Development of Marking System for Construction

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Abstract

In the history of construction, marking has been one of the most critical work items, including some difficult and troublesome points which need to be solved urgently; basically, marking work has been performed resorting to human labor by two workers, necessitating complicated preparation steps especially for marking at higher positions.

Considering these requirements, with labor saving and enhancement of safety on target, we started the development of an automatic marking system which is capable of completing accurate marking work in a short span of time.

The automatic marking system is designed with a rotary laser emitter and with a marking pen which traces the marking line drawn by the emitter; with this system, the marking pen is able to mark an accurate linear line even if the hand holding the marking unit oscillates during work.

This paper reports the summary of the marking system and its application to construction sites.

1. Introduction

The construction industry has made continuous efforts in the rationalization of works by mechanization, setting up the following targets: enhancement of working accuracy, labor saving and reduction of laborious and dangerous works. Currently, various development projects are implemented laying great emphasis on some specialized items, by considering harmonization between human works and mechanized works, and reviewing the effects of rationalization and the spreading of the developed systems.

Execution of construction works, including more numerous kinds of trade than other industries do, consists of work elements needing skilled workers' judgment and technologies. Among them, we selected marking work as a target of mechanization and automatization, because it's mechanization and automatization have made almost no advance, although they are keenly demanded by the industry; on this background, we have developed a very innovative marking system which is able to perform marking accurately and rationally. This paper reports the summary of the system, and the introduction to fields.

2. Summary of the System

The system scans a rotary laser beam to position the marking point on the marking surface, and reference lines from reference point. Use of the system enables to perform easy marking by a single worker, even if the marking surface includes obstacles and recesses. In this point, this method is greatly different from the conventional marking procedure resorting to human power of a couple of workers.

In this system, a rotary laser emitter is set up so that the laser beam from the emitter hits the reference point(s) which is determined in position. By using this system, it is possible to implement marking very easily; a worker,

holding a marking unit in one hand, slides it on the linear orbit which is drawn by the oscillating laser beam from the emitter on the floor, wall and ceiling. Even if the marking unit oscillates when the hand holding the marking unit vibrates on tracing the orbit, marking of lines can be performed accurately.

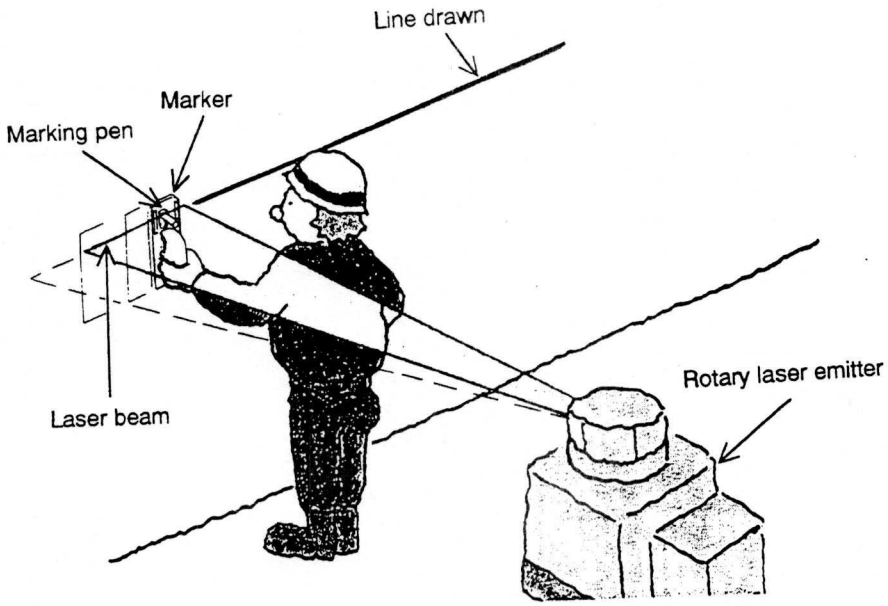


Fig.1 Marking System

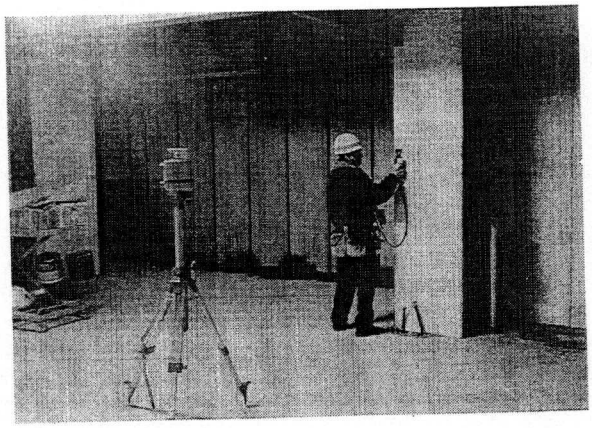


Photo- 1 Situation of the works

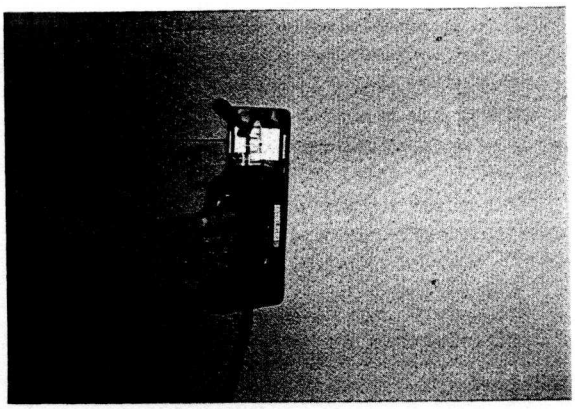


Photo- 2 Marking

3. Merits Brought about by Introduction of the System

- With a single person, marking can be completed within a short span of time.
- On wall and ceiling, marking can be implemented safely.

4. The Marking System Has the Features:

(1) The marking unit is miniaturized in size and light in weight, with a structure well designed with easy handling.
(2) The power source unit and control unit are separated from the marking unit.
(3) Marking color can be changed.
(4) As light source, it uses a laser emitter available on market.

5. Summary of the Marking System

The system consists of a marking unit and of a power-control unit.

The marking unit is provided with two laser beam detection elements (PSDs), a marking pen and a pen position control motor. The marking pen is position adjusted by control motor so that it may locate the position of the laser beam. If the laser beam is insufficient or excessive in amount, the marking unit gives a warning signal by LED lamp, and stops marking in case it may draw a line at other position than desired.

The power unit and control unit are integrated in control circuit, with 12 VDC battery as common power source which can be in service for about 4 continuous hours. The structure of the power/control unit is designed with operational simplicity, featuring two kinds of control switch only: power on/off and off-setting regulation control.

5.1 Composition of the System

Table - 1 Specifications of the system

Machine item	Specifications
Rotary laser emitter	Visible (650 nm) 1 mW or less (Class 2) Scanning rotation in both horizontal and vertical directions Automatic leveling Weight 2.7kg

Marking unit	
(Light source)	
Light source	Laser light (633 to 670 nm)
Output	1 mW or more
Spot diameter	10 mm or less
(Power source)	
Power source	12 VDC battery
Weight	1 kg approx.
(Marking unit)	
Laser light-receiving scope	48 mm
Pen	Roller pen
Ink	Water base paint
Pen-sliding range	±20 mm
Pen-sliding speed	370 mm/sec
Accuracy	±0.5 mm
Allowable temperature and humidity	0 to 40 deg.C, 10 to 90%
Weight	1 kg approx.

5.2 Rotary Laser Emitter

The rotary laser emitter is available on market, which is able to scan a beam of output of 1 mW with wavelength of 630 - 670 nm for a range of 360 degrees rotation; even if the emitter unit is inclined, the emitter is capable of being leveled automatically, using a laser scanning mechanism of automatic tracing type.

On detecting two reflection plates at the marking unit, the laser emitter stops rotating for scanning, and the laser beam follows up the reflection plates by oscillation.

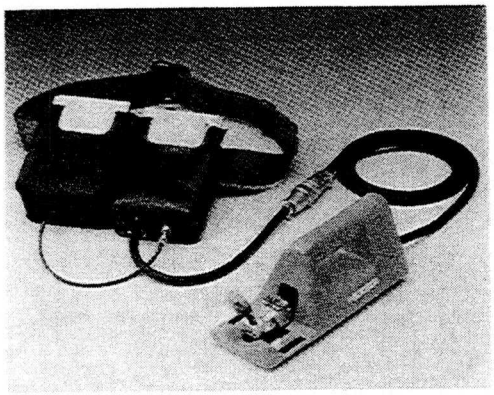


Photo 3 Marking unit and power/control unit

5.3 Structure of the Marking Unit

(1) Structure

The marking unit is provided with two reflection plates which are placed side by side across the central line, with a PSD of light weight and thin type on each side. The PSD is placed to be as close to the marking surface as possible to minimize errors. The marking unit is designed so that it may be slid easily on the surface, with sufficient consideration for size, weight and shape to facilitate handling. The marking pen has a sliding range of 40 mm, and PSD a light receiving range of 48 mm. The spot size (spot width) usable in this range is up to about 10 mm (Fig.2).

(2) Configuration of the system

The scattering light signals received by PSD from the laser beam emitter contain background lights from other light sources (fluorescent lamp, etc.) than the emitter. Therefore, the received light is treated with a high-pass filter to remove background light. The laser beam oscillates continually to drawn a virtual linear line, but it is influenced by oscillation cycle of laser light; in order to remove this effect, the value of laser intensity at the moment the PSD receives the laser beam is peak-held to be identified as a signal giving the position of the beam through analog calculation. So, the mid-point between the signals the two PSDs receive is determined as the position of the beam; the position of the pen is controlled for the pen to be positioned at that of the beam, by zeroing the potential difference between the pen-position signal and the signal of the potentiometer connected directly to the marking pen (Fig.3).

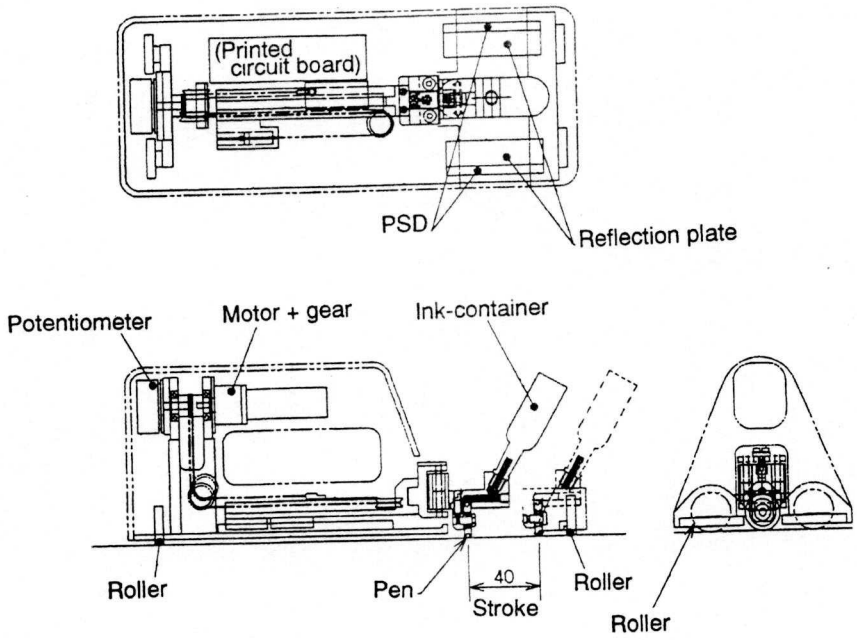


Fig. 2 Marking unit

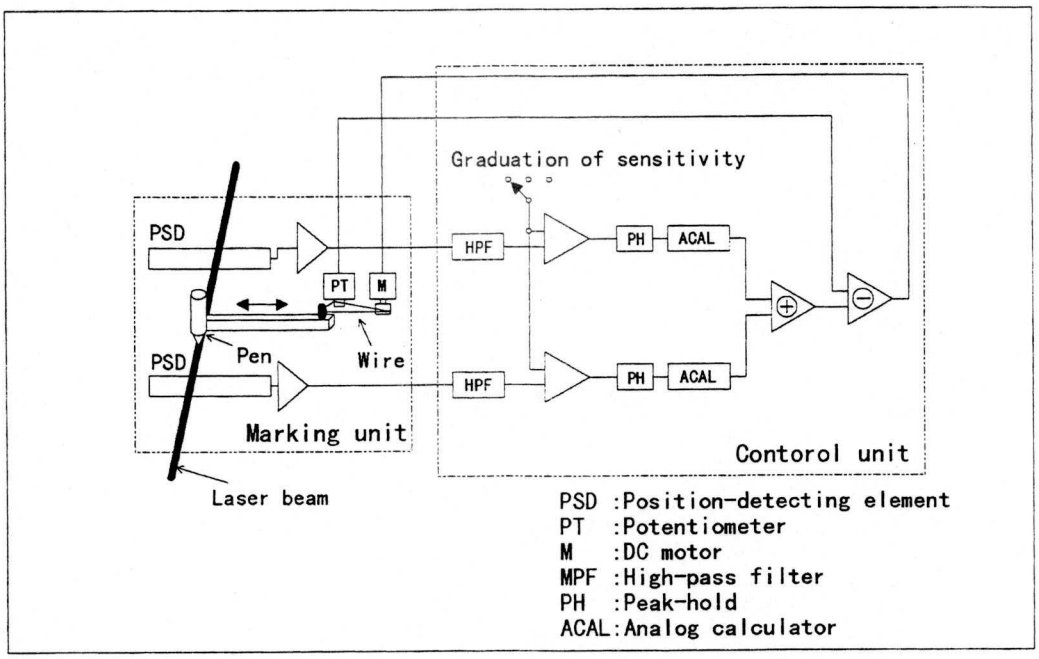


Fig. 3 Diagram

(3) Marking pen

Various kinds of marking method have been experimented and reviewed repeatedly; on the basis of these results, we selected a method of drawing with a roller pen which is ink-fed from the ink container. In this system, ink color can be changed by the attachment of replaceable type for the selection of inks.

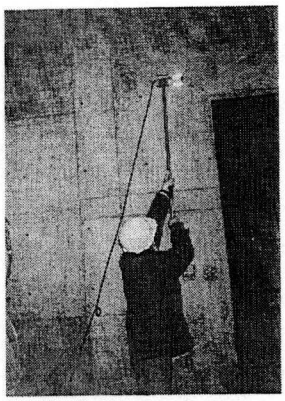


Photo 4 Marking on wall

(4) Marking at upper positions

For marking at upper positions, conventional methods use a stepladder, so the worker is obliged to use unnatural position sometimes when marking. With this system, the rotary laser emitter is directed vertically, aiming at the reference point, and the marking unit is raised using a shaft, so that marking can be performed easily and safely for upper positions (Photos 4 and 5).

Photo 5 Marking on ceiling

(5) Steps of operation (Fig.4)

a. The rotary laser emitter is adjusted in position, so that the laser beam may hit the reference point.
b. The marking unit is adjusted in position, so that the laser beam may hit the light-receiving range of the reflective plate.
c. Touch the marking pen to the marking surface.
d. Slide the marking unit, confirming that the laser beam is kept hitting the light-receiving range; at this moment, the worker should be careful not to intervene between the marking surface and the laser.

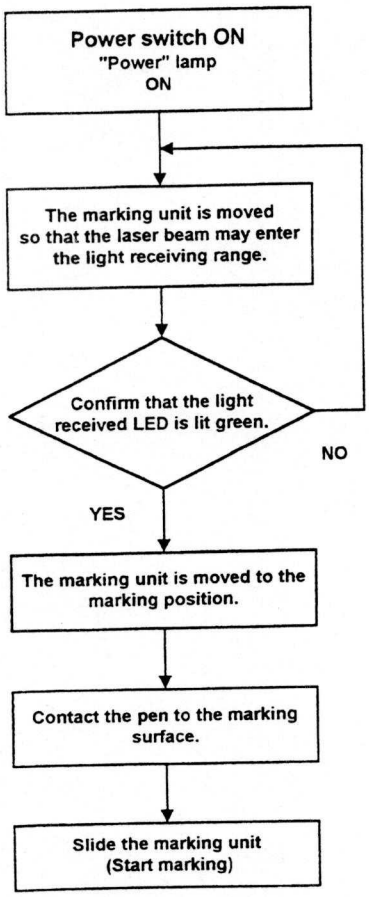
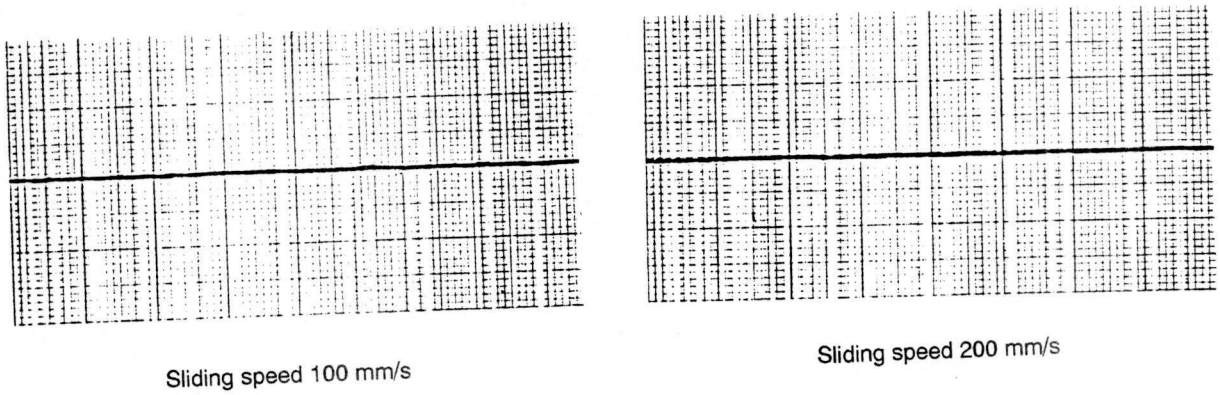


Fig. 4 Flow of Operation

5.4 Results of Marking Operation

- Through this operation, it is confirmed that marking can be satisfactorily made by a single person, and this system is especially effective for leveling.
- The accuracy of marking can be checked for, by changing the sliding speed of the marking unit and confirming that the error is ± 0.5 mm with the sliding speed of a range of 100 mm/s to 200 mm/s (Photo 6, Fig.5).

It is confirmed that the accuracy of the same level can be achieved even with the sliding speed exceeding 200 mm/s, but the line drawn suffers from blurring. So, the most effective sliding speed for the marking unit is less than 200 mm/sec.



Sliding speed 100 mm/s

Sliding speed 200 mm/s

Fig. 5 Marking line (natural size)

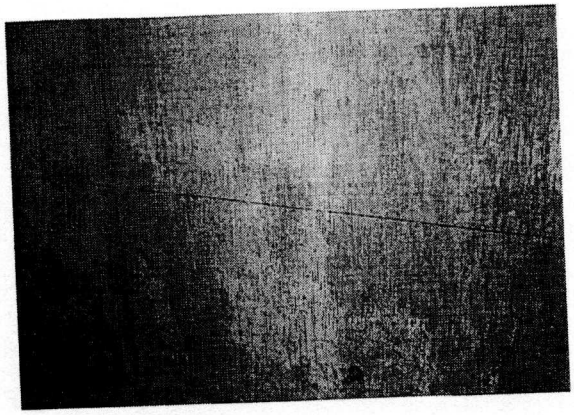


Photo 6 Marking line

Photo 7 Marking on floor

- The laser beam diameter (beam spot diameter) changes with distance from the emitter, but this presents no problems for marking.
- A considerable span of time was needed for setting the laser emitter, but this system is confirmed to be highly effective for marking, because with it, one can implement marking safely even for upper places such as ceiling.
- It is confirmed that marking is possible in a range of angle up to 30 degrees between laser beam and marking unit, i.e., that of the laser beam to the marking surface.

6. Themes to be Solved in the Future and Conclusion

For the moment, there remain some problems to be solved concerning in particular the time span which is needed in setting the rotary laser emitter in place. For the upper portions of the wall, horizontal lines can be marked at ease using a tripod, but marking of vertical lines needs some time in setting the laser emitter correctly in between the reference points, because there is no position regulator for this purpose. Therefore, some improvement should be implemented, including development of a level regulator enabling fine control.

When the marking unit is reviewed in terms of the shape and weight, the size of the marking unit is too large in respect of its handling, so some reviewing including materials is required.

In spite of some required improvements mentioned above, the whole system is assessed to be very effective in function, based upon the results of the experimental use at field.

For the future, our efforts should be directed toward collection of data, improvements based upon the data and spreading of the system in the industry.

7. Acknowledgment

We, Kumagai Gumi Co., Ltd., would like to express our gratitude for the efforts of Ando Electric Co., Ltd. and other participants, under the joint development project.

Reference

1) Development of a positioning and marking system for construction works, Tokioka et al., The 5th Construction Robot Symposium, Japan Robot Association, 1995.

2) Development of a marking robot for construction works, Fujii et al., Ando Technical Journal, 1995.