

Introduction of Products

ICT Bulldozer D61EXi/PXi-24, Automatic Dozing Control Improved Technology

Junji Harada

Eiji Ishibashi

As the automatic dozing function based on machine control mounted on D61EXi/PXi-24 has been improved by running change, we make a report on it.

Komatsu released a machine-controlled bulldozer with built-in automatic dozing function in 2013 by combining vehicle body control technology and Global Navigation Satellite System (GNSS). Appearance of the machine-controlled bulldozer has reduced fatigue of operators work and making it possible for less-experienced operators to carry out operation comparable to experienced operators. In addition, it has become possible to obtain three-dimensional data of present topography through traveling by adding positional information beneath the track shoe of bulldozer. It is consistent with the approach of “i-Construction” issued by the Ministry of Land, Infrastructure, Transport and Tourism which aims at improving construction efficiency by combining the whole construction works with three-dimensional data. Komatsu has shown successful results by also utilizing three-dimensional data for construction administration of solution business called “Smart Construction”.

With accumulated actual result in use at various sites across the world, it has been highly recognized after being introduced to the market. On the other hand, there is an evaluation that when the shape of present topography is complicated, automatic dozing work; which can carry out operation comparable to experienced operators, cannot be carried out and therefore operator’s fatigue can not be reduced.

In response to feedback received from the market, running change has been carried out in order to achieve dozing work which is easy for operators to use and comparable to experienced operators.

Key Words: D61EXi/PXi-24, Machine-controlled bulldozer, GNSS surveying technology, Dozing control

1. Introduction

Construction machines that utilize GNSS surveying technology have greatly contributed to reduction of man-hours by abolishing finishing stakes. Also, for the construction machines which perform the finish leveling, a system called Machine Control (hereinafter referred to as MC) has been merchandised which controls work equipment to automatically operate along designed surface. As mentioned at the beginning part, Komatsu has released MC bulldozer mounted with automatic dozing function. Therefore, it was possible to collect demands regarding automatic dozing functions from the market. As the function has been improved by analyzing the demands, we introduce the function focusing on the features.

2. Features of Functions

In case of conventional MC bulldozer, dozing and soil carrying work had been automatized by optimally controlling load to be applied to work equipment and detecting shoe slip from track shoe speed. However, as a result of market research, it has been revealed that efficient construction work cannot be achieved just by controlling load to the work equipment and shoe slip in case of complicated present topography. Specific examples are described below.

- 1) Projections and recesses are generated on the construction surface after automatic dozing.
- 2) Work efficiency is reduced compared with experienced operators.

The most remarkable feature of the machine developed to resolve such problems is that three-dimensional data of present topography obtained by traveling of MC bulldozer is utilized also for automatic dozing.

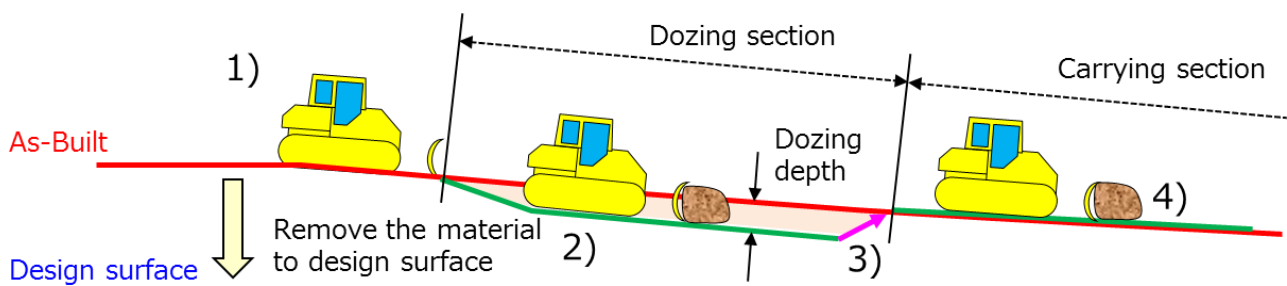
3. New Function of MC

3.1 Automatic Dozing Control Improvement

Firstly, let introduce about the relation to conventional automatic dozing control, in which a control of load to be applied to work equipment is carried out. Blade edge height of work equipment is controlled by operating hydraulic cylinder to be consistent with target load set for the controller in advance. In addition, with a hydrostatic drive type transmission (hereinafter HST) adopted for power train, this machine is capable of calculating traction of the machine body from circuit pressure and rotating speed of hydraulic motor mounted on the left and right sprockets. Load of work equipment is calculated based on the traction considering with correction terms.

Next, let introduce how to detect shoe slip. Speed of moving body of the machine is obtained based on positional information measured in real time from GNSS antenna mounted on the machine body. On the other hand, theoretical travel speed is obtained from rotating speed of sprocket. Slip of track shoe is detected by a ratio of the both. For example, in case moving body speed is less than theoretical travel speed, the track shoe is determined to be slipping. By detection of certain amount of slip during operation, slip is avoided by automatically raising the work equipment to lower the load. However, controlling of blade edge height of work equipment after calculating load applied to it is unable to respond promptly to move up/down the work equipment in a case when machine body speed is high, or steep mountain and valley are on the present topography. Therefore, necessity of operation to move up/down the work equipment in order to compensate such condition was a burden to operators.

This function is capable of recognizing shape of present topography for construction work in advance from three-dimensional data of the present topography obtained by traveling of MC bulldozer. Based on a locus for dozing efficiently calculated automatically from recognized shape of topography, blade edge of the work equipment is controlled to move along the locus. Because of this function, it has become possible to achieve work efficiency comparable to experienced operators even for complicated shape of present topography. In addition, operator comfort at the time of backward traveling has been improved with further smoothed working surface by smoothing dozing locus more than present topography every time. Therefore, ratio of operation to move up/down the work equipment by operator has been drastically reduced. (Fig. 1)






- 1) Moving to a site to start dozing, turn AUTO switch ON of the blade control lever.
- 2) Carry out “Forward traveling + Blade lowering” operation to start automatic dozing.
At this time, dozing locus (green) is automatically generated smoothly and efficiently based on the present topography surface.
Dozing depth can be adjusted by modifying blade load mode.
- 3) It shifts smoothly from dozing to soil carrying before the vehicle slips similarly to conventional models.
- 4) In soil carrying section, blade is controlled to move along the topography to carry soil.

Fig. 1

3.2 Reduction of the Number of Dozing Modes

In case of conventional control, operator was required to select optimal operation mode from three modes (cutting & carry, cutting, and spreading) according to contents of work. However, it is difficult for operators to determine which of the dozing modes is suitable for the current work, and as such it has been revealed in the market that respective dozing modes are not successfully used depending on the purpose. Since the function has been improved such that all of assumed work contents are covered by one of the dozing modes (cutting and carry), operator does not need to select a mode. (Table 1)




Table 1

Contents of work	Conventional options	New Functions
Dozing and soil carrying	 Cutting & Carry	 Cutting & Carry
Dozing	 Cutting	
Spreading and grading of soil	 Spreading	

3.3 Selection Function of Dozing Locus Depth

In conventional control, three patterns of “Blade load mode” have been prepared for operators to select load quantity to be applied to work equipment depending on the work contents and type of soil. In case of this function, what is important in automatically calculating dozing locus is “how deep does the operator intend to doze”. Since the “depth” is considered to differ depending on the work contents and type of soil similarly to conventional control, its operability is kept by incorporating “depth” setting in the “blade load mode” of conventional control without increasing number of patterns. (Table 2)

Table 2

	Blade load mode	Reference of dozing depth	Contents of work
	Light load	Depth: 10cm {0.3 ft.}	Work for dozing shallowly and long
	Standard (Medium load)	Depth: 15cm {0.5 ft.}	During normal operation
	Heavy load	Depth: 20cm {0.7 ft.}	Work for dozing deeply and shortly

3.4 Introduction of Manual Collaborative Control

In case of MC bulldozer, operator’s operation is prioritized for safety reason if the operator operated work equipment during automatic control. However, conventional control has two problems. The first problem is that target of load to be applied to work equipment is not set by operator’s operation. Therefore, after operator moved up/down the work equipment trying to adjust load quantity to be applied to the blade during automatic control, the control works to achieve the target load again. The second problem is that target of tilting angle is not set by operator’s operation. The target tilting angle is controlled so as to be parallel to the final finishing design surface. Therefore, even if the operation of tilting direction is performed in order to change the target tilting angle, the control works to make it in parallel again with the design surface after the operation is stopped. Thus, it has been revealed that operators feel disaffected by the fact that results of their operation of the work equipment are not reflected on automatic control.

As a solution for the two problems, manual collaborative control has been introduced. This control always monitors how the operator operates work equipment during automatic control and judge what the operator intends to do from the operation of the work equipment. By reflecting the judgement results in the automatic control, automatic control has become operable by operator at will. The control is introduced below in detail.

3.4.1 Operation to Move Up/Down the Work Equipment

The control determines whether operator intends to increase/decrease load to be applied to work equipment or depth of dozing based on the operation to move up/down the work equipment during automatic control. It is possible to increase/decrease load or adjust dozing depth as intended by operator by automatically modifying the dozing locus from the determined results. (Fig. 2)

3.4.2 Tilting Direction Operation of Work Equipment

The control determines by what tilting angle operator intends to operate based on the operation in tilting direction. Target tilting angle before operation is in parallel with final finishing design surface. However, it is possible for operators to adjust tilting angle at their will by automatically modifying target tilting angle from determination results after operation. (Fig. 3)

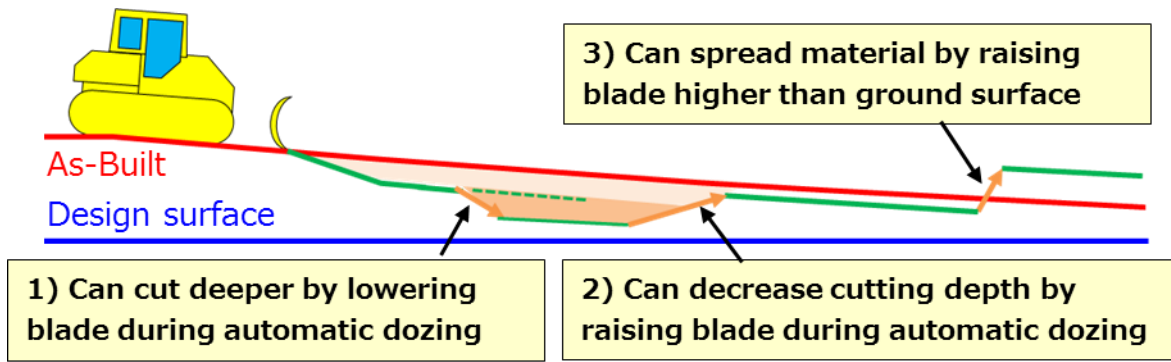


Fig. 2

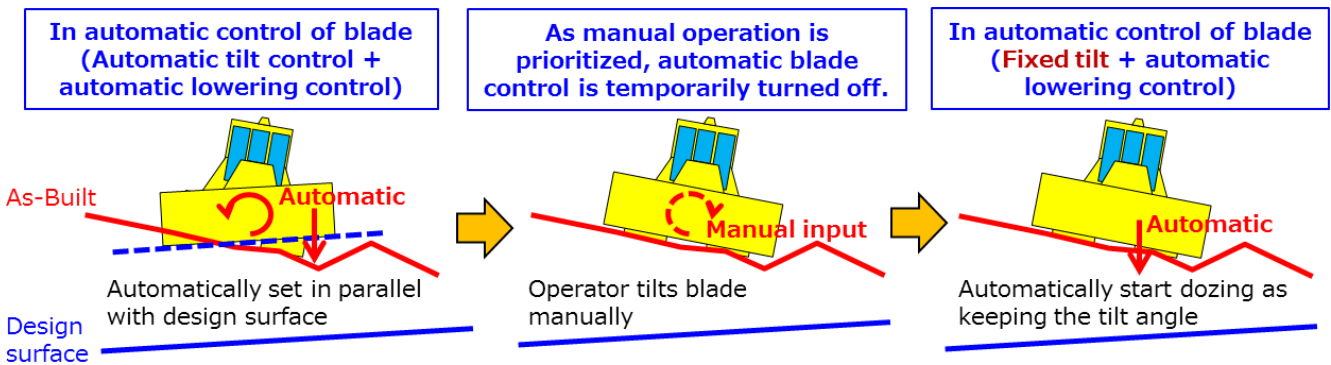


Fig. 3

4. Evaluation of New Functions

In order to confirm effects of new functions, comparison data of automatic dozing work test is shown below. Work equipment is not operated during automatic control. Soil

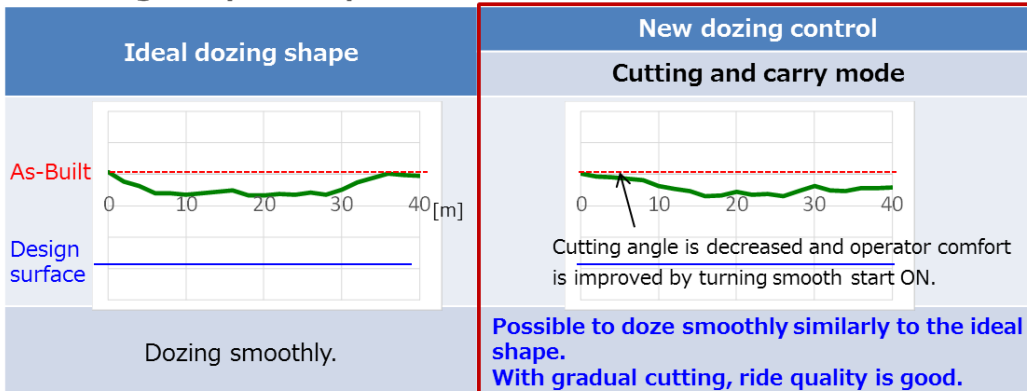
dozing quantity per hour has significantly increased compared with a case of conventional control. In addition, it is possible to realize dozing shape close to ideal one and smooth shape to provide good operator comfort. (Table 3)

Table 3

<Comparison test result>

	New dozing control	Conventional control
	Cutting and carry mode	Cutting and carry mode
Soil quantity ratio per hour	1.4	1.0

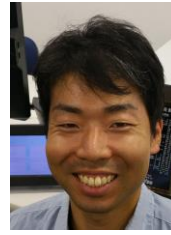
<Dozing shape comparison>



5. Conclusion

In relation to MC bulldozer “D61EXi/PXi-24”, three-dimension data of present topography was not applied to MC by conventional control and only used as construction management by site supervisor. Currently, we have successfully improved construction efficiency of automatic dozing to equivalent level of experienced operator by developing it to be able to utilize present topography for MC. Furthermore, it has evolved into MC bulldozer easier for operators to handle by introduction of manual collaborative control which performs automatic adjustment by operator’s work equipment operation. It is results of earlier merchandising of MC bulldozer mounted with automatic dozing function as well as collection and analysis of clients’ requests. As ICT and construction technologies keep developing, we will strive to continuously improve MC bulldozers through field surveys and analyses as well as to work as a business partner indispensable for clients.

Introduction of the authors



Junji Harada

Joined Komatsu Ltd. in 2007.
Development Center 2,
Development Division



Eiji Ishibashi

Joined Komatsu Ltd. in 1999.
Development Center 2,
Development Division

[A comment from the authors]

I thought it was totally impossible for me to operate the bulldozer when I rode it for the first time due to the difficult operation. However, when I tried to operate a bulldozer developed by myself which could perform automatic dozing and leveling, I was able to enjoy the operation feeling as if I had full command of the operation. I’m convinced that clients who want to operate bulldozer may increase triggered by this function. We have determined to continuously pursue such product development that may fully satisfy clients.