APPLICATION OF 3D-MC FOR ROAD CONSTRUCTION MACHINE

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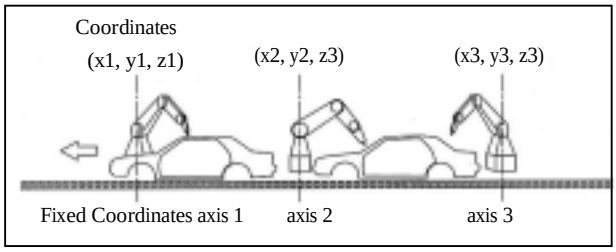
Abstract : Rapid development of computer or communication technology brought the IT, Information Technology, to the road construction field also. IT may include possibility for rationalization of job site work. Among them, new technology 3D-MC, 3 Dimensional Machine Control system, can unify following data, field design, survey, and machine control. Therefore 3D-MC is able to control the construction machine direct with field design data based on CAD. By using 3D-MC will bring cost down to job site.
Kajima Road had applied 3D-MC since 2000, and adapted to bulldozer, asphalt paver, and motor grader. By actual work, we had confirmed the efficiency and the accuracy of the 3D-MC installed construction machines. So we present about 3D-MC installed motor grader.

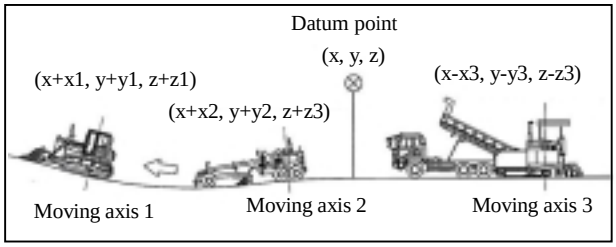
Keyword : Information Technology, 3 Dimensional-Machine Control system, Auto tracking, Total Station, System flow, High Accuracy

1 COPMARE OF JOB-SITE WORK AND FACTORY WORK

As we talk about rationalization of construction work at job site, it is always compared with factory work, and pointed out irrationality of construction work. When the industrial factory robots work, they are controlled with exact position information between tools of robots and processed object. About the job site, construction work is based on the information of coordinates that had been surveyed. As an operator controls construction machine, he uses such surveyed information indirect.



(a) Factory work: The coordinate axis is fixed, easy to sense the coordinates



(b) Job site work: The coordinate axes are always moving, difficult to sense the coordinates

Figure 1. Difference of sensing coordinates axis between factory work and construction work

Information technology, supported by computer, realized survey instruments gained automatic measu-rement function. Such instruments are used not only surveying but also machine control, which contribute rationalization of construction work.
These instruments can transfer coordinates data to construction machine, the transferred data controls actuators of the construction machine directly, this process is very similar to the industrial factory robots. We would like to say automation is no longer only factory robots.

1-1. Manual operation of usual machine control

About job site work, The thing should be do first is setting survey stakes at even interval they are used as reference points while construction work. Machine operator refers these stakes with his eyes as he operate the machine but he need to correct declination of stakes and actual working face, because stakes were set higher than actual working face.
Therefore result of working face or accuracy includes difference in the cause of level of operator's ability.

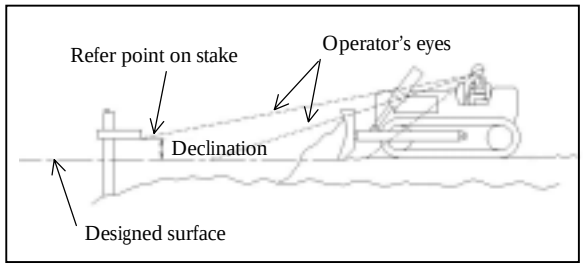


Figure 2. Manual operation, operator refers reference the stakes

1-2. Actual example of machine automation

There is an actual example system of machine automation, is setting surveyed string wires for machine control along the working lane. The sensor, installed on machine, which traces these wires to copy designed shape. This system can reduce the difference of operator's ability, and expect improvement of the accuracy. Especially, this system is used for paving machine. But setting the wire needs a lot of survey work and a large amount of labor.

Photo 1. Stakes for machine control set on slope

1-3. A sphere of construction machine automation

Process condition of construction work is not stayed constant, so almost part of machine work rely on human operation. Therefore the machine full-automation is much more difficult than industrial machine control. Accordingly, we do not need fully automated system, just need the system which supports operator to gain high quality unaffected by difference of operator's ability.

3D-MC can control the construction machine directly with design data, does not need to put stake, can save manpower to put stake and reduce operator load, and can increase safety in the job site, because 3D-MC does not require labors who do measuring around the construction machine. And in the case of using 3D-MC for survey work, a foreman of job site can unify data management.

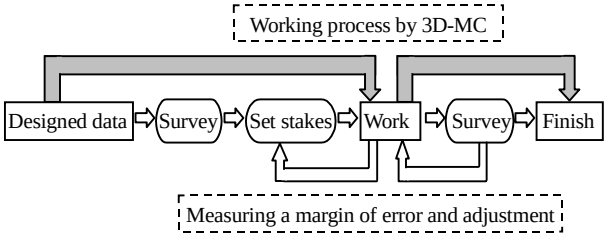


Figure 3. Comparing working process 3D-MC and existing way

2. 3D-MC BASED ON SURVEY INSTRUMENT FUNCTION

In case, the job site design had various longitudinal gradient or cross slope change, a lot of stakes had to be needed. 3D-MC is a system that can be applied the construction work with variable slope.

There are two types of 3D-MC to obtain the coordinates information., one is using GPS, Global Positioning System, satellite data. The other system is using advanced survey instrument total station. This system is known as LPS, Local Positioning System. This report explains concerning LPS 3D-MC.

Total station is a survey instrument that provides the function to sense the coordinates of machine by measuring the distance and the angle of machine from reference point. And total station can record sensed coordinates data. Total station was developed in the 1980s. After that it was added auto tracking function. With this function, survey work could be done by one-man surveyor. LPS-3D-MC is a automation system at construction work based on the technology of the auto tracking total station.

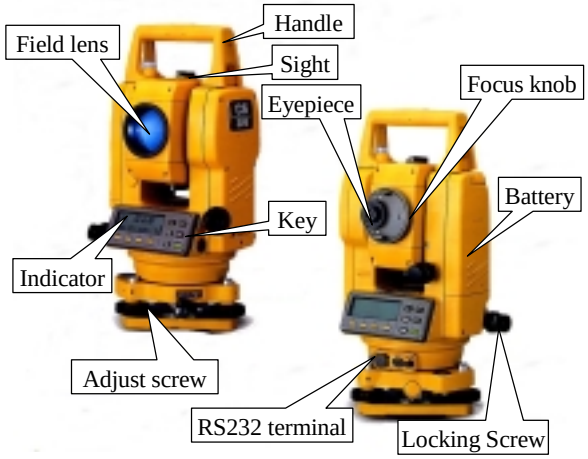


Figure 4. Auto tracking total station

3. OVERVIEW OF 3D-MC

3D-MC, Kajima Road owned, is Topcon made. Topcon is a manufacturer of surveying and optical instrument. The feature of this system is not needed to install a control computer and data communication device in construction machine. Because control laser beam, emitted from total station, provides optical communication function.

System component of 3D-MC grader is shown as figure5. Control process is expressed as follows.

- Total station tracks target prisms fitted on laser receiver on 3D-MC grader, and surveys the coordinates of 3D-MC grader.

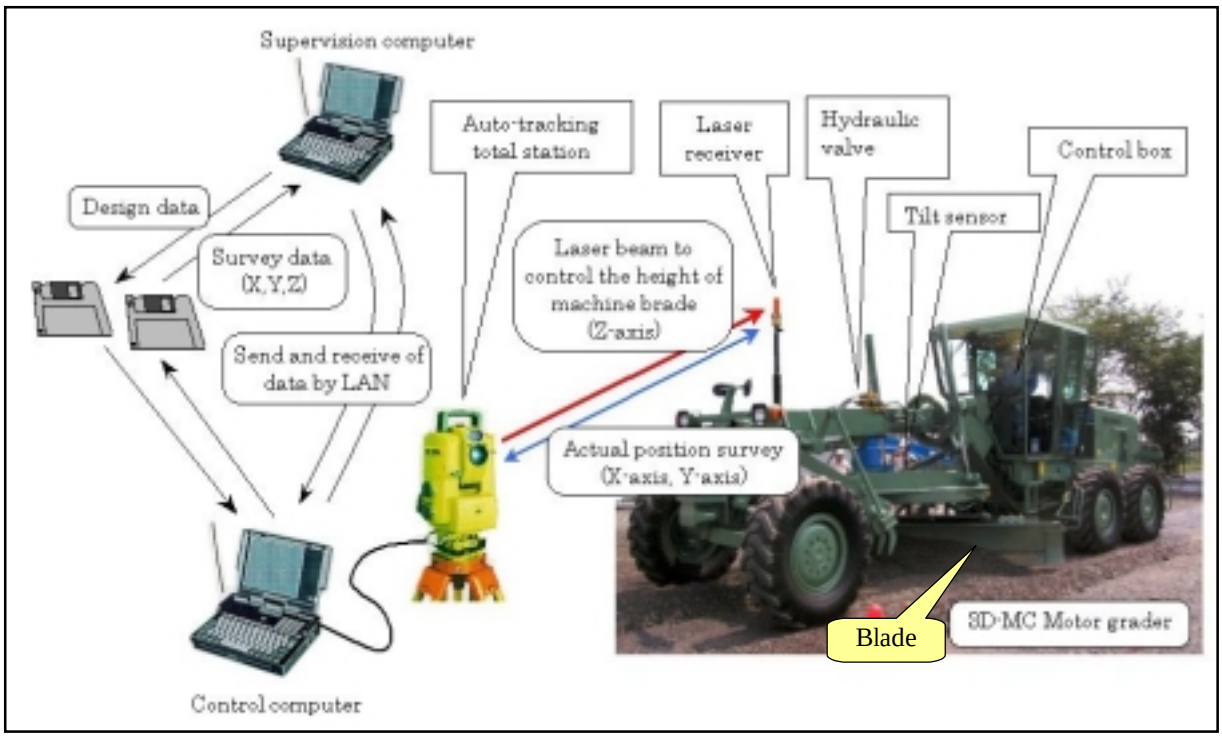


Figure 5. Component of 3D-MC grader

- Total station extracts height and slope data these are consisted with the surveyed coordinates from control computer.
- These data are sent as optical communication on laser beam emitted from total station to laser receiver on 3D-MC grader.
- A blade, actuator of 3D-MC grader, is controlled its height and gradient consisted with the data from transferred total station.

By this means, design data controls construction machine directly. Therefore there is no need to set stakes. And surveyor gets his work easier or burden of operator is much reduced.

4. FUNCTION OF 3D-MC COMPONENTS

3D-MC grader's system flow chart is shown as Figure6.
Main components of this system are explained below.

(1) Auto tracking total station : GRT-2000
Auto tracking total station has been described. It is a main instrument of 3D-MC. Refer figure4.

(2) Laser receiver : LS-2000
Laser receiver is a sensor to receive optical communication data contained laser beam from total station. It transfers the received data to machine control box.

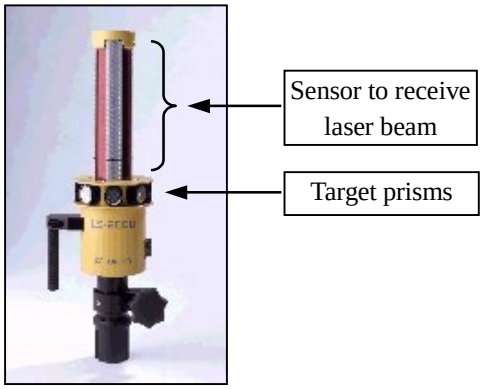


Photo 2. Laser receiver

(3) Machine control box : System five
This is an interface between man and machine, installed in the cabin of grader, provides indicator of the control states of machine. It controls the blade with transferred data. Operator can adjust height of the laser receiver or sensitivity of hydraulic response with the dial on this control box.

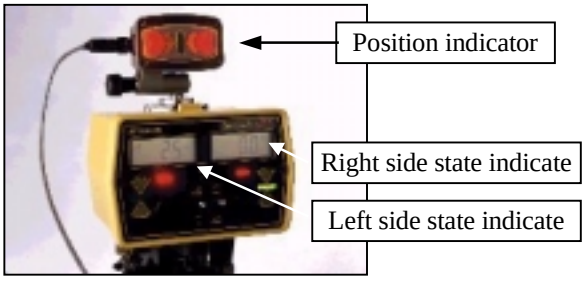


Photo 3. Machine control box

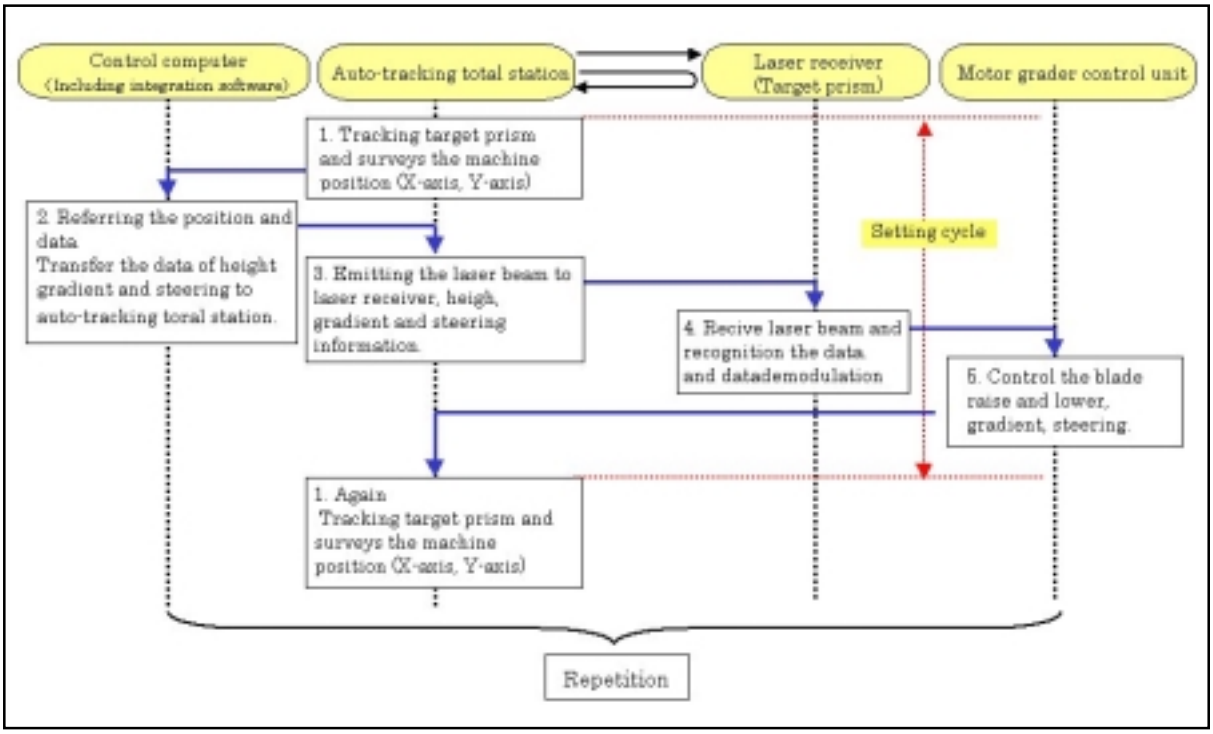


Figure 6. System flow of 3D-MC grader

(4) Software : MS-2000

The control computer is installed 3D-MC special software as MS-2000 that governs 3D-MC. It transfers height and gradient data to total station based on the coordinates data which surveyed by total station.

(5) Control computer : Heavy-duty type

MS-2000 is installed on laptop control computer, connected with total station. It is always brought to job site, so it should be chosen rain proof or dust proof heavy-duty type.

5. OVERVIEW OF TRIAL WORK AND RESULT

5-1. Operation of trial work

Trial work was operated to confirm the accuracy of height and gradient control or responses at inter-section point of cross slope of 3D-MC grader. Trial cases are shown as figure7 and 8.

(1) Trial work : Case1

Setting cross slope superelevation, and separated a few gradient variable area, +2.5%, transition, 0.0%, transition, and -2.5% area.

Such case, rapid change of slope like trial work, is not exist in the actual work. But needed to confirm the response of the actuator.

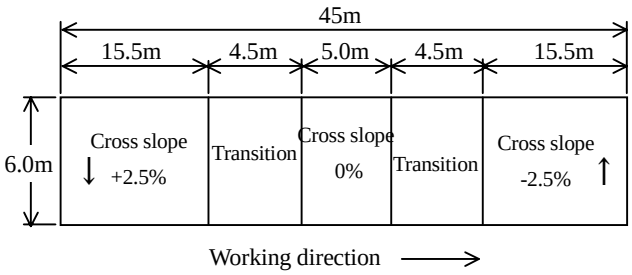


Figure 7. Trail yard : Case 1

(2) Trial work : Case2

The other trial work, amphi-gradiedt cross slope was set. Area is 0.0%, transition, and +-2.0 amphi-gradient. Also confirmed behavior of controlled blade.

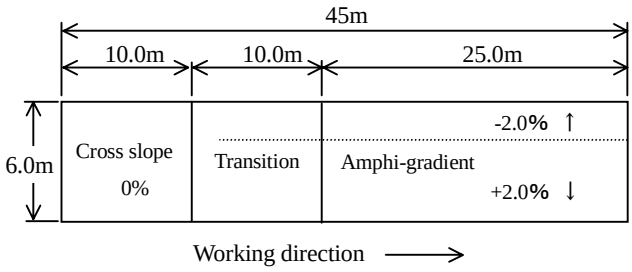


Figure 8. Trial yard : Case 2

5-2. Result of trial work

(1) Accuracy of height level

The result of accuracy of height level is shown as table1. Average of the accuracy of height level was +-2.0mm, even the most difference was within +-15.0mm. Such result was almost same or better than human control. We found one important thing, the value of dead-band affects the result of height level. Setting appropriate value of dead-band brought high accuracy.

	Cross slope	Average	Maximum	Minimum
Case 1	+2.5%	0	11	-9
	0.0%	0	8	-11
	-2.5%	5	15	-3
	Total	2	15	-11
Case 2	0.0%	-7	6	-14
	Amphi-gradient	0	13	-8
	Total	-2	13	-14

(Unit : mm)

Table 1. Accuracy of height level

(2) Sensing of the broken line of amphi-gradient

Software MS-2000 calculates where the center point of the blade is, with surveyed coordinates, and tries to control the blade of 3D-MC grader fits on designed gradient. This control is decided with the position of the center point of the blade, not the position of laser receiver. In the case2, it function was confirmed and controlled better. Figure9 shows this control image.

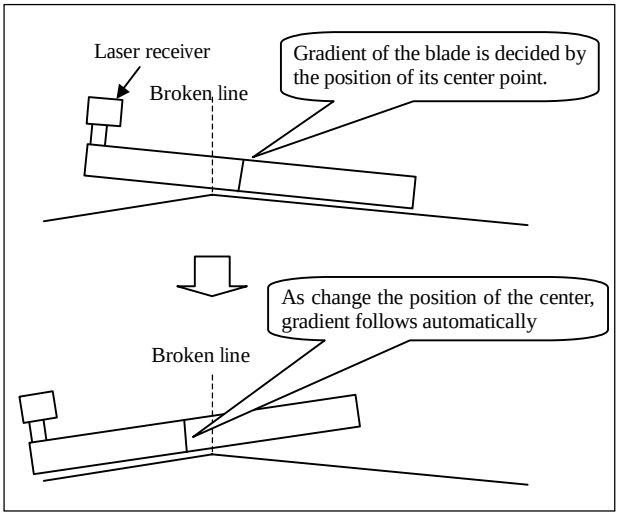


Figure 9. Control image on the broken line

6. APPLIED TO THE ACTUAL WORK

Based on the result of trial work, 3D-MC grader was applied to the actual work.

(1) Actual job site

- Job site : Expressway in Hokkaido Japan
- Total length : 6,560m
- Square : 135,000m2

(2) Result and effect

After working at actual job site work, we obtained advanced term about 3D-MC grader as follows.

- Increase of the productivity

Productivity was more than 3,000m2 by the day constantly. Or more than 4,000m2 productivity was achieved in case of an area with better condition.

By the way, ordinary way of human control was about 2,500m2 productivity by the day.

- Increase of accuracy

Existing method of measuring the height level was done with stakes, therefore measuring points were only stake set points. So the height level between stake and stake were nobody's measurement, accuracy of these interval was depend upon operator's ability. Figure10 shows the image of this relation.

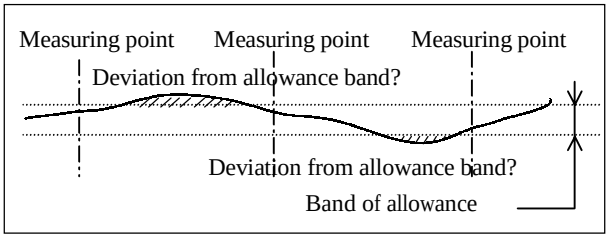


Figure 10. Relation between Height level and allowed band by manual control

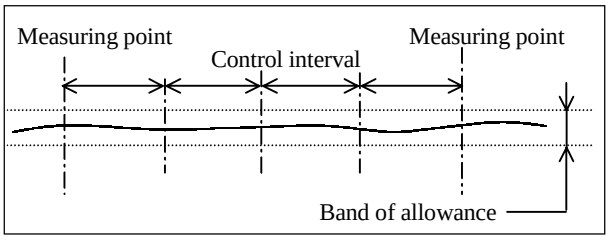


Figure 11. Relation between Height level and allowed band by 3D-MC

3D-MC grader was able to obtain high accuracy of the height level continuously by just once confirm-ation of height level with any stake. In the case of this job site, more than 80% measured point was within +-10mm. This result suggests the possibility for reduction of stakes in the job site and brings the rationality to the next job stage.

Photo 4. Job site work of 3D-MC grader

● Easy adjustment of height control

Operator was able to adjust the height level of the blade in millimeter unit with seeing the indicator of control box, without his intuition.

● Laborsaving and safety improvement

Working by 3D-MC grader was able to reduce the height level measurement, which realized labor-saving. Laborsaving affect to prevent the accident like labor gets hit by machine.

● Unification of data management.

By using 3D-MC, unification of data management was realized.

As same as grader, bulldozer or asphalt paver can be installed 3D-MC to achieve each individual work and can be controlled same design data.

Photo 5. 3D-MC bull-dozer at dam construction

Photo 6. Paving work of 3D-MC asphalt finisher

7. CONCLUSION

We were able to confirm the advantage of 3D-MC.

At the job site, there was a thing worthy mention. An expert operator of grader told he had never seen such superior evenness by grader's work. Which had been worked by 3D-MC grader.

His praise expressed the advantage of this system justly. Hereafter, by applied 3D-MC to various job sites to bring rationalization and we would like to contribute to the lack of veteran operator.

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