

## **Recent Development in Corrosion Resistance of Steel for Society**

### **1 Introduction**

With the coming of the 21st century, a mission required for the industries has greatly changed with strong demands of structuring a recycle-oriented society, and preventing the global warming. Steel products are used extensively as the important raw material of consumption and capital goods, and therefore expected to make a technical contribution toward the accomplishment of the above mission.

Corrosion-resistant steel is widely used in the places where the working conditions and requirement for corrosion resistance are ramified. Corrosion is an intrinsic problem for utility metals. In case of steel, stainless steel, galvanized, electro galvanized, and weathering steel of which corrosion can be prevented or moderated have been put to practical use. This has led to an increase in the volume of steel used along with the improvement in performance for corrosion resistance.

Figure 1 shows the relationship of variation in market demand and the product development as well as its technical progress by Nippon Steel. The horizontal-axis shows some corrosion resistant steel products in daily use, among which those with short service life only last a few years , and those with long service life can last over 100 years. A lot of steel made daily necessities, durable consumer goods, antirust packing boxes, etc. have found wide uses. In the field of social and industrial infrastructures, a target is set for a long service life of over 50 years, and corrosion-resistant steel is mainly used. The main technical issue is how to make service life longer, including how to maintain and applied to all fields.

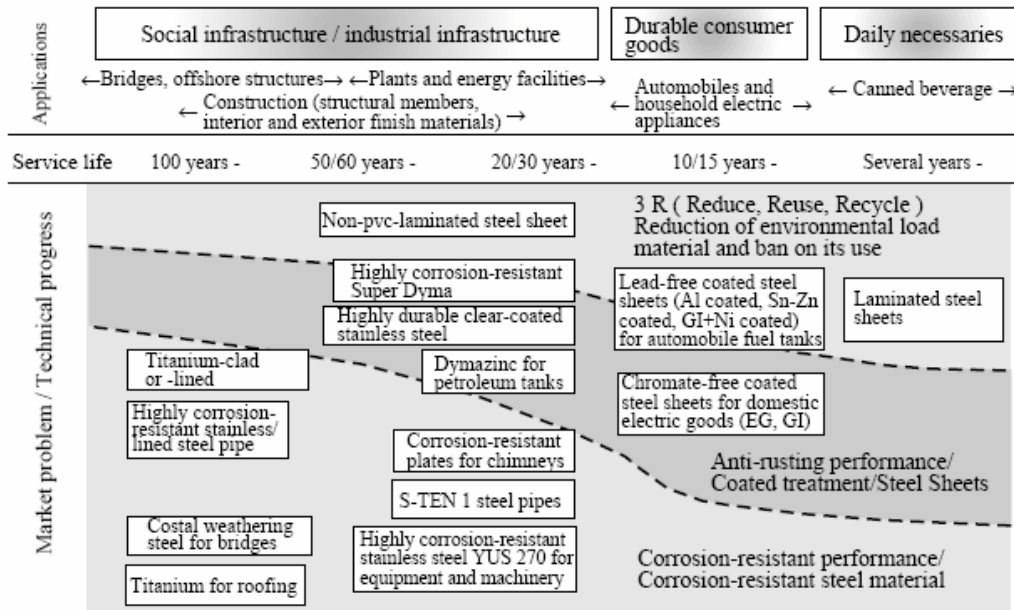
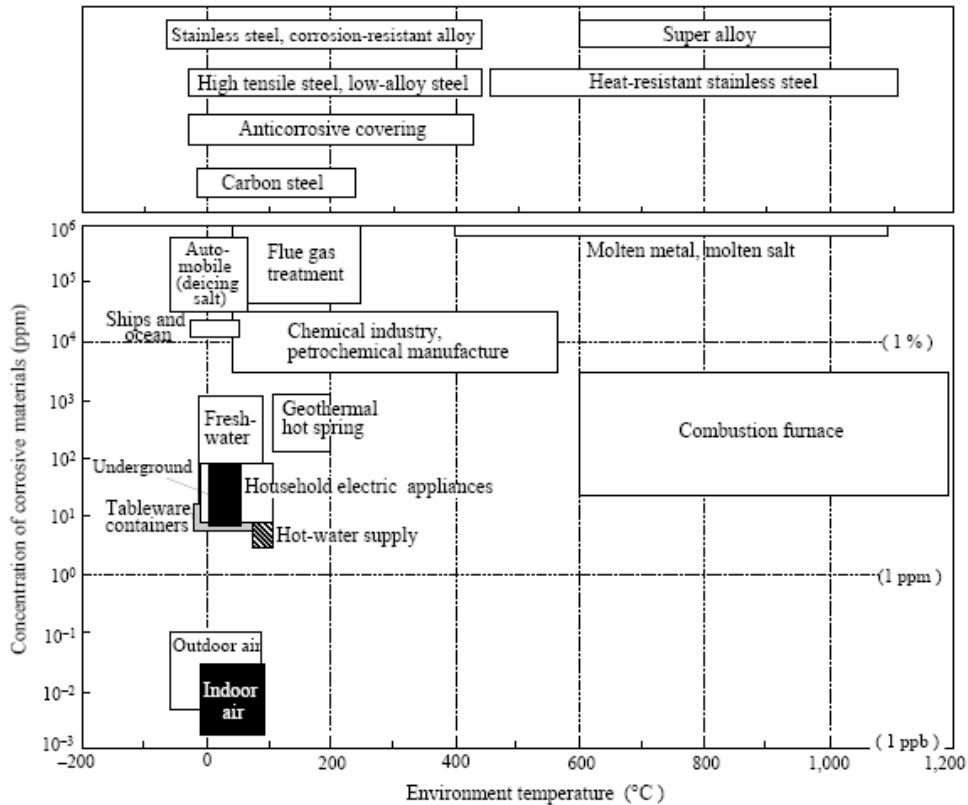


Fig.1 Changes in social needs and recent improvement in technology and products in Nippon Steel

This paper, after supplementing the working environment and requirements for corrosion resistance, introduces the important development in corrosion-resistant materials and corrosion protection technology.

## 2 Working environment and request for corrosion resistant steel sheet

Figure 2 shows examples of corrosion for some materials at different temperatures and corrosion conditions<sup>[1]</sup>. This figure is not an exact one, but reveals that the environment conditions are various and the combination of materials is diversified. Corrosion resistance, though expressed in a word, is requested to have various performances, for example, tableware's rust prevention, hull's and offshore structure's corrosion rate, and food packaging materials' harmlessness. All these involve in steel's corrosion resistance.



**Fig. 2 An example of outlining the configuration of major equipment in respective fields in terms of material surface temperatures and corrosive condition (Edited by the National Institute of Resources, Science and Technology Agency: Rust close to us and its protection, partly revised by referring to 1986 edition)**

As freshwater is used at room temperature, its corrosion to household electric appliances, and tableware is comparatively weak. For hulls and offshore structures, as they are in special environment, the corrosion is relative ly strong. The most corrosive environment can be those where high temperature steam and electric motor are used. Some chemical plants are classified into the latter category. Again, the environment for chemical and petrochemical plants, exposed to high temperature, and for automobiles, exposed to the highly salt-concentrated corrosive environment arising from the deicing salt, is classified into the highly corrosive category. Furthermore, the extremely corrosive environment is found in the exhaust system of an internal combustion engine, exposed to very high temperature, a hot-dipping tank for molten metals, and a fuel cell using molten salt.

As described above, although the corrosiveness in the specified environment and the requirements for corrosion resistance are diversified, it becomes possible to select

appropriate materials available for practical use in almost all the fields at present, as a result of our efforts and accumulation of the technical understanding, collaborated with the users, on both the material and the working environment.

### 3 Recent advancement in corrosion resistance and corrosion protection technologies

#### 3.1 Recent R&D in corrosion resistance and corrosion protection technologies

Table 1 shows some steel corrosion problems in the corrosion-resistant steel materials and coated steel sheets.

Table 1 Research and problems about steel<sup>[2]</sup>

	Construction/civil engineering	Energy/chemical	Automobile	Household electric appliances/electronic equipment	Offshore structure
Corrosion condition	<ul style="list-style-type: none"> <li>• Atmospheric corrosion</li> <li>• Freshwater corrosion</li> <li>• Salt damage corrosion</li> </ul>	<ul style="list-style-type: none"> <li>• Acid and alkali</li> <li>• Salts</li> <li>• High-temperature gas corrosion</li> <li>• Hot water corrosion</li> </ul>	<ul style="list-style-type: none"> <li>• Atmospheric corrosion</li> <li>• Salt damage corrosion</li> <li>• Fuel tank corrosion</li> </ul>	<ul style="list-style-type: none"> <li>• Atmospheric corrosion</li> <li>• Freshwater corrosion</li> <li>• Salt damage corrosion</li> </ul>	<ul style="list-style-type: none"> <li>• Seawater corrosion</li> <li>• Salt damage corrosion</li> </ul>
Problems and antirust technology	<ul style="list-style-type: none"> <li>• Security of social infrastructure</li> <li>• Security of long service life</li> <li>• coated steel sheet</li> </ul>	<ul style="list-style-type: none"> <li>• Measures against acid and alkali corrosion</li> <li>• Measures against high temperature corrosion</li> <li>• Measures against stress corrosion cracking</li> </ul>	<ul style="list-style-type: none"> <li>• Simultaneous security of anti-corrosiveness, drawability</li> <li>• Technique against corrosion free of environmental load</li> </ul>	<ul style="list-style-type: none"> <li>• Techniques against corrosion free of environmental load</li> </ul>	<ul style="list-style-type: none"> <li>• Measures against seawater corrosion</li> <li>• Measures against seawater corrosion</li> <li>• Security of long service life</li> </ul>

<p>Newly developed steel and corrosion resistant technology</p>	<ul style="list-style-type: none"> <li>• Costal weathering steel for bridges</li> <li>• Technique of predicting weathering steel corrosion</li> <li>• Highly corrosion-resistant stainless steel</li> </ul>	<ul style="list-style-type: none"> <li>• Zn-Mg-coated steel sheet for tank</li> <li>• Water corrosion proof element steel sheet</li> </ul>	<ul style="list-style-type: none"> <li>• Zn-Al coated steel sheet</li> <li>• Various high tensile coated steel sheets</li> <li>• Stainless steel for exhaust system</li> </ul>	<ul style="list-style-type: none"> <li>• Lead-free coated steel sheet</li> <li>• Chromate-free coated steel sheet</li> <li>• Pre-coated steel sheet</li> </ul>	<ul style="list-style-type: none"> <li>• High performance of line-pipe</li> </ul>
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### 3.2 Corrosion resistant steel products

In this field, steel material is used in many parts, such as outer and inner plates of automobiles. The demand for higher corrosion resistance of steel is growing year after year. Steel material for automobiles is required to be resistant not only to atmospheric corrosion but also to salt corrosion from deicing salt. Therefore, stainless steel and coated steel sheets have been developed which are more excellent in corrosion resistance<sup>[3]</sup>. Particularly in recent years steel material is required to be excellent not only in corrosion resistance but also in other performances, such as drawability, coating adhesiveness, and weldability. This has led to developing various high-performance coated steel sheets. In addition, highly corrosion-resistant stainless steel has been developed for an exhaust gas system, including a muffler and an exhaust manifold.

### 3.3 Steel for reducing environment load

To cope with the regulations for reduction of environmental load, European, Japanese and Chinese customers have made a proposal for the reduction. It was stipulated in Europe as the regulations of ELV (End of Life Vehicle) that lead, mercury, cadmium, and hexavalent chromium should not be used in new automobiles produced after July, 2003<sup>[4]</sup>. In the case of coated steel sheets for automobiles, lead/tin-coated steel sheets have so far been used for fuel tanks, and for zinc-coated steel sheets used in automobile parts and other car goods, chromate coated ones have been used. However, due to the above regulations, the use of environmental load materials, including lead

and hexavalent chromium, will be limited. As alternative coated steel sheets, Al coated steel sheet for fuel tanks, Sn-Zn coated steel sheets, GI + Ni coated steel sheets, and chromate-free coated steel sheets have been developed and already supplied for many customers.

#### **4 Future prospects**

In the field of social and industrial infrastructures, corrosion protection technology, including its evaluation methods, should be developed together with the establishment of the corresponding research system and its members. In addition, plentifully accumulated knowledge of corrosion protection should be systematically organized so that it can be used to meet the demand of further development for the future.

#### **References**

- 1 National Institute of Science and Technology: Rust Close to Us and Its Protection. 1986.
- 2 Example, Corrosion of Metals and Alloys Accelerated Cyclic Test. (Juridical Foundation) The Japan Iron and Steel Federation, etc., 2001.
- 3 Masaru Sagiya, Present and Future Development of Coated Steel Sheets, The Iron and Steel Institute of Japan, 2004, 9 (6): 15~23.
- 4 Hiromichi Yanagihara etc., Feature and Differences in Research & Development Methodology between Europe and Japan, Journal of Society of Automotive Engineers of Japan, 2004, 58(1):24~28.

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