required for parts far from the engine (cold end).

For exhaust manifolds at the hot end, steel development has advanced in response to increasing exhaust gas temperature. Nippon Steel Stainless Steel has developed and applied various proprietary stainless steels such as the NSSC FHZ (13Cr-1Si-Nb) and NSSC 190EM (18Cr-1.6Mo-Nb-Ti) in this application. The NSSC 429NF (14Cr-1.2Cu-Ti), NSSC 448EM (17Cr-1.2Cu-0.2Mo-Nb-Ti),[8] and NSSC EM-C (17Cr-1.4Cu-Nb)[9] with the contents of rare metals Nb and Mo reduced by microalloying with Cu have also been developed and utilized. Development of steels with higher heat resistance has been demanded to accommodate increasing exhaust gas temperature in recent years.

Many stainless steels are used for mufflers at the cold end. Nippon Steel Stainless Steel has developed and applied stainless steels according to the required properties, such as the NSSC 409L (11Cr-Ti), NSSC 409M1 (11Cr-Ti) and aluminum-coated versions, and the NSSC 432 (17Cr-0.5Mo-0.2Ti) and NSSC 436S (17Cr-1.2Mo-Ti).

Regulations are becoming increasingly severe for improvement in fuel efficiency and reduction in exhaust gas emissions to protect the world environment. New parts are installed to meet these regulations, including exhaust gas recirculation (EGR) coolers, waste heat recovery systems, diesel particulate filters (DPFs), and urea selective catalytic reduction (SCR) systems. For these new parts, various stainless steels are used according to their properties. Turbochargers are also installed, not to increase the output as done in the past, but to conserve the environment. Stainless steels such as the SUS310S are used in variable nozzle vane turbochargers. Nippon Steel Stainless Steel has developed the austenitic stainless steel NSSC LHT™ (19Cr-13Ni-3.1Si)[10] with better cost performance and high-temperature tribological properties. This new austenitic stainless steel is now used in many turbochargers.

Finished SUS301 H sheets with a thickness of about 0.2 mm are often used for the cylinder head gaskets inserted between the cylinder heads and cylinder blocks of engines. For this application, Nippon Steel Stainless Steel has developed and applied stainless steels such as the NSSC 301 HS1 (17Cr-7Ni-Nb-N) with excellent required properties and the NSSC 431DP-2 (17Cr-2Ni) with excellent cost performance. Austenitic stainless steels have been developed and utilized for heat-resistant gaskets in high-temperature connections in catalytic converters directly under exhaust manifolds.

The automobile industry is said to reach a turning point once every 100 years. It is anticipated that conventional gasoline engine cars will be replaced by electric cars and that the ratio of next-generation automobiles will increase. **Table 1**[11] shows that Japan targets a next-generation vehicle diffusion ratio of 50 to 70% in 2030. According to the document[11] distributed at the first meeting of the Strategic Commission for the New Automobile Era, the number of electric vehicles will increase from 15% in 2020 to 51% in 2040. Also, hybrid vehicles (HVs), plug-in hybrid vehicles (PHVs), electric vehicles (EVs), and fuel cell vehicles (FCVs) will increase. Stainless steel forms a passive film on the surface and does not alloy with Li. For example, it is studied for use in the cathode and anode electrode collectors of high-energy density lithium-ion secondary batteries and battery cases, and the separators of polymer electrolyte fuel cells (PEFCs) for the FCVs. Stainless steel is expected to find increasing use in these new applications.

Various studies have been conducted toward the realization of a hydrogen-based society. Also, in this field, the SUS316L that has satisfied the specified requirements is used as material for high-pressure hydrogen members in the FCVs that run on hydrogen and hydrogen filling stations, among other applications. Nippon Steel Stainless Steel has also developed the proprietary low-Ni, Mo-saving austenitic stainless steel with excellent cost performance.[12] This

Table 1 2030 target/diffusion rate of next-generation vehicle in Japan

	2017 (Sales quantity)	2030 (target)
Conventional vehicle	63.5% (2 791 thousand units)	30–50%
Next-generation vehicle	36.4% (1 595 thousand units)	50–70%
Hybrid electric vehicle	31.6% (1 385 thousand units)	30–40%
Battery electric vehicle Plug in hybrid electric vehicle	0.41% (18 thousand units) 0.82% (36 thousand units)	20–30%
Fuel cell electric vehicle	0.02% (849 units)	– 3%
Clean diesel vehicle	3.5% (155 thousand units)	5–10%

and our other stainless steels are expected to be used as hydrogen energy component members.

For motorcycles, martensitic stainless steel is mainly used for disc brakes. Our proprietary martensitic stainless steels such as the NSSC 410DE (12Cr-0.04C) and NSSC 410M4 (12Cr-0.7Mn-0.07C) are applied to disk brakes. Exhaust gas regulations have also been tightened for motorcycles. The ferritic stainless steels NSSC 205M1 (20Cr-5Al-Ti-REM), NSSC 21M (18Cr-2Al-Ti), and NSSC NCA-1 (18Cr-3Al-Ti) are used for catalytic converters.

3.5.3 Rolling stock field

Stainless steel is also used in the rolling stock thanks to its excellent life cycle cost and recyclability. Structural members that require strength also require weld metal corrosion resistance. The hard SUS301L is applied as material to satisfy the rolling stock standards that specify strength and elongation by grade in strict ranges. The SUS304 is mainly used in panels and other rolling stock members.

Steels to be used near superconducting magnets in linear motor cars under development as future rolling stock must be non-magnetic. Austenitic stainless steels and high-manganese steels are studied for this application.[13] Stainless steels that satisfy non-magnetism, corrosion resistance, and other required properties are utilized and are expected to increase in usage.

4. Changes in Situation Surrounding Stainless Steels and Response of Nippon Steel Stainless Steel to Changes

Huge overseas steelmakers, mainly in China, are sweeping the general-purpose stainless steel market with their overwhelming cost competitiveness.

Japan's stainless steelmakers have maintained their quality competitiveness, centering on high-grade stainless steels. Taking advantage of the strength of our product development efforts up to now, we must supply value-added stainless steels with functional properties to support diversification and sophistication in information and communication technology (ICT) and other growing fields in addition to new energy fields associated with environmental control measures. Our products must also meet social needs for resource conservation, safety, security, and maintenance-free operation.

At Nippon Steel Stainless Steel, we have developed distinctive new stainless steels such as lean stainless steels and high-performance stainless steels by tapping our technological expertise. We have also strengthened our capability to provide solutions helpful in solving the problems of corrosion resistance, formability, weldability, and surface quality as demanded by our customers.

4.1 Lean stainless steels

The SUS304, the most widely used stainless steel in the world, contains the rare metals Cr and Ni in large amounts of 18% and 8%, respectively. In particular, the Ni has the disadvantage of being expensive and having large price fluctuations. It is the main cause of the soaring and steeply changing prices of stainless steels.

We have developed the lean stainless NSSC FW series and New lean Duplex series as substitutes for general-purpose stainless steels represented by the SUS304.

4.1.1 NSSC FW™ (forward) series

Japan has developed Ni-free, high-purity ferritic stainless steels. The high-purity ferritic stainless steels have the contents of C, N, and other impurities reduced and are microalloyed with the stabilizing elements Nb and Ti to increase corrosion resistance and formability. The Cr content is increased to ensure corrosion resistance. For example, the stainless steels SUS430J1L and SUS443J1 with a high Cr content of 19 to 21% are adopted as substitutes for the SUS304.

Nippon Steel Stainless Steel has developed the high-purity ferritic stainless steels NSSC FW (FW0: 13Cr-Sn, FW1: 14Cr-Sn, FW2: 17Cr-Sn) with the contents of the rare metals Ni and Cr reduced by microalloying with Sn, instead of increasing the Cr content.[14] **Figure 4** shows the applicable range of the NSSC FW series. As next-generation general-purpose stainless steels that can be used in a wide range of applications of the conventional general-purpose stainless steels such as the SUS304 and SUS430, the stainless steels of the NSSC FW series are expanding their application range in kitchen equipment, cooking containers, interior and exterior materials of home appliances, interior and exterior building materials, metal fittings, and solar panel mounts (**Photo 6**).

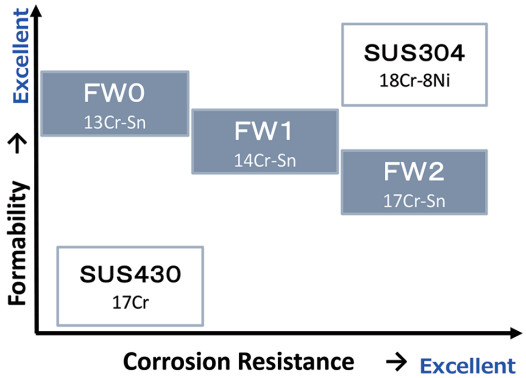


Fig. 4 Scope of application of FW series

Photo 6 Application of FW to solar panel mount

4.1.2 New lean duplex series

Duplex steel is a stainless steel with a ferrite-austenite duplex microstructure. Because it has high strength and high corrosion resistance, it is suitable for structural applications where the advantages of more thinner and light weight reduction can be appreciated. **Figure 5** shows the classification and positioning of the duplex steels. The S32101 (21Cr-1.5Ni-5Mn-0.22N) is available as a lean duplex steel equivalent to the SUS304. Because of its poor weldability, its adoption is limited.

Nippon Steel Stainless Steel has developed the proprietary duplex steel NSSC 2120 (21Cr-2Ni-3Mn-0.2N) by its proprietary composition design. The precipitation of nitrides responsible for poor corrosion resistance and toughness in weld heat-affected zones is suppressed.[15] Since it has excellent corrosion resistance and strength, the NSSC 2120 can replace the SUS304 and improve equipment performance and economic efficiency at the time of construction. For these reasons, the NSSC 2120 is adopted in many public infrastructure facilities such as dams and floodgates related to earthquake disaster reconstruction and national resilience projects. Thus, the NSSC 2120 contributes to the realization of a safe, secure, and maintenance-free society (**Photo 7**). It is also widely used in industrial machinery, linings, metal fittings, etc.

In September 2019, we developed our proprietary duplex steel NSSC 2351 (23Cr-5Ni-1Mo-0.17N) as a possible replacement for the SUS316 and with improved weldability. Together with the NSSC 2120, the NSSC 2351 has completed our lineup of the next-generation duplex steel series with excellent weldability.

4.2 High-performance stainless steels

Stainless steels have been developed with characteristic functions such as non-magnetism, high strength, high fatigue strength, and ultrafine grain size, in addition to characteristic high corrosion resistance.

Nippon Steel Stainless Steel has a lineup of non-magnetic stainless steels, such as the NSSC 130S (18Cr-6Ni-10Mn-0.3N), NSSC 305M1 (16Cr-12Ni-3Mn), NSSC 305M3 (19Cr-12Ni-3Mn-0.15N), and NSSC 304N (18Cr-8Ni-0.2N). Our non-magnetic stainless steels are widely used in the fields of automobiles and industrial equipment. Their demand is expected to increase in the growing fields of ICT and medical care. Our high-strength stainless steels are represented by the NSSC 431DP-2 (16.5Cr-2Ni) with a fine-grained duplex microstructure, high strength and good springiness and by the work hardening austenite stain steel NSSC HT2000 (14Cr-8Ni-3Si-2Mo) with the world's highest level of strength (tensile strength: 2 000 MPa) and fatigue strength. As fine-grained stainless steel, we are touting precision processing fine-grained stainless steel sheets under the brand FYGRAS™.[16] The FYGRAS features the world's smallest grain size of the micron class required for etching, press forming, bending, and laser processing. It also provides thickness accuracy, flatness, and low residual stress. These properties help to enhance the performance of and reduce the size of electronic devices. The FYGRAS is expected to see its demand expanding in the future (**Photo 8**).

4.3 Provision of solutions

Our new stainless steels introduced here have properties not totally the same as those of conventional stainless steels. When our customers use our new stainless steels, they need to select the grade to suit their use environment and to set their processing method, processing conditions, and welding conditions to suit the selected grade. On the other hand, we need to present recommended conditions to our customers and cooperate with them in tuning their application. We must grasp material properties, accumulate processing know-how, and closely exchange information with our users. We will have to engage in development work jointly with our users, to develop materials to match their needs, and to help our users to create new products with enhanced competitiveness by taking advantage of our materials.

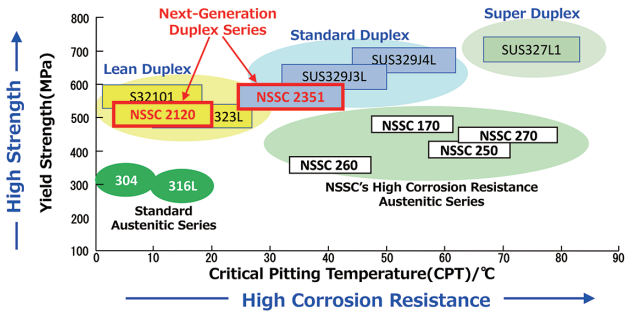


Fig. 5 Classification and positioning of duplex stainless steel

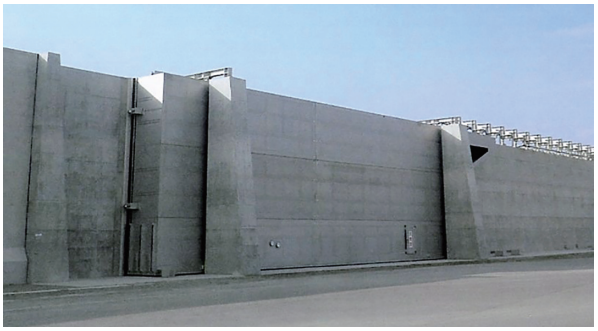
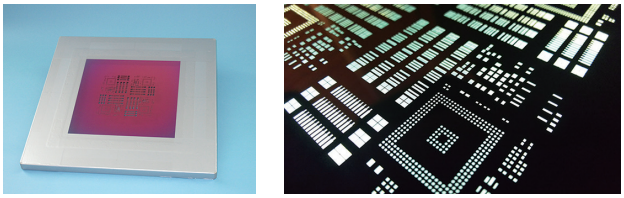


Photo 7 Largest land lock gate (Miyako City, Iwate Prefecture) (NSSC 2120)



(a) Stencil appearance **(b) Expansion of small holes making by laser processing**

Photo 8 High performance stainless steel stencil for surface mounting technology (SMT)

5. Conclusions

We have developed many stainless steels and have advanced together with the users of our products. Although we expect the supply and demand environment of stainless steels in the world to continue to be tough, stainless steels have a history of more than 100 years and still have plenty of room for development. Taking advantage of changes in needs such as resource conservation, environmental protection, new energy, ICT, and maintenance-free operation, we will utilize the world's top-level technological development capabilities we have accumulated over many years to provide new products and solutions that meet those needs of our customers in a timely manner. By doing so, we will aim to expand the stainless steel market.

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