

Expanding in Application of Titanium by Nippon Steel & Sumitomo Metal Corporation

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Abstract

Approaches of Nippon Steel & Sumitomo Metal Corporation (NSSMC) for developing and expanding titanium market are mentioned in this article. NSSMC had succeed to add superior characteristic features to titanium like formability, heat resistance, fascinated surface, and so on, for creating newly titanium applications or developing titanium markets. Besides, NSSMC also innovates various usage techniques of titanium products like welding and forming techniques, or measures characteristic data in various conditions for the customer. These activities also help to expand titanium market. In this article, further trend of titanium market expanding and agendas are mentioned also.

1. Introduction

In October 2012, the Titanium Division of Nippon Steel & Sumitomo Metal Corporation made a fresh start as a world-class manufacturer of general wrought products. By integrating the management resources that the two companies have so far separately accumulated and effectively coordinating the activities in their specialized fields, we are determined to continue offering products and services that meet customer needs. In addition, our main mission is to make the most of the excellent properties of titanium and create a new market for it by accelerating our R&D activity.

So far, we have pressed ahead with R&D for titanium, with a focus on titanium users: developing various new uses for titanium and titanium alloys that take advantage of their small density, high strength and excellent corrosion resistance; imparting new properties (formability, aesthetic appeal, heat resistance, etc.) to titanium and titanium alloys.

In this report, we first explain the present condition of the titanium market and then take a look at the expanse of the titanium market for each individual field of application. At the end of the report, we discuss the direction of development of the titanium market in the future.

Nippon Steel & Sumitomo Metal is determined to maximum the effects of the last merger and promote its R&D for making the most of the benefits of titanium in order to help expand the titanium market further, so as to fully utilize the excellent properties of titanium within diverse fields.

2. Condition of the Titanium Market

The recovery of the world's economy from the Lehman shock of 2008 has been slow. However, the recovery of the demand for titanium in the field of aircraft and in general industries has been smooth. In the field of aircraft, in particular, there was concern about a temporary stagnation of the titanium market due to the delay in placement of Boeing 787s in commission. Nevertheless, since the increase in the production of advanced airplanes using an unexpectedly larger amount of titanium per body, the demand for titanium is expected to steadily expand in the future.

In the general industries, on the other hand, the demand for titanium tubes for power capacitors that had been steadily expanding in Asia, etc. has sharply declined since 2011 mainly because of the deceleration of the Chinese economy and the check for construction plans of new nuclear power stations in Japan, in the wake of the disaster of Fukushima nuclear power plant. In addition, considering the consumption of titanium for electrodes in electrolysis and plate-type heat exchangers, which are major consumers of titanium, the growth of demand for titanium has slowed down due to the sluggish economic activities in China and Europe, causing the overall titanium demand in the general industries to remain stagnant. As a result, the shipment of wrought titanium products in Japan was 12,000 tons for fiscal 2012—a sharp decline of 9,000 tons (47%) from the previous year.

On the other hand, the suppliers of titanium products for general industries are increasing in number, intensifying the price competi-

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tion still more. The sharp price fluctuation attributed to a titanium supply–demand gap in the process of expansion of the titanium market in the past has been relaxed by a marked increase in titanium sponge production capacity in Asia and other countries. Hence, the present market situation could be severe for many of the titanium suppliers.

With respect to the future of the titanium market, which now reflects the robust economic growth of NIES in Asia, and the tight energy demand situation on a global basis, there are some bright signs on the horizon, such as the resumption of positive development of power generating plants (mainly thermal power) and the start of a number of large-scale seawater desalination plant construction projects. Furthermore, demand for titanium in the field of aircraft is expected to steadily increase—a growth largely attributable to demand in Asian countries. Therefore, one main task to tackle in the future is the development and maintenance of a titanium alloy manufacturing system that can cope with a rapid increase in the production of aircraft and engines in Asia and the establishment of a network for the scrap and recycling of titanium products.

From the standpoint of further expanding the titanium market, such strenuous efforts for the development of new uses for titanium products are indispensable. For example, we consider it possible to expand the titanium market significantly by developing new uses of titanium in the fields of automobiles, consumer electronics, and environment and energy, including water treatment, medicine, and welfare-related industries in our aging society and by making constant efforts to cut production costs and develop new titanium products that can replace existing materials.

3. Trends in Development of New Uses of Titanium

In the preceding section, we reviewed the present condition of the titanium market and explained the need to develop a new demand and uses for titanium. In this section, we describe the current trends in the development of new uses for titanium and our activity to widen its application scope.

More than 60 years have passed since the production of titanium was started on an industrial basis. During that period, the application

scope of titanium has been mainly expanded in the following three fields (Fig. 1).

The first field—“current application”—focused on industrial uses. Typically, this field embraces titanium uses that take advantage of the three major features of titanium: light weight, strong, and superior anti-corrosion performance. This field accounts for the majority of the current titanium demand. As for the reason why this field has become the volume zone, we can cite not only the users’ positive efforts to apply titanium but also the strenuous efforts of Nippon Steel & Sumitomo Metal in continuing to improve their titanium product quality and their manufacturing technologies in order to meet the diversified user needs. These are described in detail below.

First, let us consider the use of titanium for “heat exchanger.” The principal example of this application of titanium is the plate type heat exchanger (PHE). The PHE performs the exchange of heat by passing hot liquid and cooling water (seawater, etc.) on either sides of a plate. Since the plate is stretch-formed to a corrugated plate in order to enhance its heat-exchanging performance, it is generally made from a material containing few impurities. However, the press patterns used by PHE makers are so complicated that the plate material—titanium sheet—requires good formability. To secure good formability required by titanium sheet, it is important not only to select the optimum titanium material but also to control its microstructure by utilizing sophisticated rolling and heat-treatment techniques. Nippon Steel & Sumitomo Metal has standardized its titanium manufacturing processes on the basis of comprehensive production data and rich experience. In addition, utilizing its microstructure prediction technology that applies computer simulations, the company manufactures a titanium sheet having formability most suitable for press-forming by each individual PHE maker.

Incidentally, there is a growing tendency for PHE makers to use thinner, wider plates in order to enhance PHE performance. To this end and through various improvements on its manufacturing techniques and facilities, Nippon Steel & Sumitomo Metal has established a sophisticated technology for manufacturing “thin & wide titanium sheets” that are uniform in thickness across the width and have a flat, beautiful surface. By supplying those titanium sheets to

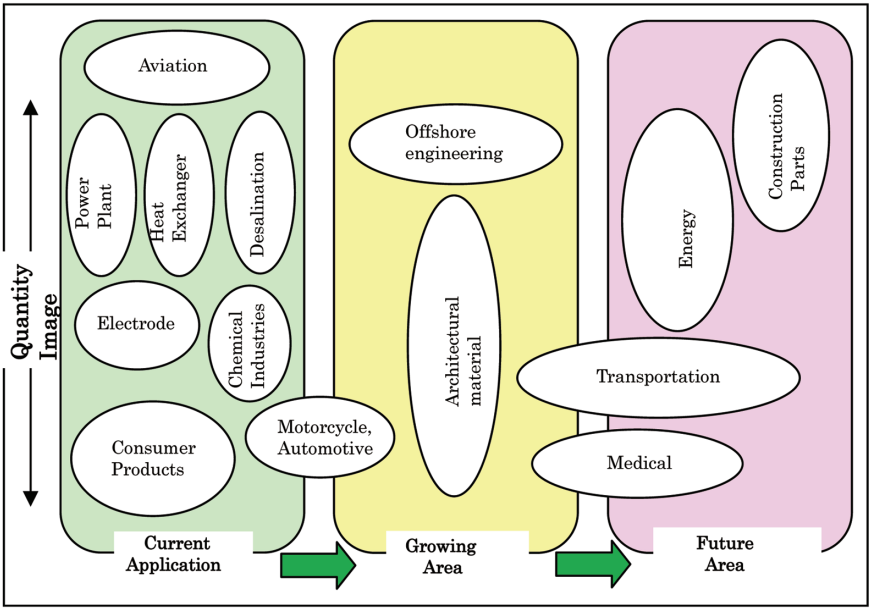


Fig. 1 Titanium products exploitation map by application

the PHE users on a stable basis, we assist PHE makers in manufacturing larger PHEs having higher performance.

Next, let us consider the use of titanium for seawater desalination and power plants. In seawater desalination plants, titanium is used for heat-transfer tubes needed for the multi-stage flash (MSF) and multi-effect desalination (MED) processes, whereas in power plants, welded titanium tubes are used as heat-transfer tubes for condensers. The reason why titanium has come to find those uses is that titanium is judged to enhance the stability of equipment and eliminate the need of equipment maintenance since titanium not only offers better erosion resistance than the nickel-copper alloy that had originally been used as a seawater-resisting material, but it is also free from deposit attack and ammonia corrosion. Today, thanks to the availability of thin, wide titanium sheets made possible by improvements on the thin sheet manufacturing technology and thanks to the use of thin-walled welded tubes made possible by improvements on the welded-tube manufacturing technology, it has become possible to cut the cost of structural members by a reducing the weight of the entire plant. Thus, considering the costs of plant equipment and maintenance, the welded titanium tube, which gives the image of being costly, has become a material which is by means costly. In addition, because of its excellent low-temperature toughness and corrosion resistance, titanium has come to be increasingly used for heat exchangers and vaporizers in LNG plants and for suitable devices in petrochemical plants.

The caustic soda (NaOH) plant is a typical example wherein titanium is used as an electrode. NaOH is manufactured together with chlorine and hydrogen by the electrolysis of salt water. Today, from the standpoint of environmental protection, the ion-exchange membrane process using an ion-exchange membrane is most widely employed in the manufacture of NaOH. Titanium is used for the anode that contains salt water, whereas stainless steel or nickel is used for the cathode where NaOH is produced. The part that supports the ion-exchange membrane is exposed to a high-temperature, high-concentration chloride ion environment, under which pure titanium is susceptible to crevice corrosion. Therefore, a corrosion-resisting titanium alloy is used in that part.¹⁾

Ordinary corrosion-resisting titanium alloys contain 0.12% to 0.25% palladium, which is a noble metal. They are provided for in the JIS and ASTM. However, considering the high cost of palladium, Nippon Steel & Sumitomo Metal has developed and owns two types of low-cost, corrosion-resisting titanium alloys: SMIACE™ (Ti-0.06%Pd-0.5%Co: JIS Classes 17-20/ASTM Gr. 16, 17, 30, 31) and TICOREX (Ti-0.05%Pd-0.5%Ni: JIS Classes 21-23/ASTM Gr. 13-15). These are also used for electrodes in the production of NaOH. Each type is almost the same in corrosion resistance (crevice corrosion resistance) as the ordinary corrosion-resisting titanium alloy, although it has reduced the consumption of the noble metal to about one-third. Thus, the two new titanium alloys of Nippon Steel & Sumitomo Metal help enhance the cost competitiveness of the users. For a detailed description of those corrosion-resisting titanium alloys, please refer to the separate article under “Properties and Uses of Corrosion-Resisting Titanium Alloys” in this special issue.

As a typical example of application of titanium in “chemical,” titanium plates for industrial plants can be cited. There are cases in which either of the low-cost, corrosion-resisting titanium alloys mentioned above is directly used in manufacturing reaction equipment of an industrial plant. In other cases, a clad plate consisting of titanium plate and steel plate, etc. is used. Clad plates are manufactured by the explosive bonding process or the rolling process. In ei-

ther case, a high degree of surface flatness and exceptional cleanliness of the jointed faces are strictly required of the clad plate. Nippon Steel & Sumitomo Metal has established a sophisticated clad plate manufacturing process to meet the abovementioned exacting demands and the specific user needs.

The use of titanium in aviation is especially popular in the United States and Europe. The Ti-6Al-4V alloy bar of Nippon Steel & Sumitomo Metal has been approved by Rolls Royce as a material for aircraft engine blades. Nippon Steel & Sumitomo Metal also supplies Ti-6Al-4V springs for separating off the stages of Japan’s domestic rockets H2A/B. The company supplies pure titanium sheets and coils to Airbus for its aircraft fuselages. This represents a commendable in making the most of the many advantageous features of titanium such as lightweight, high specific strength, good corrosion resistance, and excellent low-temperature toughness. For a detailed description of the titanium for aviation, please refer to the separate article under “Current Application of Titanium for Aircraft and Tasks to Tackle in the Future” in this special issue.

The uses of titanium in “consumer products” have been developed to utilize the superior properties of titanium. Originally, they began with wristwatches, glass frames, etc. Here, let us look at some of the uses of titanium that have been developed under the leadership of Nippon Steel & Sumitomo Metal.

First, there is the titanium casing of IT devices. From the very beginning, titanium was considered suitable for the casing of IT devices because its feel, quality, and color were judged as desirable in terms of a material for the purpose. Besides, titanium was known as a material having a number of superior properties such as small specific weight, high strength, excellent corrosion resistance, no risk of causing metallic allergies. However, titanium had the problem of being slightly poor in workability for IT devices. The company solved that difficult problem by developing ultradeep-drawing titanium “Super-PureFlex™” and providing user support utilizing even press simulation techniques. As a result, thin sheets of titanium of Nippon Steel & Sumitomo Metal were adopted in succession for the casing of Sony’s Network Walkman in 2003, Sony’s Linear PCM Recorder in 2006 (**Photo 1**), Canon’s digital camera in the same year (**Photo 2**), and Sony’s Digital HD Video Camera Recorder in 2008.²⁾



Photo 1 Linear PCM recorder with titanium body
Provided by SONY Corp.



Photo 2 Digital camera with titanium body
Canon IXY, provided by CANON, Inc.

In the field of sports, golf clubs are a representative application of titanium. Furthermore, the SLE rule (an official rule regulating the restitution coefficient of driver's clubfaces) was introduced in 2008, as a result of which the use of β -type titanium alloy that had been the most popular because of its high restitution coefficient was prevented. Under that condition, Nippon Steel & Sumitomo Metal proposed its originally developed titanium alloy "Super-TIX™51AF" featuring small specific weight, superior strength, and high Young's modulus. The new titanium alloy is used for golf clubs (**Photo 3**) of SRI Sports (the present Dunlop Sports Co., Ltd.).³⁾ For a detailed description of this titanium alloy, please refer to the separate article under "Development of Ti-Al-Fe Based Titanium Alloy Super-TIX™51AF Hot Rolled Strip Products" in this special issue.

In baseball, Nippon Steel & Sumitomo Metal's titanium for aircraft was adopted in 2004 in spike shoes by NIKE Japan (**Photo 4**)—the world's first mass-produced spike shoes made from titanium.

As the original β alloy of Nippon Steel & Sumitomo Metal, there is SSAT™-2041CF (Ti-20V-4Al-1Sn). Originally, this alloy was developed as a material for automotive engines. Because of its superior cold workability, the alloy is currently used in the manufacture of high-grade bicycle gears and ski sticks (made from welded alloy tube). Because of their ability to absorb shock and bend flexibly when stuck into the snow, ski sticks made from the alloy were used by the Japanese representative skiers in the Winter Olympics of 2010. It is expected that they will also be used in the Winter Olympics of 2014. For a detailed description of this alloy, please refer to the separate article under "Unique Titanium Alloy Developed by Nippon Steel & Sumitomo Metal" in this special issue.

Audio speakers are another example of titanium use in the field of consumer products. Nippon Steel & Sumitomo Metal manufactures titanium foils having a minimum thickness of 20 μ m. The superior corrosion resistance and nonmagnetic properties of titanium foil are suitable for audio speakers. **Photo 5** shows examples of speakers made from titanium foil.⁴⁾ Any material used for manufacturing speakers is required to have good formability and ability to reproduce sounds faithfully. Nippon Steel & Sumitomo Metal has optimized the material properties and manufacturing conditions to secure the formability and homogeneity required of materials for audio speakers. The titanium foils of Nippon Steel & Sumitomo Metal contribute in the production of speakers having stable tone qualities. For a detailed description of the titanium foils of Nippon Steel & Sumitomo Metal, please refer to the separate article under "Properties and Uses of Special Stainless Steels, Pure Nickel, and Pure Titanium" in this special issue.

Now, let us move into the second field in Fig. 1. This field represents a growing area in which the properties of titanium are im-



Photo 3 Super-TIX™51AF applied golf club
"XXIO7", provided by Dunlop Sports Co, Ltd.



Photo 4 Baseball shoes with titanium spikes
"NIKE Air Zoom Vaper J Leather", provided by NIKE, Inc.

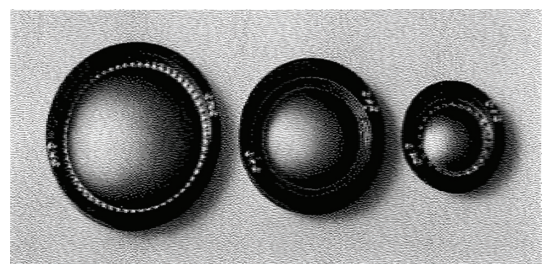


Photo 5 Appearance of titanium speaker cone

proved still more than in the first field.

The representative use of titanium in this particular field is "construction material." The application of titanium as a construction material began because titanium has excellent corrosion resistance and good appearance. As the problem regarding the partial discoloration of titanium became conspicuous, it was of urgent necessity to investigate the cause thereof and take suitable measures. Nippon Steel & Sumitomo Metal started studying the phenomenon in 1997, and as a result, found that when TiC (or a similar material) is stuck onto the surface of titanium, it causes an oxide film to form on the

surface in acid rain, and this film presents an interference color.^{5,6)} After that, the company established a technique to prevent the discoloration of titanium. For a detailed description thereof, please refer to the separate article under “Development of Titanium Sheet Having Excellent Resistance to Discoloration and Examples of Application Thereof” in this special issue. Incidentally, this technique won a Technical Award from the Japan Institute of Metals and Materials in 2004.⁷⁾

When applying titanium to a large structure, it is important to impart a uniform appearance to the finished structure. Therefore, Nippon Steel & Sumitomo Metal reviewed its entire titanium production process and decided to implement special management of titanium material for each individual construction project. As a result, it became possible to mass-produce titanium material having uniform appearance. Since titanium sheets having uniformly blast or colored surfaces could be mass-produced, the company could propose a wide variety of titanium surface specifications to building constructors and designers, thereby widening the scope of application of titanium as a construction material. Typical application examples include the Houzomon Gate and Main Hall of Sensoji Temple (**Photo 6**) and the Kyushu National Museum (**Photo 7**). Hence, titanium sheet is shown to be widely applied in traditional and modern architecture. Titanium sheet not only has aesthetic appeal but can also be used as an exceptionally light roofing material. For example, titanium sheet made it possible to reduce the weight of the roofing of Sensoji Temple to one-fifth. In addition, it helps improve the earthquake resistance of buildings. Incidentally, Nippon Steel Corporation, Shimizu Corporation, Caname Co. Ltd., Roof System Co., Ltd., and Hibiki Corporation jointly won a 2006 Otani Museum Award for the roofing of Houzomon Gate, and Nippon Steel, Shi-

mizu, and Sensoji Temple jointly won a 2010 Otani Museum Award for the roofing of the Main Hall.

In offshore civil engineering, titanium sheets, which have excellent resistance to seawater, are utilized to prevent corrosion of bridges and offshore structures. For example, Nippon Steel and Nittetsu Sumikin Anti-Corrosion Co., Ltd. jointly developed the “TP method” (titanium-covered petrolatum lining method) to prevent corrosion of offshore steel structures. Compared with the conventional FRP corrosion-preventive method, the TP method offers a longer service life and is superior in life cycle cost. In 2003, the TP method was adopted for the first time by an electric company (**Photo 8**). Since then, it has been applied to many offshore structures.

As a recent application example, “titanium cover plate” takes advantage of the excellent seawater resistance of titanium. The titanium cover plate is used for D Runway of Tokyo International Airport, which was put into service in December of 2010. The cover plate is a panel consisting of a nonflammable urethane core sandwiched between a titanium sheet and a painted steel sheet. It is applied to the rear and side walls of the runway pier (**Photo 9**). In a



Photo 6 Titanium roof of Sensoji Temple Main Hall



Photo 7 Titanium roof of Kyushu National Museum



Photo 8 Example of employment of TP construction method



Photo 9 Titanium cover plates for corrosion protection installed on the rear and the side walls of Runway D of Haneda, Tokyo International Airport



Photo 10 Super-TIX™10CUNB applied muffler example for motorcycle
Provided by AKRAPOVIC

highly corrosive environment, the steel girders on the jacket that supports the runway are covered with titanium cover plate and the humidity in the internal space is properly controlled to prevent corrosion of the steel materials used. Thus, the titanium cover plate takes advantage of the superior corrosion resistance of titanium. This was a large-scale project involving a total area of 570,000 m² and titanium consumption of some 1,000 tons.

Examples of planned uses of titanium in the field of automobiles include the suspension, spring, engine valve, connecting rod, and interior decoration. The most popular use of titanium is in the manufacture of mufflers, mainly those of motorcycles. At first, pure titanium sheet was used for that purpose. However, with the rise in exhaust gas temperature as a result of the enhancement of catalyst performance, it became necessary to employ a heat-resisting titanium alloy. Under that condition, Nippon Steel developed two types of heat-resisting titanium alloys, Super-TIX™10CU and Super-TIX™10CUNB, on the assumption that they would be used in the temperature range of 700 to 800°C.⁸⁻¹⁰⁾ At normal temperatures, those titanium alloys display mechanical properties comparable to those of JIS Class 2 and have good formability. In addition, at high temperatures, they are about twice as strong as pure titanium. The two newly developed titanium alloys are used in mufflers of not only motorcycles but also four-wheeled vehicles both at home and abroad (**Photo 10**).

Nippon Steel won the 1st Titanium Application Development Award from the International Titanium Association (ITA) in 2007 for its remarkable achievements in the development of titanium uses for automotive parts, and Super-TIX™10CU and Super-TIX™10CUNB won a Technical Award of the Japan Institute of Metals and Materials in 2010.

Lastly, the third field in Fig. 1 is an area that is expected to develop in the future. Characteristically, this field has great potential demand for titanium and is expected to become a big market for titanium with the development of new technology enabling economical manufacturing of titanium.

In the field of energy, titanium is expected to become a promising material in the development of petroleum alternative energy. For example, titanium that has excellent corrosion resistance will be increasingly applied in geothermal power generation, ocean energy power generation, etc. There is also a possibility that titanium will be used in photovoltaic generation, fuel cells, etc. Any project in this particular field entails a huge amount of investment in the plant and equipment. When it is carried out successfully, it should greatly boost the demand for titanium.

In the field of transportation equipment, further reduction of equipment weight will be called for in the future. Therefore, if a new technology for manufacturing titanium economically is devel-

oped, exceptionally light and strong titanium will expectedly become an important material for various types of transportation equipment.

In medicine, the application of titanium utilizing its biocompatibility is already growing in our aging society, and medicine is considered to become a very promising market for titanium. In this particular field, the application of titanium is markedly advancing in foreign countries. For example, 80% of artificial bones and joints used in Japan are imported from overseas. In view of the increasingly aging society of Japan, the increase in demand for inexpensive yet high-quality medical materials is certain to continue. In this context, it is expected that the market for domestically produced titanium products for medical use will expand in the future.

In the future, in order to build a safe and secure society in Japan—a country that sees frequent earthquakes—it will become necessary to develop advanced new structural members of titanium. By taking advantage of light, strong titanium, it is possible to reduce the weight and enhance the safety of high-rise buildings, bridges, etc.

As a problem in titanium application common to the above three fields, it is necessary to develop and maintain environmental conditions that allow for not only the development of titanium applications in each individual field but also the technology development on a national level and the activity to enact related laws and regulations.

4. Conclusion

We have so far described developments in the applications of titanium at Nippon Steel & Sumitomo Metal. Last October, the company made a fresh start as Japan's largest titanium maker. The merger made it possible to strengthen the lineup of newly developed products and widen the scope of manufacturing significantly. In addition, the merger helped improve the existing manufacturing technology through synergism and augment the capacity for development of new functions appropriate to specific uses. By fully utilizing those management resources, the company is intended to press ahead with the development of new uses of titanium while always paying careful attention to new needs of the market and users. At present, titanium is known as a rare metal. However, we continue our technology development so that titanium will, in the future, come to be called a common metal—one which will be used widely and abundantly around the world.

References

- 1) Taki, C., Sakatsume, T., Takahashi, K., Shindo, T., Kaneko, M.: Shinnittetsu Giho. (375), 73 (2001)
- 2) Oda, T.: Metals. 125, 78 (2008)
- 3) Fujii, H., Saga, M.: Shinnittetsu Giho. (391), 169 (2011)
- 4) Kyoya, M., Kojima, T., Matsushita, T., Fujii, K.: Nippon Stainless Technical Report. 137, 23 (1988)
- 5) Takahashi, K., Kaneko, M., Hayashi, T., Muto, I., Tamenari, J., Tokuno, K.: Tetsu-to-Hagané. 90, 278 (2004)
- 6) Kaneko, M., Takahashi, K., Hayashi, T., Muto, I., Tokuno, K.: Tetsu-to-Hagané. 89, 833 (2003)
- 7) Kaneko, M., Takahashi, K., Hayashi, T., Tokuno, K., Muto, I.: Materia. 43, 61 (2004)
- 8) Otsuka, H., Fujii, H., Takahashi, K.: Titanium. 55, 282 (2007)
- 9) Otsuka, H., Fujii, H., Takahashi, K., Ishii, M.: Ti-2007 Sci. and Tech., Ed. Niinomi, M., Akiyama, S., Ikeda, M., Hagiwara, M., Maruyama, K. JIM, 2007, p. 1391
- 10) Otsuka, H., Fujii, H., Takahashi, K., Masaki, M., Sato, M.: Materia. 49, 75 (2010)

NIPPON STEEL & SUMITOMO METAL TECHNICAL REPORT No. 106 JULY 2014



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