Development of Remote Monitoring System for Tunnel Machine

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In recent years, more and more tunnel machines (shields and TBMs) of Komatsu have been operated not only in Japan but also in China and other countries. In order to ensure efficient service of many tunnel machines in operation at home and abroad, it is necessary to establish a system which helps prevent machine troubles before they happen and which permits taking suitable measures promptly in case some trouble should occur.

With the remote monitoring system for tunnel machine that has been developed recently, it is possible to link to the Internet the personal computers installed at tunnel construction sites for excavation control and to remote-monitor the conditions of the tunnel machines on the screens similar to those used for monitoring in the fields. In the personal computers for on-site excavation control, data about machine operations and sensor-supplied information are stored in files on a time-serial basis. These files are helpful for factor analysis of various troubles. In addition, it is possible to connect the system to the PLCs (sequencers) that are controlling the tunnel machines in operation and to check the machine conditions in detail and modify the programs from a remote site.

This paper describes the configuration and features of the system and the direction of system development in the future.

Key Words: *Remote Monitoring System for Tunnel Machine, Real-time Monitoring, Software for Remote Control, Dial-up Connection to the Internet, Collection of Machine Data.*

1. Purpose of development

In many cases, when it comes to checking the condition of a tunnel machine being operated at a tunnel construction site, it is necessary to dispatch servicepersons to the site. In recent years, more and more of the tunnel machines of Komatsu have been operated both at home and abroad. Therefore, visiting every tunnel construction site to check the tunnel machine condition would take large amounts of money. Besides, since the conventional excavation control system was managed by each individual customer, the machine maker could hardly grasp time-serial data about the machines of the customers. Therefore, it was difficult for the machine maker to determine proper maintenance timings for those machines. In view of those conditions, we developed a remote monitoring system for tunnel machine which permits remote monitoring of tunnel construction sites from the service bases and which can be used to take suitable measures promptly in case some trouble should occur and to implement maintenance of each individual machine at the right time.

2. Outline of the system

The system configuration is shown in **Fig. 1**.

The operation panel of a tunnel machine is equipped with a PLC for controlling the machine. This PLC is used to output operation commands to the individual actuators and to input information obtained by the sensors that are installed in the machine. The tunnel machine is also equipped with a measuring and linearity control system for measuring the current excavation position. This information is also input to the PLC. These pieces of information about excavation are transmitted via a modem from the PLC to the personal computer for excavation control installed in the construction office on the ground several kilometers away from the tunnel construction site so that they can be monitored on a real-time basis. In the construction office, they collect relevant data and control the excavation work and machine condition. All this is the way the conventional control system works at a tunnel construction site.

In the newly-developed control system, the personal computers for excavation control installed in the individual construction offices are linked to the Internet so that the same screens as those displayed on the field personal computers for excavation control are displayed on the remote monitoring personal computers at the service bases. In addition, not only the information obtained by the sensors installed to the machine but also data about machine operations by switches, etc. can be collected and transmitted to the remote monitoring personal computer in the form of files. Thus, the same screen as that of the excavation control personal computer in the field can be seen on a real-time basis and collected data can be managed at the service base far away from the tunnel construction site. This means that the service base can grasp the right maintenance timing for each individual tunnel machine and decide on suitable measures to take in the case of some machine trouble without dispatching any serviceperson to the construction site.

In addition, since the system employs a trade edition of software for remote control, even if the excavation control personal computer installed in the field is not one of Komatsu make, it can be connected directly to the remote monitoring personal computer. Furthermore, since the remote monitoring personal computer allows for 1-to-n connection, it is possible to monitor more than one construction site by a single remote monitoring personal computer of the service base.

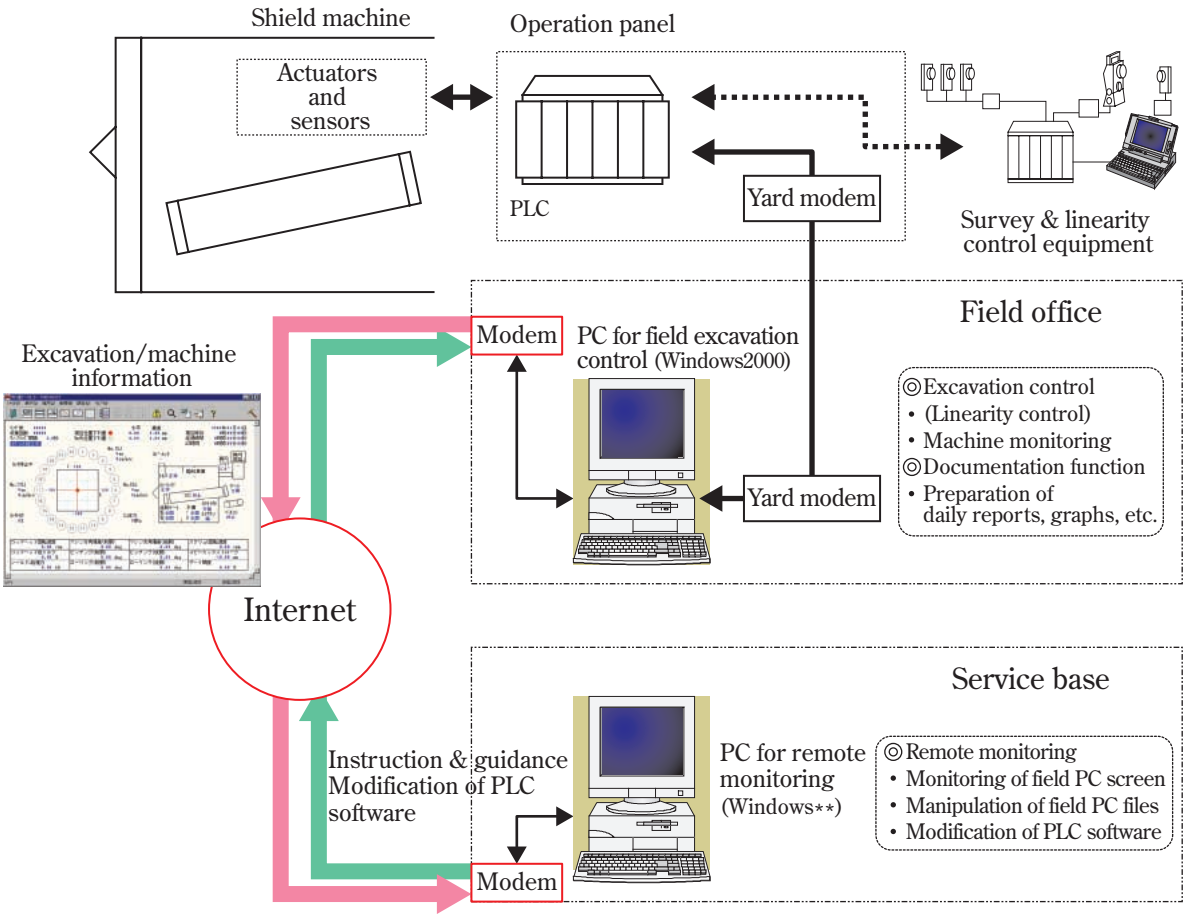

Fig. 1 System configuration

3. Functions of field excavation control personal computer

The personal computer for excavation control installed in the ground construction office at the tunnel construction site is loaded with an excavation control program prepared for each tunnel machine to perform the functions described below. The personal computer is also provided with software for remote control.

① Real-time monitoring

The amount of deviation of the tunnel machine being monitored and the data about machine condition and operation are displayed on a real-time basis on the screen in the form of graphs.

- Monitoring of excavation condition

  An example of excavation condition monitoring is shown in **Fig. 2**.

  The sensor-supplied data (e.g., jack stroke), the excavation condition (e.g., work mode), and the amount of deviation from the planned line measured by the survey & linearity control device are displayed directly and in the form of graphs.

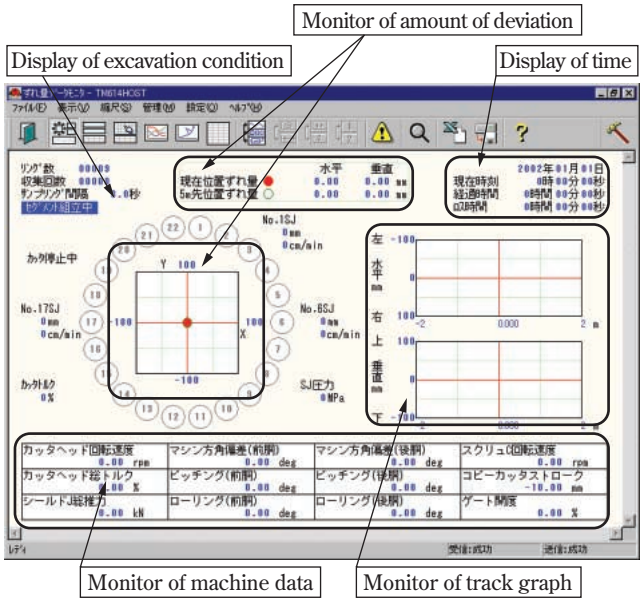

Fig. 2 Example of monitoring of excavation conditions

- Monitoring of machine condition

  An example of machine condition monitoring is shown in **Fig. 3**.

  In addition to the amount of deviation and machine-supplied data, the current operating condition of the machine is displayed on the screen.

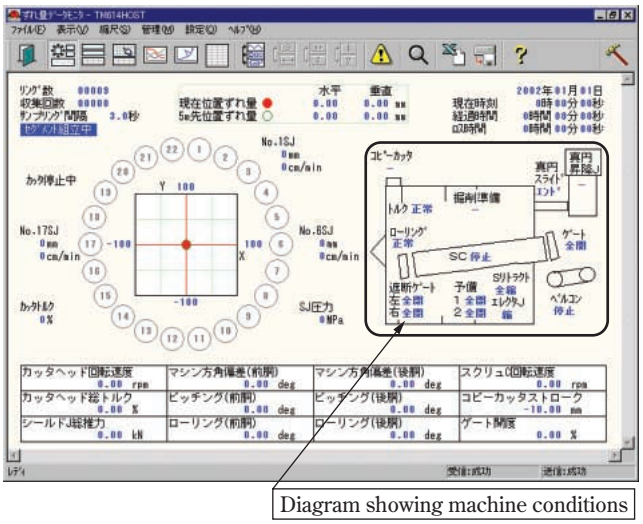

Fig. 3 Example of monitoring of machine conditions

- Monitoring of machine operation

  An example of machine operation monitoring is shown in **Fig. 4**.

  The current settings of the switches for machine operation and the pumps that have been started are displayed.

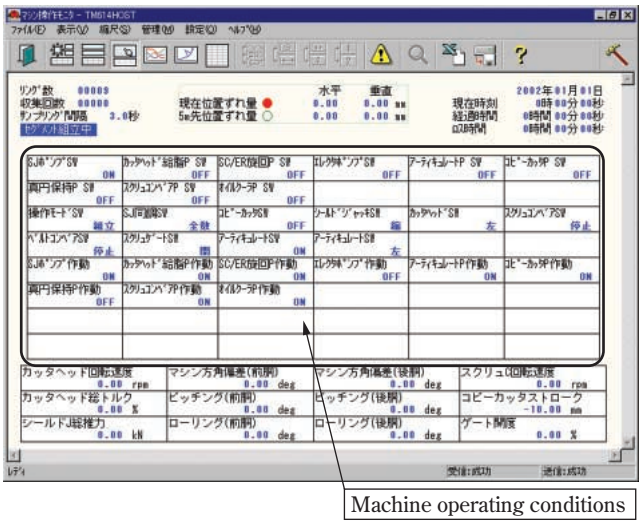

Fig. 4 Example of monitoring of machine operations

② Collection and recording of data

At a preset time interval or after every preset excavation distance, various types of machine data and information about manipulated switches, etc. are saved to a hard disk in the form of files. Since machine data and machine operation conditions are recorded on a time-serial basis, it allows for accurate factor analysis in case some trouble has occurred.

③ Linearity control

Input of planned-line data and indication of the current position relative to the planned line. An example of display for monitoring is shown in **Fig. 5**.

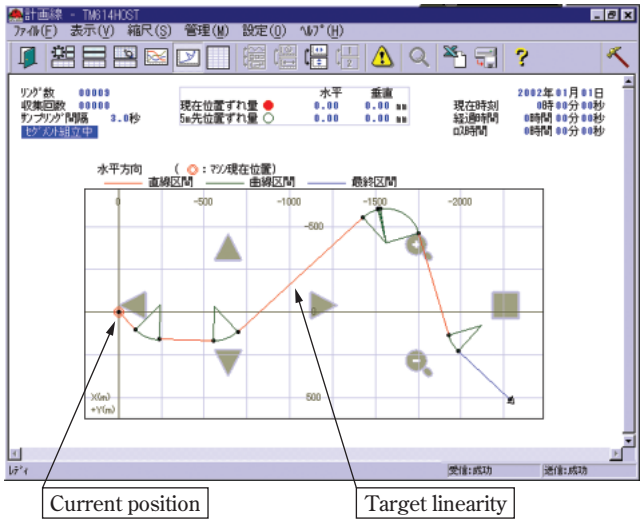

Fig. 5 Example of monitoring of linearity control (planned line data)

④Document control

Preparation of daily reports and graphs from recorded data. The files of collected data are in the form of text files. In order to permit utilizing collected data effectively, the document control software that operates on EXCEL develops the contents of the text files on EXCEL and displays the item names, switch names, etc. contained in the machine data so as to make the documents easy to read. This is intended also to facilitate sorting and printing machine data on EXCEL. An example of a daily report is shown in **Fig. 6**.

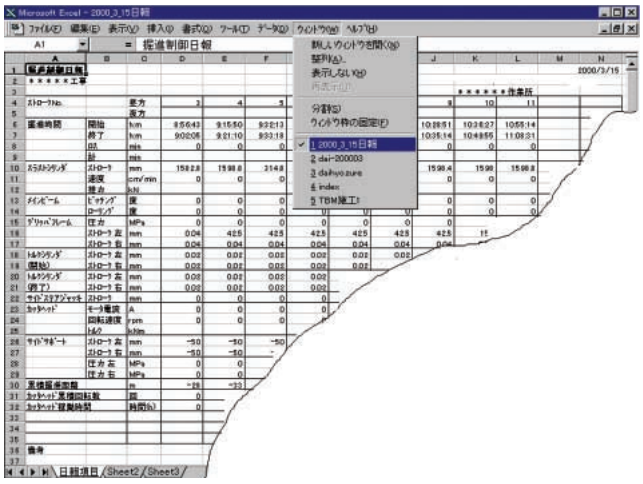

Fig. 6 Example of daily report

4. Functions of remote monitoring personal computer

The remote monitoring personal computer installed at the service base is loaded with a trade edition of software for remote control to perform the following functions.

① Display

The screen of the excavation control personal computer in the field is directly displayed on the remote monitoring personal computer on a real-time basis to permit remote monitoring.

② File transfer

Data files stored in the excavation control personal computer in the field are transferred to the remote monitoring personal computer. By periodically obtaining recorded data from the field and monitoring the machine condition, it is possible to prevent machine troubles before they happen. In addition, if some trouble has occurred, it is possible to promptly analyze factors in the trouble by using the latest data collected before the trouble occurred.

③ Chat function

The persons in the field and the service base can have a conversation and exchange messages while watching their screens.

④ Dial-up connection with the Internet

This function connects the excavation control personal computer in the field to the Internet. An example of screen setting is shown in **Fig. 7**.

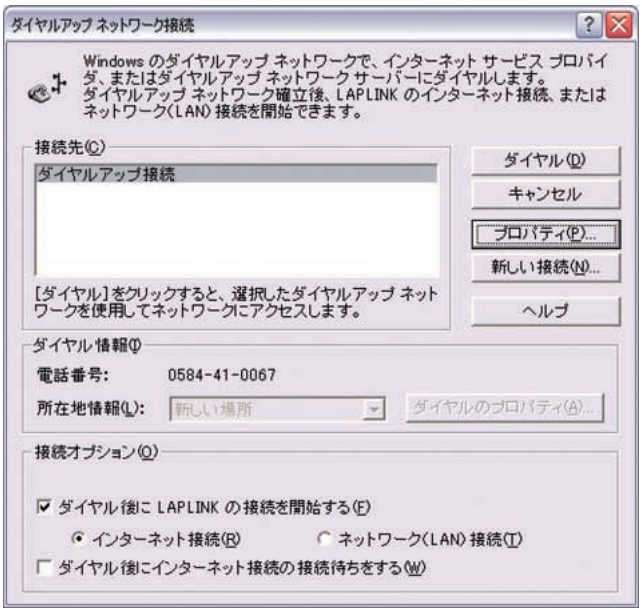

Fig. 7 Example of screen for dial-up/connection to the Internet

⑤ Remote control

This function permits the remote monitoring personal computer to work on the system of excavation control personal computers and Windows applications in the field.

⑥ Control of PLC for controlling machine

By installing the PLC ladder editing software (GPP) in the excavation control personal computer in the field and connecting the remote controlling personal computer to the PLC for machine control via a modem, it becomes possible for

the remote monitoring personal computer to start the ladder editing software of the excavation control personal computer and thereby monitor or control the PLC for controlling the machine. With this function, even the information which cannot be monitored by the excavation control personal computer can be monitored by the remote monitoring personal computer as long as it is connected to the PLC. In addition, when it becomes necessary to modify the PLC software, the necessary modification can be made from the remote monitoring personal computer (as though the modification were made from the excavation control personal computer).

5. Software for remote control

The excavation control program installed in the excavation control personal computer in the field is prepared according to specifications of the tunnel machine used. Therefore, the method of display, the data handled, etc. differ from one program to another. Besides, the program installed in the personal computer must not necessarily be one of Komatsu make. It would require large amounts of investment to develop a remote monitoring software package for each of excavation control programs which differ from one field to another. Besides, it is impracticable because all the tunnel machines in operation must be controlled independently.

Therefore, it was decided to install a trade edition of remote control software in each excavation control personal computer so as to enable it to deal with diverse situations at reasonable cost.

6. Connection test results

A personal computer for excavation control and a personal computer for remote monitoring, each equipped with a 56k modem, were connected to an Internet provider by dialing up from a company telephone to confirm whether or not they would display data correctly and perform their functions properly while execution of remote control. The communication speed used was 28.8kbps.

At first, the excavation control program was obtaining machine data serially from the PLC every one second and reproducing and displaying the entire screen at that timing.

As long as the excavation control personal computer was used independently (without implementing remote control), it was operating properly without any problems with its display capability and operational performance. However, when remote control was put into effect, the operational performance of the excavation control personal computer declined (i.e., slowdown in speed of movement of the mouse pointer, display of dialogs, etc.).

In addition, at the remote monitoring personal computer, the time interval of screen display (renewal) increased to more than 10 seconds, showing no real-time capability.

That was ascribable not only to the slow communication speed but also to the fact that the frequent reproduction of the entire screen caused the volume of communication data to become substantially large. Therefore, we modified the excavation control program so that it reproduces only those parts of the screen which undergo an alteration of data and/or status.

As a result, the excavation control personal computer improved in both display capability and operational performance to such a level that it would pose no practical problems in implementing remote monitoring.

We carried out another test assuming our Komatsu plant in Ishikawa Prefecture as the construction site (excavation control personal computer) and Kanagawa Prefecture as the service base (remote monitoring personal computer). In this test, the PLC ladder editing software installed in the excavation control personal computer was started from the remote monitoring personal computer to modify the PLC software. The two personal computers were connected to the Internet in the same way as mentioned above.

Because of the slow communication speed (28.8kbps), the response speed was slow. Nevertheless, the modification of the PLC program could be made as planned. This fact made us think that the system would be workable even with such a slow communication speed.

7. Direction of system development in the future

We consider that with a higher communication speed, the problem of slow response observed in the above tests will dissolve itself. However, unlike business offices or general homes, construction offices are temporary establishments which are only needed during the period of construction work. In order to have our customers adopt a high-speed communication line and the present system for the purpose of maintenance of their machines, it is important to improve not only the hardware but also the software for follow-up customer services. In the future, we intend to put the system into practical use and strive to become able to offer high levels of customer services in cooperation with the staff of Customer Service.

Introduction of the writers

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[A few words from the writers]

We developed the present system with the aim of allowing the cause of trouble with a construction machine in operation at a construction site to be analyzed from a remote site. We also thought it would be nice if the machine control software too could be modified from the remote site. Our aim has been attained, even though the system is still in experimental stage. In the future, we would like to put the system into practical use with the cooperation of the staff of Customer Services.