Remote Control System of the Concrete Cutting Machine

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ABSTRACT

The JPDR (Japan Power Demonstration Reactor) is a power reactor which was first built in Japan. The life of a reactor is generally considered to be 30 to 40 years. So the decommissioning will be needed. Therefore, it is now necessary to develop decommissioning technologies, including dismantling techniques of these power plants.

The concrete cutting robot with sawing and coring units by the remote control system has been developed for the highly activated biological shield dismantling. And this cutting system can remove cut concrete blocks from the biological shield wall.

In the test, the cutting speed was controlled automatically and remotely. And this proves that the heavily reinforced concrete can be cut speedily, safely and continuously with precision.

This system has been applied to the dismantling of the highly activated concrete of the JPDR.

1. Introduction

Concrete structures of reactor facilities are designed,taking earthquake-proof ability into consideration,and very solidly constructed with massive amount of materials. And different from pulling down general structures, workers are hard to approach them because objects are activated. So it is needed to remove by machines and to operate them by remote control, to decrease workers exposure and economized labors.

Now developed cutting system installs sawing machine with diamond blade and coring machine with diamond bit. To operate this system by remote control makes it possible to cut activated concrete structures into blocks and take them out.

2.Biological Shield Concrete

A biological shield surrounding a reactor vessel is constructed, intended to shield γ rays and neutron rays. The biological shield is thick,laying with reinforcing bars and steel pipes of high density, and it surface is covered with steel plates. The JPDR biological shield is a cylindrical type and its diameter is 2.7m or 3.5m, and it is about 21m in height. An estimated radioactivity range and cross section of this structure are shown in Figure 1.

A range of a dismantling part by this cutting system is 10.90m~12.15m height and 2.7m~3.5m in diameter. In this part, D29mm reinforcing bars are crosswise laid at 150mm intervals, and steel tubes whose diameter is 38mm are lengthwise laid at 150mm intervals. And its surface is covered with steel plates of 13mm in thick. Besides them there are steel angles for reinforcing openings.

3. A Method for Dismantling

Different from pulling down general structures, while working of dismantling reactors, it is needed to guarantee security of the public and workers engaged on the job, satisfying following three terms.

1. Prevent spreading of radioactive material
2. Minimize worker exposure
3. Minimize radioactive waste volume

This cutting system carries a sawing unit with a diamond blade and a coring unit with a diamond bit, and takes a method to cut reactor's biological shielding concrete into blocks and take them out. In this method, dismantling dusts are little, and it makes possible to cut along the premeditated lines. This method makes remote control easy. Furthermore it is easy to handle the cutting pieces after taking them out, because it makes possible to cut concrete walls into blocks. We affirm that this method satisfies above three terms and is suitable for removing activated concrete structures.

The diamond blade is made that its circumference has notch grooves at regular intervals, and segments stiffening diamond particles with metal bond are fixed on the circumference of each grooves. The diamond bit is made that notch grooves and segments are fixed to the tip of cylindrical tube. With progress of cutting, diamond particles are worn away and the metal bond is worn away at the same time, so projection of diamond particles are regularly kept, and efficiency of cutting is also maintained. When cutting, water is used to cool edges and to discharge trash.

An example of a sequence of removing concrete structures with sawing and coring is shown in Figure 2.

4. Cutting Robot and Dismantling System

The cutting robot is constructed with cutting units, a manipulator, a fixing unit, and equipments needed when sawing and coring. Figure 3 shows the overview and Table 1 shows specifications of the cutting robot.

The sawing unit makes a diamond blade of 42 inches in diameter by high frequency motor. The coring unit makes a diamond bit of 6 inches in diameter by high frequency motor. The cutting units are attached to the end of arms in opposite direction in order to reduce the tool changing time.

The manipulator carries the cutting units to the desired position. This robot has cylindrical coordinate system. Within the movable area of the cylindrical coordinate, it can cut the biological shield concrete wall into blocks. The manipulator can also change the blade direction for vertical and horizontal cuts. Each axis is driven by a rotary servo actuator (RSA). RSA is a kind of mechanical feedback type hydraulic servo motor whose control valve is connected to an electric stepping motor and provides digital open loop servo control.

The cutting robot is suspended by a crane and fixed in the cylindric biological shielding wall by its outriggers and adjusts the horizontal level of the manipulator using level adjuster.

The cutting robot is operated from the control console set in the emergency ventilation building(out of the reactor building) of the JPDR.

Besides the cutting robot, the dismantling system of the biological shielding wall is composed with a grasping machine, circular crane, cables and hydraulic hoses lift, ventilation system and drainage disposal system. The concrete block is held by the grasping machine. The circular crane transfers the grasping machine from the biological shielding wall to the container in which the concrete blocks are put into. The cables and hydraulic hoses lift regulate winding-up and drawing-down them with the cutting robot. The ventilation system collects dust and mist generated in cutting and prevents the diffusion of activated materials. The drainage disposal system collects and disposes slurry and cooling water used for cutting. The sub-control console is set on a service floor of the JPDR and used for operating the grasping machine and the circular crane. It has a function of operating and maintaining the cutting robot manually.

Figure 4 shows the arrangement of the machines and devices for the JPDR shield wall dismantling.

5. Control System

The concrete cutting machine is remotely controlled in an operating room out of the reactor building. Operators need to manipulate always watching a condition of the cutting system by the monitors of television cameras for watching and by signal indicating machines from every kind of sensors which the cutting system carries. Sawing and coring works takes a lot of time, and that makes the burden for workers because a large quantity of reinforcement and steel plates is cut. To reduce this burden, the computer is used in control system and an automatic function of sawing and coring is set. Composition of the control system is shown in Figure 5. This system used three microprocessors. (two INTEL 8088 and a INTEL 8085) One of the 8088 works as man-machine interface and the other has a function calculation. The 8085 is used for process I/O.

The flow chart of automatic operation is shown by Figure 6.

5.1 Sawing procedure

The cutting robot can perform sawing in three directions: vertical cut, circular(horizontal)cut, and radial(plunge) cut. This allows a cylindrical reactor shielding wall to be cut easily.

Sawing is generally made in a step cut produced by repeating plunge cut and vertical or horizontal cut into the full depth.(Figure 7.) This procedure is done by executing the cutting program.

5.2 Cutting program

An automatic operation is executed following the cutting program made establishing an order of motion, direction, distance of removing,conditions of motion etc. The cutting program is checked automatically in order not to exceed the motion space and an order which leads to damage of the system.

5.3 Cutting control

There are 3 cutting modes which are classified according to how the blade or bit is fed.

(1) Constant speed mode
The blade or bit is fed at a constant speed while cutting.

(2) Constant current mode
The blade or bit is fed in such a manner that the cutting motor current is constant.

(3) Manual mode
The blade or bit is manually moved to any position. This mode is done by using push buttons and speed setting switches.

Most part of cutting is done by constant current mode. The outline of constant cutting is described as follows.

Cutting of steel burdens more than that of concrete. The longer contact length of edge and steel becomes, the more cutting load becomes. A part cut by this cutting system is not an equable concrete, and contains a large amount of steel plates and reinforcement. When sawing and coring such a part, cutting load fluctuates widely. The diamond tools can cut the concrete at high speed. If the edge contacts reinforcement, the cutting load changes suddenly. This burdens the edge and the cutting machine. So it is needed to grasp cutting condition exactly, whether cutting concrete or cutting reinforcement and steel plates. To do this, it is needed to regulate the cutting speed. This system controls a speed so that electric current value equals the setting value. A block diagram of cutting control is shown in Figure 8. A feedback control system is composed by direct digital control with PI control law. In this system, manipulated variable is the speed command of RSA and the controlled variable is the cutting current value. A change of manipulated variable per one sampling period is as follow.

$$v_n = K_P(i_{n-1} - i_n) + K_i(i_{set} - i_n)$$

where K_P is proportional constant, K_i is integral time constant, i_n is the (N)th sample value of cutting current, and i_{set} is the set point of cutting current.

An example of a result of coring the reinforcement concrete by the current constant mode is shown in Figure 9.

5.4 Monitoring system

In this system, the cutting motion is done by automatic operation and other works (fixation and positioning of the cutting machine) are done by operator's judgment and remote control based on it. So the monitoring system is formed to be easy for operators to use. ITV cameras in the system, television monitors which indicate pictures of television cameras hung down in the shielding wall, CRT indicating cutting speed, distance ,electric current of the cutting motor, etc. are provided.

The television camera for watching the blade is mounted on the sawing arm. This is mainly used for positioning of the blade at the datum point of the biological shield wall. The ITV camera hanging down from the service floor watches the condition of the cutting robot. These two television cameras and the load cell installed between the sawing unit and the arm make it possible to decide the position of the blade. For example we can position the blade of 5mm in thickness in the cutting groove of 5.5mm in width again.

Sawing and coring forces are continuously monitored by means of the load cells.

5.5 Abnormal operation detecting function.

The control system of the cutting machine has a protecting function whose purpose is to prevent trouble of cutting machine and accidents. These function watches whether there is anything unusual or not. If some unusual condition has happened, the cutting robot stops automatically and gives a warning.

6. Cutting sequence

The cutting sequence by this cutting robot is as follows.

(1) Height adjusting of the cutting robot

Seeing an indicative value of the height measurement device, we hang up the cutting robot to an expected cutting height by a crane.

(2) Fixation of the cutting robot

We spread out 3 outriggers to equal each strokes, and fix them in shielding concrete wall. There are an openings and pipes for neutron detector at the position where outriggers are spread in the JPDR. So we fixed them after setting up a television camera for watching outriggers and making the fixing machine turn to the position where outriggers can be spread.

(3) Horizontal level adjusting

We operate 2 screw jacks for adjusting an inclination of direction falling at right angles each other, and produce the level of the blade side. (The amount of the intentions are measured by 2 inclination sensors and indicated on CRT.)

(4) Origin adjusting

Watching the monitors of the TV cameras hung down in shielding concrete and TV cameras installed on the cutting arm, we make the cutting robot rotate and make blade agree with an edge of the opening of the shielding concrete wall or already cut vertical cutting groove. And then, we figure out a connection of the position of the cutting robot and the shielding concrete wall.

(5) Positioning

After removing blade to the expected cutting position, we make blade advance at a low speed and make it contact to the shielding concrete wall. Cutting depth is acquired by reading stroke of blade. Contact with wall side and blade is measured by a load cell describe as before.

(6) Programming

We make out a cutting program which consists of an sequence of motion and control parameters. Then we make sure there is no error by checking function.

(7) Execution of the cutting program.

By pushed the start button, the cutting robot is started to move and motion is practiced following the cutting program.

7. Actual dismantling test

Actual dismantling test of the biological shielding with this system was practiced from October 1990 to March 1991. We could cut activated concrete wall of $4.3m^3$ in volume into 8 blocks and 99 cores and take them out in a short period. We used new developed diamond blades which can efficiently cut reinforced concrete and CBN blades which can cut steel plate at high speed. The control system of the cutting robot could be used according to the purpose we expected.

Hereafter we are going to develop the dismantling system of a large scale commercial reactor, based on the knowledge and data acquired through the actual JPDR dismantling test.

The commercial reactor is more than 10 times as large as the JPDR, and works are done under high radiation. We must consider following specifications for a remote control system of the dismantling of a commercial reactor.

(1) The countermeasure for protecting machines to the high radiation, not having mattered in the JPDR.

(2) To miniaturize and lighten systems

(3) To decrease the number of the cable

(4) Automatic exchange system of blades and core bits

This cutting system carries the sawing unit and the coring unit. It can also carry a nozzle of water jet. We are going to develop a cutting system putting both advantages into practical use.

8. Conclusion

The study on dismantling JPDR commenced in 1981. One of the subjects, the cutting dismantling system of the biological shielding concrete wall, has been been studied and developed for no less than 9 years.

In this actual dismantling test, its efficiencies have been proved. Hereafter we have an intention to construct the dismantling system of commercial reactors, putting this experience into practical use.

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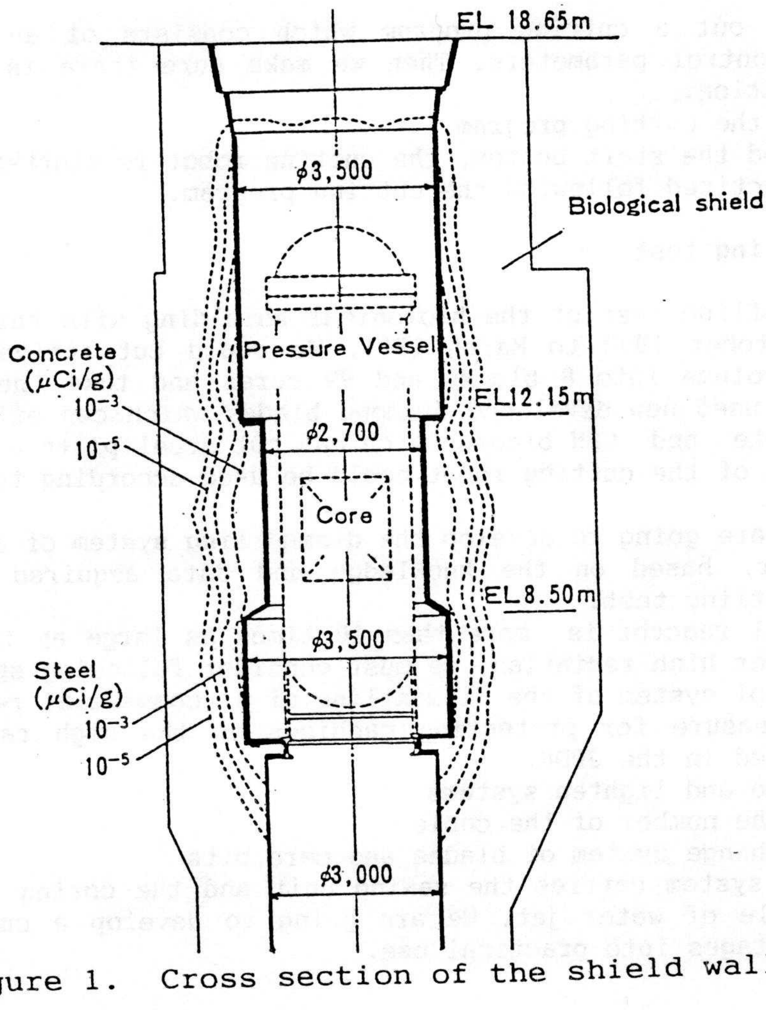

Figure 1. Cross section of the shield wall

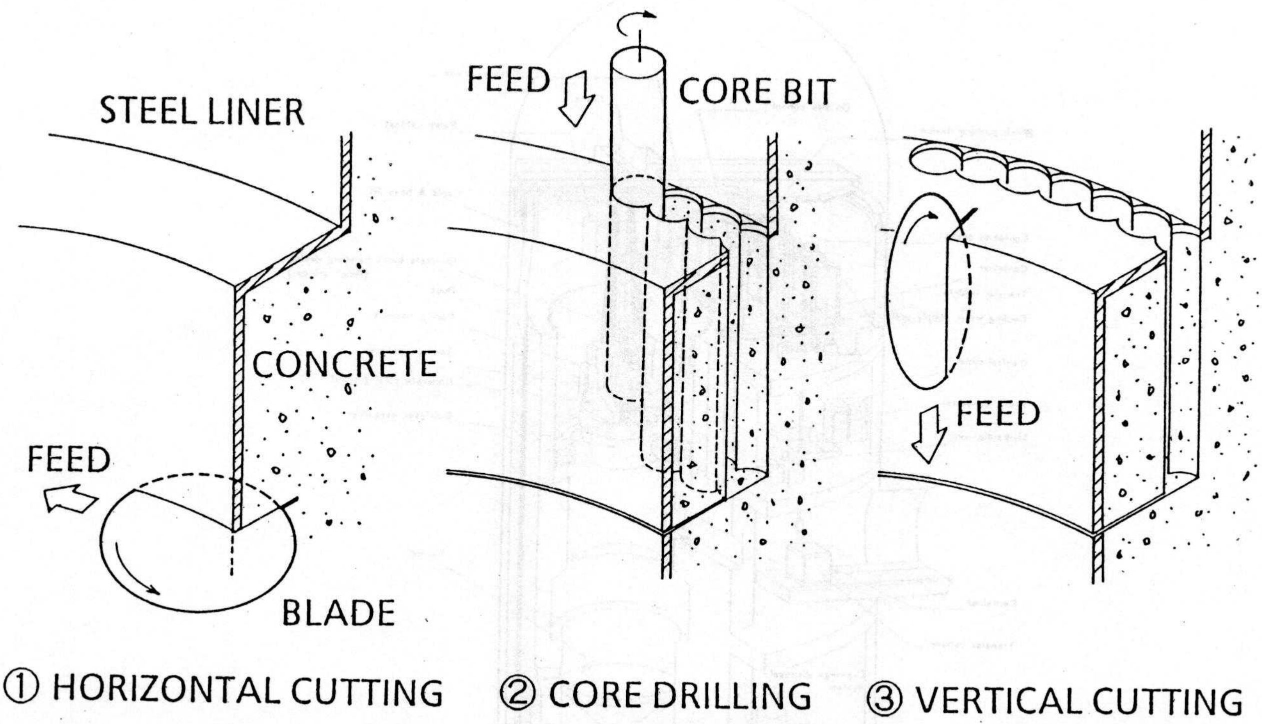

Figure 2. Concrete removal sequence

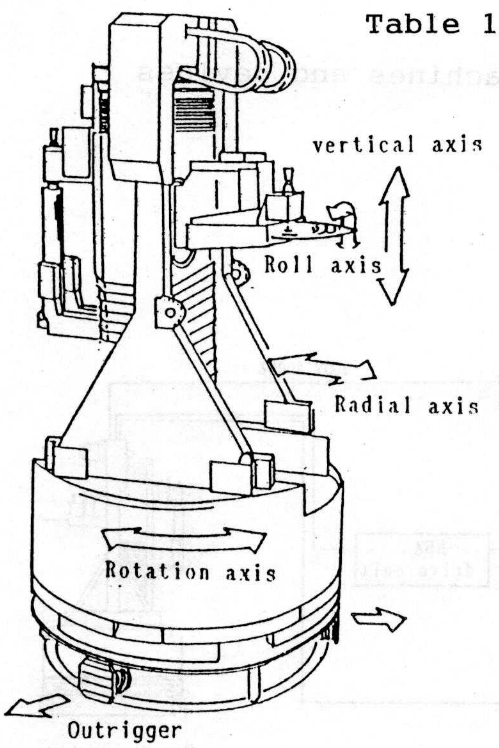

Figure 3. Overview of the cutting robot

Table 1. Specifications of the cutting robot

Item		performance
Height		5.0 m
Outside diamter		2.55 m
Weight		15ton
Cutting load		300kg
Number of outriggers		3
Mobility	axial	1050 mm
	radial	945 mm~ -485 mm
	circumferential	380°

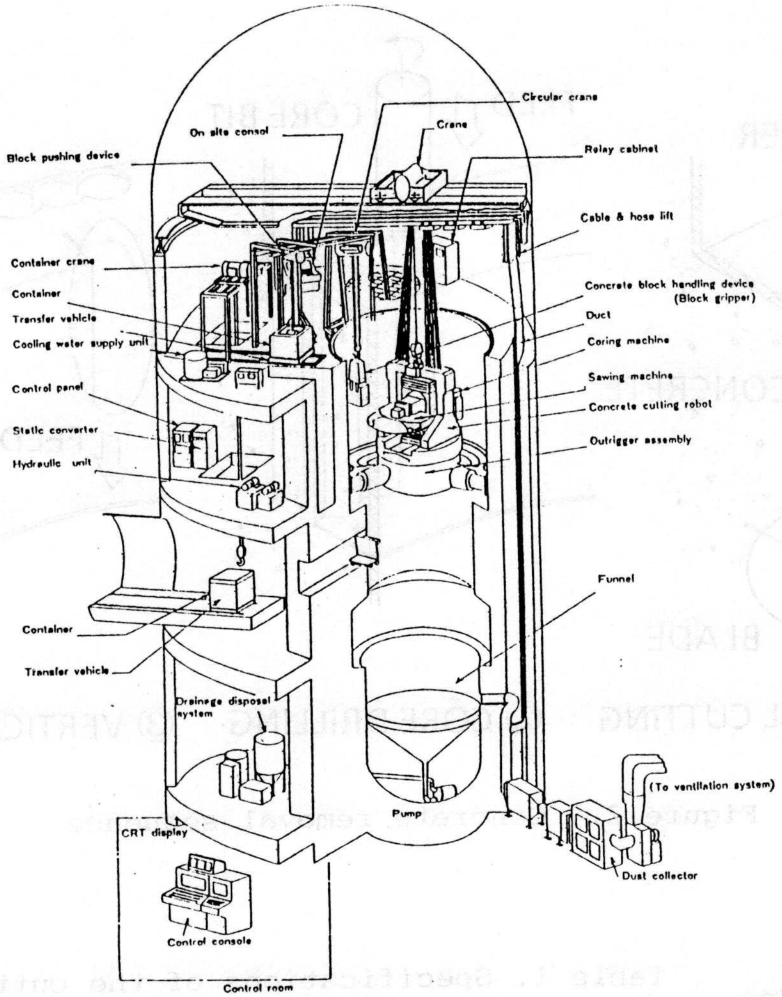

Figure 4. Arrangement of the machines and devices

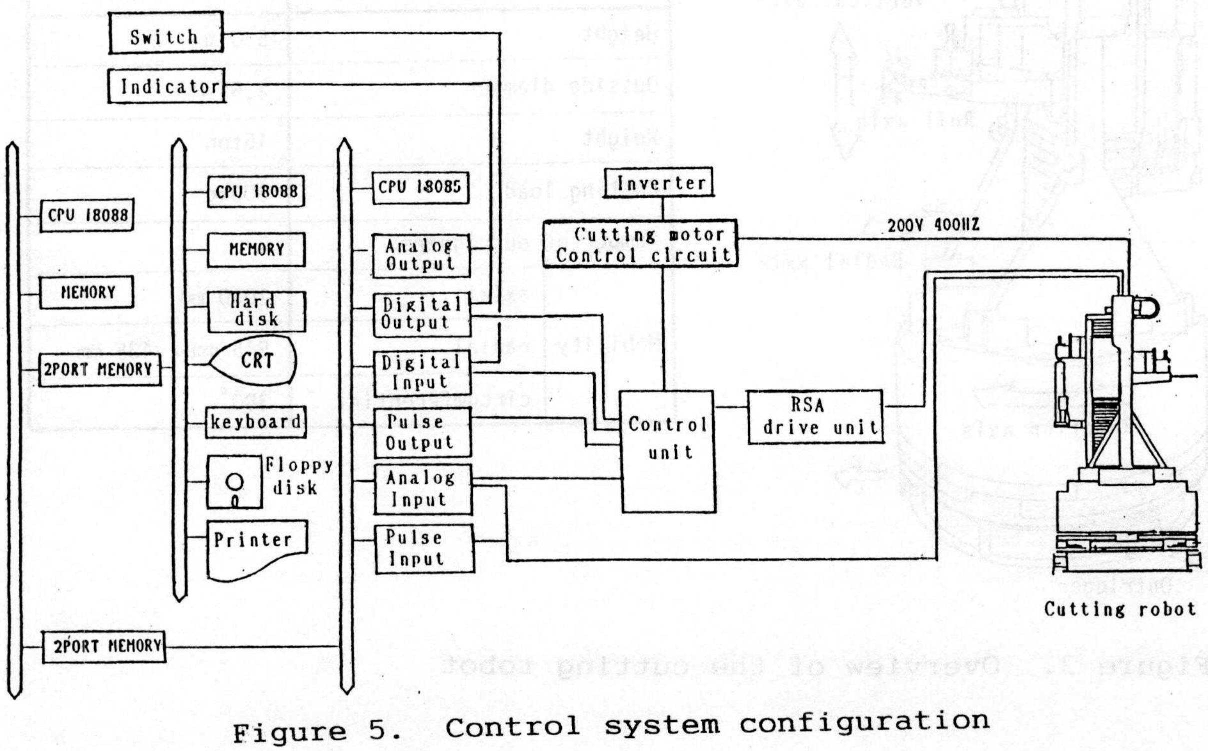

Figure 5. Control system configuration

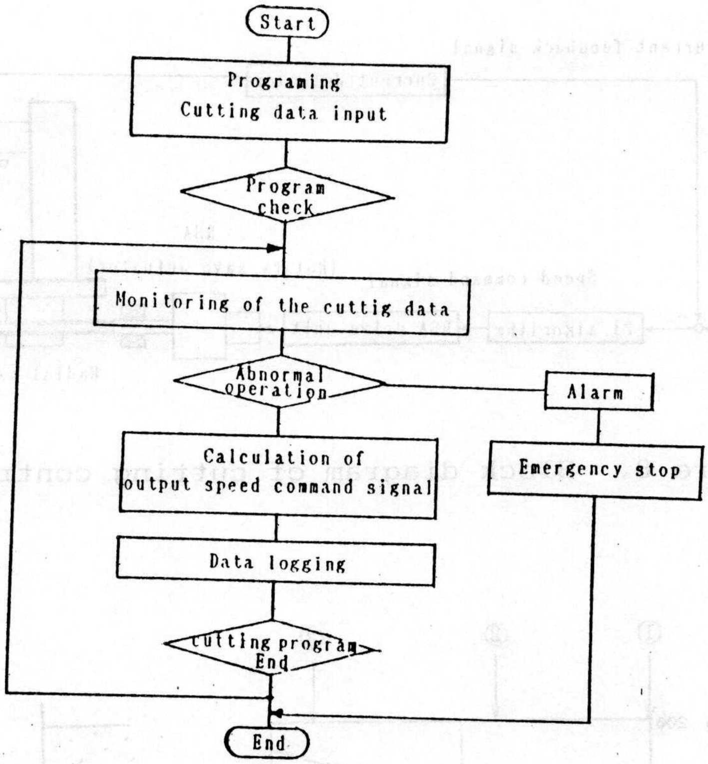

Figure 6. Flow chart of automatic operation

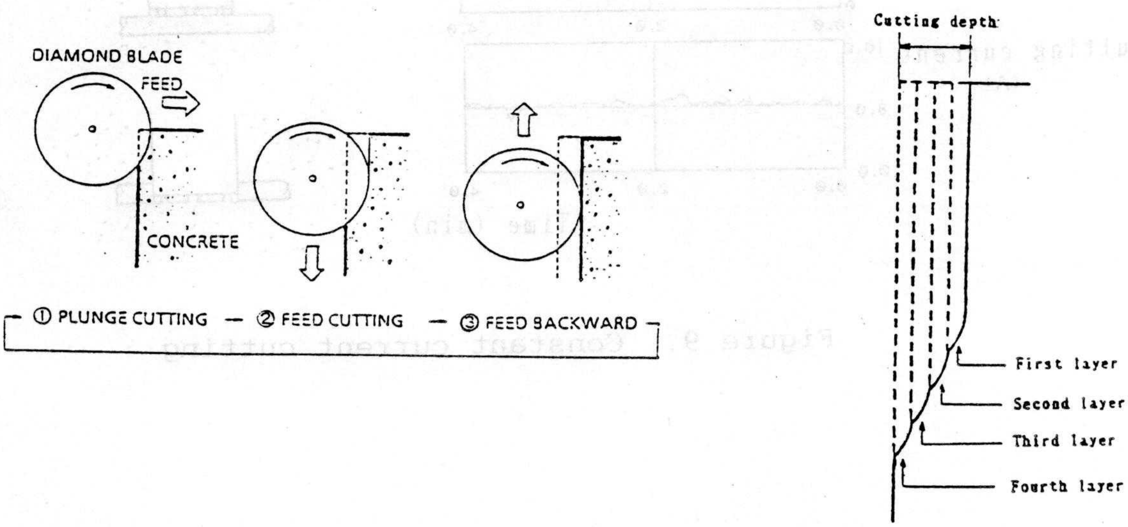

Figure 7. Step cutting

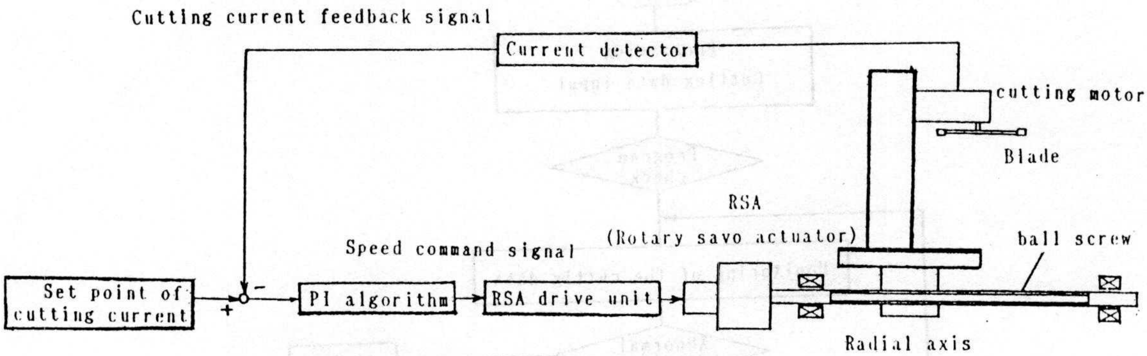

Figure 8. Block diagram of cutting control system

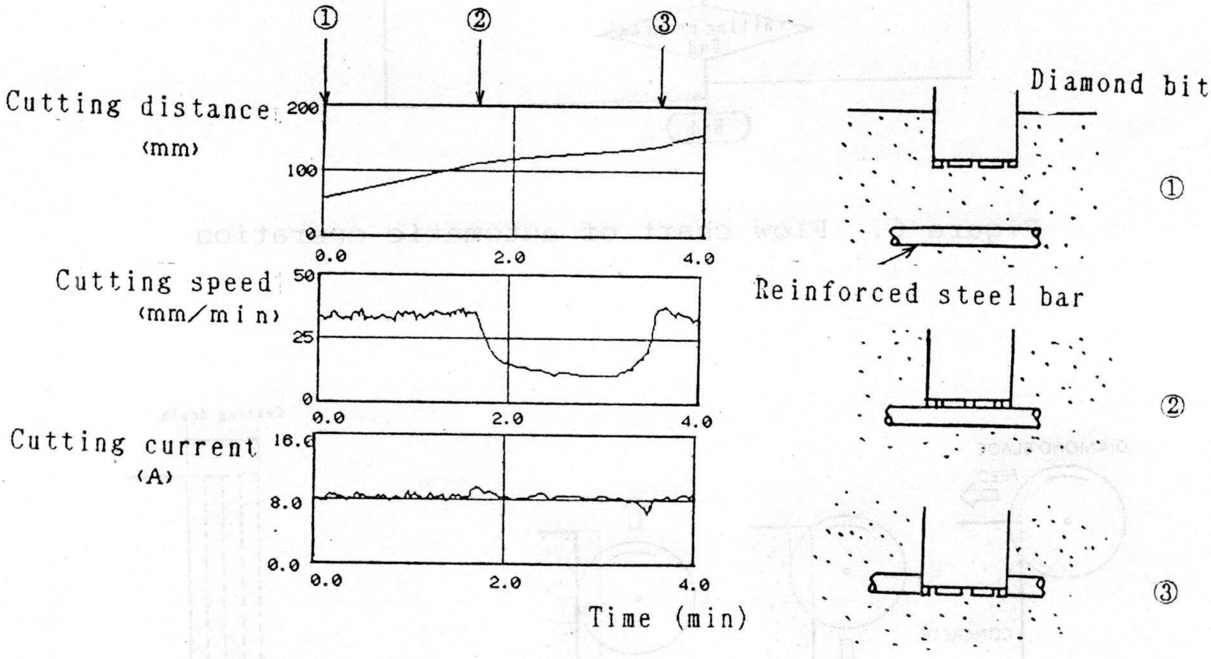

Figure 9. Constant current cutting