ROBOTIZED PAINTING BY THE WALL SURFACE-FINISH ROBOT (FR-1)

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ABSTRACT

In order to improve the hand-based finishing works, a wall-surface finishing robot (FR-1) is developed, enabling us to achieve labor-saving. The system as a whole is a multifunctional robot, composed basically of a carriage with sucker which can move freely on the concrete-made wall, and of a diagnosis function of wall conditions, and as option, is provided with cleaning, shot-blasting and painting mechanisms; according to necessity, they are mounted to the cariage to perform a series of finishing works. This report discusses the robotized painting which was conducted in 1988 for repairing the walls of the Nuclear Power Plant. The results of the experiment showed that the robotized painting excellent in safety and its work efficiency is twice as much as that of the hand-based conventional spraying method. The quality obtained is almost equivalent to that of the hand spraying.

1. Introduction

Until the present time, wall finishing work for the purpose of increasing the durability of concrete outer walls was done manually by workmen using a scaffolding erected along the wall, or a gondola. With this method, especially in the case of large scale concrete buildings, because a lot of the work is done high above the ground, the potential danger is great. Moreover, painting a large surface area requires a large number of laborers. Further, in manual labor instances of uneven quality are bound to occur. Thus, in response to the need to reduce the number of laborers required in wall finishing and raise the safety lavel, we began the development of the painting and finishing robot in October of 1986.

This report summarizes the use of robotized painting in the painting of the sea water heat exchange machine building at the Tokyo electric Fukushima Nuclear Power Plant No.2 in August of 1988, as well as prospects for the future.

2. The Structure of the Painting and Finishing Robot

The painting and finishing robot, as shown in figure 1, is made up of the diagnostic robot, which examines the surface condition of the concrete structure and checks whether or not there are any cracks, etc., the various surface preparation robots (shot blasting robot, washing robot) which remove deteriorated sections of the concrete surface, plus any dust or laitance, and the painting robot, which paints the outer surface.

The special feature of this development, as shown in figure 1 is, first of all, the development of wall-climbing robot, which can move about freely on the surface of the concrete wall, and the development, one after the other, of the different types of mechanisms for the various stages of the finishing process, and then mounting them all on wall-climbing robot to enable the performance of a series of finishing tasks.

3. Painting Robot Overview

The main mechanism of this robot carries the auto painting mechanism as shown in figure 2. It is fastened to the wall by means of a sucker in its body and moves about on the surface of the wall. The robot system is composed of a vacuum unit which creates suction force in the sucker, a material feeding pump, which supplies paint to the automatic painting mechanism, a center control panel, which handles robot operation, and also an emergency winch prevents falls in a power failure.

The machine can be operated either manually or automatically. In automatic operation, the machine is controlled by an on-line-teaching program.

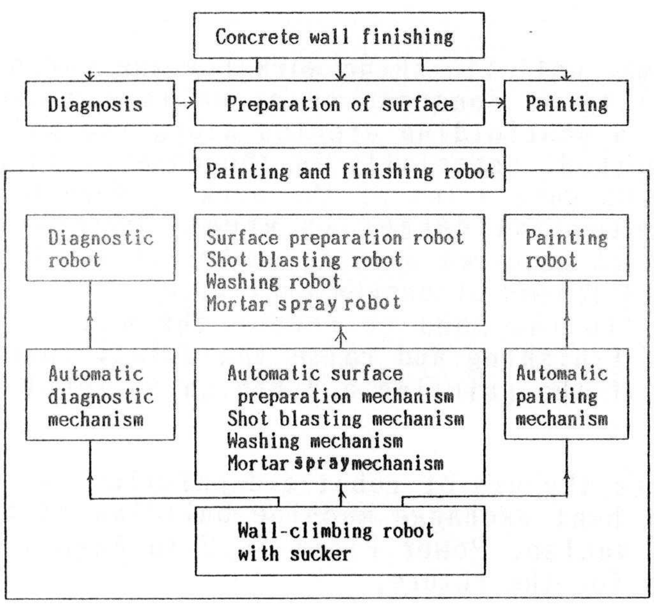

Fig. 1 The structure of the painting and finishing robot

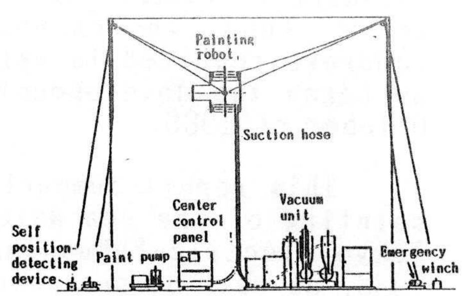

Fig. 2 Painting robot general plan

4. Robotization Planning of the Painting Process

4.1 Specification of the Building and Painting

Wall shape : approximately 28 meters wide and 14 meters high (about 400 sq m)

Wall condition : fair-faced concrete; joints of width of 30 mm and 20 mm depth in a horizontal and vertical direction

Figure 3 shows the shape of the building.

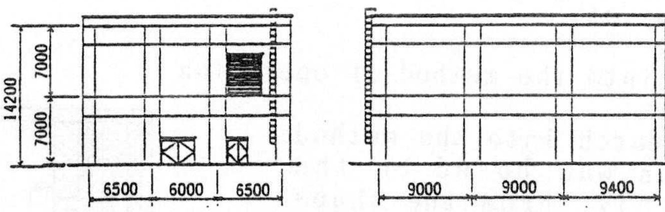

Fig. 3 Form of the building

Paint used : elastomeric paint
Painting method : shown in Table 1

Table 1 Painting method

Work stage	Quality of paint	No. coats of paint	Time elapsed (H) During	Time elapsed (H) Between	Remarks
Primer coat	$\geqq 0.3 kg/m^2$	1	over 1	over 1	
Middle coat;					
Base	$\geqq 800$ μm(dry)	1	over 2	over 2	
Pattern	approx. $0.5 kg/m^2$	1		over 18	
Finishing coat	$0.3 \sim 0.4 kg/m^2$	2	1 to 4		

4.2 Surveying and Planning

The procedure for implementing robotized painting is shown in figure 4.

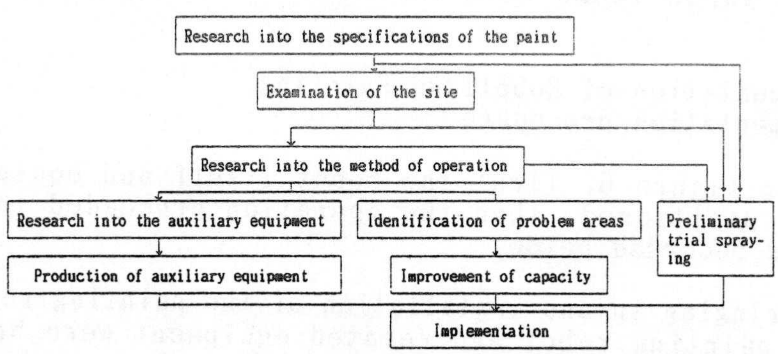

Figure 4 Flow of plan to robotize painting

(1) Study of the specifications and survey of the site

After the plan of the building, the required quality of the paint, and the overall process were checked against the appropriate specifications, an examination of the actual site was carried out. The surrounding environment was examined, including the shape of the building, wall conditions (particularly the shape of the joints and their positions), the approach to the roof and wall surfaces, etc.

(2) Research into the method of operation

The research into the method of operation was based on the research in (1). From the shape and size of the building, the plan for the painting pattern was made. A plan was made for the positioning of the equipment, and an overall method of operation was decided. Figure 5 shows the painting pattern.

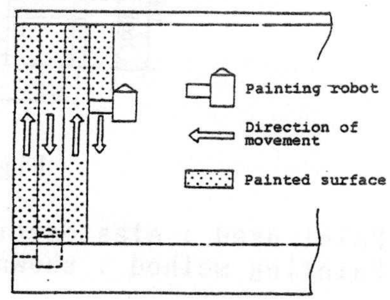

Figure 5 Painting pattern

(3) Preliminary trial spraying

The condition and the handling technique of the paint to be used were checked against the specifications for that paint. Then an experiment was conducted to obtain the necessary settings for the various devices (pump pressure, nozzle pitch, etc.).

(4) Improvement of functional capacity

- Prevention of poor spraying at the beginning of painting
- Improvement of safety when moving about on the surface of the wall
- Improved ease of operation

The above three items were examined and the measures required taken.

5. Implementation of Robotized Painting

5.1 Implementation procedure

As in figure 6, first the robot itself and equipment to be used were positioned, then the operation proceeded in the order (1)-(3) as recorded below.

(1) The bringing in and installation of the painting robot

The painting robot and related equipment were brought onto the site and the equipment was installed as shown in figure 6.

(2) Preparation for painting

After verifying by a test run that the robot was functioning satisfactorily, the course for painting was inputted into the center control panel computer by means of a personal computer.

(3) Painting
The primer coat, middle coat (base spray, pattern spray) and finishing coat were sprayed on by the robot according to the procedure in Table 1.

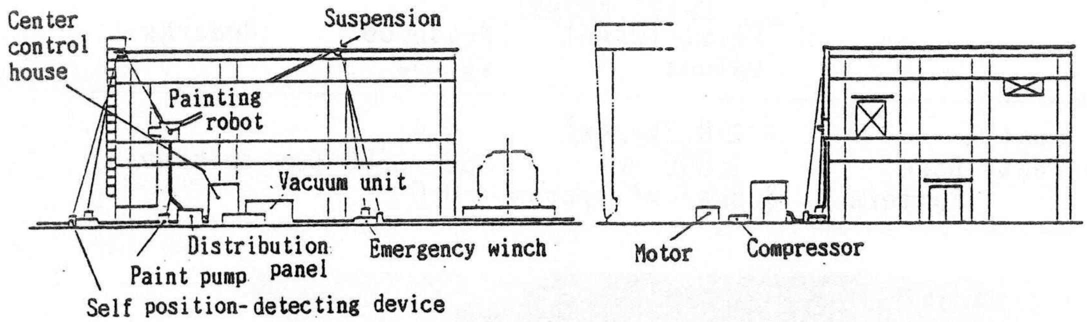

Fig. 6 Equipment layout

5.2 Performance Results

(1) Painting rate
The painting rate was about 45 to 50 sq m/hour for the main coat (base spray). Moreover, three workers, the operator, paint manager, and overall supervisor, were necessary for actual painting. Dividing the area among the three workers, gives an average per worker rate of 15 to 17 sq m/hour per person. At the same location, another wall was painted manually using a scaffold and gondola. The painting rate in that case was approximately 8 to 9 sq m/ hour per person. In comparison with this rate, robotized painting was about twice as fast as manual. The painting results are shown in Table 2.

Table 2 Painting results (Base spray)

	Middle coat; base spray
Paint thickness(μm)	850~1200 (dry)
Painting width (cm)	52
Painting speed (m/min)	3
Painting rate (sq/hr)	45~50
Per person rate (sq/hr/person)	16~17

(2) Painting quality
Based on the data obtained in the preliminary trial spraying, just prior to painting, a specimen was sprayed and the distribution of coat thickness, and whether or not there were any irregularities in painted coat were checked with a wet gauge. Once this had been verified, the actual painting commenced. Furthermore, paint thickness was controlled during the operation by measuring the amont of paint used and comparing that with the

total surface area. The result was that the target value for the amount of paint used was attained, as Table 3 shows. Also, thickness distribution of the middle coat (base spray) had fewer uneven places when compared with manual spray painting. Photos 1 and 2 show the painting set-up for the robot at the site.

Table 3 Paint amount measurement results

		Paint amount		
		Paint target values	Measured values	Remarks
Primer coat		$\geqq 0.3 kg/cm^2$	0.4	
Middle coat	Base	$\geqq 800\ \mu m$	850~1200	Dry thickness
	Pattern	$0.5 kg/cm^2$ approx.	0.6	

Photo 1 Painting (close-up)

6. Results Achieved

(1) Painting rate

The rate attained in this operation (middle coat; base spray) was twice as fast when compared with manual labor. However, it was determined that it would be possible to plan toward further increased capacity by making various movements of the robot smoother (point turns, horizontal motion).

(2) Paint quality

Prior to this job, a preliminary trial was conducted and at the site, before start of the actual painting, the spray was tested. During the operation, the thickness of the paint was controlled through the paint volume.

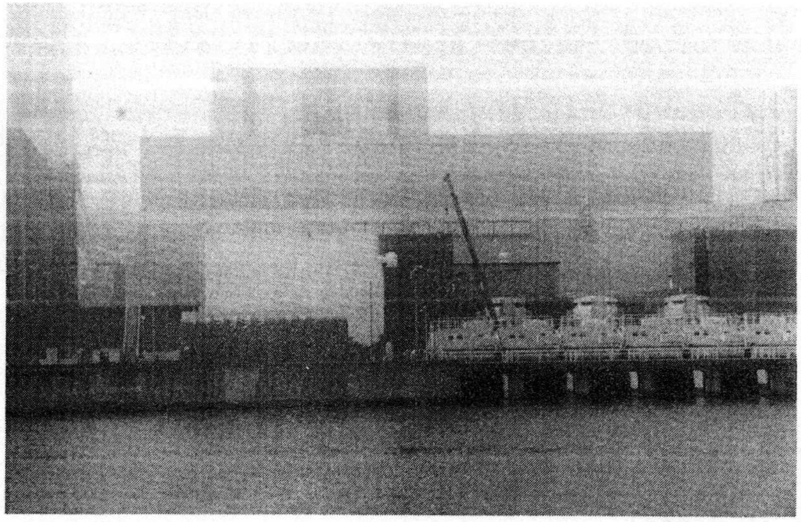

Photo 2 Painting (general view)

(3) Safety

This robot insures safety by employing an emergency mechanism capable of halting operation if any gaps in the wall or obstracles are encountered, as well as an emergency wire that prevents falls in the unlikely event they should occur. However, this task was conducted smoothly without resort to emergency equipment.

7. Future Research Topics

From the results of this operation, the following topics for study were identified in order to move toward practical on site application.

(1) Research into suitable auxiliary equipment

This time because the suspensions for the emrgency winch were attached directly on the parapet and due to the fact that the metal fittings and other auxiliary equipment were large, a few small areas were left unpainted. Thus it is necessary that the attached apparatus be improved to insure suitability for the particular location.

(2) Reduction in the size and weight of the robot

The handling of the robot at the site and the installation and transporting of equipment required over two workers and use of a crane about an hour to accomplish. It is thus necessary that the robot be made easier to handle by reducing its size and weight.

Through this procedure, painting operation was achieved in half the time the same job would require to be done manually, has been the case until now. The quality of the work achieved was good as there were no painting irregularities and the variations in coat thickness were minimal. Moreover, the work was done safely.

These were a few of the successful results attained.

Currently, we are in the middle of development of a wall diagnostic device, a surface preparation robot (automatic shot blasting mechanism, automatic washing mechanism) in order to bring these to the level of practical application. Through the realization of robotization of a series of finishing tasks, we hope to be on the front edge of the anticipation of increased robotization based on a reduction in the number of skilled workers.

References

1) Tokioka et al., Painting and Finishing Robot for Concrete Walls ; "Robot" No. 65, 1988
2) The 3rd Construction Robot Symposium 1989 (Architectural Institute of Japan)