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Future Prospects for Steel Coating Technology

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Abstract:

Steel coating technology has made great progress to meet changing social needs. Particularly, coated steel sheets of various types have been developed with increasing production in response to the brisk demand in the automobile, construction, and household electrical appliance industries. This development has been accompanied by steady progress in manufacturing and application technologies. This paper describes the future prospects of coated steel sheet technology and the so-called heavy-duty organic coatings for steel products and structures.

1. Introduction

More than 10 years have passed since the publication of the last special issue of the Nippon Steel Technical Report on coated steel products. In the intervening years, the coated steel demand has come to emphasize longer service life and higher functionality reflecting the call of the times for energy and resources saving, and environmental protection on a global scale, as well as the shunning by young wakers of difficult, dirty and dangerous jobs (often referred to as 3D jobs in Japan). The coated steel products made great progress in terms of both production tonnage and technology. Unfortunately, the demand for coated steels peaked in 1991 and was compelled to decrease thereafter. The current change in the economic structure may be a best opportunity for pondering over the future course of coated steel technology. Nippon Steel's coated steel technology covers a wide spectrum of products from the surface treatment of sheet and strip through the organic coating of shapes and pipe to the heavy-duty corrosion protection of steel structures. It is no exaggeration to say that Nippon Steel's coated steel technologies are used in all steel-consuming areas, including containers, automobiles, household appliances, office equipment, industrial and electrical machines, buildings, bridges, and offshore structures.

This report first gives a general picture of coated steel sheets and then describes the past development and future prospect of coated steel demand, as well as industry-wise application technologies, manufacturing technology, and heavy-duty corrosion protection technology, and fundamental technology.

2. Coated Steel Sheets

The production of coated steel sheets has rapidly grown despite fluctuations in the crude steel output, exceeding 17 million tons and accounting for 16% of total crude steel production in fiscal 1991 in Japan. The change in the coated steel sheet output is shown in **Fig. 1**[1]. The solid line indicates the ratio of coated sheet products to cold-rolled products. The increase in this ratio means that demand for coated steel sheets is mostly for replacing uncoated cold-rolled sheets.

Fig. 2 shows changes in the coated steel demand by industry in Japan[1]. The demand grew in every field of application with the automobile industry by far the largest. The proportion of coated steel sheet demand for automotive use in the total demand

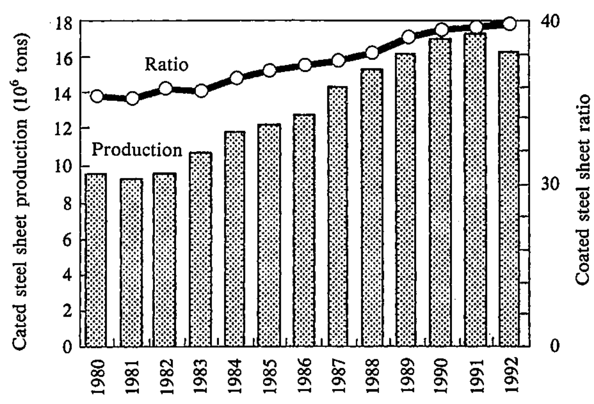

Fig. 1 Change in coated steel sheet production

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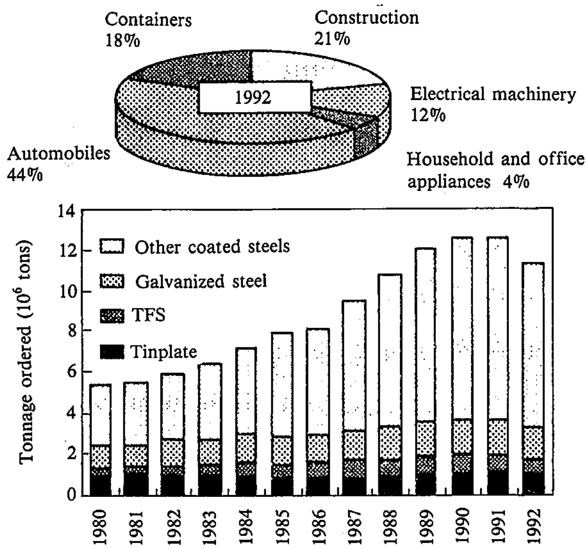

Fig. 2 Proportions of orders received by type and application of coated steel sheet in Japan

was 24% in fiscal 1982, and nearly doubled at 44% in fiscal 1992, the last fiscal year for which data are available. The automobile industry is followed by construction (21%), containers (18%), electrical machines (12%), and household and office appliances (4%) in the order mentioned. **Fig. 2** also shows that by type of product, the others category registered the largest increase. This category is not broken down in the available data of the Committee for Iron and Steel Statistics in the Japan Iron and Steel Federation, but is known to consist of electrogalvanized steel (EG), galvannealed steel (GA), organic composite-coated zinc-nickel alloy-electroplated steel (WU), and two-layer zinc-iron alloy-electroplated steel (EL).

Among the new coated steel products that appeared during this period are WU and two-layered AS for automobiles; various prepainted steel sheets, inorganic composite-coated steel sheets with various functions and black-colored steel sheet for household electrical appliances; lightly tin-coated steel (LTS) and other steel sheets for welded cans and plastic film-laminated steel sheet for a new type of drawn cans.

Many coating lines were constructed or modified to meet increasing coated steel production volumes and types. **Fig. 3** shows the increase in the rated capacity of continuous hot-dip galvanizing lines (CGLs) and electrogalvanizing lines (EGLs). In the mid-1980s, the EGL capacity markedly increased in response to the adoption of zinc alloy-electroplated steel sheets in automobiles. In mid-1990s, the CGL production capacity dramatically grew to meet the need for the increased corrosion resistance of automobiles. These capacity increases are due mostly to the construction of new CGL and EGL facilities, and many new technologies were introduced to meet severe quality requirements. Many coil coating lines (CCLs) were also built to satisfy demand for prepainted coil products from the electric appliance and construction industries, in paralled with the development of new manufacturing technologies. Only two tin-free steel (TFS) lines were constructed as new coated steel production lines for containers, but it deserves special mention that new lines were built to produce plastic film-laminated steel for two-piece cans.

Also to be noted in this connection is the establishment of overseas coated sheet steel production and supply bases by Japanese steelmakers in line with the increase of automobile production abroad by Japanese automakers. The Japanese steel companies extended technical cooperation to European mills and set up joint ventures with American mills to locally manufacture coated steel products. These efforts initially encountered some technical difficulties, but are now steadily bearing fruit.

3. Coated Steel Sheets for Automobiles

Among the coated steel sheets for automobiles are zinc-and zinc alloy-coated corrosion-resistant steel sheets for automobile bodies, terne-coated steel sheet for fuel tanks, and aluminum- and aluminum alloy-coated steel sheets for exhaust systems.

3.1 Corrosion-resistant steel sheets for automobile bodies

In Japan, corrosion-resistant steel sheets for automobile bodies started as one-side ground galvannealed steel (GA), zinc-nickel alloy-electroplated steel, and Zincrometal in the early 1980s. They grew in two major streams as shown in **Fig. 4**[2]. One is the galvannealed steel group that emphasizes corrosion resistance after painting. The galvannealed group went two sided for improvement in cosmetic corrosion resistance, changed to electrogalvanized steel (EL) with good surface quality and formability, and evolved into two-layer galvannealed steel for better perforation corrosion resistance. For two-layer galvannealed steel, refer to the "Development and Properties of Iron-Zinc Alloy-Electroplated Galvannealed Sheet Steel" in this issue. The galvannealed steel group changed from hot-dip coating to electrolytic coating and then back to hot-dip coating. The other group emphasizes corrosion resistance before painting and developed

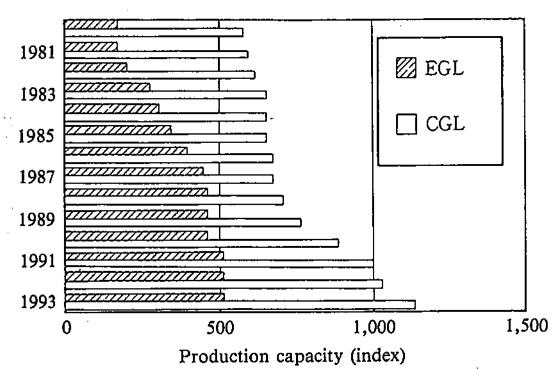

Fig. 3 Change in CGL and EGL capacities

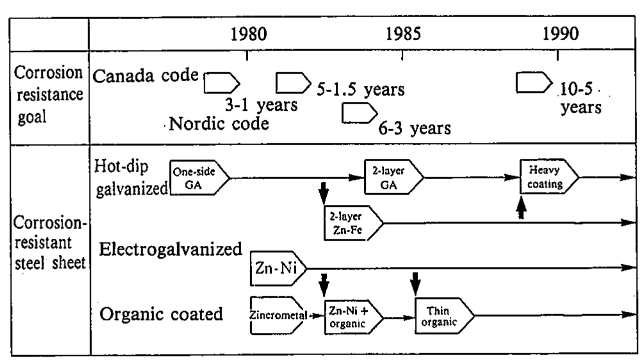

Fig. 4 Changes in corrosion-resistant steel sheets

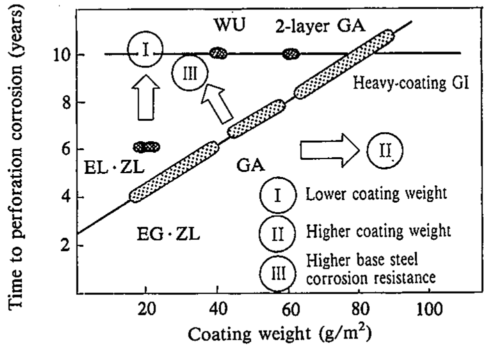

Fig. 5 Perforation corrosion resistance and course of development of coated steel sheets

into organic composite-coated steel (WU) that combines the advantages of both zinc-nickel alloy-electroplated steel (ZL) and prepainted steel. Today's mass-production type organic composite-coated steel was completed in 1986 and has since been improved for color coating and enhanced resistance to iron rust-induced corrosion. The two groups are claimed to be able to meet the "10-5-2" target, that is, 10 years of perforation corrosion resistance, 5 years of cosmetic corrosion resistance, and 2 years of engine room corrosion resistance.

In foreign countries, simple hot-dip galvanized steel (GI), electrogalvanized steel, and galvannealed steel are principal types of corrosion-resistant sheet products used for automobile bodies. The coating weight has converged to an medium level of 60 g/m^2 from a heavy 90 to 120 g/m^2 range. Zinc-nickel alloy-electroplated steel (ZL) and Zincrox are also used in some cases. Japan's transplants have strong tendencies to adopt coated steel products of the same type and quality as in Japan, and the Japanese steel industry has responded to this move as noted previously.

Fig. 5 shows the effect of coating weight on the perforation corrosion resistance of various corrosion-resistant steel sheets[2]. About 10 years ago, the Japanese steel industry set the three major development goals shown in **Fig. 5**. Goal I was enhanced service performance with light coating, Goal II was enhanced service performance with heavy coating, and Goal III was enhanced service performance by improving the corrosion resistance of base steel as an auxiliary measure. The three goals were accomplished by organic composite-coated steel, two-layer galvannealed steel, and copper and phosphorus-bearing steel, respectively. These coated sheet products were developed through close cooperation with the automakers.

Research and development efforts are being expended in the direction of Goal I, but no seeds are yet to be commercialized. The results published thus far include a zinc-chromium alloy-coated steel sheet[3], an inorganic composite-coated zinc alloy-electroplated steel sheet[4], and zinc-magnesium alloy vapor-deposited steel sheet[5].

As discussed above, the steelmakers have developed various different types of corrosion-resistant steel sheets despite their identical objective, that is, realizing the proper auto body corrosion protection function. This is due to difference in the concept of corrosion protection on the part of automobile manufacturers. In the future, corrosion-resistant steel sheets should be made available on the market in a smaller number of types.

3.2 Coated steel sheets for fuel tanks and exhaust system

Lead-tin alloy-coated (terne-coated) steel sheet has become a representative type of coated steel for fuel tanks through years in Japan. Although there are such competitive materials as plastics, terne-coated steel has not undergone a great change since the appearance of a nickel-preplated product. Nevertheless, active research and development efforts have continued to meet the apparent and latent needs for better fuel tank materials. Coming in the former category are the terne-coated steel sheet with very high formability to suit tank shape complexity, and tin-plated terne-coated steel sheet to handle gasoline of poor quality. In the latter category, new terne-coated materials adapted to clean fuel or alcohol fuel have been developed.

More problems are expected to appear in the future for solution by Nippon Steel as Japan's only automobile fuel tank steel supplier.

Hot-dip aluminum-silicon alloy-coated steel sheet (trade named Alsheet) was used mainly for exhaust system components in general and low-temperature mufflers in particular. As automobile emission control regulations were tightened, exhaust gas cleaning catalysts changed from oxidation catalysts to three-way catalysts. The use of three-way catalysts raised the pH of the condensate formed in the mufflers, which called for Alsheet to be replaced by chromium stainless steel as material for main parts of the exhaust system. Of course, Alsheet is used in large quantities in such applications as heat barriers and tail pipes.

The problems facing the exhaust system materials are further stiffening of exhaust emission control, as represented by the ultra-low emission vehicle (ULEV), and control of diesel NO_X and particulate emissions. Although the effects of these regulations on the exhaust system materials are not clear yet, they definitely call for closer cooperation between the coating and base steel divisions in the steelworks.

4. Coated Steel Sheets for Household Electric Appliances and Construction

4.1 Coated steel sheets for household electric appliances

In recent years, the quality requirement of coated steel sheets for household electric appliances has become strongly concerned with functional chemical conversion coatings, such as color and color uniformity, lubricity, fingerprint resistance and groundability, in addition to corrosion resistance. Postpainted steel for appliance housings is replaced by prepainted steel, and there are exacting requirements to meet for aesthetic appearance as represented by high image clarity and decorative effect. New prepainted steels are developed through the application of electron beam curing and powder coating techniques. Trends toward greater functionality are particularly noteworthy. Electrogalvanized steel, hot-dip galvanized steel and galvannealed steel are extensively used as coated sheet products, and zinc-nickel alloy-electroplated steel and terne-coated steel are also used. Chemical conversion coating techniques as posttreatment techniques in pursuit of higher functionality and prepainted steels are described here.

4.1.1 Chromated steel sheet with high corrosion resistance

When conventional reaction-type chromate was applied to a high chromium coating weight to improve corrosion resistance, the resultant chromate coating appeared yellowish brown. The chromium coating weight can be increased by applying the coating-type chromate. In the coating-type chromate treatment, colloidal silica and anions such as phosphoric acid are added to a chromic acid solution having a high chromium reduction ratio, and the resultant solution is applied to electrogalvanized steel or other coated steel. The coating-type chromate treatment method has made it possible to assure high corrosion resistance and to improve color tone at the same time[6].

4.1.2 Thin-film organic composite-coated steel sheets

The thin-film organic composite-coated steel sheet has an organic coating film of about 1 to 3 μm thickness applied to zinc alloy-coated steel with chromating. It has relatively good weldability and excellent corrosion resistance, fingerprint resistance and lubricity. A water-base paint containing colloidal silica is generally used as the organic film. A new type of organic composite-coated steel was developed that has organic wax added to the organic film so that it can be press formed dry[7].

4.1.3 Prepainted steel sheets

From a practical point of view, prepainted steel sheets must balance formability against paint film hardness and stain resistance to a high degree. As paints for prepainted steel sheets, polyester and acrylic resin paints are available to ensure good paint film hardness and stain resistance, and high-molecular polyester paint is available to obtain good formability. The prepainted steel sheet introduced in the separate article "Development of Prepainted Steel Sheet with Excellent Formability, Stain Resistance, and Hardness" was developed on the basis of the latter paint.

There also are prepainted steel sheets with such functions as heat resistance, adhesive jointability and decorative effect. These prepainted products are of the so-called heat curing type in which a solvent-type paint is cured by hot air or high frequency. Electron beam-cured prepainted steel sheet[8] and powder-coated prepainted steel sheet[9] have also been developed. The former provides a very high paint film hardness and finds wide usage also in tunnel inner panels. Various new types of plastic resin film-laminated steel sheets are being developed, capitalizing on the ability of plastic resins to be embossed into desired designs and patterns, in addition to superior corrosion resistance, stain resistance and chemicals resistance. The aforementioned heat-resistant Alsheet and black zinc-nickel alloy-coated steel sheet were developed also as functional products for household electric appliances.

4.2 Coated steel sheets for construction

Coated steel sheets for building construction find main usage in roofing and siding. Hot-dip galvanized steel has been traditionally used in these applications. At the beginning of the 1980s, zinc-55% aluminum alloy-coated steel sheet was introduced and put to commercial production in Japan, followed by the zinc-5% aluminum alloy-coated steel sheet, in response to the customer need for long-term durability. These hot-dip zinc-aluminum alloy-coated steel sheets steadily grew in production tonnage. In addition, weather-resistant Alsheet and zinc-1% aluminum alloy-coated steel sheet have appeared recently[10]. Chromium stainless steel sheets coated with zinc and aluminum have also been developed for roofing and siding. Prepainted steel sheets for building construction combine in themselves the long durability of coated steels with the weather-resistance of fluorocarbon paints. Also worth noting is the development of functional roofing materials, such as weldable prepainted steel for waterproof roofs and snow-slip roofs.

The corrosion of prepainted steel sheets is considered to occur in: a) flat areas; b) cracked areas caused by bending; c) damaged areas caused during construction; and d) cut edge areas. Corrosion in areas b) and c) are particularly important. Recently, data have been accumulated concerning the corrosion of various coated steel sheets. For the edge creep of prepainted zinc-55% aluminum alloy-coated steel sheet, refer to the separate article "Edge Creep of Prepainted Zinc-55% Aluminum Alloy-Coated Steel Sheet". The article reports that the edge creep of the prepainted zinc-55% aluminum alloy-coated steel, traditionally cited as a shortcoming of the product, is slow in propagation in long-term outdoor exposure tests, slower even than that of prepainted galvanized steel.

Various types of coated steel sheets for building construction have been developed, mainly for use as roofing and siding as noted previously. Their field of application is still to be expanded to cover structural members and exterior panels, with due consideration being paid to harmony with the surrounding environment, decorative effect, and other functions.

5. Coated Steel Sheets for Containers

Containers come as food cans, general cans for oil, chemicals and paints, among others. Food cans are discussed here. The demand for food cans declined owing to a cold summer and business recession last year, but through the past decade, it has steadily grown. **Fig. 6** shows the changes in food can production by content and can type. Food can production has drastically increased on the whole, main contributors to which being such non-carbonated beverages as coffee, Oolong tea and green tea, and beer.

By type of can, aluminum drawn and ironed (DI) cans grew in the field of beer and carbonated beverage cans. Steel DI cans increased as carbonated beverage cans, and welded cans as non-carbonated beverage cans. Despite the increase in the number of cans produced, the consumption of tinplate and tin-free steel (TFS) as can materials has increased only by a few percent in the past decade because of the decrease of can weight and substitution by aluminum. The increase of aluminum cans is attributable to a drop in aluminum ingot prices due largely to the

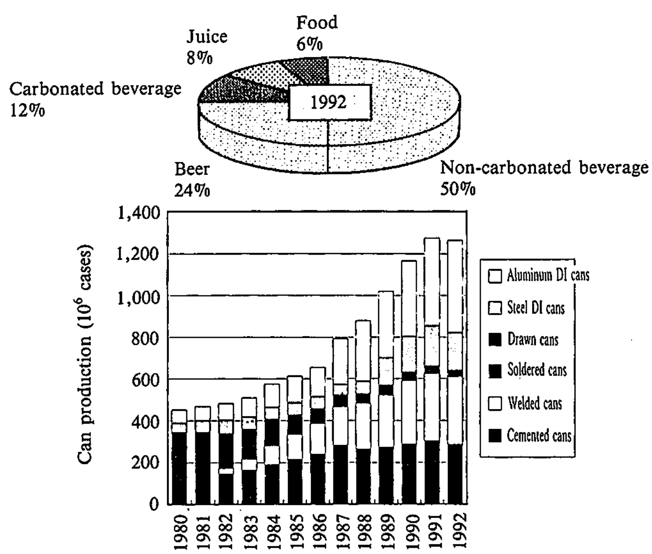

Fig. 6 Can production by can type and content

Table 1 Changes in steel DI can materials

Thickness (mm)	0.32 → 0.24
Temper	T1 → T4
Coating weight (#)	#50 → #25
End diameter	211 → 206

higher yen, and competitiveness in such a quality aspect as the preservation of good beer flavor. The steel industry has been making strenuous effort to compete with aluminum in this field of application. The advances made by steel as can stock are introduced below by type of can.

5.1 Lightweighting of DI cans

Cost-saving needs have gradually changed the steel sheet gage, coating weight and end size of steel DI cans as shown in **Table 1**. This lightweighting of steel DI cans has been achieved by control of nonmetallic inclusions in the base steel, enhancement of thickness accuracy, increase in hardness, and improvement in surface quality. The lightweighting move is still in progress, and various types of development work are under way to take advantage of the high strength of steel.

To prevent the dissolution of iron into contents, a major weak point of steel compared with aluminum, a new container material, PET-laminated steel is being developed. The product also should come in line with overall cost-saving encompassing the canmaking process.

5.2 Materials for welded cans

New can materials lower in cost than conventional tinplate have been developed in response to the increasing canmaking speed and decreasing sheet gage. For details, refer to the separate article "Development and Performance Properties of New Coated Steels for Welded Cans". Nickel-coated steel, nickel-preplated tin-coated steel, and lightly tin-coated steel with the lowest possible tin coating weight have been developed. A new TFS material has also been commercialized for 18-liter cans.

5.3 New type of drawn can

In 1991, a new stretch drawn can made from TFS laminated with polyester on both sides was developed and commercialized[11]. Unlike the DI can, the stretch drawn can eliminates washing and internal and external coating, is environmentally friendly, and is claimed to be of high quality. It is a significant event that plastic film-laminated steel sheet, commercialized for use in limited applications, has appeared as material for beverage cans.

5.4 Miscellaneous cans

Cemented cans are not discussed under a separate section because cemented can materials have made no progress, although the cemented can manufacturing technology has greatly advanced and achieved a high speed of 1,000 cans/minute. Another item to be mentioned is easy-open end materials. All can ends except those for some juice cans are made of aluminum. Many efforts have been made to substitute steel for aluminum, but have not yet succeeded because of score forming difficulty and the iron dissolution problem.

In the container field, steel must increase its competitiveness, mainly in terms of cost, against aluminum. Its overall cost, not only the material cost, but also the canmaking cost, must be reduced.

6. Coated Steel Sheet Manufacturing Technologies

Main production facilities of coated steel sheet are hot-dip coating, electroplating, and coil coating lines. The technological trends of newly built electrogalvanizing lines (EGLs), continuous hot-dip galvanizing lines (CGLs), and coil coating lines (CCLs) are described here. In 1993, a new laminated steel production line for containers was brought into commercial operation, but its details are yet to be published.

6.1 EGLs

There are many EGLs of large capacities. High-electrolyte flow and high-current density cells for fast processing and alloy electroplating are their common features. Cell types vary from line to line, which may be horizontal, vertical or radial. Most EGLs use insoluble anodes to ensure uniform electrolyte velocity distribution in the strip width direction. Some of the EGLs are equipped with painting equipment and heating ovens for in-line production of organic composite-coated steel.

6.2 CGLs

Most CGLs are built to produce automotive steel sheets to severe quality requirements, and therefore are characterized by a large scale and integration of various techniques. To eliminate strip surface defects in the pretreatment section, they have cleaning equipment, direct-flame reduction burners or radiant tube furnace in place of the non-oxidizing furnace, and a vertical annealing furnace. Various dross countermeasures and uniform wiping techniques are incorporated around the pot. Direct-flame jet burners and induction heating elements are introduced in the galvannealing furnace, and alloying degree measuring instruments are installed to control the alloying degree with high accuracy. In the exit section, a four-high skinpass mill and chromium-plated rolls are generally adopted to ensure high surface quality.

6.3 CCLs

The principal CCL type is two-coat, two-bake. Improving the surface quality is a major challenge for the prepainted steel sheet manufacturing technology to meet the increasingly strict demand from the electric appliance industry. The coil coating line (CCL) is composed mainly of a coater and a baking furnace. A new curtain flow coater provides good paint finish with high controllability. A clean induction heating furnace is adopted as the baking furnace. CCLs have thus improved in total cleanliness. Kimitsu Works' new CCL boasts Class 10,000 cleanliness in its painting chamber.

7. Heavy-Duty Corrosion Protection Technologies

The heavy-duty corrosion protection field calls for durability over a much longer period than provided by the coated steel sheet products discussed above. There is no difference in the basic concept of corrosion protection, but the heavy duty field involves protective coating to a film thickness of several hundred micrometers or more. Heavy-duty corrosion protection covers a wide range of objects and a diversity of service environments. For convenience, this subject is discussed in three classified areas: a) mill coating; b) corrosion protection of structures; and c) repair.

7.1 Mill coating

Steel pipes, steel pipe piles, and sheet piles are coated with organic materials using special coating equipment at the mill. Typical examples of mill coating are the outside coating of crude oil and natural gas transmission line pipes, the outside coating of steel pipe piles and sheet piles, and the inside coating of water line pipes.

The outside coating of oil transmission line pipes is discussed in the separate article "Durability of Polyethylene-Coated Steel Pipe at Elevated Temperature". In recent years, the pipeline operating temperature has been rising owing to such factors as increasing oil heaviness. Coating materials to withstand the rising operating temperature is under active development throughout the world.

Organic-coated steel pipe piles and other shapes are used in offshore structures and sea walls, among other things. To meet the demand for longer service life, polyethylene and polyurethane elastomer have come to be extensively used in place of tar epoxy coatings. The coating thickness is 2 to 3 mm. Polyethylene is applied by extrusion or lamination, while polyurethane is applied by spraying. These organic coatings have carbon black added to increase weather resistance. They are now being colored and otherwise designed to assure harmony with the surroundings.

7.2 Corrosion protection of structures

Jackets and other offshore structures, bridges, harbor facilities, and surface and underground structures are all subjects of corrosion protection. Offshore structures and very long bridge cables are discussed here as typical examples. Nippon Steel has contributed to the determination of corrosion protection specifications for two projects. **Table 2**[12] shows specifications of some of the corrosion protection methods used in offshore structures. The jacket of a Kawasaki-side artificial island for the Trans-Tokyo Bay Highway now under construction is protected by an epoxy resin lining and the combination of a polyethylene resin lining and cathodic protection with aluminum anodes. Bridge piers on the Kisarazu side are lined with titanium for protection against corrosion. Each suspension cable for the Akashi Kaikyo Ohashi Bridge consists of more than 36,000 wires, each measuring 5.23 mm in diameter. The wires are given final corrosion protection in the last stage of cable installation. They are exposed to a corrosive environment with many airborne salt particles for about three years from initial installation to final corrosion protection. They are thus given a special hot-dip galvanized coating at the mill[13].

7.3 Repair

Joints in prefabricated structures and portions damaged during installation must be repaired in addition to portions of natural degradation. Repair work is subject to weather and other natural conditions, and its quality is difficult to control. Repair methods are varied according to specific application fields. An example is a paint that can be cured in seawater.

The corrosion loss of steel structures in Japan is estimated at 1.8% of the gross national product (GNP)[14]. This amounts to 10 trillion yen in 1992. Now that difficult, dirty, and dangerous jobs are shunned by young workers, development of more man- and earth-friendly construction techniques and corrosion protection techniques is strongly called for.

8. Progress of Basic Technologies

The recent progress of surface analysis techniques is remarkable. Besides Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS), there are too many surface analysis techniques to enumerate here. Among them are structure analysis techniques, such as high-resolution stereoscopic scanning electron microscopy (SEM), analytical electron microscopy (AEM), field-emission electron microscopy, synchrotron orbital radiation (SOR) and microscopic Fourier transform infrared spectroscopy (FTIR); electrochemical measuring techniques, such as the vibrating electrode technique and AC impedance technique; and such in-situ measuring techniques as scanning tunneling electron microscopy (STEM), atomic force microscopy (AFM), and Raman spectroscopy.

The coated steel sheet area has not yet seen many studies utilizing in-situ measuring techniques. Many studies have been made, however, using latest analytical techniques for clarifying the underfilm corrosion and perforation corrosion mechanisms of automobile body panels; deposition mechanisms of zinc alloy coatings and inorganic dispersion coatings since the middle 1980s; alloying process, coating structure and powdering mechanism of galvannealed steel since the late 1980s; and the coating curing process and coating properties of prepainted steel and organic-coated steel. These analytical techniques have played a significant role in developing new coated steel manufacturing technologies and products and improving the coated steel quality. For details, refer to the articles "Corrosion Mechanisms of Zinc Alloy Coated Steel Sheets for Automobile Body Use," "Mechanism of Adhesion of Epoxy Resin to Steel Surface", and "Development of Cross-Sectional TEM Analysis Techniques for Coated Steel Sheets" separately presented.

Table 2 Corrosion protection methods for sea wall structures and their service life

Environment of structure to be protected	Corrosion protection method	Corrosion protection specification		Estimated time to repair (years)
		Lining material and cathodic protection	Lining thickness (mm)	
Atmospheric, splash, and tidal zones	Organic lining	Polyethylene	2.5	40
	Organic lining	Polyurethane	2.5	40
	Organic lining	Epoxy	2.5	40
	Inorganic lining	Concrete (cover)	100	50
	Corrosion-resistant metal lining	Seawater-resistant stainless steel	3	100
	Corrosion-resistant metal lining	Titanium	1	100
Submerged zone	Cathodic protection	Aluminum anode		30
	Organic lining	Polyethylene	2.5	40
	Organic lining	Polyurethane	2.5	40
	Inorganic lining	Concrete (cover)	100	60
	Organic lining + cathodic protection	Polyethylene + aluminum anode	2.5	70
Seabed zone	Cathodic protection	Aluminum anode		30

These fundametal technologies have played an important role in enhancing the progress of coated steel production technology and raising the potential capability of coated steel researchers. It should be noted that fundametal technologies at research laboratories of business entities should be studied always for specific purposes and not for study's sake. Those engaged in the research and development of coated steel products should keep this in mind.

9. Conclusions

The global environmental issue and the social environment are expected to grow harsher for steel products as noted at the beginning of this report. In this connection, coated steel sheets will encounter stricter requirements concerning service life and functionality. Given the calls for resource conservation and recycling from an environmental point of view, there will appear increasing demand for products of right quality or durability at right price. In the past, we have diversified product types and specifications even at the sacrifice of economics to meet the exacting quality requirements of customers. We must reflect on this excess in the past.

Commercially applied coated surfaces are composed basically of: a) steel substrate; b) metal coating (absent in some products); c) treatment before painting or after metal coating; and d) organic coating. For example, corrosion-resistant steel sheets for automobile body panels are shipped in the condition b), but the anti-corrosion performance of automobiles depends on the conditions b) through d). This calls on coated steel sheet steel manufacturers to have full knowledge about these individual factors and their combinations. Since fabrication and assembly processes and service environments greatly vary according to the area of application, techniques of performing intermediate and final evaluation on these processes and operating environments are of equal importance. Here lies the reason why coated steel sheet producers must closely cooperate with customers.

As steel coating technology assumes increasing importance and the coated steel sheet is expected to expand its scope of application, we intend to continue on our research and elevelopment to realize technologies of still higher reliability.

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