Path Generation and Posture Angle Control of Tool for Robotic Polishing System

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Path Generation and Posture Angle Control of Tool for Robotic Polishing System

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Abstract. To improve the quality and efficiency of the finish, industrial robots are used to polish the workpiece cavities with complex shapes. This paper presents key technologies of robotic polishing system including path generation, tool orientation control and G-code converting. Robot path data is generated automatically from the NC data, and tool posture angle is superadded to the robotic polishing path according to the requirement of the robotic polishing technology. Specialized software is developed to automatically generate a program, which includes the path data and tool posture angle, for the die polishing process and this program is uploaded to the robot controller.

Introduction

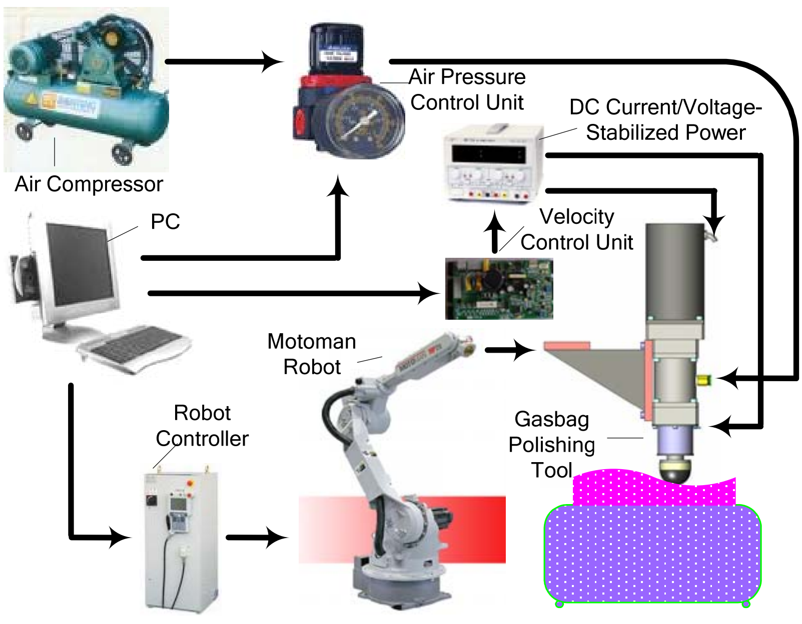

Fig.1 Schematic diagram of the robotic polishing system

Polishing is expensive and time-consuming task which continue to be performed by human workers. Some workers tend to gradually avoid the polishing work because of the poor working conditions caused by dust and noise[1]. It is important that industrial robots can relieve skilled and semi-skilled workers of this hazardous and monotonous operation. There are some amount of research has been reported on polishing the mold cavities with complex shapes using robot systems[2, 3]. Most of all, many techniques have been presented for the representation of position and orientation data of a robot end-effector[4-7]. However, the level of research in terms of a smooth surface finish and precision is far from satisfactory, while the feasibility is particularly weak. This paper presents some key technologies of robotic polishing system consisting of tool posture angle planning, robot program for polishing applications, G-code converting, aiming to meet t he request s of the robotic polishing for the complex mold cavities.

Robotic Polishing System

A schematic drawing of the robotic polishing system is shown in Fig.1. The system consists of the air compressor, an air pressure control unit, a DC current/voltage-stabilized power and velocity control unit, a gasbag polishing tool, a six-degree-of-freedom industrial robot, a dedicated robot controller, a PC. The PC uses a CPU Intel 2.5GHz with 2 GB RAM of memory. The robot is supposed to have the ability to withstand continuous reaction forces, the rigidity of the wrist, and a resistance to dust. Therefore, this research selects a Motoman hp20 manufactured by YASKAWA company, Japan. This robot is widely used in flexible manufacturing industry, such as assembly, handling, machine tending, packaging, palletizing, painting, welding, and so on. It is a six-degree-of-freedom articulated robot which uses high precision, speed reduction gears in place of harmonic drives, timing belts, or RV speed reducers.

The robot also uses a dedicated controller (NX100) that bipolartransmit the robot control data with the PC. When the operator uploads a set of data to the robot controller through the PC, the robot executes the polishing task.

Path generation for polishing application

In order for the robot tool to trace the polishing path accurately, position and orientation data must be provided to the robot controller. The robot control data that includes both position and orientation data of the robot on the moving path can be generated based on computer aided manufacturing (commonly abbreviated as CAM) module. The CAM system used in this paper is UG NX3 which is one of the most popular three-dimensional CAD/CAM software packages. This system generates the automatically programmed tool (commonly abbreviated as APT) source for NC machining process. The APT source obtained from UG is transformed into cutter contact data, which is finally written into standard CNC G-Code programs. Each point of transformed cutter contact data consists of three position coordinates (i.e., X, Y, Z) and three orientations (i.e., a, b, c), and the position coordinates is extracted to path data for robotic polishing.

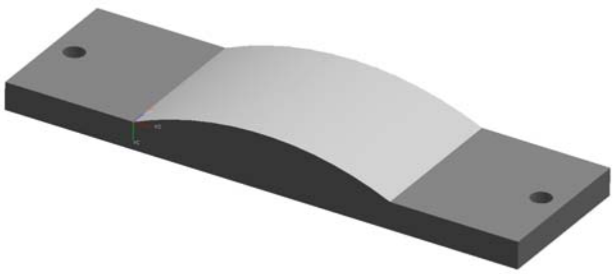

Fig.2 Workpiece for the polishing experiment

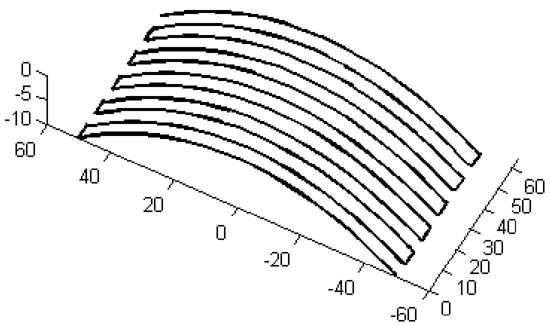

Fig.3 The path of polishing surface

The three-dimensional polishing path can be generated on any arbitrarily inclined surface and on any free-form surface. In this paper, the mild steel block used as workpiece for the polishing experiment is shown in Fig.2, and the polishing path generated using the reciprocating pattern is shown in Fig.3.

Tool orientation representation for posture angle control

The robot is controlled so that the polishing tool maintains a specified skew angle with the surface and moves along a proper polishing path. There are several methods for the representation of position and orientation data of a tool. The most popular and widely accepted representation technique is based on homogeneous transformation matrices. Some robot manufacturers have adopted the method based on quaternion algebra[8].

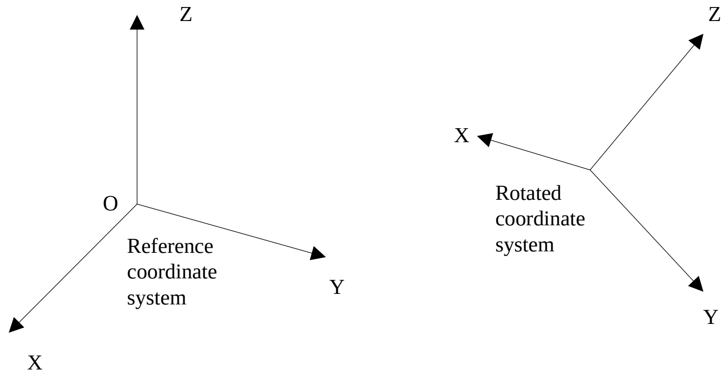

Fig.4 The orientation of tool coordinate system

The orientation of tool coordinate system can be described by a rotational matrix that describes the direction of the axes of the coordinate system in relation to a reference system, which is shown in figure.4. The rotated coordinate system axes (x,y,z) are vectors which can be expressed in the reference coordinate system as follows:

$$x = (x1, x2, x3)$$
$$y = (y1, y2, y3) \quad (1)$$
$$z = (z1, z2, z3)$$

This means that the x-component of the x-vector in the reference coordinate system will be x1, the y-component will be x2, etc. These three vectors can be put together in a matrix (a rotational matrix) where each of the vectors forms one of the columns:

$$\begin{bmatrix} x1 & y1 & z1 \\ x2 & y2 & z2 \\ x3 & y3 & z3 \end{bmatrix} \quad (2)$$

A quaternion is just a more concise way to describe this rotational matrix. This method uses three-dimensional data for the position and four-dimensional data for the orientation of a tool, the quaternion are calculated based on the elements of the rotational matrix:

$$q1 = \frac{\sqrt{x1 + y2 + z3 + 1}}{2} \quad (3)$$

$$q2 = \frac{\sqrt{x1 - y2 - z3 + 1}}{2}$$, sign q2 = sign (y3-z2) (4)

$$q3 = \frac{\sqrt{y2 - x1 - z3 + 1}}{2}$$, sign q3 =sign (z1-x3) (5)

$$q4 = \frac{\sqrt{z3 - x1 - y2 + 1}}{2}$$, sign q4 =sign (x2-y1) (6)

Most of the commercially available robot controllers use similar forms of position data. However, the controller for the Motoman robot use typically forms of orientation data, as follows:

P0002=69.726,905.45,-118.16,180,18.096,-45; (7)

(969.726, 905.45,-118.16) is the position of tool in Cartesian coordinate system, and (180, 18.096, -45) is the orientation of tool. The direction of the tool is rotated 180 about the X-, 18.096 about Y-axes and -45 about Z- axes in relation to the wrist coordinate system.

During the polishing process, the central part of the polishing pad does not rotate and work, therefore, we set the tool tilted from the surface normal vector. In this research, the tool posture angle is set at 15 after a number of polishing experiments.

G-code converting

Specialized software is developed here where the robot path data is generated automatically from the NC data of previous machining process. In the program, standard CNC G-Code programs generated from UG/CAM system are converted into Motoman robot programs to control the robotic polishing. The software is developed in a Visual C++ 6.0 environment and the total program structure is shown in fig.5.

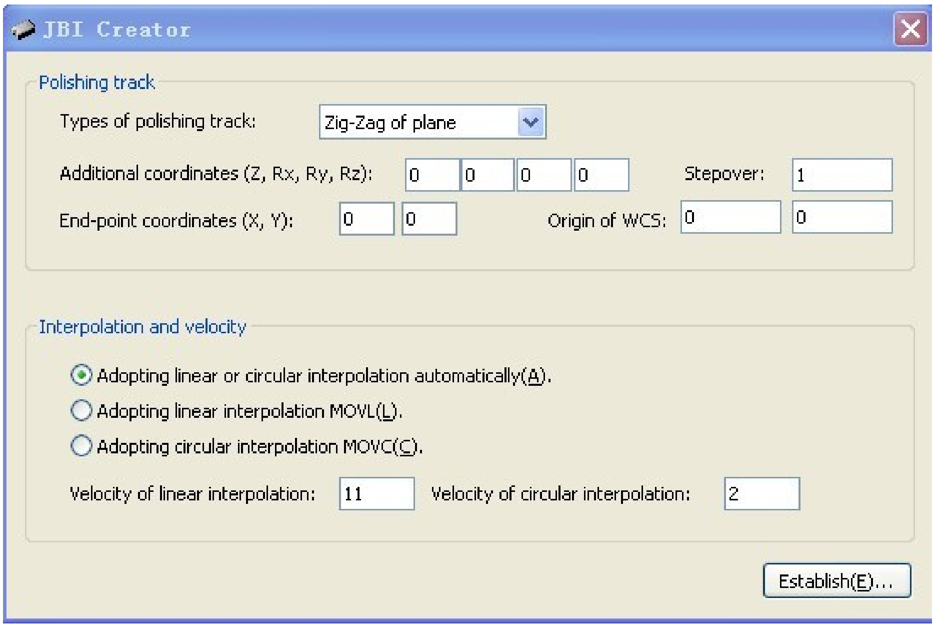

Fig.5 Program structure

The translated robot programs include I/O and other non-motion commands, such as path data, orientation, interpolation, velocity, and so on. CNC programs as large as 30,000 points can be converted in approximately 1 to 5 minutes and are complete and ready to run. The software provides the interface for input for origin of WCS. As Momtoman robot can read data including no more than 999 points, the software split automatically the path data into multiple files after the CNC programs being translated.

The polishing program is finally uploaded to the robot controller for robot operation.

Experiment and result

Table.1 The gasbag polishing parameters

Order	Items	Value
1	Workpiece material	Steel
2	Spindle rotation (r/min)	2000
3	Feed speed (mm/min)	60
4	Gasbag pressure (KPa)	20
5	Abrasive particle	synthetic diamond micro-powder
6	Polishing film	cotton fibre

For the experimental work in this paper, the workpiece is a machined mild steel block. The three-dimensional shape is designed by the software UG. The modeling data is transformed into APT source for NC machining, which gives the robot polishing data for the robot controller. The mild steel block used as workpiece for the polishing experiment is shown in Fig.2. The mold is machined by an 8 mm diameter ball end-mill with a 0.3 mm feed width. The mold is a simple convex surface (180 mm · 60 mm). The polishing path data of mold is shown in Fig.3. The spindle rotates at a constant speed of 3600 rpm. The details of the polishing parameters are presented in Table 1.

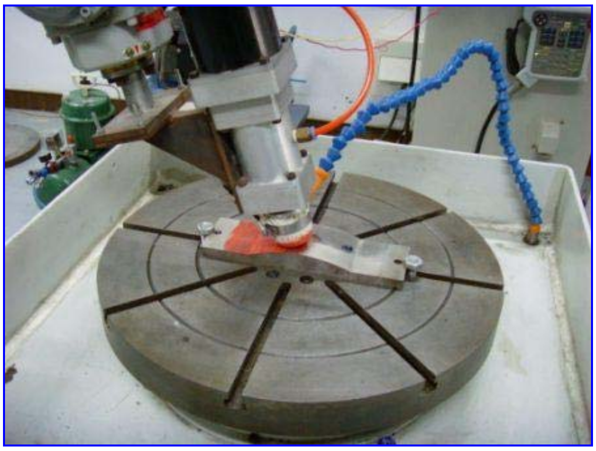

Fig.6 The tool and mold

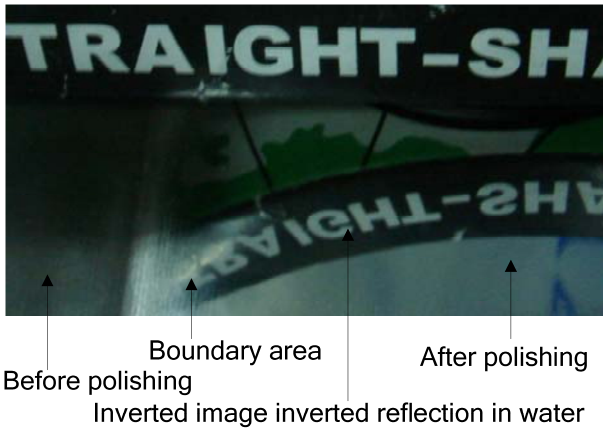

Fig.7 The mirror-finished mold

To increase the contact surface area between the tool and the mold, urethane rubber is inserted between the polishing pad and the polishing film as shown in fig.6. The mirror-finished mold after the final process is shown in Fig.7.

Conclusions

In this paper, a schematic drawing of the robotic polishing system is built. Method extracting path data from CNC G-Code programs is proposed, and methods of tool orientation representation are discussed. Specialized software is developed to convert CNC programs into Motoman robot programs for robotic polishing operation. Experiment is executed and result demonstrates the Correctness and efficiency of tool path generation and posture angle control for robotic polishing.

Acknowledgment

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Literature References

[1] H. Tam, O.C. Lui, and A.C.K. Mok, Robotic polishing of free-form surfaces using scanning paths. Journal of Materials Processing Technology, 1999. 95(1): pp. 191-200.
[2] Z. He, et al., A novel arc-spraying robot for rapid tooling. The International Journal of Advanced Manufacturing Technology, 2007. 31(9): pp. 1012-1020.
[3] B.S. Ryuh, S.M. Park, and G.R. Pennock, An automatic tool changer and integrated software for a robotic die polishing station. Mechanism and machine theory, 2006. 41(4): pp. 415-432.
[4] S.C. Clemson, A GEOMETRIC DECOMPOSITION FRAMEWORK FOR CAD BASED AUTOMATED POLISHING. 1990: pp. 81.
[5] U. Cho, et al., A flexible polishing robot system for die and mould. 1992. pp. 449-456.
[6] Y. Mizugaki, , M. Sakamoto, and T. Sata, Fractal path generation for a metal-mold polishing robot system and its evaluation by the operability. 1992. 41(1): pp. 531-534.
[7] Y. Kashimura, and N. Yashima. Study on Simplification of Teaching Method for Polishing Robot. 1993: JAP SOC PRESISION ENG.
[8] B.S. Ryuh, Robot trajectory planning using the curvature theory of ruled surfaces, in ETD Collection for Purdue University. 1989.