Technical Paper

Application of ICT to construction machinery

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ICT (Information and Communication Technology) has been developed at increasing speed recently and is applied to the KOMTRAX® to improve the efficiency of operation, management, and support of construction machinery and to the intelligent execution system to improve the efficiency, accuracy, and safety of civil engineering work. Those systems are overviewed in this paper.

1. Introduction

Recently, ICT (Information Communication Technology) such as GNSS (Global Navigation Satellite Systems) for positioning, satellite communication, cellular phone, Internet, etc., have been developed remarkably and applied to various fields of production, logistics, sales, and service activities. This also applies to construction machinery used in the mines and job sites of civil engineering, the environment of which seem to be far from the ICT. It is an important business issue for each construction machinery manufacturer to construct a low-cost and high-efficiency system of business operation for the customers, distributors, and the manufacturer itself by using the ICT.

It is often said that the ICT is a tool, it is not our purpose to introduce the ICT into Komatsu construction machinery. Our final purpose is to create a system which contributes to the reduction of operating cost for the customers by improving their operation management, the increase of customer satisfaction level for the distributors by providing proper and efficient product support tool, and the increase of competitive edge of our products. In other word, we aim to create a system that benefits the customers, distributors and us, creating a win-win tripartite relationship among them. (**Fig. 1**)

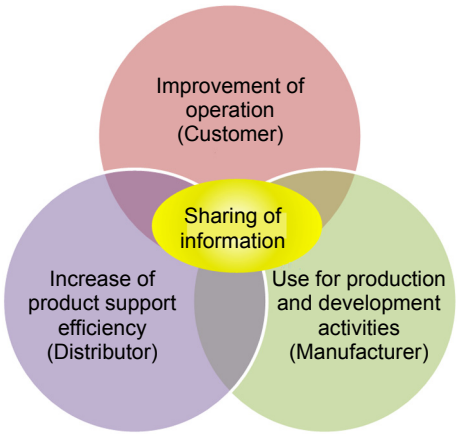


Fig. 1 Purpose of application of ICT to construction machinery

In this paper, among the ICTs introduced into Komatsu's construction machinery, we will focus on remote machine operation management system "KOMTRAX®" used to improve the product support activities and assistance for customers' activity and intelligent execution system "iB" (Intelligent Blade control system) to be developed as an execution supporting technology for the customers.

2. Remote machine operation management system “KOMTRAX®”

Many readers may know KOMTRAX® since it has been introduced in many occasions and media. The number of machines equipped with this system has exceeded 200,000 in the end of 2010. While KOMTRAX® has spread as a full-fledged global ICT system for construction machinery since 2007, issues associated with its global diffusion have appeared.

The communication function is essential to a remote machine operation management system such as KOMTRAX®. In general, a communication business or a communication device is required to have official approval or a license in each country. The communication service provider or terminal manufacturer for KOMTRAX® must obtain the communication business license or the terminal authorization from the government of each country where KOMTRAX® will be used, and this is an obstacle to the global diffusion.

Komatsu is now using the satellite communication or the ground wave communication as the communication infrastructure of KOMTRAX®. Each communication method has advantages and disadvantages in service area, communication cost, etc. and we cannot find a communication method perfect for global use.

These problems of the regulations and communication infrastructure cannot be solved easily by only the efforts of a private company, and it takes time to solve them. But considering the service area and communication cost, Komatsu will promote the KOMTRAX® service using the best communication carrier at the time while looking for substitutes constantly.

3. Increasing efficiency of product support activity with KOMTRAX®

3.1 Consumable parts replacement recommendation activity

KOMTRAX® has a function of notifying the replacement time of the consumable parts based on the operating hours. (**Fig. 2**)

[Latest SMR : 5406.0 H (12/20/2010)]

Item	Replace Date	SMR at The Time of Exchange	Hours on Item
Hydraulic Oil	10/12/2010	5131.7 H	274.3 H
Engine Oil	10/12/2010	5131.7 H	274.3 H
Engine Oil Filter	10/12/2010	5131.7 H	274.3 H
Fuel Filter	10/12/2010	5131.7 H	274.3 H
Hydraulic Oil Filter	10/12/2010	5131.7 H	274.3 H
Hydraulic Tank Breather	10/12/2010	5131.7 H	274.3 H
Fuel Pre Filter	10/12/2010	5131.7 H	274.3 H
Hydraulic Oil	10/04/2010	5101.3 H	30.4 H
Engine Oil Filter	07/26/2010	4828.7 H	302.9 H
Engine Oil	07/19/2010	4793.6 H	338.0 H
Engine Oil Filter	02/10/2010	4327.5 H	501.1 H

Fig. 2 Screen for notifying consumable parts replacement time (Image)

Komatsu distributors can check the conditions of machines which they are in charge of servicing by referring to this information. If needed, they can recommend the customers to replace the parts on the phone or replace the parts actually. This information from KOMTRAX® allows the distributor to have chances to increase the sales of the consumable parts and the customers to take proper remedies before their machines are damaged seriously, preventing a large repair cost in future.

3.2 Increasing efficiency of service person visiting activity

On the KOMTRAX® screen, it is possible to list the machines that need replacement of consumable parts or have errors or cautions and indicate those machines on the map. When there was not a remote machine operation management system like this, service persons had to visit the customers and check their machines, and it was not easy actually. Since the job site of a customer is not always fixed but is changed frequently in general, a service person had to visit the current job site while contacting the customer’s office by the cellular phone. It took several hours to reach the job site in some cases.

With KOMTRAX®, the service person can check the location of the machine on the map and can grasp the occurring errors and machine conditions, so he (she) can prepare the necessary replacement parts and tools efficiently before visiting the machine. In addition, by using a cellular phone or a GPS terminal, the manager of the distributor can check the location of a traveling service person or service car and have him (her) visit the nearest customer who needs service.

4. Subjects in customer operation improvement activities with KOMTRAX® and solution of them

As described in the opening of this paper, application of ICT to the construction machinery must increase the operation efficiency and reduce the operating cost, resulting in an increase of customers’ profits.

Generally, the owning and operating cost of a construction

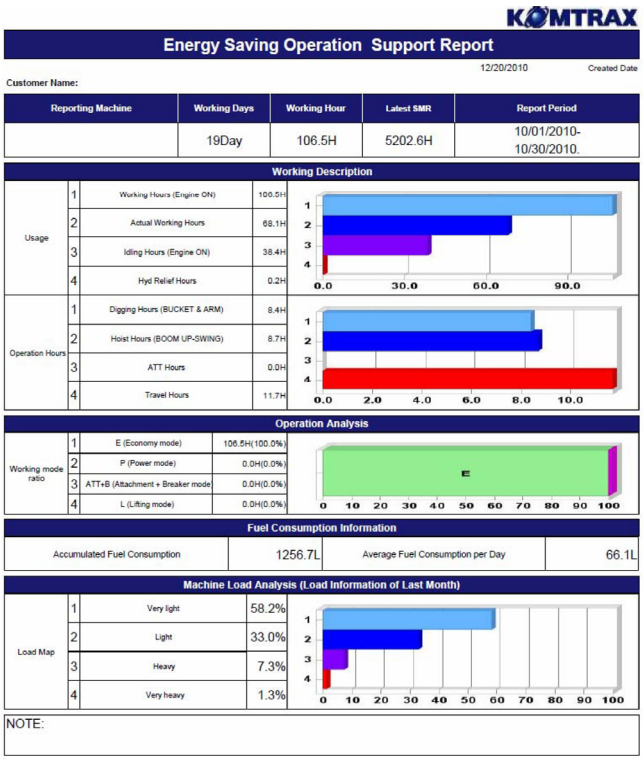
machine including the fuel cost, maintenance cost, operator cost is much higher than the purchase price considering the life cycle cost of the machine. [2] Accordingly, if we propose an effective reduction measure of the owning and operating cost, including the fuel cost and operator cost, the customers' operating cost can be reduced largely.

4.1 Proposing energy saving operation

As the concern about the environmental issues increases and the fuel cost rises, restriction of the fuel cost becomes the most important issue to the construction machine users and development of energy saving machines is the supreme task to the construction machinery manufacturers.

Meanwhile, it is known that the operation method affects the fuel consumption largely. In the examples of the energy saving operation training held in Komatsu Techno Center, the fuel consumption of the same hydraulic excavator operated by the trainees was improved by about 10% on average after the fuel saving operation training. Some trainees improved the fuel consumption per production by more than 30%.

In an effort to assist energy saving operation like this, KOMTRAX® provides the customers with the "Fuel saving operation assistance report" that includes the information on the machine operation and the advices for fuel saving operation. (**Fig. 3**)


KOMTRAX

Energy Saving Operation Support Report

12/20/2010 Created Date

Customer Name:

Reporting Machine	Working Days	Working Hour	Latest SMR	Report Period
	19Day	106.5H	5202.6H	10/01/2010-10/30/2010.

Working Description

Usage	1	Working Hours (Engine ON)	106.5H
	2	Actual Working Hours	68.1H
	3	Idling Hours (Engine ON)	38.4H
	4	Hyd Relief Hours	0.2H
Operation Hours	1	Digging Hours (BUCKET & ARM)	8.4H
	2	Hoist Hours (BOOM UP-SWING)	8.7H
	3	ATT Hours	0.0H
	4	Travel Hours	11.7H

Operation Analysis

Working mode ratio	1	E (Economy mode)	106.5H(100.0%)
	2	P (Power mode)	0.0H(0.0%)
	3	ATT+B (Attachment + Breaker mode)	0.0H(0.0%)
	4	L (Lifting mode)	0.0H(0.0%)

Fuel Consumption Information

Accumulated Fuel Consumption	1256.7L	Average Fuel Consumption per Day	66.1L

Machine Load Analysis (Load Information of Last Month)

Load Map	1	Very light	58.2%
	2	Light	33.0%
	3	Heavy	7.3%
	4	Very heavy	1.3%

NOTE:

Fig. 3 Fuel saving operation assistance report

4.2 Increasing trade-in value

As described above, if the trade-in value of the machine is increased, the customers' owning and operating cost can be reduced. Normally, the trade-in value of a used machine depends on the appearance, age, and service meter reading. It can be increased if the operating conditions of the machine are disclosed to the buyers in more detail to convince them that the machine has been maintained securely by using the maintenance record, work load record, etc. saved in KOMTRAX®.

5. Intelligent execution system

Positioning with the GPS has become familiar as used for car navigation or cellular phone, and the method called RTK-GPS for measuring 3-dimensional coordinates precisely has been applied to survey and measurement since it was put to practical use in the middle of the '90s. The computerized execution system that uses this high precision GPS installed on the construction machines appeared around 2000 almost at the same time as the remote machine operation management system. [3]

The intelligent execution system automatically controls the blade of a bulldozer or a motor grader according to the design working diagram for the civil engineering work made with the 3-dimensional CAD. It started spreading rapidly in Europe and USA around 2003. In Japan, Ministry of Land, Infrastructure, Transport and Tourism established the strategy to promote this system for the following purposes; (1) Spread and establish the intelligent execution system as the standard working method in 2012, (2) Spread the construction machines applicable to this system, and (3) Raise talent for this system. (The term "GPS" has been replaced by "GNSS".)

6. Outline of intelligent execution system

The intelligent execution system "iB" is explained below, using the system installed on a bulldozer as an example. As shown in **Fig. 4**, the GNSS antenna is installed directly to the blade through the pole to calculate the horizontal and vertical positions of the blade. The tiltmeter installed to the back of the blade measures inclination of the blade.

The working diagram design data made with the 3-dimensional CAD are installed to the GNSS box, which consists of a color display and control unit and is installed in front of the operator's seat, by using a compact flash memory that is also used for a digital camera, etc.

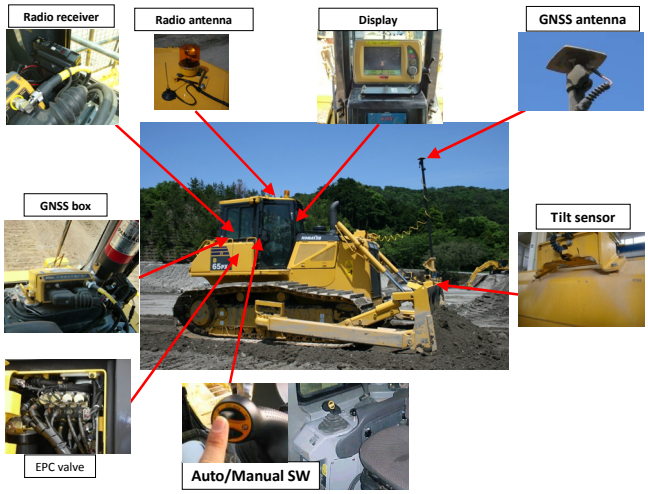


Fig. 4 Example of devices mounted on machine

The display installed in front of the operator's seat displays the current position of the construction machine on the design working diagram in real time so that the operator can check the working condition constantly. (**Fig. 5**)

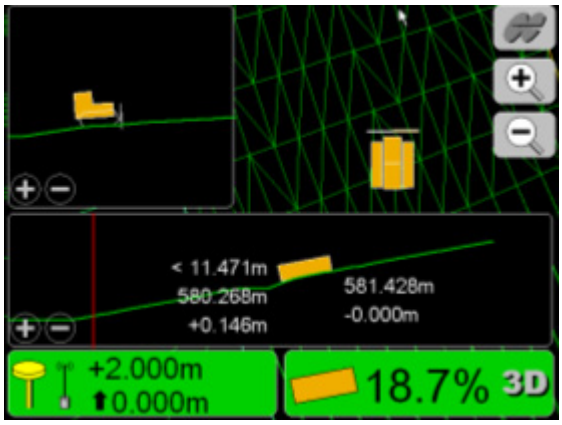


Fig. 5 Example of control screen

The GNSS box also compares the design working diagram data with the position and posture of the blade in real time and actuates the hydraulic valve to control the blade automatically.

7. Improvement of intelligent execution system

The former execution procedure for the civil engineering work is as follows.

① Executing survey of job site
② Making design working diagram according to survey result
③ Installing poles as marks for work in job site according to working diagram
④ Executing work according to marking poles
⑤ Checking that execution is done according to design working diagram

Usually, the poles are reinstalled repeatedly according to repeated inspection and work and progress of the work. Meanwhile, if the intelligent execution system is used, the work equipment of the construction machine is controlled automatically, thus the marking poles are not necessary and the leveling accuracy increases. As a result, the execution efficiency increases.

The above is the intelligent execution system that uses the positioning function of the high-precision GNSS. Recently, sensor-fusion systems have been introduced.

7.1 mmGPS system

This system is made up by combining the GNSS and rotary laser transmitter to increase the vertical positioning accuracy. This system uses the GNSS for horizontal positioning and uses a laser system for vertical positioning. As a result, the leveling accuracy is improved to about ±10 mm, while it is about ±30 mm when only the GNSS is used. (**Fig. 6**)

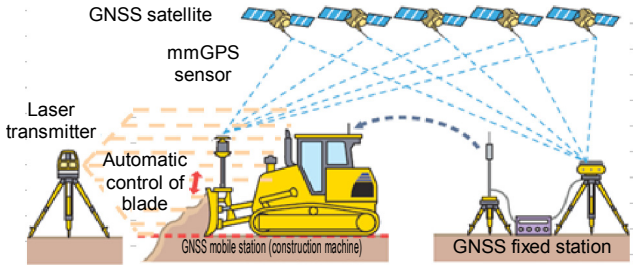


Fig. 6 mmGPS system

7.2 TS system

This system does not use the GNSS for positioning but uses optical measuring instruments. The automatic tracking total station (TS) monitors the prism installed on the blade to calculate the position of the work equipment. This system can increase the leveling accuracy to as high as about ±10 mm.

This system is used depending on the scale and condition of the job site, such as urban civil engineering, tunnel construction, indoor work, etc. (**Fig. 7**)

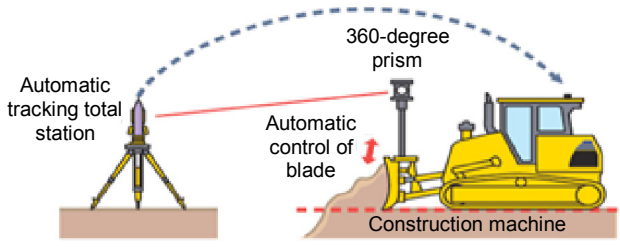


Fig. 7 TS system

7.3 3D-MC^2 System

While the GNSS positioning update frequency is 10 to 20 Hz usually, this system increases it to about 100 Hz by combining with a gyro. As a result, the usable speed range of the machine for executing the work, which is virtually limited to F1 for the former systems, can be increased to F3 virtually to attain high working efficiency, although that depends on the soil type and machine characteristics. (**Fig. 8**)

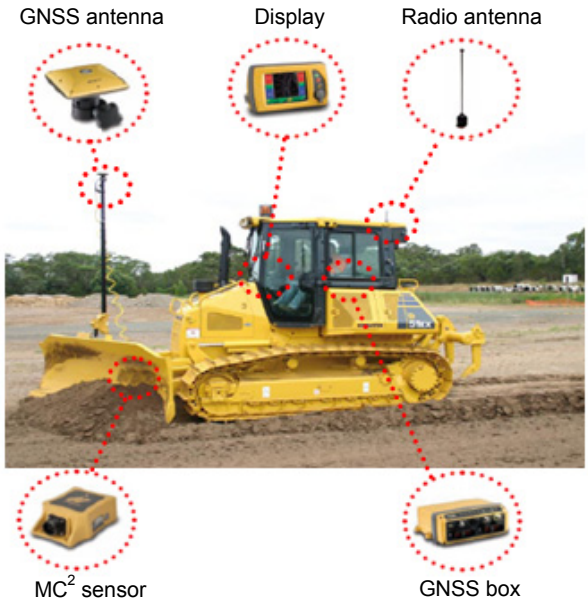


Fig. 8 3D-MC^2 system

Fig. 9 and **Fig. 10** show an example of leveling work on a sandy test ground executed with an 8-ton class straight tiltdozer at high travel speed in F3, etc. The level dispersion is ±10 mm showing that the leveling accuracy and quality of the system is excellent. A similar result is obtained from the test with a 20-ton class machine.

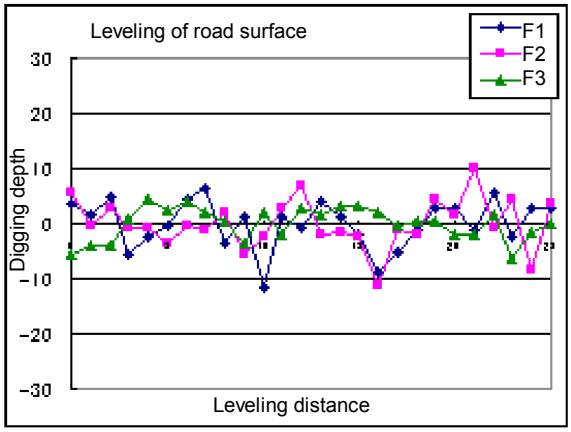


Fig. 9 Leveling accuracy (8-ton class)

Fig. 10 3D-MC^2 leveling performance test

8. Conclusion

Introduction and application of the innovative to the construction machinery have started. We will endeavor to improve and spread our system so that it will be helpful to not only the customers but also development, production, logistics, etc.

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Introduction of the writers

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[A few words from writers]

We introduced the systems of positioning, communication, and display which are in the same technology field but totally different from each other. Improvement of the civil engineering work with construction machinery has been pursued constantly, and we will be glad if we can contribute to development of the construction machinery by using the ICT.