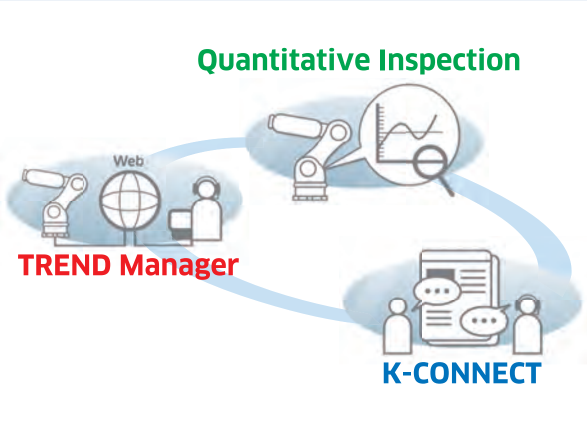
An Innovative Maintenance Service, K-COMMIT



We have developed and launched an innovative maintenance service, K-COMMIT, to eliminate downtime for users' robotic equipment and their peripheral equipment, as well as reducing lifecycle costs. This service can provide users with timely support via constant remote monitoring. This innovative service has been already introduced at many Kawasaki robot users and has achieved an excellent track record.

Introduction

With the increase in the global demand for industrial robots in recent years, the number of shipments is increasing dramatically. Along with this, the number of robots being managed is also increasing. Under such circumstances, conventional services centering on inspection, repair, and maintenance can no longer sufficiently satisfy users.

1 Background

In order to break away from conventional services and enhance customer satisfaction, new, more innovative proposal-based services and the development and practical application of tools and systems for supporting such services are desired.

2 Concept of the innovative maintenance service "K-COMMIT"

"K-COMMIT" (Kawasaki COmmunication Maintenance Management Inspection Total) is based on the concept of "zero downtime," "lifecycle cost reduction" for users and "information sharing" with users.

(1) Zero downtime

Factory equipment requires time for parts replacement after inspections or for maintenance. However, sudden failures cause large decreases in factory utilization rates. K-COMMIT aims to eliminate downtime of users' robotic equipment by avoiding sudden failures by predicting when the failures will occur.

(2) Lifecycle cost reduction

In the past, we have recommended that users perform annual inspections of their facilities from the perspective of preventive maintenance. However, in production sites, the loads put on robots vary, depending on the robot operation speed, operation time, temperature, and ambient environment. Therefore, K-COMMIT suggests the optimal maintenance cycle for each user to reduce lifecycle costs.

(3) Information sharing with users

We are currently rolling out a service based on making proposals to users instead of a service based on waiting for contact from users. To put a proposal-based service into practice, it is essential to closely share information with users in order to know what issues they are facing or their needs in a timely fashion. Therefore, we developed a new information sharing system that replaces conventional communications via telephone and e-mail.

3 Outline of K-COMMIT

K-COMMIT is an innovative maintenance service consisting of three pillars. The first is "TREND Manager," which performs failure prediction via constant and remote monitoring. Second is "Quantitative Inspection," which performs accurate equipment diagnosis. The third is the user communication tool "K-CONNECT." In developing this service, M2M (Machine-to-Machine) and IoT (Internet of Things) technologies were utilized to remotely connect the robots operating in the production field to the service centers, making maintenance via constant and remote monitoring possible.

(1) TREND Manager

TREND Manager is software that performs constant and remote monitoring of robotic equipment to ascertain its condition and acquire and analyze the operation data, in order to predict failures. It is equipped with an automatic e-mail transmission function, and is capable of automatically sending the results of failure prediction through constant monitoring.

(2) Quantitative Inspection

Quantitative inspection is an inspection method in which inspection results are quantified and stored in a database and the equipment conditions are quantitatively managed. In addition to the diagnoses provided in the conventional service, including reduction gear lost motion and iron contamination measurement, "direct-reading ferrography" has been introduced as a new diagnosis method.

(3) K-CONNECT

With the conventional service, the person in charge on the user side and our service staff would carry out person-to-person communication for maintenance purposes. In contrast, the communication tool K-CONNECT enables the user and service center to share information with each other and communicate in a systematic fashion, while allowing robotic equipment maintenance history information and maintenance proposals to be managed on the K-CONNECT web browser. Moreover, manuals and technical materials are now viewable on the web browser.

We will describe TREND Manager and Quantitative Inspection in the following sections.

4 Detailed functions of TREND Manager

TREND Manager utilizes the high-security network environment realized by the after-sales service support information infrastructure (K-Cube) of the Kawasaki Heavy Industries Group.

(1) Constant monitoring function for robotic equipment

As illustrated in **Fig. 1**, TREND Manager is capable of constantly monitoring multiple robots operating in the

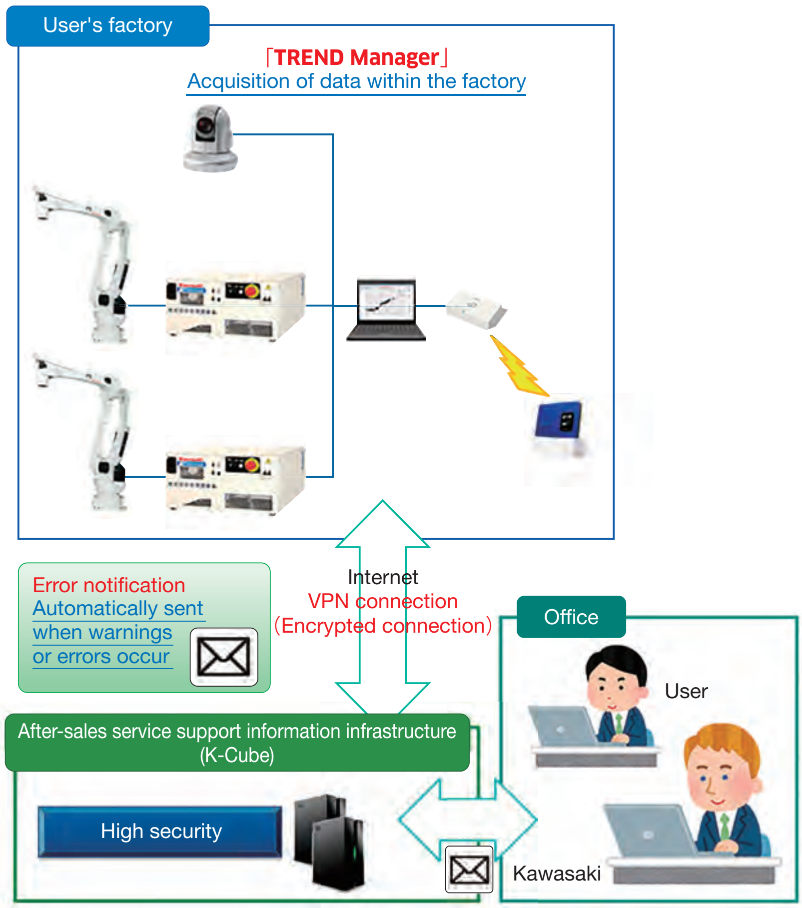


Fig. 1 TREND Manager system diagram

user's site. In addition, it obtains data for predicting the robots' operations and load conditions and creates a database. It analyzes the acquired data and performs failure prediction, enabling accurate and optimal preventive maintenance.

(i) Example of failure prediction (current value analysis)

For example, TREND Manager can predict the failure occurrence date and issue a warning by performing statistical analysis of changes in its current value and the trend of the servo motor. Since this allows the user to implement preventive maintenance by planning maintenance before the predicted failure occurrence date, it becomes possible to avoid sudden failures. From the trend graph of TREND Manager illustrated in **Fig. 2**, changes in the current value over time and its trend can be grasped.

(ii) Enhancement of the failure diagnosis function

In order to respond to more requests from users, we are working to enhance the functionality of TREND Manager. In order to identify the failure parts of the reduction gear that significantly affects downtime, FFT (FFT: Fast Fourier Transform) analysis of the waveform of the motor current was developed, and we are working to improve the prediction accuracy to utilize it for early diagnosis that matches the users' maintenance plans. We are planning to further enhance the functionality of TREND Manager by incorporating technologies such as machine learning and AI.

(2) Extensibility into systems

TREND Manager is capable of acquiring the data of painting equipment, pneumatic equipment, and the PLC

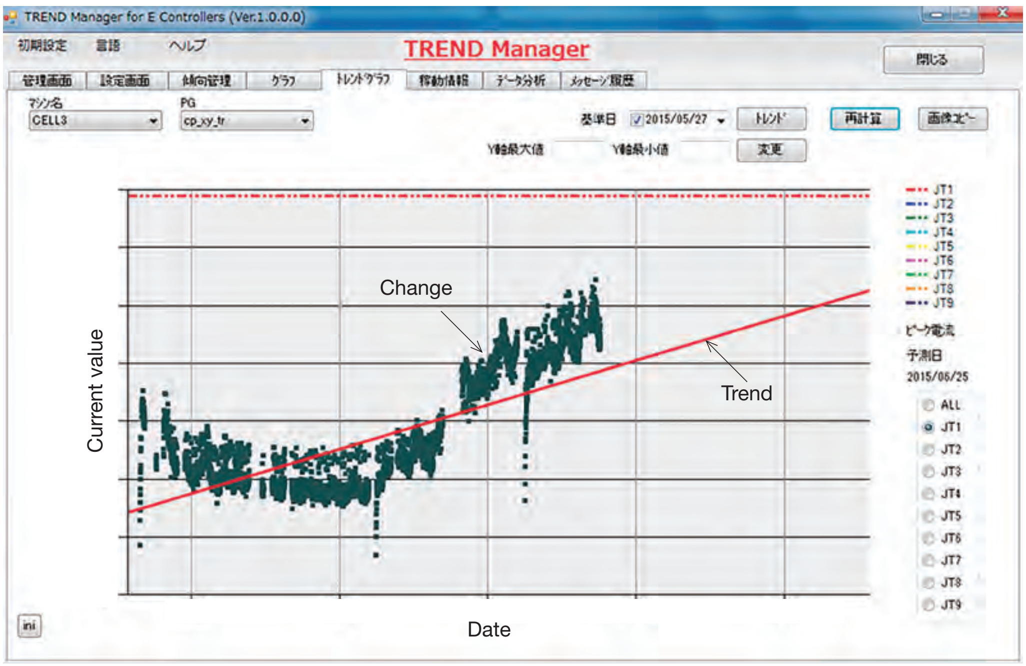


Fig. 2 Trend Graph of TREND Manager

(Programmable Logic Controller) that controls robot peripheral equipment and then performing trend management.

(3) Mail notification function

When an abnormality occurs, TREND Manager issues a warning or an alarm to pre-configured e-mail accounts. In addition, detailed data to be used for analysis, such as the motor current for each axis, is sent.

(4) Traceability function

In addition to the function of comparing the current and past data for each robot, TREND Manager can visualize the operation amount, operation time, and alarm occurrence frequency for each axis and trace past robot conditions from such data.

(5) Remote monitoring/maintenance function

All of the functions described above can also be used through remote operation from the service center via a network. In addition, the state of the robotic equipment operating in the users' production sites can be made visible by installing network cameras. If the robotic equipment stops, and if fixing the problem does not require parts replacement, troubleshooting can be performed through remote control operation by watching the network camera image. This makes it possible to recover robots without visiting the users' sites, bringing significant advantages in recovery speed and cost.

5 Quantitative Inspection

Direct-reading ferrography analysis has been incorporated into the existing Quantitative Inspection as a new diagnosis method.

(1) Direct-reading ferrography analysis

Direct-reading ferrography analysis is a method in which quantitative changes of wear particles in lubricant or hydraulic oil by particle size are analyzed using the analyzer described in **Fig. 3**. We have succeeded in diagnosing the failure trend of reduction gears more accurately than with the conventional iron contamination measurement. Applying this method has made it possible to grasp the ratio of large and small particles in the grease of the reduction gear by diluting the grease using our unique method and analyzing it. We obtained the threshold value from accumulated data, and determine that a failure occurs to the reduction gear when the value calculated based on the ratio between the large and small particles exceeded the threshold value.

Fig. 3 Direct-reading ferrography analyzer

(2) Issues with iron contamination measurement

Conventionally, the state of wear of a reduction gear was determined by measuring the iron contamination of the grease and judging the value to be a “normal value,” “warning value,” or “abnormal value.” Although iron contamination of the reduction gear grease rapidly increases when abnormal wear of the reduction gear occurs, a certain degree of increase was observed in the iron contamination even under a normal state of wear, as iron contamination measurement is a method that measures the total amount of iron particle in the grease. In addition, even for a reduction gear in an abnormal state of wear, the iron contamination value temporarily decreases if the grease is replaced even once, which interrupts judging to be “abnormal.” That was an issue with using iron contamination.

(3) Resolution of issues by direct-reading ferrography analysis

In order to resolve the above issues, the direct-reading ferrography analysis method has been adopted. For a while since the use of a robot is started, many particles in the reduction gear grease have a diameter smaller than 5 μm (small particles). However, when an abnormality occurs in the reduction gear and abnormal wear starts, particles having a diameter of 5 μm or larger (large particles) increase in the reduction gear grease. Based on this phenomenon, the IS value (Wear Severity Index) and LWPC (Large Wear Particle Concentration) are calculated by grasping the amount of large and small particles using the ferrography analyzer and they are used as the wear diagnosis index for the reduction gear. As has been described, by evaluating the diameters of wear particles in the grease using direct-reading ferrography analysis, the wear condition of the reduction gear can now be diagnosed more accurately than ever. The distribution of the iron contamination and IS values of collected grease samples is shown in **Fig. 4**. The red points indicate the grease samples from reduction gears in which actual abnormal wear was observed, and region ①, which was overlooked by iron contamination measurement, is now detected as being abnormal.

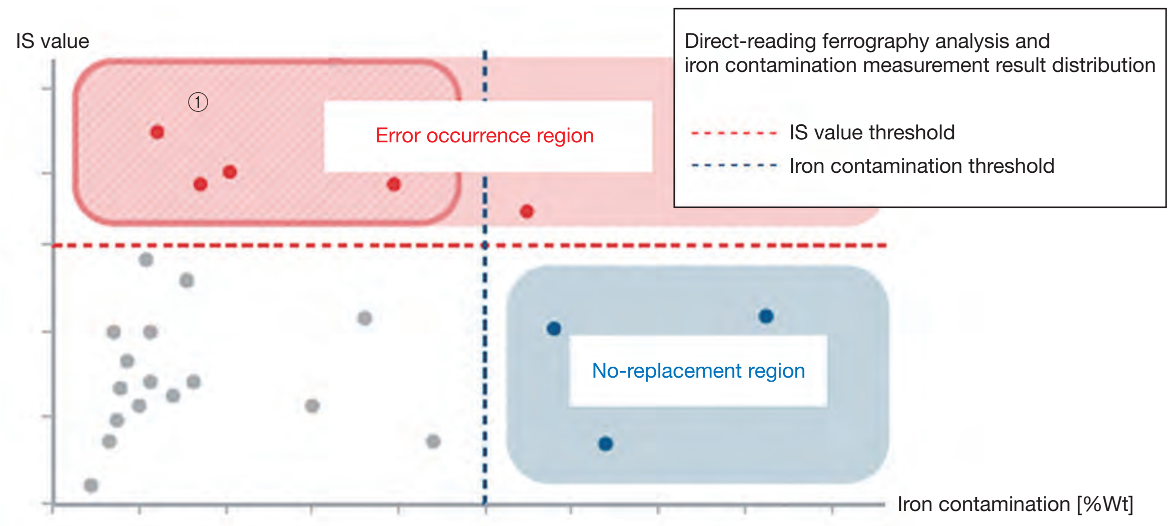


Fig. 4 Regions detectable for ferrography analysis

6 Application example of K-COMMIT

(1) Kawasaki Good Times World

Kawasaki Good Times World is a corporate museum where visitors can learn about some of Kawasaki Group's products in a fun way by seeing and touching them. The robot booth contains different types of robots and various demonstrations are performed. K-COMMIT is used for the robots in this booth.

There used to be issues such as those described below when a robot stopped.

① Upon receiving a notification, our service staff would travel for more than an hour to the site from the service center to investigate the cause of the stop and perform recovery work.

② If it turned out that there was a part failure as a result of the investigation into the cause, the staff would need to return to the service center to get the replacement part.

Due to these two things, a significant amount of time was required for recovery in some cases.

(2) Resolution of the issue by the introduction of K-COMMIT

The introduction of K-COMMIT has made it possible to investigate the causes of failures through remote control operation via network cameras and remote connection. Error recovery used to take a long time before its introduction. However, now minor errors can be recovered in a short time, since it is no longer necessary to go to the site.

In addition, since information on the necessary replacement parts is delivered to the service center via e-mail, quick response has become possible.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Conclusion

The development of K-COMMIT has made eliminating downtime and reducing lifecycle costs a reality. These have been challenges for managers taking care of robotic equipment for a long time. Our aim is to spread K-COMMIT Kawasaki Robot Anshin lifecycle support to more users that is optimally customized for the robotic equipment of each user.