Automatic Hydraulic Excavator System

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Abstract:-Being really versatile machinery, hydraulic excavators are widely used in earthmoving applications. A standard test procedure requires four main working conditions to evaluate machine performance: trench digging, soil levelling, straight travelling, and low idling standby; for each of them, a standard operating cycle is defined. Among the working conditions, trench digging can be reasonably considered the most significant, therefore, a method to outline energy use characteristic in a trench digging cycle is proposed here along with some applications. The first activity is a real-time acquisition of hydraulic system supply pressure(s) and flow(s) during machine opera-tion, which provides a cycle load map and defines operational sequence (arm retraction, bucket close, boom up, upper-structure swing left, bucket dump, upperstructure swing right, and arm extension). A second step is the discrete integra-tion of hydraulic power values calculated at each acquisition step, which gives a machine energy use characteristic related to hydraulic system working, for the whole cycle and for each cycle phase. A third step is the comparison of energy use characteristics of the same machine doing the cycle without actually moving earth (simulated digging) and moving earth (actual digging). This approach allows the definition of external load influence. A different approach compares energy use characteristics of different machinery performing the same simulated digging. This alternative approach highlights effects of different hydraulic system architectures in machine operation.

Keywords - hydraulic excavator, working cycle, energy use

I. INTRODUCTION

Recently, in the construction industry, the development of automatization and robotization were carried out in order to solve the serious problems such as the shortage of skilled labors, the stagnancy of the labor productivity, and the frequent occurrence of labor accident. However, at the earth works, conventional construction machines are still used with labors.

A skilled operator and a lot of labors are necessary for excavating and finishing ditches by a excavator. But it has become difficult to employ enough labors because of harsh work environment. To accomplish planned works, the development of a new excavator system which is possible to reduce labors and to be operated by an unskilled man, is urgent. In order to meet these needs, we developed the new construction system, in which a laser guide system and an automatic surface finishing system are added to the standard excavator. This paper reports on the outline of this system, the results of field test, and a comparison with the conventional method.

Numerous design variables and constraint functions as well as huge computational cost during the structure reliability evaluation process are associated with the multidisciplinary design optimization (MDO) of the hydraulic excavator working device.

II. THE CONCEPT OF DEVELOPMENT

2.1 Problems of the Conventional Method

At first, the works of excavating of ditches are done by measurement at the previous day and setting finishing-stakes which is a basis of excavation depth.

In excavation works, an assistant labor checks a depth based on finishing-stakes, and teaches its result to the operator in the excavator. And then the operator excavates ditches to the desired depth. By repeating these, they excavate and finish it. After finishing of excavation from a manhole to a manhole, the measurement work and setting finishing-stakes in the ditch are done once again.

The finishing-stakes become the standard position and height of laying a drainpipe. And then, the excavator places crushed stones in the ditch, and a few labors average basing on the finishing-stakes, tighten up with tamping machine, and finish a ditch evenly. These works need a lot of hands. And also, it is necessary to finish accurately with the inclination (generally 1%) for the drainpipe, so accurate finishing of ditches is one of the very difficult works even with a skilled operator.

2.2 Object of the Automatization

To solve above problems, this new system introduces laser guide to make reduction of measurement works and to make assistant members unnecessary. The new system aims that it is possible to finish only by pushing one button even with an unskilled operator. Moreover, it aims to develop the new method that is able to finish crushed stones every stroke with the excavator.

The process of laying the drainpipe is shown as follows.

1) Measurement and setting finishing-stakes

2) Excavating

3) Finishing

4) Placing crushed stones and finishing

5) Tamping

6) Laying a drainpipe

In this system, the object works are limited from 1) to 4) by using the excavator. 5) and 6) works are excepted because the other machines are used in these works.

III. SYSTEM

3.1 System Outline

Automatic excavation system is shown in Fig.l and the system scheme is shown

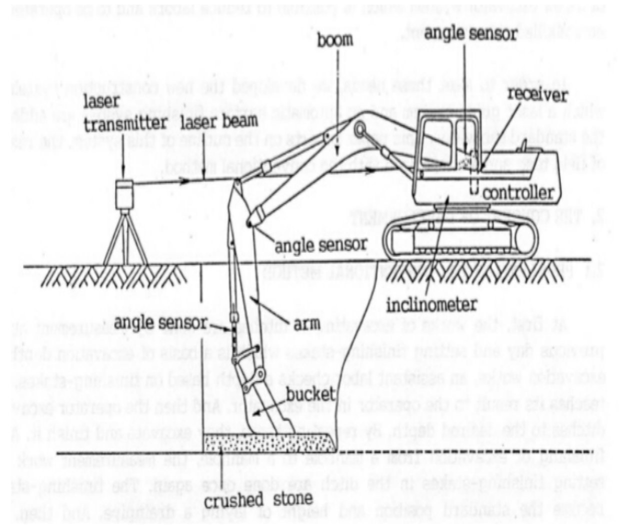

Fig.1 Automatic Hydraulic Excavator System

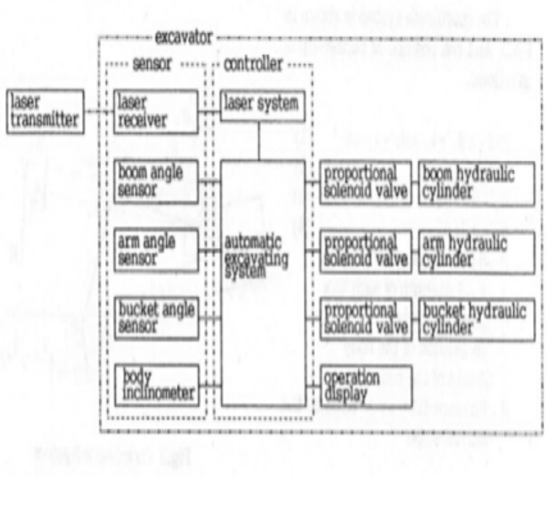

Fig.2 System Scheme

In Fig.2. This system is composed of a rotating laser transmitter which projects laser beam to indicate a desired surface, and the excavator, on which a laser beam receiver, angle sensors, an operation display, a controller and proportional solenoid valves are equipped.

The position of laser beam is detected by laser receiver, and the height information of the excavator body is calculated, and sent to the automatic surface finishing system. In the automatic surface finishing system, with the height information and each sensor's information, a distance from the desired surface to the bucket-tip position is calculated, and is sent as a signal to each proportional solenoid valve to follow the desired trajectory, and each hydraulic cylinder is controlled automatically. In using this system, 1) With the laser system, assistant members are reduced, because the excavation is done without setting finishing-stakes, and the finishing of crushed stones which was done by labors in the conventional method, is done with the excavator. 2) With the automatic surface finishing system, even an unskilled operator can finish accurately.

3.2 Automatic Surface Finishing System

In this system, the starting point for finishing is positioned by manual operation at first, and the excavator automatically finishes a slope gradient which is given by laser plane, move straight line by pushing only one button. This automatic excavator has three angle sensors detecting angle of each joint, and inclinometer detecting the inclination of the body.

The excavator doesn't have a good response like an industrial robot, and also the response of each degree of freedom is very different. So using feedback only of each degree of freedom like an industrial robot can't achieve the desired accuracy. Then we always compute the position of a bucket-tip from the sensors, and compare it with a desired trajectory, and using feedback this result controls each valve.

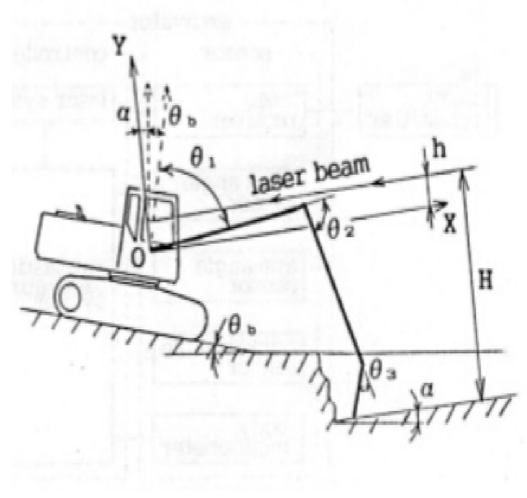

Fig.3: Coordinating System

The coordinate system is shown in Fig.3. And the position of bucket-tip is as follows.

y= 2 1GOS01'+2 2COS 02' + 23 (0503' (1)

0 1'= 0 1+ 0 u- a (2)

0 2'= 0 1'+02 (3)

03'=02'+03 (4)

01,0 2 1 0 .:Angle of each joint

2 1, 2 2, 2 3:Length of each link

a :Slope gradient

0 :inclination of the body

h :Height of the body

H :Distance from laser beam to the desired slope

The desired slope is y,- =-(H-h), so the distance from the bucket-tip to the desired slope is (yr -y), and each valve is controlled so as to reduce this distance. Using this control, it achieved accuracy ± 20[mm]. It shows the example of the trajectory in Fig.4.

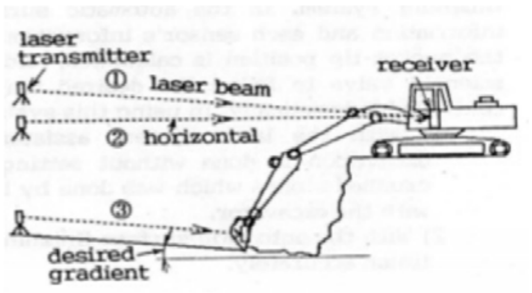

Fig.4: Laser Position

3.3 Laser System

In excavating a long ditch with a constant slope gradient, the positionerror gradually accumulates by using only the automatic surface finishing system, with following reason.

1) Because the operator positions to the starting point for finishing by manual operation,the error accumulates.

2) Because the starting point of next time is connected to the end point which have completed in the last time, the position error which is caused by the control and the use of internal sensors, accumulates.

So we have developed the system which uses laser beam as a guide with a constant slope gradient and watches over the depth of an excavation every time.

When laser beam projects to the horizontal (Z, the depth gradually changes by the distance from the transmitter to the receiver, so it is necessary to measure a distance between the 'transmitter and the receiver. On the other hand, if laser beam is projected parallel with a desired slope gradient, the depth from laser beam to the desired slope is always constant, so (1is more desirable than Q2. Also, as the position of the receiver, because of the bucket-tip control, (3 is the most desirable, but we are afraid of damage of the receiver. Finally, method Q1 was chosen.

With detecting the position of laser beam by the laser receiver, it is possible to detect the height h between the excavator body and laser beam (see Fig.3). Because the bucket-tip position is calculated by internal sensors (angle sensors), the distance from bucket-tip to the desired slope (yr -y) is calculated when the operator input the distance H from laser beam to the desired slope, on the operation display. In this system, this distance (y,, -y) is displayed on the operation display in real time and the operator can confirm it, and also an alarm sound informs the distance when the bucket-tip approaches the desired surface. The specifications of laser equipment used in this system, is shown in Table 1.

3.4 Process of the Works

Process of the work is shown in Fig.5

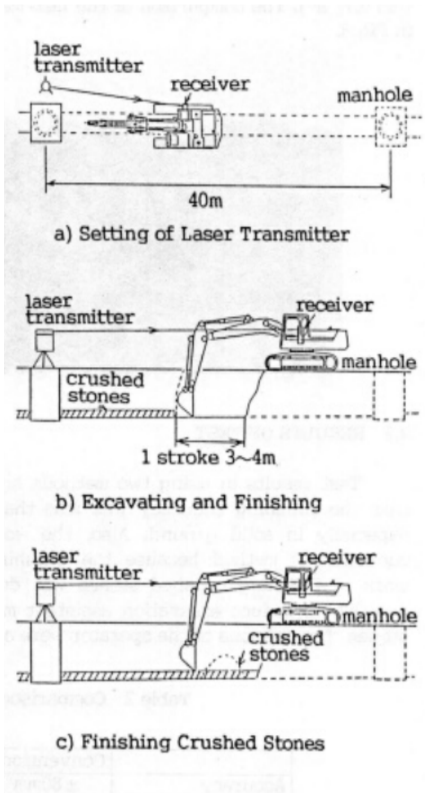

Fig 5 : Process of Work

1) Setting of the laser transmitter Set laser transmitter on the side of a manhole and project the beam horizontally by self leveling function. Incline the transmitter to be parallel with the desired slope gradient. Measure the distance H from thedesired slope to the transmitter and input it on the operation display (every 40[m] from a manhole to a manhole). 2) Excavation (manual operation) Excavate by manual operation until an alarm, which becomes to sound within 100[mm] of the desired depth. On the operation display, the distance of the desired depth is always displayed. 3) Finishing (automatic) Position the bucket to the desired depth by manual operation, by looking at the depth on the operation display. After positioning, push a start button, finishing startsautomatically and releasing the button makes finishing stop. 4) Placing crushed stones

(manual operation) Place crushed stones in the portion of 1 stroke. 5) Finishing crushed stones (automatic) Finish in the same as 3), confirming the thickness of crushed stones (generally 100 [mm]) with the operation display. 6) Moving excavator backward(manual operation) After finishing about 3 or 4[m] by 2) 5), move the excavator backward in 1 stroke, and repeat from 2) to 6).

IV. FIELD TEST

4.1 Test Site

The test scenery is shown in Fig.7. It is a construction site for housing, the works of excavating ditches is a total of 8[km]. To compare the new method with the conventional method, ditches were excavated with two excavators, which were automatic excavator and standard excavator, of the same size which bucket capacity was 0.7[The comparison of the new method with the conventional one is shown in Fig.7.

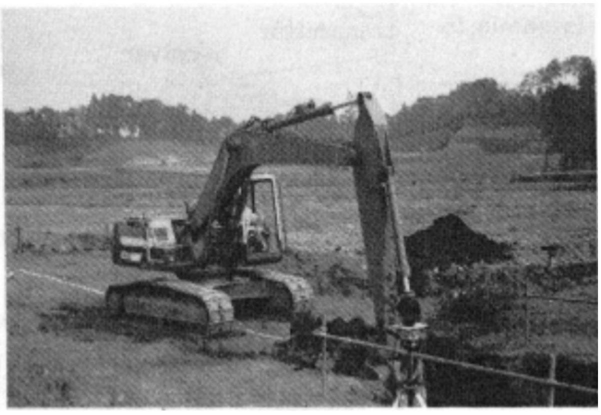

Fig.6 Test Scenery

4.2 Results of Test

Test results in using two methods are shown in Table 2. New system realized that the finishing accuracy was less than ± 20[mm], and it was more effective, especially in solid ground. Also, the work efficiency increased to 1.6 times of conventional method because the finishing-stakes became unnecessary and the work of finishing crushed stones was done by using the excavator. And it was possible to reduce excavation assistant members and labors of finishing crushed stones. The opinions of the operator were as follows.

Table 2: Comparison of Two Method

	Conventional Method	Automatic Method
Accuracy	± 80mm	± 20mm
Efficiency	40m/day	65m/day
Number of labour	7 person	3 person

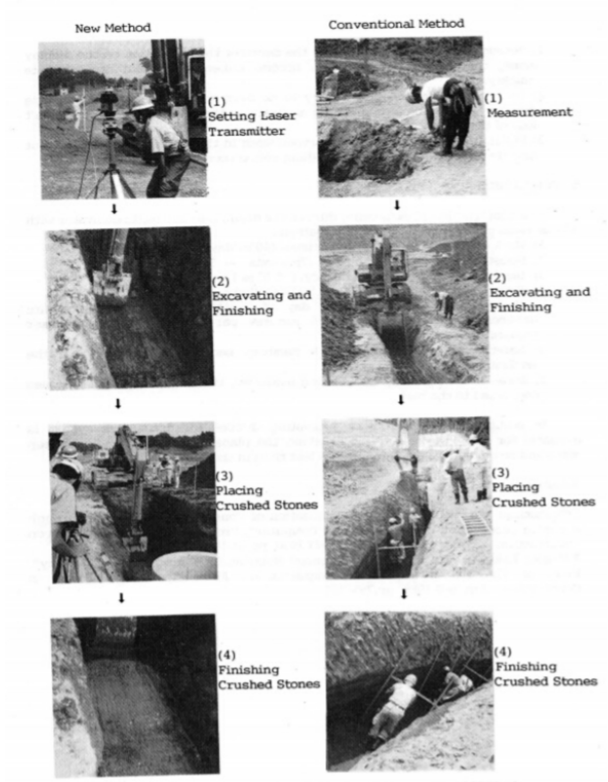

Fig. 8 Comparison between New Method and Conventional Method

Conventional Method

1) Because it is possible to confirm the depth of the excavation on the display alone, the excavation assistants become unnecessary, and can excavate quickly. 2) In finishing, it is not necessary to do over again, because the real time display always indicates finishing accuracy to the operator. Thus there isn't loss of time. 3) Finishing is one of the most nervous work in the conventional method, but now the function of automatic finishing sets us comfortable.

V. CONCLUSION

In a construction of excavating ditches for drain, new automatic excavator with a laser beam guide proved the following effects.

1) Work efficiency improves to 1.6 times. (40[m/day] 65[m/day])

2) Substantial reduction of labors. (7persons - 3persons)

3) Improving of a finishing accuracy. (± 8[cm] --> ± 2[cm])

4) Finishing work is possible even by unskilled operator.

5) Measurement in the previous day and setting of finishing-stakes are unnecessary. (It takes only 20 minutes per day for setting of laser transmitter.)

6) Safety improves because work members become unnecessary near the excavator.

7) Because the accuracy of finishing improved, the amount of crushed stones decreased to the half.

In addition to the works of excavating ditches for drain, this system is available for many works such as finishing the plane of wide area and the steep slope and so on, and we are intending to test them in the future.

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