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Maintenance-Free Technology for Hydraulic Equipment

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Synopsis :

The life of equipment relys on the balance of its strength and load. The balance is influenced by its surrounding circumstances as well as by the amount of strength and load. In other words, the life of equipment can be made longer by heightening its strength and lightening the load which are achieved on the basis of material technology, the diagnosis, the analysis and the design technology of equipment. A longer service life can be made possible also by cleaning fluid, the development of fluid quality and, moreover, sealing technology, and the like, as circumstance improvement. As a consequence of that, maintenance-free of equipment will be accomplished. This paper describes the maintenance-free technology of hydraulic equipment, which has been accomplished by cleaning lubrication oil, hydraulic pressure oil and air and still more, the maintenance free of cleaning system for rolling oil and fluid which has been established, is also discussed.

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Maintenance-Free Technology for Hydraulic Equipment*

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1 Introduction

The iron and steel industry is a capital-intensive industry that manufactures products using large-scale equipment such as the blast furnace, continuous casting machine, and rolling mills. Improving the reliability and maintainability of this mechanical equipment is necessary and indispensable for reducing production costs and improving production efficiency. Under the circumstances, Kawasaki Steel has taken up the challenge of the "maintenance revolution," centering on the development of new maintenance technologies in the company itself, with the aim of realizing further improvements in conventional equipment maintenance. In particular, it is necessary to improve reliability, extend life, and reduce maintenance costs in hydraulic machinery (hydraulic devices, lubrication devices, factory air equipment, lubricants, etc.), which is used with a wide range of mechanical equipment. In the circumstances, Kawasaki Steel, as part of the "maintenance revolution,"[1] is promoting activities which it calls "realizing maintenance-free hydraulic equipment" to achieve high reliability in hydraulic equipment economically. An outline of these activities is presented in this report.

2 Concept of Maintenance-Free Equipment

The life of equipment depends on the balance of equipment strength and load. This balance is governed not only by the equipment strength and degree of the load, but also by the environmental factors affecting the equipment. In attempting to realize long life in equipment, efforts involving diverse analysis methods and perspectives are necessary. Specifically, it is possible to extend the life of equipment by adopting high strength equipment and reducing loads, which can be achieved through material technology and diagnosis, analysis, and design techniques. In addition, it is possible to attain the purpose, by environmental improvements, such as purifying fluids and improving the quality of fluids as such, and by adopting hydraulic and lubrication technologies such as sealing technology. As a result, maintenance-free equipment can be realized.

A variety of mechanical equipment has been introduced in steel manufacturing plants. However, problems related to hydraulic devices happen frequently in the repairs of such equipment. Because hydraulic equipment accounts for approximately 30% of the man-hours used annually in total equipment maintenance in steel works, to realize maintenance-free for hydraulic equipment is important.

Figure 1 shows a breakdown of the maintenance work

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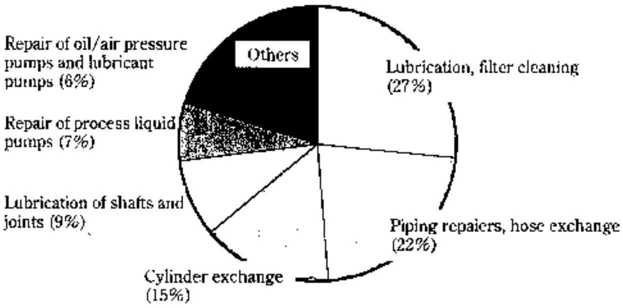

Fig. 1 Profile of works related to hydraulic equipment

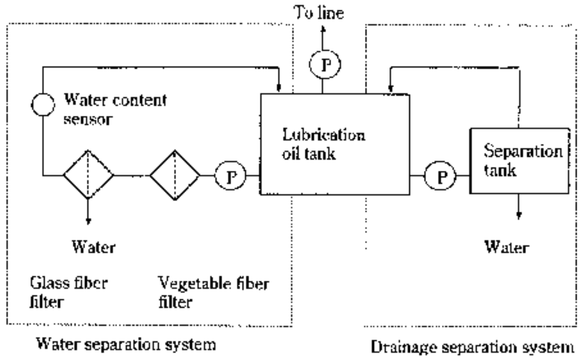

Fig. 2 Lubricating oil-purifying system

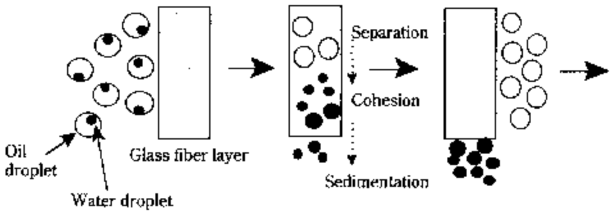

Fig. 3 Mechanism of water removal filter

related to hydraulic equipment in cold rolling mills. To realize maintenance-free for hydraulic equipment, it is necessary to extend the cycle of filter exchanges, extend the lives of cylinders and pumps, and extend the lubricating cycle of shafts and joints. It should be noted that the breakdown of work related to hydraulic equipment in the iron- and steelmaking plants is virtually the same as that in the cold rolling mill, and similar countermeasures are therefore necessary.[2)]

If the content of repairs and unscheduled maintenance of hydraulic equipment is analyzed, the majority of problems have their origin in the quality of the fluid, and it is therefore possible to realize maintenance-free equipment by purifying fluids and developing high quality fluids, and by developing hydraulic equipment. This report describes maintenance-free equipment realized by purification of lubricating oils, hydraulic operating oil, and compressed air, and further, maintenance-free technologies for the rolling oil and alkaline cleaning fluid purification systems themselves.

3 Concrete Examples of Improvements

3.1 Lubricating Oil Purification System

The lubrication systems in steel works are characterized by large capacity and high viscosity of the lubricating oil, and breaking in water and contamination is frequently a problem. The circulation volume of the lubricant in such systems is usually large, and due to the high viscosity of the lubricants, the use of mesh filters is unavoidable. This caused problems because the dust removal quantity was small and the filter cleaning and exchange cycle was short. Therefore, purification was improved and the filter exchange cycle was extended by introducing a depth element filter, which features an increased surface area. Lubrication systems at rolling mills where penetration by water is common are prone to various problems such as deterioration of the lubricating oil by water and the growth of bacteria. In addition to debris elimination filters, water removal filters have also been installed in such systems.[3)]

Figure 2 shows a system diagram of the lubricating oil purification system that was developed in the present work. Two lubricating oil purification systems are installed in the system that leads to the line in the lubricating oil tank. One is the water separation system, which increase the water droplet size of emulsion and thereby removes water while also removing contamination in the oil. The second is the drainage separation system, which eliminates water that has been settled to the bottom of the tank.

The water separation system comprises a vegetable fiber filter and a glass fiber filter. The vegetable fiber filter removes contamination and increases the size of water droplets. The purpose of the vegetable fiber filter installation is to extend the filter exchange cycle by introducing a depth element filter with an increased filter surface area. After the size of water droplets has been increased, water droplets are absorbed and coarsened by cohesion in the glass fiber filter, followed by sedimentation and removal, by the mechanisms shown in **Fig. 3**.[4)] In the drainage separation system water that has settled to the bottom of the tank is discharged out of the tank.

This type of system has made it possible to maintain a debris content of less than 20 ppm and a water content of less than 500 ppm, as shown in **Fig. 4**, enabling extension of the filter exchange cycle of terminal filters in the lubricating oil system.

3.2 Hydraulic Fluid Cleaning System

Because hydraulic systems can transmit high energy power with high accuracy by using various control valves to control the high pressure fluid, they are generally applied to a wide range of steel manufacturing

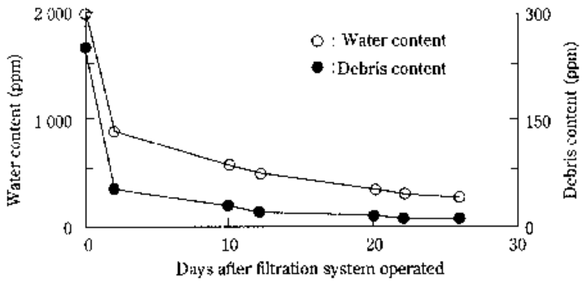

Fig. 4 Transition of lubricant purity

equipment and are required to provide high reliability. Failures of hydraulic system valves in equipment are an important cause of failures of mechanical elements, accounting for approximately 6% of all such mechanical failures. **Figure 5** shows the failure cause analysis of hydraulic valves over a period of 3 years. Approximately 90% of the total failuc were operating malfunctions collectively called "stick." Of these failures, 11% were caused by clearly recognized solid particle problems, 24% by sticky oxidized products of the hydraulic fluid, and remaining 54% cannot be easily recognized visibly a cause of foreign matter. Thus, it can be understood that it is necessary to remove these types of contaminants in order to improve the reliability of the hydraulic system.[5] Further, contaminants in the hydraulic fluid also clog strainers, and are a major cause of wear related life problems in pumps and cylinders, and therefore are a factor that causes a remarkable increase in the hydraulic system maintenance jobs.

Precise oil cleaning equipment is necessary for cleaning hydraulic fluid. However, how to achieve the targeted level of cleanliness economically is important. The surface filter is the most generally used type, but there are limits to the precision of foreign matter removal and the amount of foreign matter that can be captured, and only removal of solid particles can be expected. Because the depth element filter has an extremely large capacity of foreign matter capture and can remove both solid particles and oxidized products efficiently, and can also be used for water separation, it has been adopted as the most economical oil cleaner. On the other hand, electrostatic oil cleaners can in principle remove all types of contaminants with high precision, regardless of particle size, but in cases where the water content in the oil exceeds 500 ppm, this type needs to use in combination with a water separation device.

Based on these characteristics of oil cleaners, a depth element filter and an electrostatic oil cleaner were installed in the circulation bypass lines of the main tank in an actual hydraulic system in order to confirm their oil cleaning effects. Using the method[6] shown in **Fig. 6**, oil samples were filtered by a 0.45 μm membrane filter, separated into organic contaminants (oil oxidized products, etc.) and inorganic contaminants, and the resulting samples were weighed. **Figure 7** shows the average values of the analysis results taken from multiple systems. It can be understood that the fresh oil samples already contained a certain amount of inorganic contaminants due to the process of transferring the oil from the drums, and a very small amount of organic contaminants was also present. With the depth element filter, it was possible to remove inorganic contaminants to extremely high extent, but the content of organic contaminants increased to approximately two times that of fresh oil. On the other hand, in the line where the electrostatic oil cleaner was installed, inorganic contaminant removal was inferior to that with the depth element filter by approximately two times, while organic contaminants could be maintained at about 1/2 and it is almost the

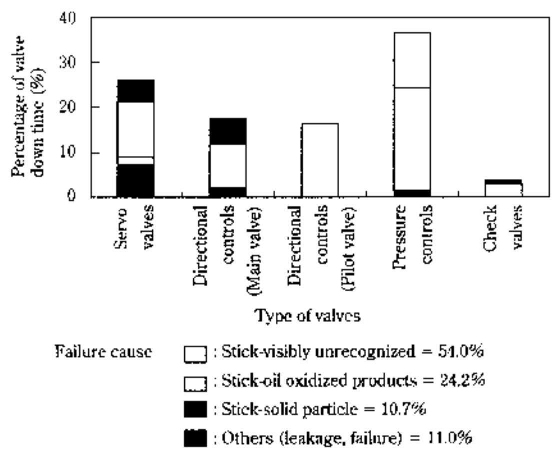

Fig. 5 Failure cause analysis of valves in hydraulic system

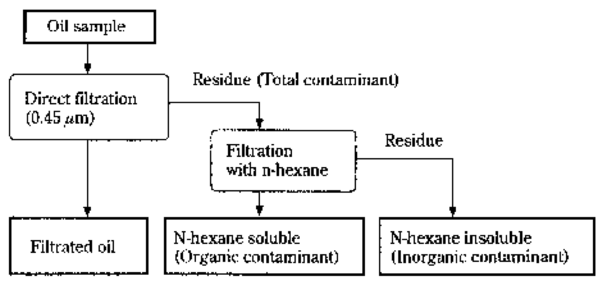

Fig. 6 Schematic of hydraulic fluids analysis

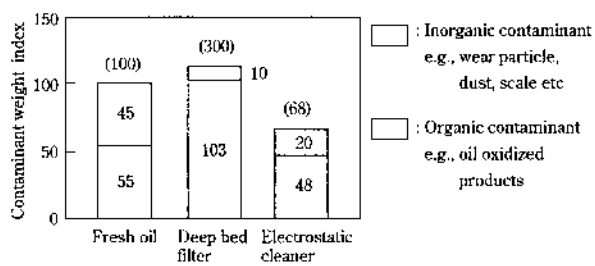

Fig. 7 Contaminant weight of hydraulic fluids

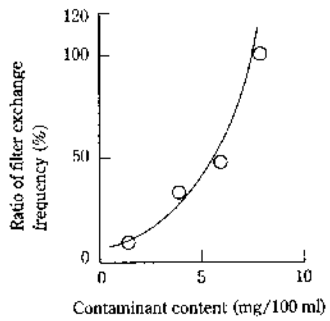

Fig. 8 Contaminant content and frequency of valve filter exchanges

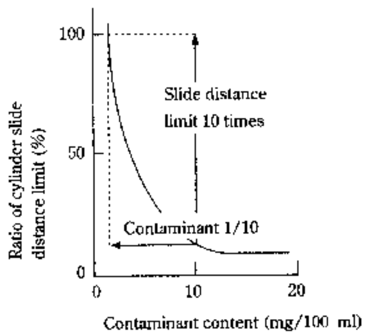

Fig. 9 Contaminant and cylinder slide distance limit

same level of fresh oil. Based on these analysis results, in cases where deterioration of the hydraulic fluid by oxidation is rapid due to severe service conditions, and in cases where the content level of solid particles is high due to wear or other factors, the depth element filter is applied, as this type provides economical oil cleaning performance. In cases where higher precision oil cleaning to the level of fresh oil is required, the electrostatic oil cleaner is suitable.

Based on this finding, the most appropriate high performance oil filters were selected and introduced, as required by the condition of deterioration and other distinctive characteristics of existing hydraulic systems. **Figure 8** shows the frequency of exchange of filters installed on the proportional solenoid valves at rolling mills, and indicates that the frequency of filter exchanges was reduced to approximately 1/10 the previous level by reducing the level of oil contamination. **Figure 9** shows the slide distance limit of hydraulic cylinders used at cold rolling mills, pickling lines, and other facilities. Here, the wear life of seals was improved dramatically by reducing the level of contamination.[7] **Figure 10** shows that the level of contamination in oil at main tanks was improved to less than NAS7 and the frequency of valve sticks was reduced to approximately 1/4 the previous rate by introducing high performance oil cleaning equipment at 12 cold rolling plants, including cold rolling lines, coating mills, and others.

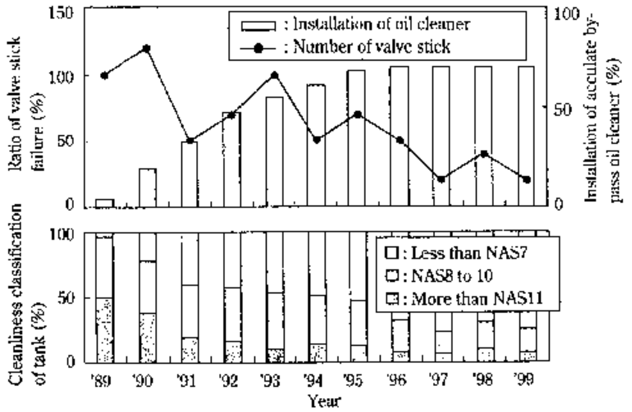

Fig. 10 Improvement of fluid cleanliness and number of valve stick in cold rolling facilities

The implementation of this type of high cleanliness hydraulic control system was expanded to the steel works level, achieving improved reliability and maintenance free operation in hydraulic equipment.

3.3 Purification of Factory Compressed Air

The conventional method of purifying factory compressed air was to install three popular processes, consisting of a filter, a lubricator, and a pressure reducing valve at each solenoid valve. In many cases, a drier was not provided. As a result, equipment problems such as poor operation of the solenoid valves and clogging of filters were common, and work was frequently required to remove drain from the system. **Figure 11** shows a comparison of the ratio of unscheduled inspections and repairs by equipment managers in the case of equipment that is supplied with dry air, indexed to the occurrence of such problems before dry air was adopted as 100%. The number of unscheduled inspections and repairs of equipment that receives dry air was reduced to approximately 1/10 the former number.

Further, comparing the number of cases of removal of drain from equipment with and without air drying, the number of cases in which it was necessary to remove drain from equipment that uses dry air was zero.

Based on these facts, in addition to air purification at

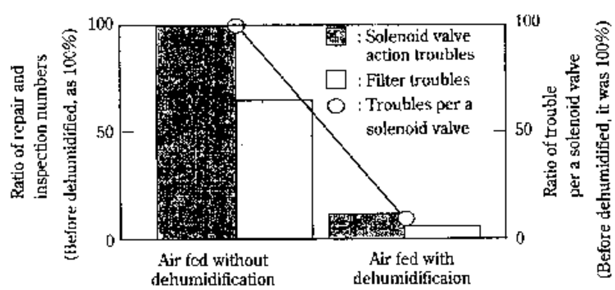

Fig. 11 Unscheduled repairs and inspection numbers ratio of equipment maintenance section

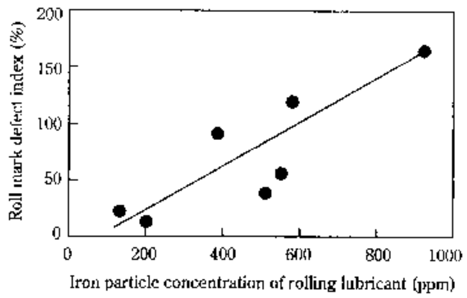

Fig. 12 Relationship between roll mark defect and iron particle concentration of rolling lubricant

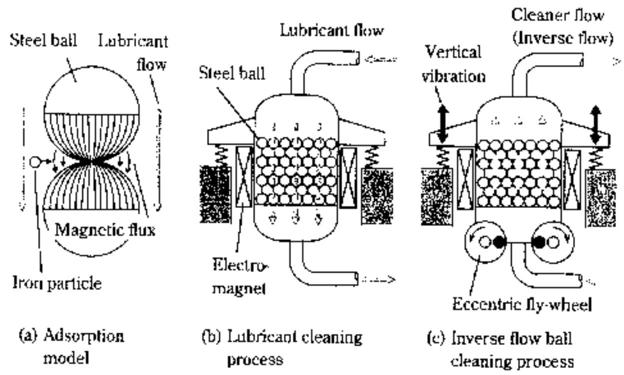

Fig. 13 Schematic of magnetic ball cleaner

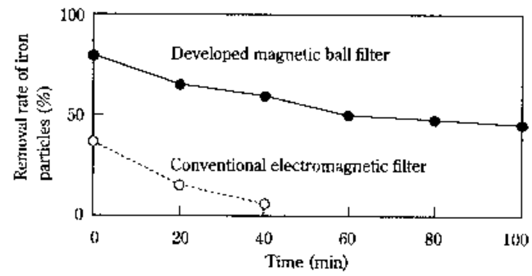

Fig. 14 Transition of iron particle removal rate

the equipment unit level, filters and driers were installed at the main on the exit side of the compressor for air purification at the shop unit level. These measures improved the reliability of compressed air equipment such as solenoid valves and cylinders, and also realized labor savings in inspection and adjustment work.

3.4 Maintenance Free Technology for Rolling Oil Cleaning System

In order to realize high quality in the surface properties of cold rolled materials, it is necessary to achieve a high level of cleanliness, less than 200 ppm, in the iron particle concentration in the rolling oil, as in the relationship between the iron particle concentration of the rolling lubricant and roll mark defect index shown in **Fig. 12.**[8] The electromagnetic filter is generally used as the iron particle removal device for rolling oil. However, because the removal rate is low in the low iron particle concentration region, and further, iron particles and high viscosity sludge mixed in the rolling oil stick firmly to the electromagnetic filter element, complete backwashing was difficult, even with hot water or steam. For this reason, cleaning overhauls at a short cycle had been necessary in order to maintain a high iron particle removal rate.

The magnetic ball filter that was developed in the present work provides high efficiency iron particle removal performance even in the low iron particle concentration region because it is possible to form a strong magnetic field. **Figure 13** shows a comparison with the conventional electromagnetic filter. With the conventional electromagnetic filter, the initial removal rate is 40%, and after about 40 mm of cleaning operation, this decreases to approximately 5% and backwashing becomes necessary. In contrast, because the initial efficiency of the magnetic ball filter is high, at 80%, and the decrease in removal efficiency is gradual, it is possible to set a long backwashing cycle, resulting in a high equipment working ratio. A new high efficiency method of backwashing was also developed,[9] in which the rolling oil is backwashed while applying mechanical vibration to the filter casing body. This eliminated the need for periodical cleaning overhauls, realizing maintenance free operation.

The results of introduction of the magnetic ball filter at cold rolling mills are shown in **Fig. 14**. It has become possible to achieve a stable iron particle concentration of less than 200 ppm. As a result, the roll mark defect index of the products and the frequency of work roll exchanges due to scratch defects have been reduced to 1/4 the conventional rates.

3.5 Maintenance-Free Technology for Alkaline Cleaning Fluid Purification System

In cleaning section equipment, oil, iron particles, and other contaminants are washed from the surface of the steel strip or plate by an alkaline cleaning fluid. However, various problems can occur if iron particles in the alkaline cleaning fluid stick to the product again. These include soiling of the product by the iron particles, dents caused by rolls to which iron particles have adhered, galvanizing defects, and others. Equipment that removes iron particles by means of a magnetic filter is frequently adopted as a countermeasure for these problems. However, with the conventional permanent magnet type, a low rate of iron particle removal and low efficiency in backwashing were problems in comparison with the electromagnetic type.

To solve these problems, a high efficiency magnetic filter that provides both high removal efficiency and high backwashing efficiency in a permanent magnet type filter was developed.[10] The newly developed filter

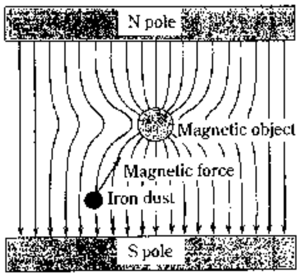

Fig. 15 Mechanism of removal iron dust

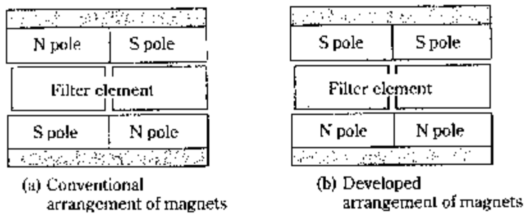

Fig. 16 Magnetic circuit

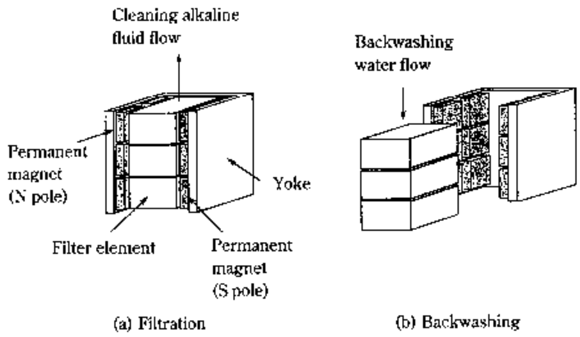

Fig. 17 Schematic view of magnetic filter

achieves maintenance-free functioning in a magnetic filter.

First, the concept of high removal efficiency will be described. The principle of iron particle removal by a magnetic filter, as shown in **Fig. 15**, is to capture the iron particles by introducing a magnetic object into the magnetic field in order to generate a magnetic gradient and generate a magnetic force. However, with permanent magnets, it is not possible to reduce the magnetic field to 0 during backwashing of the captured iron particles, as can be done with electromagnets. Therefore, the N pole and S pole were conventionally arranged in an alternating pattern, and backwashing of the captured iron particles was performed using these adjacent reverse magnetic fields. However, with this structure, it was a problem that the magnetic flux density for removing iron particles was reduced by loss of magnetic flux to adjacent magnetic fields.

In the magnetic filter that was developed in this work, the N and S poles are arranged on opposite sides of the filter in order to increase the magnetic flux density. As a

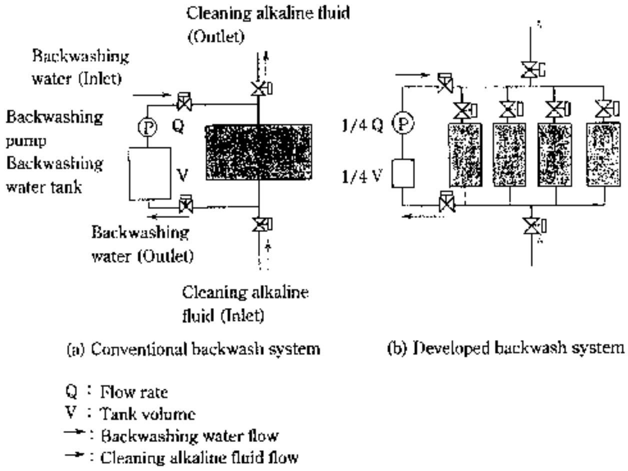

Fig. 18 Characteristic of backwashing system in developed filter

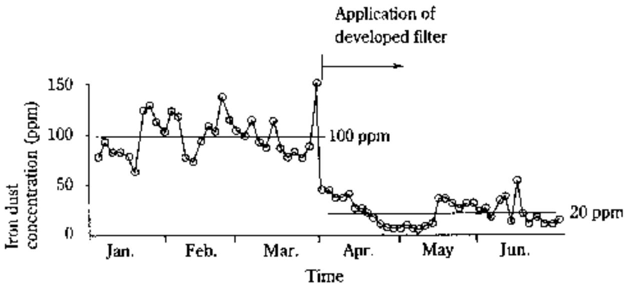

Fig. 19 Transition of iron dust concentration

result, even when stainless steel parts are used in high magnetic permeability parts such as the amorphous fine lines that were conventionally used in filter elements, high efficiency iron particle removal is possible.

Figure 16 shows the arrangement of the permanent magnets, and **Fig. 17** shows the structure of the newly developed magnetic filter. The structure of the filter makes it possible to remove the magnets from the filter elements in order to reduce the magnetic flux density to 0 during backwashing.

Further, in order to realize a compact system without reducing the filter capacity, the filter elements are divided and backwashing is performed separately in units of one element. Adopting this design made it possible to reduce the capacity of the pump and tank in the backwashing system and thereby realize a compact system, as shown in **Fig. 18**.

The newly developed technology described above resulted in the development of a high removal efficiency magnetic filter which is maintenance free and can maintain a low concentration of iron particles, as shown in **Fig. 19**.

4 Conclusion

By adopting maintenance-free technologies for

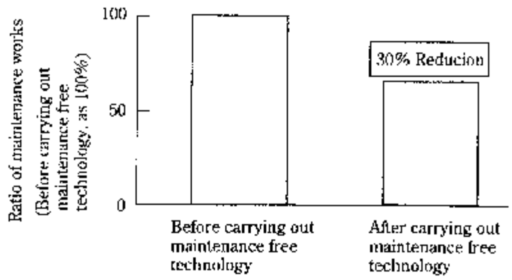

Fig. 20 Transition of ratio of maintenance works at hydraulic equipment

hydraulic equipment, it was possible to reduce maintenance work related to the hydraulic equipment by approximately 30%, as shown in **Fig. 20**.

Maintenance-free technology is an important topic for equipment control, and is not limited to hydraulic equipment. In particular, in industries such as the steel industry that use large-scale equipment to manufacture products, it is no exaggeration to say that the reliability and maintainability of mechanical equipment is linked directly to cost competitiveness. In the circumstance, maintenance-free technology has been implemented on the steel works scale, with hydraulic equipment as a starting point, and has had important benefits.

In the future, efforts that also consider the development of materials and equipment will be necessary in order to achieve even longer equipment life. In any case, however, joint efforts by the makers and users of machinery, hydraulic equipment and fluids, bearings, seals, lubricants, and other components and materials will be required.

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