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"Developed Machinery Maintenance Technology
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Maintenance Revolution—Mechanical Maintenance Technologies Developed to Support the Steel Industry of the 21st Century

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Maintenance Revolution —Mechanical Maintenance Technologies Developed to Support the Steel Industry of the 21st Century*



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1 Introduction

More than 50 years have passed since Kawasaki Steel was established in 1950, and the Japanese iron and steel industry now finds itself at a truly historic turning point. The steel industry is a representative equipment-intensive industry, and the progress achieved during these fifty years was the result of a fusion of various technologies, which include product development technologies, operational technologies, and equipment technologies. Moreover, in order to respond to the environment surrounding the steel industry in recent years, Kawasaki Steel has also begun to set up new business strategies to deal with rapid globalization and ongoing restructuring of the financial system.

This report presents an outline of the trends in equipment maintenance technology at Kawasaki Steel up to the present, together with perspectives on plant engineering technology, which is expected to provide a firm foundation for the iron and steel industry of the 21st century, with emphasizing examples of recently developed technologies in the company.

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2 Changes in the Environment Surrounding the Iron and Steel Industry and Trends in Equipment Maintenance Technology

Figure 1 shows apparent consumption of crude steel per capita in Japan, together with the major changes in the economic environment. Quantitative expansion of the steel industry was no longer possible in the midst of the economic changes during the period from the First Oil Crises in 1973 through the Plaza Accord of 1985, which marked the beginning of the appreciation of the yen. In this environment, the company continued to make efforts to develop a variety of technologies to meet the needs of high value added steel products, employment cutbacks, equipment concentration, cost

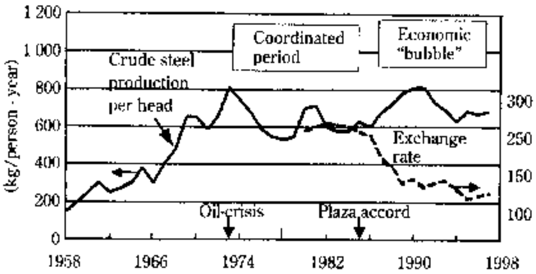


Fig. 1 Trend of economy and crude steel production

reductions, and others, and to maintain its international competitiveness through corporate efforts and restructuring.[1]

Among this series of corporate activities, Kawasaki Steel conducted plant engineering activities intended to contribute to the maximum effective use of assets on hand and the establishment of a steel business with unequalled cost competitiveness, based on the maintenance concepts shown in **Fig. 2**. Specific items include maximizing total operating time, minimizing maintenance costs, and realizing iron and steel manufacturing processes that simultaneously secure high efficiency and high product quality.

Figure 3 shows the progress of equipment maintenance technology at Kawasaki Steel. Based on the above-mentioned concept of plant engineering, the 1980s were a period characterized by efforts to develop and apply appropriate countermeasures for respective equipment conditions in use, responding to trouble, and standardization of maintenance skills. From the beginning of the 1990s, the company developed and applied individual technologies covering the entire range of maintenance, including structural design, the development of new materials, and in-company development of individual tools and methods for efficient repair work corresponding to equipment use conditions, thereby contributing to a stable, high efficiency production system. Since around the mid-1990s, the company has constructed a system which allows equipment to demonstrate its maximum capabilities at the minimum maintenance cost by applying an advanced plant engineering system that effectively combines maintenance planning methods and diagnostic technologies.[2]

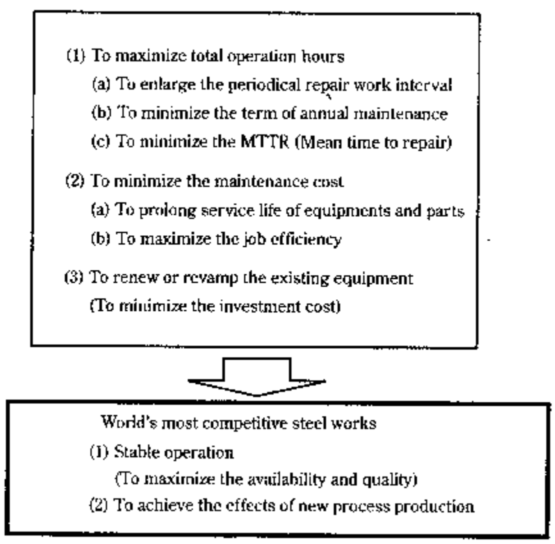


Fig. 2 Conceptual illustration of maintenance in Kawasaki Steel

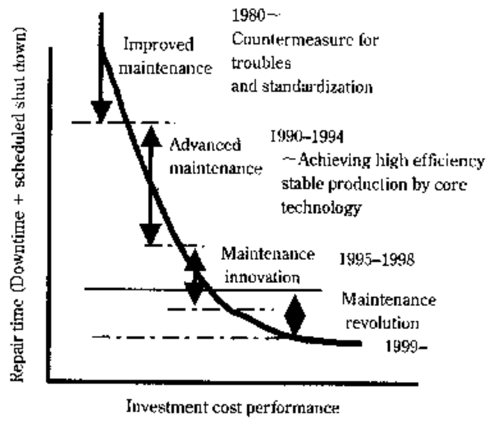


Fig. 3 Progress of equipment technology

Table 1 Periodical plant shut down interval

	BF Iron-making	LD Steel-making	HOT Hot rolling	TCM Cold rolling
Improvement maintenance (~1990)	3 months	4 weeks	2 weeks	2 weeks
Advanced maintenance (1990~1994)	3 months	6 weeks	2 weeks	4 weeks
Maintenance innovation (1995~1998)	6 months	8 weeks	3 weeks	8 weeks

By developing plant engineering technologies as described above, Kawasaki Steel has approximately doubled the periodical plant shutdown interval over a period of somewhat more than 10 years, as can be seen from the examples in **Table 1**.

The management environment surrounding the Japanese steel industry as it enters the 21st century, as shown in **Fig. 4**, includes the strong yen, the growth of the developing nations of Southeast Asia, and quantitative saturation of demand for steel products. Under these circumstances, simply maintaining international competitiveness within the stagnant and ordered steel business is not sufficient. In order to ensure survival in an age of mega-competition, Kawasaki Steel is progressively expanding into the environmental business and semiconductor industry on the base of a high-profitability steel business so as to obtain the satisfaction of its share-

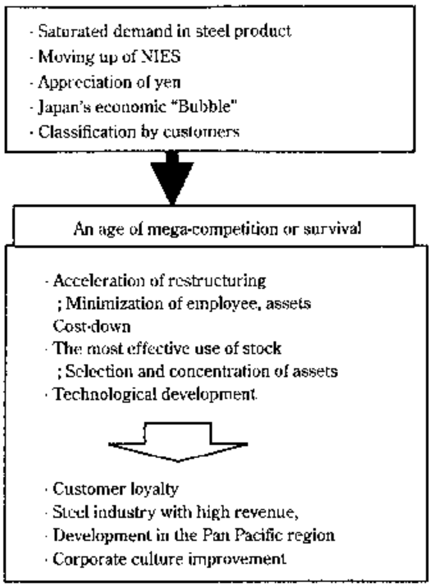


Fig. 4 Circumstances of administration around steel-making companies in Japan

holders, employees, and customers as a business enterprise with value, against the background of maximum utilization of assets and a high technical capability. In particular, the company is endeavoring to maintain its strength in steel business by making strong ties with the Asian nations.

3 Maintenance Tasks for the 21st Century

Under the environment surrounding the iron and steel industry as described in Chapter 2 and the corporate policies of this company, the goal of plant engineering technology are to construct a more efficient maintenance system for production equipment, which is capable of providing high quality products with high efficiency in the company's core iron and steel business. The key technologies are: quantitative monitoring of machine conditions, strict control of machine accuracy, high reliability, and high maintainability of equipment. At the same time, it is also necessary to strengthen the production equipment of the Kawasaki Steel Group as a whole, e.g., extending the application of developed technologies to companies with which Kawasaki Steel has tie-ups. **Figure 5** shows the goals for equipment maintenance in the 21st century.

With regard to maintenance technology for mechanical equipment, Kawasaki Steel began activities to achieve the above-mentioned goals of equipment maintenance, with the aim of achieving substantial advances in equipment maintenance technology through in-company efforts. Specifically, these activities set a goal to develop individual technologies corresponding to the use environment without relying only on the technical capabilities of equipment manufacturers. These activities were based on a recognition that it would be impossible to respond completely to rapid change in the current era by proceeding the improvement and development activities in a traditional manner. The concept of this series of activities, which was given the name "maintenance revolution," is show in **Fig. 6**.

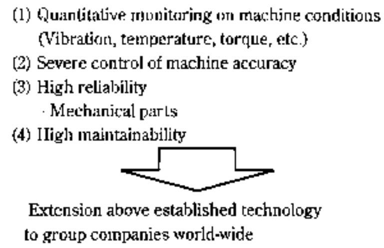


Fig. 5 Aim of maintenance to the 21st century

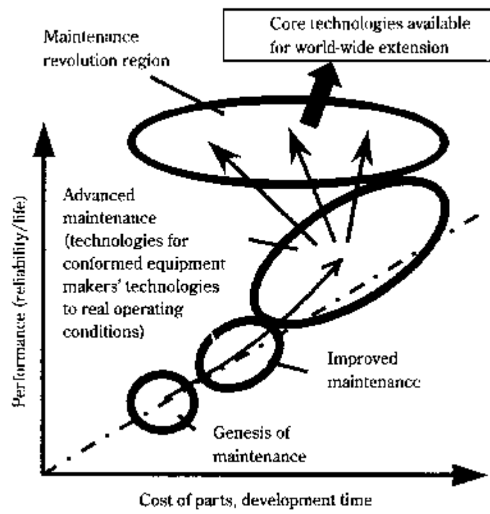


Fig. 6 A concept maintenance revolution activities

4 Maintenance Revolution—A Revolution in Maintenance Technology for Mechanical Equipment

For production equipment to demonstrate its maximum capabilities, it is necessary to monitor accurately the condition of each piece of existing equipment and carry out the most appropriate repairs. At Kawasaki Steel, the seven items shown in **Table 2** were established as practical tasks for the development of the concepts of the "maintenance revolution," and activities were developed. These are:

(1) Development of high reliability mechanical parts
(2) Technologies for responding to factors causing forced deterioration due to the equipment use environment
(3) Development of new materials
(4) Technologies for preventing deterioration
(5) Technologies for diagnosing and estimating the

Table 2 Theme of maintenance revolution

Maximize total operation hours −1: Minimize the periodical repair −2: Minimize the MTTR	(1) Reinforce of mechanical parts (2) Counter-measure to severe condition (3) Development of material (4) Prevention from deterioration (5) Diagnosis and estimation of service life (6) Free from maintenance experience and knowledge (7) Shortening time of repair work

remaining life of equipment

(6) "Experienced knowledge-free" technologies that eliminate the need for maintenance experience and knowledge

(7) Technologies for shortening the time required for maintenance work

The following presents some of examples of development in these activities.

4.1 Development of High Reliability Mechanical Parts

The number of mechanical parts in a typical steel works can be roughly estimated as exceeding 4.7 million. Basically, parts with standard specifications are used in all of these mechanical parts. Furthermore, with these mechanical parts, in order to achieve high reliability in the production equipment, it is necessary to improve the reliability of each mechanical part itself without adopting an equipment design with redundancy, comprising multiple systems, as is done with aircraft and railway cars. **Figure 7** shows the results of a statistics of the maintenance cost and index of downtime caused by mechanical parts in Kawasaki Steel's steel works. Because the index of downtime attributable to these mechanical parts accounts for 85% of all downtime, obviously it is necessary to develop technologies for improving reliability at the mechanical part level. As examples of technologies developed in-house by Kawasaki Steel based on the results of this downtime statistics, **Table 3** shows the high reliability non-loosening nut, improving the nuts and bolts combination, which had the worst cause for mechanical trouble,[3] the development of bearings applicable to low speed and heavy load conditions (double row tapered roller bearings with spherical seat),[4] and a technology which prolongs the service life of wire rope for cranes (non-rotating profile wire rope).[5]

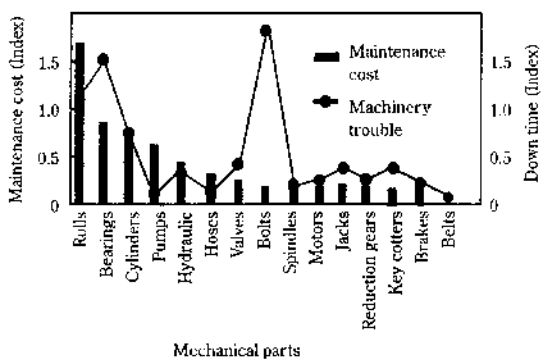
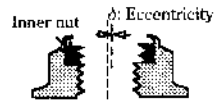
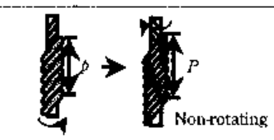
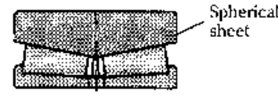


Fig. 7 Needs for maintenance revolution in mechanical parts

Table 3 Technology to prolong mechanical parts' service-life

Theme	Function and effect
Non-loosening nut	 Effect of non-loosening = Above 50 times (compared with JIS nut)
Non-rotating profile wire rope	 Fatigue life = Above 2 times
Double raw tapered roller bearing with spherical sheet	 Service life = Above 2 times

4.2 Life Extension Technologies

In attempting to realize long life in production equipment, a technology which combines at a high level the previously mentioned technology for suppressing factors that cause acceralated deterioration due to the equipment service environment, material development, and diagnostic technology becomes necessary. The concept of the causal relationship among the factors that decide the life of mechanical equipment is shown in **Fig. 8**.

Figure 9 shows that the factors which cause accerlated deterioration of the production equipment in the respective iron- and steelmaking processes. It is apparent that the factors are in a diversed range that includes thermal load, erosion, corrosion, seizure, impact loads.

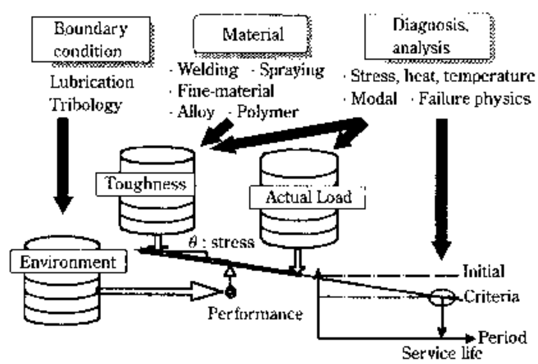
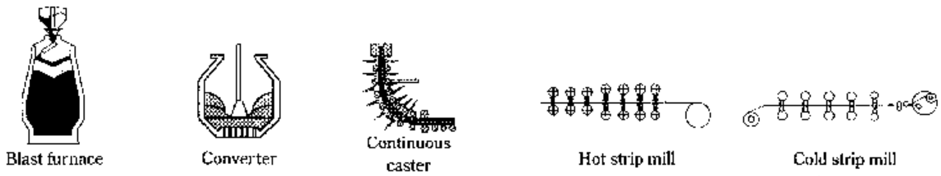


Fig. 8 Decision factors for mechanical service life



	Ironmaking	Converter	Continuous caster	Hot strip mill	Cold strip mill
Temperature (°C)	1 500	1 500	1 200	1 000	200
Speed (m/min)			2.5	1 680	2 800
Environment	Dust	Dust, moisture	Dust, scale, water	Scale, water	Oil, water
Damage mode	Heat, wear corrosion	Heat	Heat, corrosion	Heat, impact seizure	Slip, seizure wear

Fig. 9 Factors to restrict equipment service life

Table 4 Developed technologies to prolong service life

Deterioration \ Process	Ironmaking	Steelmaking	Hot strip, plate, shapes	Cold strip
Vibration	Non-loosening nut	Non-loosening nut	Non-loosening nut; In-company developed UJ spindle	Non-loosening nut; In-company developed UJ spindle
Fatigue	Seal valve		In-company developed UJ spindle	Blister resistant rubber lining
Water		Heat crack resistant, corrosion resistant, and wear resistant material	Heat crack resistant, corrosion resistant, and wear resistant material	Blister resistant rubber lining
Heat		Heat crack resistant, corrosion resistant, and wear resistant material	Heat crack resistant, corrosion resistant, and wear resistant material; Functionally graded multi layered overlay	Functionally graded multi layered overlay
Corrosion	Strong-and-tough seal	Molten scale reactivity resistant material	Molten scale reactivity resistant material	MnO build-up resistant material
Friction wear	Strong-and-tough seal		Corrosion resistant, and wear resistant rubber	Corrosion resistant, and wear resistant rubber

As shown in **Table 4**, Kawasaki Steel has been assigned establishing technologies for prolonging service life as task and carried out technical development for each process and each mode of deterioration.

As an example of in-house material development aimed at prolonging service life, **Fig. 10** shows a comparison of the performance of an overlay alloy with excellent corrosion resistance, heat crack resistance, and wear resistance for use in continuous caster rolls.[6)]

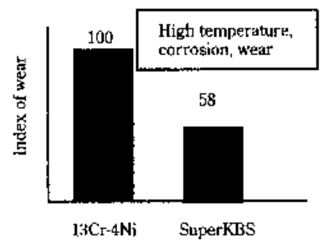


Fig. 10 An example of mechanical life prolongation technology attained by developed material

4.3 Development of Ultra-Short Term Repair Method

In addition to the above-mentioned life extension technologies for various equipment, shortening the maintenance time is also an effective way to maximize the practicable operational hours of equipment. Kawasaki Steel has developed various technologies for timesaving, such as those shown in **Table 5**. Recently, these technologies have been successfully applied in the short-term revamping of blast furnace, resulting in excellent performance.[7)]

5 Outlook for the Future

In this article, the recently performed "maintenance

Table 5 Technology aiming at shortening maintenance time

Quick change method	· Enlarged block change method free from centering ⬇ Revamping of blast furnace
Automatic measurement of equipment accuracy	· Centering device using 3 dimensional gyroscope sensor
Efficient mechanical tools	· Pneumatic, hydraulic connecting device · Automatic handling-device

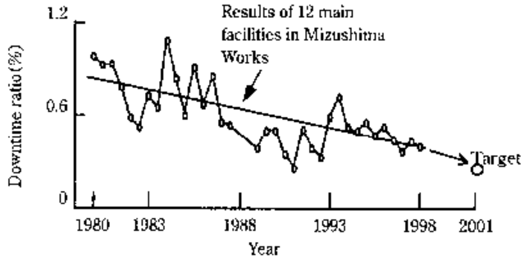


Fig. 11 Target of maintenance performance

revolution" activities at Kawasaki Steel have been presented in addition to the historical review on maintenance technology for mechanical equipment. These activities have contributed to stable operation of production equipment, which is obviously indicated from the declining trend of the downtime ratio shown in **Fig. 11**. By positively developing the present "maintenance revolution" activities with a view to the 21st century, Kawasaki Steel hopes to attain enhanced levels of high performance mechanical parts, new material development and other life extension technologies, and much more sophisticated technologies, for examples, equipment diagnostic technology, analysis for judgment. The company aims to apply those developments to its plant engineering system, contributing to the strengthening of the foundation of its steel business. By combining the developed technologies and information technologies, the company also hopes to realize remote control maintenance and telecommuting maintenance work at home, linked to the worldwide development of maintenance technology.

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