Development of Omni-directional Miniature Robot for Machining

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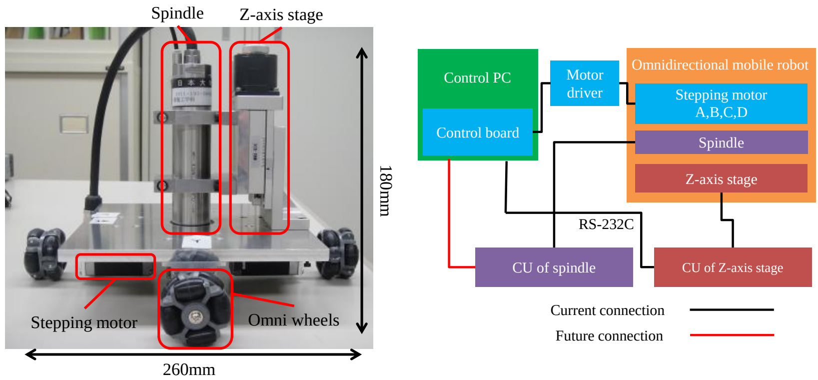
Abstract

When adding surface texture to large workpieces, large machines which are costly and take up considerable space are required. In this work, we therefore developed a low-cost omnidirectional miniature robot for machining, and performed basic experiments on surface texturing with the robot. With workpieces of 30mm × 30mm in size, the average error was found to be within ± 0.5mm for length and ± 0.5deg for angle. The results confirmed that the robot is capable of linear and perpendicular machining. We also proposed a rapid machining method using multiple robots simultaneously.

1. Introduction

In recent years, industrial products are artificially added with irregular or bumpy surface texture to improve visual quality or provide anti-skid effects. Surface texture is created by sandblasting or etching. Recently, studies are being conducted on creating texture by machining [1]. However, with these methods, the sandblasting and etching processes for texturing large workpieces of about 1000mm×1000mm in size for example require considerable time and effort. Moreover, large workpieces require large machines corresponding to their size, which lead to high costs and need for wide space. For this reason, we attempted to develop miniature robots capable of machining large workpieces at low costs, and succeeded in doing so by mounting the spindle and tool on mobile robot on omni-wheels. We also verified the effectiveness of the robots for texturing through basic machining experiments, and found that using multiple robots together enables texturing to be carried out faster and more efficiently than conventional large machines.



(a) Robot configuration **(b) System configuration**

Figure1. Configuration of our developed robot and system

2. Outline of omni-directional miniature robot for machining

2. 1 Robot configuration

Figure 1 (a) shows the configuration of the omni-directional mobile robot. The developed robot is approximately 260mm×260mm×180mm in size, and it is mounted on four omni-wheels. An omni-wheel is a special wheel with multiple rollers that can be rotated around the orthogonal direction at the wheel axis, thus allowing the wheel to be moved omnidirectionally. In addition, the wheels can move independently to each other. By setting four omni-wheels at an interval of 90° to each other, combined force is generated, allowing the robot to be moved in all directions. The spindle unit is secured to the Z-axis stage to control up/down motions and the cutting depth.

2.2 System configuration

Figure 1 (b) shows the system configuration of the omni-directional mobile robot. At this stage, the following two can be controlled using the control PC; the stepping motor which is connected via the motor driver and control board, and the Z-axis stage connected to the second control unit (CU) using RS-232C. The spindle must be manually operated using a separate controller. In the future, we plan to serially connect the CU of the spindle and control PC as shown by the red line in Figure 1 (b) and automate the machining process.

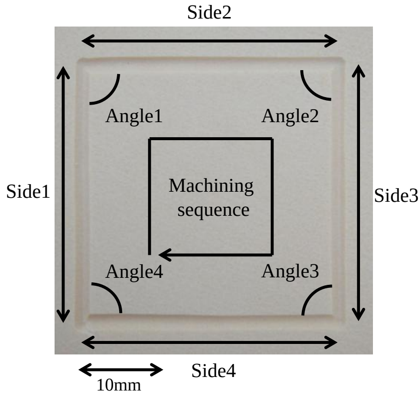


Figure2. Machining results

3. Basic experiments and accuracy evaluation

3.1 Outline of experiments

Basic experiments were conducted to evaluate the effectiveness of the robot using a 30mm×30mm workpiece made of chemical wood and a ball end mill tool with R1mm. We performed machining ten times under the conditions; cutting depth of 0.5mm, spindle speed of 30,000 rpm, moving speed of 19.6mm/s, and ten machinings. Figure 2 shows the machining results.

3.2 Accuracy evaluation

To evaluate the machining accuracy, the lengths and angles of each workpiece were measured as shown in Figure 2 using a protractor and ruler. Table 1 shows the average and standard deviations of the results after ten machinings. The average error is within ± 0.5mm for the length of one side and ± 0.5deg for angle. In addition, no large variation was observed for standard deviation. These results indicate that the robot is capable of linear and perpendicular machining.

4. Proposal of rapid machining method using multiple robots simultaneously

In this study, we also proposed a method of rapid machining workpieces using multiple robots simultaneously. First, the height of a template to serve as the

Table1. Average and standard deviation after ten times machining

(a) Length

	Side1	Side2	Side3	Side4
Average	29.65	29.85	29.75	29.50
Standard deviation	0.34	0.24	0.26	0.33

Unit: mm

(b) Angle

	Angle1	Angle2	Angle3	Angle4
Average	89.90	90.40	89.90	89.80
Standard deviation	0.57	0.70	0.57	0.63

Unit: deg

reference for measuring the circumference of the target workpiece using a ranging sensor was fixed at about 200mm high. The workpiece was then segmented into smaller pieces, one robot was assigned to each segmented piece, and machining was performed by the multiple robots simultaneously. The machining data, composed of the X, Y, Z coordinates centred at the spindle unit of the robot, was also categorized according to the workpiece segment, and each individual data was transmitted to the corresponding robot. The data was also stored in the control PC.

5. Conclusion & Future Work

Basic experiments on surface texturing using robots that can move omnidirectionally were conducted. With workpieces of 30mm × 30mm in size, the average error was found to be within ± 0.5mm for length and ± 0.5deg for angle. The results confirmed that the robot is capable of linear and perpendicular machining. In future work, machining experiments will be continued using various conditions to demonstrate the effectiveness of this robot for texturing, and improvements will be made to achieve higher machining precision.

Reference:

[1] Y. Kobayashi, K. Shirai, M. Sato, K. Tozawa : Development of Surface Texturing System by Mechanical Machining, ASPE, CD-R, 5p., 2004.