DEVELOPMENT OF WALL PAINTING ROBOT

Takuya Gokyu, Masayuki Takasu, Sumio Fukuda
Tokyu Construction Co. ,Ltd.
1-16-14 Shibuya-ku , Tokyo , Japan

ABSTRACT

Wall painting as well as inspection works for structures, so far, have been performed manually through use of scaffolds or gondolas provisionally built all around the subject wall, which, therefore, having raised many problems such as high personal risks, unclean work environments, etc.. The wall painting robot developed this time can perform, as moving attracted on a wall as being pre-programmed, not only general type of coating in a single color through use of spray guns mounted on the arm but also picture painting in multiple colors based on picture data incorporated in the robot controlling computer. No.2 model, an improved type of the above, can perform not only the original functions but also various other works on a wall such as wall cleaning and tile separation sensing through changing of an attachment.

As this system is easy in handling, it is applicable to various works for a wide range of structures without limiting work subjects.

1. INTRODUCTION

In recent years, as townscape harmony of structures and civil structures in the surrounding environments have raised problems, civic designing has become an important issue in city development. As one example under this commitment, wall paintings are sometimes prepared on walls and retaining walls of apartments, etc. aiming to lessen oppressive impression of a structure and to please people's eyes. However, at present, most of those paintings are drawn manually. For the purpose of labor saving and improvement in work environments, therefore, a wall painting robot of porous vacuum attraction type was developed, with which picture drawing work in multiple colors was made available according to the data input in a personal computer. Further, based on customers' needs, a new type wall-surface operation robot which can perform not only painting work but also, with an attachment changed, various additional works such as wall cleaning and tile separation sensing has been developed.

2. OBJECTIVES OF DEVELOPMENT

2.1 OBJECTIVES

Wall painting, conventionally, has been carried out by human hands on scaffolds provisionally built around a subject wall. This, however, not only is a kind of work performed on dangerous elevated spots and in unclean environment but also requires extra work to take down the scaffolds, thus often making it difficult to shorten a construction term or to reduce cost. There were some robots available on the market which were, however, able to perform painting in a single color. Few of them had wide applicability and their use was rather limited depending on a structure applied. Further, prior to drawing of a picture, a rough sketch needs to be prepared on a wall, taking much time for drawing the original picture as being enlarged.

The actual targets for development of the wall painting robot, in order to solve the aforementioned situation, were set as follows:

(1) To improve safety by eliminating works on scaffolds.
(2) To make machine structure simple to enable easy mounting.
(3) To perform not only painting in a single color but also drawing in multiple colors.
(4) To be usable not only on external walls of structures but also in various other places such as on walls of civil structures.

2.2 CONDITIONS OF DEVELOPMENT

The following conditions have been set to satisfy the aforementioned targets:

(1) Based on a program having been input, to automatically perform painting work.
(2) To be smoothly moved on a wall and be stopped at any one spot.
(3) A falling preventive device alone can be mounted on a wall. Other devices and equipments should be placed on the ground.
(4) For facilitating transport into a job site, to make the minimum split weight of the machine should be 100 kgf or less.
(5) In drawing, minimum 4 colors can be used at one time.

For reproduction of the original picture, in general, one widely recognized method is to mix and blow with different intensity the three primary colors plus black as adopted in color printing. However, this method is only applicable with ink and not practicable with paint. A method adoped in this development, therefore, is spraying of each paint in ϕ 100mm dots.

2.3 SYSTEM CONFIGURATION AND OUTLINE

Fig. 1 shows a wall painting robot designed and manufactured based on the aforementioned conditions.

The wall painting robot consists of the exhausting vacuum attraction type robot main body equipped with travelling wheels, the painting arm with a number of spraying guns, and the airless painting device. Table 1 shows the specifications of the wall painting robot and Fig. 2 the system configuration drawing.

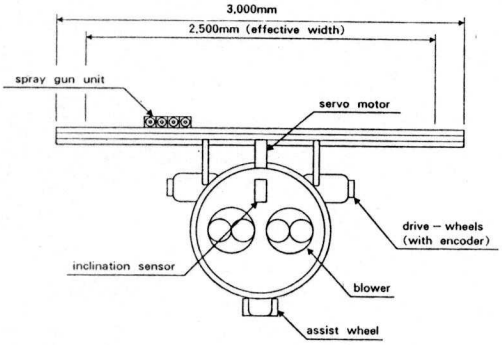

Fig. 1 Wall Painting Robot

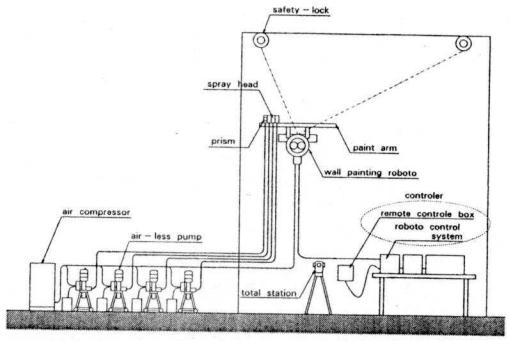

Fig. 2 System Configuration

painting system	airless spray , 4head
width of painting	3000mm
sprey head transfer speed	max30m/min
1dot spray speed	5sec/1dot
positioning accuracy	±0.5mm(move at 100mm)
max transfer speed	10m/min
weight	82kg(without control cable)

Table 1 Specification of the Robot

2.4 DRAWING DATA CONVERTING METHOD

Drawing is conducted based on the original picture information taken in a computer. The procedures to convert the original picture into drawing data are as follows:

(1) Preparation of the original picture.
(2) To express, on a personal computer, the manually drawn original picture as the dot image and subject it to correction.
(3) To convert the final drawn image into picture image data which serve to designate drawing position and paint colors, based on which opening/closing positions of the spray guns are specified for each different color.
The wall design adopted this time is composed of a big tree in a plain as shown in Fig. 3(a). Drawn data after conversion are shown in Fig. 3(b).

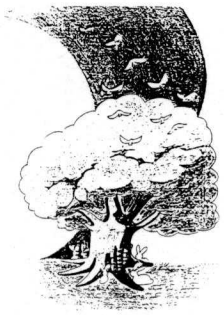

Fig.3(a) Dsign of Wall Paint

Fig3.(b) Drawn Data

Photo.1 Completed Wall Painting

2.5 CONSTRUCTION RESULTS

The four kinds of paint used this time included one single-liquid type and three two-liquid type (principal agent + hardener). The two-liquid type paint is increased in viscosity, reducing sprayed patterns in size with time after mixing. This problem has been handled by increased paint feeding pressure.

The estimated work capacity, according to data obtained, includes 400m2/day for rouch coating or approximately 2.5 seconds for one circle to be drawn in picture painting. For the latter, therefore, approximately 100m^2/day can be estimated for picture painting in four colors. This roughly equals 10 times of the work capacity usually attained by manual labour (10m^2/day).

When work area is about 100m^2, the estimated work cost for processes up to picture painting is almost equal to that of the conventional method using scaffolding. When work area exceeds the above, lowering in cost can be attained through application of this robot. Photo 1 shows the completed wall painting.

3. DEVELOPMENT OF NO. 2 WALL-SURFACE OPERATION ROBOT

3.1 BACKGROUND OF DEVELOPMENT

A survey was conducted once again to study market demands based on the construction results of the wall-surface operation robot (hereinafter referred to as No.1 Machine) having painting function. As a result, high demands in the field of structural renewal including, for example, cleaning, repairing, and tile separation sensing were identified in addition to the demands for painting work. No.2 Machine was developed to serve a range of renewal works through changing of the attachment.

3.2 CONFIGURATION AND FUNCTION

Wall-Surface Operation Robot No.2 Machine consists of X axis as the base, Y axis which slides on X axis, the attachment holder which slides on Y axis, and two attraction pads which fix the entire X and Y axes on a wall. Fig. 4 shows a drawing of the main body of Wall Robot No.2 Machine and Table 2 the relevant specifications.

Travelling on a wall is enabled by two winches mounted on both sides on the ground. The winches are fixed on the base frame at equal distances from the center to be always held horizontal to the wall reference line through use of jacks. The winch base is equipped with two encoders serving to measure the level with which two winches are synchronized to maintain horizontality of the main body. (Fig. 5 System Configuration Drawing)

The work volume covered by one setting of winches is called one panel (22,500mm wide). On completion of one panel of work, shift the winch base rightward and repeat the same procedure.

Wall-Surface Operation Robot No.2 Machine is equipped with a vacuum attraction pad to prevent shaking in operation, which, however, may not be effectively attracted when the wall has level difference of 5mm or more or deep joints. Therefore, a level difference avoidance program has been incorporated in Machine, serving to measure level difference with a sensor while in climbing of the main body and to avoid level difference for a place of attraction while in descending.

Wall-Surface Operation Robot No.2, through changing of an attachment, can perform the following works:

(1) Single-color painting work
(2) Picture painting work (ϕ 50～100mm/dot, max. 10 colors)
(3) Cleaning work (with wire brush)
(4) Tile separation sensing (with a ultrasonic sensor)
(5) Repair work

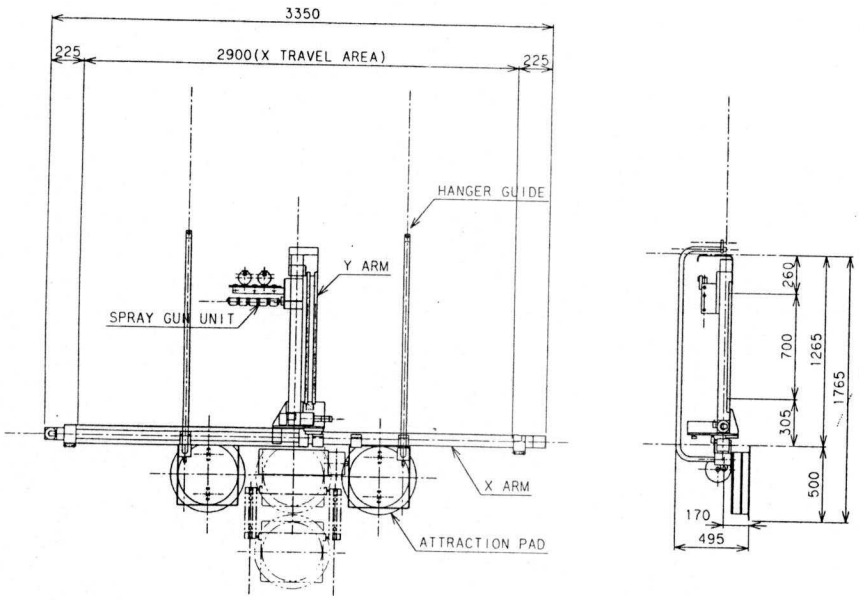

Fig.4 Wall Sarface Operation Robot (No.2)

Table 2 Specification of the Robot(No.2)

outwardform dimensions	length 1,765、width 3,350、height 495mm
weight	80kg
paint arm dimensions	3,350mm (X axis)、1,050mm (Y axis)
working area	2,900mm (X axis)、700mm (Y axis)
painting system	high volum low pressure、5 head

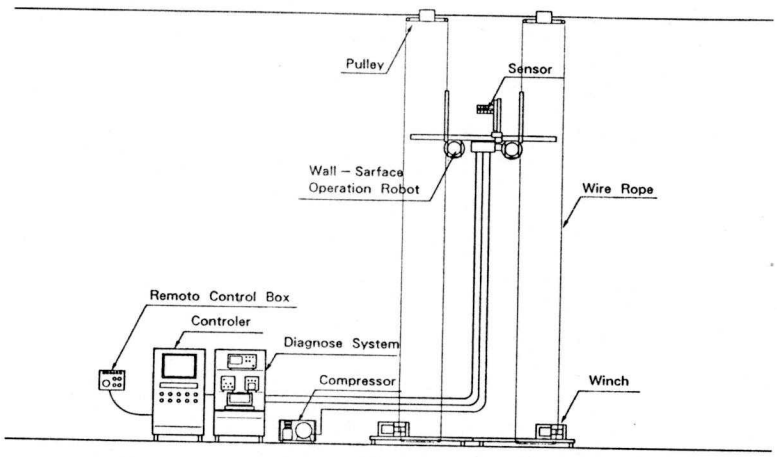

Fig. 5 System Configuration Drawing

3.3 CONSTRUCTION RESULTS

As above mentioned, Wall-Surface Operation Robot No.2 Machine has realized multiple applications on a wall. Tile separation sensing, so far, has been conducted by a man riding in a chair-shaped temporarily built gondola who, by patting tiles with an sensing bar with a ball attached on the edge, judges separation state from the sound. The work not only is dangerous as being carried out at an elevated spot but also tends to produce variation among inspectors as it totally depends on their experience and sense.

Sensing through use of this robot was conducted by using two sensors including one for the transmission side and the other for the receiving side each capable to cover sound waves within the auditory sensation area, mounted ona wall by air cylinders.

One cycle of the tile separation sensing through use of the robot consists of climbing as measuring deep joint position by a program, lowering as sensing tile separation, and moving of the winch base to the next panel. On completion of the work, results of the inspection including positions on a wall and judgment are stored as numerical data in a computer.

As it has been found that each cycle took 80 minutes, tile separation sensing capacity of 42.5m^2 per hour or 320m^2 per day was obtained. The actual sensing situation is shown in Photo 2.

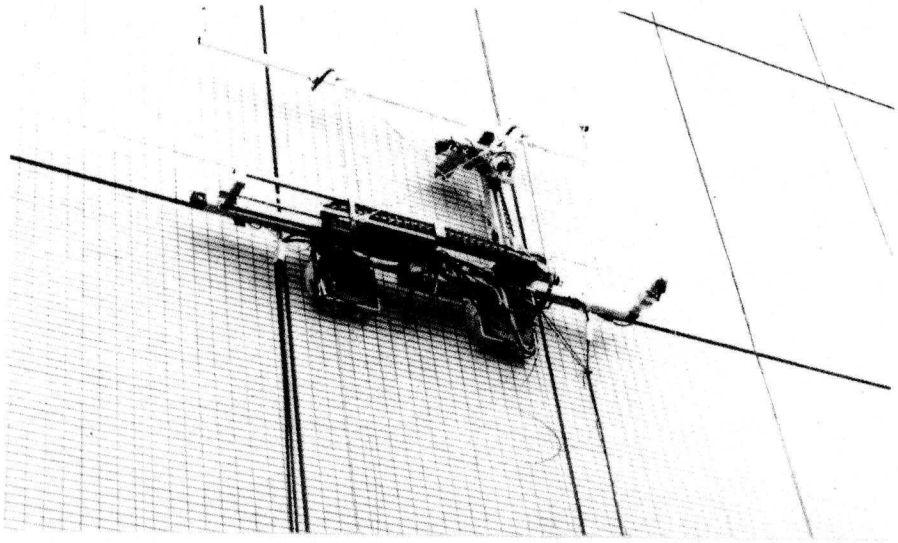

Photo 2 Sensing Situation

4. CONCLUSION

Trend of structures seems to be shifting from the age of mass supply to the age of stock adjustment, where the renewal market serving for maintenance improvement in function of existing structures is expected to expand in future.

Wall-Surface Operation Robot (No.2 Machine) aims to automate and improve in efficiency a series of renewal works by adding, through changing of an attachment, new functions for cleaning, tile separation sensing and repair work to the original functions of picture painting in a single and multiple colors.

The inspection of this example was conducted as a periodic inspection of the 10th year for the office building concerned. And, high marketability is expected because of existence of many similar structures.

In future, we would like to expand applications of Wall-Surface Operation Robot, not limiting to outer walls of a structure, even to civil structures like dams and bridge piers.