Recent Progress and Future Trends in the Research and Development of Steel

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1. Introduction

NKK was founded in Kawasaki, the center of the Keihin industrial area, in 1912. Its technology development started when the first chief engineer, Kaichiro Imaizumi, and his team challenged the then-undeveloped methods of manufacturing seamless steel-pipes and finally succeeded in producing industrial steel-pipes domestically[1).

Kaichiro Imaizumi was appointed general manager of the newly-organized Technology Research Department of NKK in 1935. Later on, in 1948, the Technology Laboratory was founded, establishing NKK's research and development system. Since 1933, the Steel Division has appointed technical development managers by process and by product to shorten the time between development and commercialization.

Fig.1 shows the transition in the number of steel research engineers in the past five years; NKK has maintained the number of researchers despite the difficult times in order to preserve its research and development strength.

Recently, our efforts have been bearing fruit. Taking, for example, NKK's latest world-leading technologies such as the ZSP (Zero Slag Process), the *Super*-OLAC (Online Accelerated Cooling) of thick plates, and the online detection of surface defects in automobile steel-sheets (Delta Eye), this paper traces the products of NKK's technology development groups and looks ahead to the future.

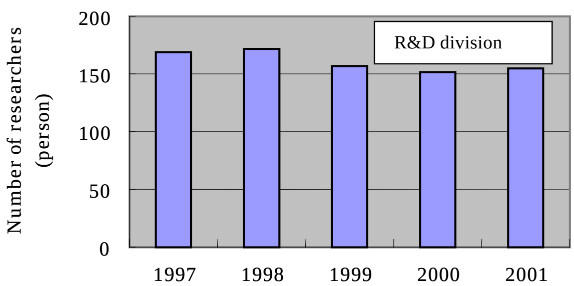

Fig.1 Transition in the number of steel research engineers

2. Progress of steel producing technology

Fig.2 shows the zero-slag process[2) for steelmaking. Conventional methods use silicon to make a large amount of slag for furnace dephosphorization. The zero slag steelmaking process is an epoch-making technology that minimizes the amount of silicon and reacts a minimum amount of lime with phosphorus oxides to accelerate the speed of dephosphorization. As a result, no slag is required for converter dephosphorization. To complete the process, the following technologies combined with advanced operation technologies are needed: advanced processing technologies, such as low-silicon pig-making technology that effectively desiliconizes blast-furnace pig within ladles to produce a large volume of ultra-low-silicon pig in a short time, the new dephosphorization technology described above, and the blast-furnace decarbonization technology with a high iron-manganese yield accomplished by using new types of lance-nozzle, online dust-meter, and manganese sensor. These technologies have combined to create an efficient new process of making high-purity steel.

In the case of thick plates, based on the OLAC technology industrialized at the thick-plate plant in Fukuyama Works for the first time in the world in 1980, and adopting a new convergent-cooling stream control technology, we initiated the *Super*-OLAC (**Photo 1**). This process technology makes the crystal grains of thick plates finer, thus improving the strengths of the plates. The combination of properly-controlled rolling and trace-quantity alloy design has enabled the consistent manufacturing of steel with improved strength, toughness, weldability, and workability, while the use of low-carbon materials has increased the flexibility of component design. Furthermore, a high-accuracy cooling-shutdown temperature control system has significantly reduced variations in the strengths of thick plates. The convergent cooling technology is applied to deformed steels such as section steels and to mobile

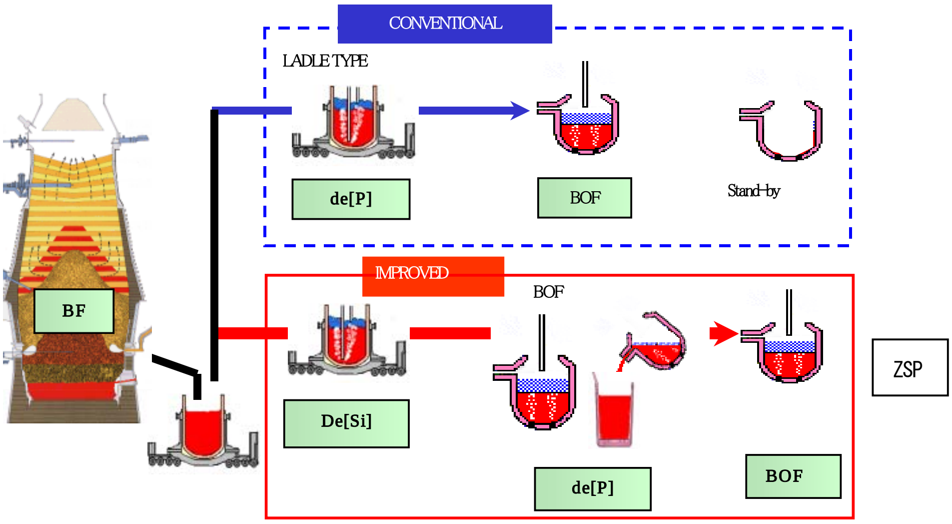

Fig.2 ZSP (Zero Slag Process) at Keihin Works

sheets just after the finish hot-rolling process.

As for steel sheets, we have been developing various technologies to raise the quality while lowering the cost of automobile steel-sheets. Examples are the in-mold flow control of molten steel to resolve inclusion defects, the low-temperature slab-heating technology by installing hot-rolled crude bar heating facility, and the countermeasure against dross defects on hot dip galvanizing lines. To assure the quality of automobile steel-sheets, we developed an original surface-inspection system using polarization (Delta Eye), enabling the detection of pattern defects, which has conventionally been difficult to do. The shipment of coils with automatically-marked defects benefits both customers and manufacturers, setting a new business standard for manufacturing and sales.

These original technologies developed by NKK have received the Okochi Prize awarded for the development of practical industrial technology nine times (including a Memorial Prize) since 1990.

Photo 1 *Super*-OLAC (Thick plate)

3. Development of new products and application technologies

To increase the strengths of automobile outer panels and under-body parts, NKK commercialized the super fine-grained type high-formability high-strength steel sheet (SFG HITEN) and the high fatigue-strength type hot-rolled high-strength steel sheet for truck frames. Applying nanometer-size ultra-fine precipitates to strengthening steel, NKK has recently commercialized 780 MPa-class hot-rolled high-strength steel (NANO HITEN) with much higher elongation and hole expanding ratio and than those of conventional steel, for delivery to customers. **Fig.3** shows the characteristics of the product quality of the NANO HITEN. The NANO HITEN is the first product having both high elongation and stretch flangeability that are essential for automobile hot-rolled high-strength steel. An important issue in using NANO HITEN is the variation in strength: the extremely narrow range of variation in strength of NANO HITEN means much more stable product quality. Compared with currently used 590 MPa-class high-strength steel, this NANO HITEN will reduce weight by about 10%.

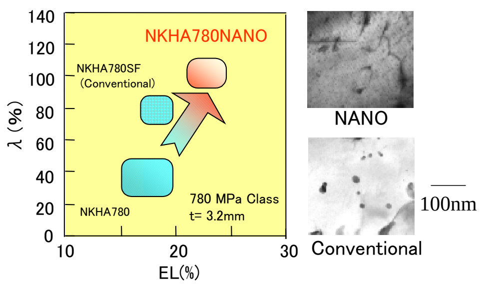

Fig.3 780 MPa high-strength steel developed by applying nanometer-size precipitates

In accordance with the tightening of standards for automobile emissions, fuel efficiency, safety, and corrosion prevention, high-performance high-strength steels are needed to increase the strength of steel sheets while reducing weight. There are also demands for a wider use of galvanized steel sheets and thicker galvanized layers to improve corrosion protection. NKK has been providing automobile manufacturers and parts manufacturers with a wide selection of unique new materials to fit their part shapes, and working methods (pressing and welding). We have also applied new processing technologies and the results of collision and corrosion analyses to the design of automobile bodies, resulting in various VA/VE proposals combining materials with processing and application technologies.

Matching emerging technologies with customer needs in the fields of consumer electric appliances, containers, civil engineering, and architecture, NKK has been developing new user-friendly products and application technologies. For example, to meet the needs of consumer electric appliances manufacturers for lower environmental influence[4], we developed chromate-free chemical-treated steel sheet that keeps its corrosion resistance after alkaline cleaning. Another example is the new screw steel-pipe pile called Tsubasa pile, in which we combined NKK's original toe-wing design technology with the technology for manufacturing structural steel-pipe piles in response to customers' needs for zero surplus soil[5].

4. Development of steel technologies based on environmental considerations

Since setting up the global environment committee in 1991 ahead of other companies, NKK has been actively addressing environmental problems[6].

For example, we developed the blowing of waste plastics into the blast furnace for resource recycling. **Fig.4** shows the transition of the volume of collected waste plastics. NKK inaugurated the recycling of waste industrial plastics at Keihin Works in 1996. Starting with container packaging plastics as reducing agents for blast furnaces in 2000, NKK can now recycle 150000 tons of waste plastics annually. Due to its strength as a structural material, low cost, and abundant reserves, steel will remain one of the most important materials in the 21st century, and therefore the steel industry must continue to deal with environmental problems.

In the field of energy-saving technologies, NKK developed the environment-friendly regenerative burner-type reheating system (see **Fig.5**) which reduces energy consumption by 30% or more and NOx emissions by at least 60%[7]. This original heating technology will significantly contribute to environmental conservation and the prevention of global warming.

NKK has developed technologies to reduce the amount of slag produced as a by-product of steelmaking and to utilize it for resource-recycling. It invented the original zero slag process to reduce the amount of slag produced in steelmaking, decreasing it to about one-third of that produced in the conventional steelmaking process. To use the slag effectively, NKK has commercialized large carbon-solidified marine blocks for seaweed farms and underwater fishing reefs by absorbing CO_2, and slow-acting potassium silicate fertilizer by adding potassium materials. NKK is thus establishing pioneering global technologies for environmental protection.

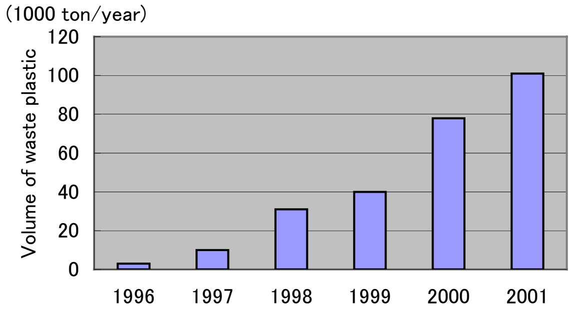

Fig.4 Collection of waste plastics

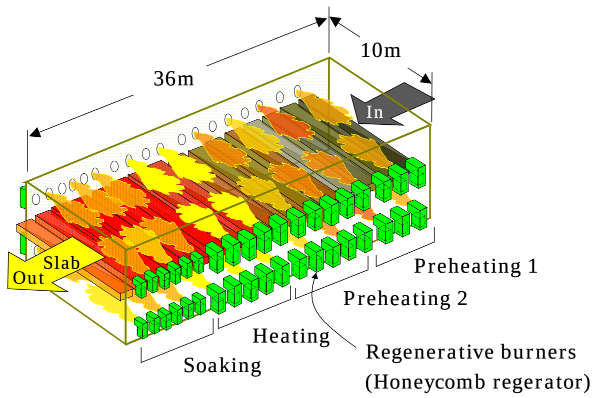

Fig.5 Regerative burner type reheating furnace

5. Conclusion

Although steel industry has long been regarded as a mature industry, steel producing technologies continue to progress. Steel manufacturers in Japan have their own strong engineering teams and compete fiercely with each other to develop new technologies, which is why Japanese steel technologies are world-class.

NKK's steel technologies have been spreading overseas as shown in **Fig.6**, and the globalization of customers will strengthen this trend. The Japanese steel industry as the world's production center will continue to evolve as a COE (Center of Excellence) for steel technologies. Engineers with a pioneering spirit to explore uncharted areas are called for, as the steel industry is still developing.

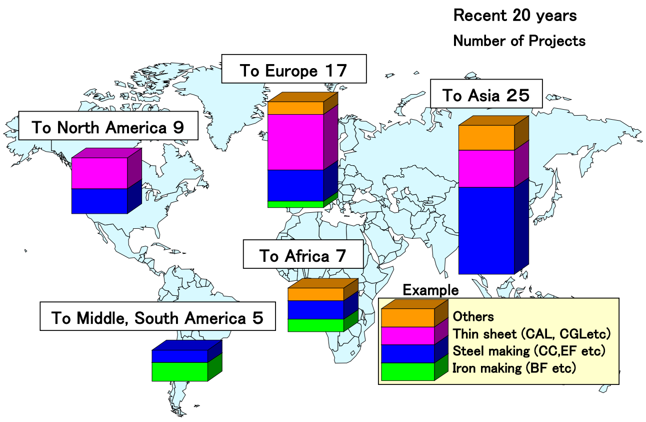

Fig.6 NKK's global technical supports

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