A Review of Novel Sensing Techniques for Automatic Polishing Robot System

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Abstract - The use of polishing robots to automate some tasks involving sensor has been restrained mainly by the difficulty of surface measurement. Therefore, there is the need of systems able to sensing a high level description of the task. The aim of this research was to identify a novel sensing techniques for automatic polishing robot system. A systematic literature review was performed gathering relevant information. The results shown several sensing technique trends related in this area. Next, the research direction has been suggested to develop the automatic polishing robot system.

Keywords - polishing robot, sensing technique, surface measurement.

I. INTRODUCTION

Polishing are final finishing processes that are widely used in many manufacturing industries including aerospace, automobile, dies and molds. Polishing is a process that uses abrasives to smooth the part surface without affecting its geometry. Traditionally, polishing has largely been a manual operation that is very labor intensive, highly skill dependent, inefficient with long process time, high cost, error prone, and hazardous due to abrasive dust. Automation is a solution to over come the above-mentioned problems of the manual operation [1].

Polishing also does not require as high a positioning accuracy, or else human operators could not have performed it. The importance of polishing automation has drawn many researchers into investigating robotic polishing technology. The major goal is to improve time efficiency together with surface quality [2].

However, the successful implementation of an automated polishing system requires in depth studies on the polishing process, there by introducing science into this traditionally ‘‘art-based’’ manufacturing process. In the past, limited research has been carried out to investigate prospective methods for designing and implementing automated polishing systems. Some significant novel sensing techniques for automatic polishing robot system has been reviewed in this paper.

II. LITERATURE REVIEW

There are several sensing techniques used for polishing robot system that can be categorized into some types that defined below.

A. CAD/CAM Based

Most of the mold makers usually employ CAD/CAM systems in order to design work pieces and to prepare the CNC programs to manufacture the parts, this CAD data can also be used to prepare programs for the actual robot finishing of these parts.

Basanez and Rosell [3] presents a formal analysis of the problem and the proposed solution, which is divided into two parts: the task specification module and the task planning module. The task specification module is a graphical user interface (GUI) that allows the user to easily specify the polishing curves over a computer-aided-design (CAD) model of the part. The task-planning module finds the time-optimum sequence of collision-free trajectories to execute the task.

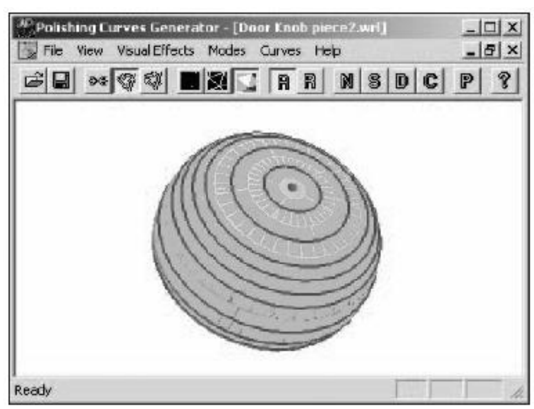

Fig.1. The polishing curves defined over a doorknob

Marquez et al. [4] provide different partial views of the aspects involved in the complex surface polishing problem. The proposed automatic robotic polishing system intend to integrate one theoretical model for finishing parameter evolution with a control system for a robotic polishing cell to automate as far as possible the finishing operations over complex geometry workpieces. To carry out this objective one process planner and one computer aided programming system have been developed within of a CAD system environment.

Lee [5] has developed automatic teaching system was developed to easily obtain teaching data and it consists of a three dimensional joystick and a proximity sensor. Also, to evaluate the performance of the integrated operating program and the polishing robot system.

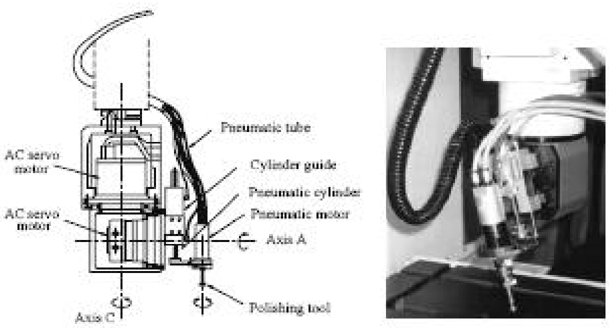

Fig.2. Two axis polishing head

The teaching system was added to obtain the polishing data of a specific area from the whole die automatically. Also, in order to evaluate the polishing performance of the polishing robot system and the stability of the integrated operating program, polishing experiments were performed on a die of a shadow mask. The polishing experiment showed that the surface was as smooth as a mirror. It may be concluded that the developed polishing robot system provides a reliable polishing performance. Cutter location (CL) data, which are tool paths generated by a CAD/CAM system, are directly used for the basic trajectory of the handy tool attached to the robot arm. The robot can be applied to the task of free formed curved surface with which conventional machines have not been able to cope [6].

B. Force Sensor

Pressure sensors are used in numerous ways for control and monitoring in thousands of everyday applications. A pressure sensor generates a signal related to the pressure imposed, such a signal is electrical. The polishing normal force may vary with the radius of the curvature of the surface to be polished when the distance between three probes is large. The range of surfaces which may be polished with this end-effector is, therefore, limited by this factor.

As polishing proceeds, the end-effector uses position sensors to measure the misalignment of the robot's wrist from the local surface normal. A personal computer is used to acquire sensory data, to compute the desired configuration of the robot wrist, and to control the robot in a point-to-point mode. Experimental performance tests show that the polishing system can function well under a variety of working conditions [7].

Nagata et al. [6] deals with a sanding system based on an industrial robot with a surface following controller for the sanding process of wooden materials constructing furniture. Handy air-driven tools can be easily attached to the tip of the robot arm via a compact force sensor. The robotic sanding system is called the 3D robot sander. The robot sander has two novel features. One is that the polishing force acting between the tool and wooden workpiece is delicately controlled to track a desired value, e.g., 2 kgf. The polishing force is defined as the resultant force of the contact force and kinetic friction force. The other is that no complicated teaching operation is required to obtain a desired trajectory of the tool.

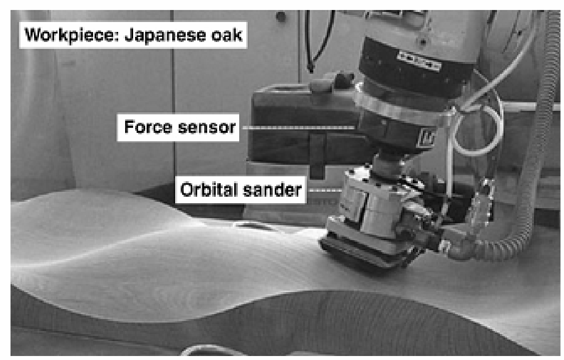

Fig.3. Sanding scene using an orbital sanding tool

It was also demonstrated that the proposed system could successfully sand the curved surface of attractive furniture with extremely good quality. The process parameters such as sanding conditions and control gains given in the experiments were tuned with trial and error in consideration of efficiency and sanded surface quality, and worked well. However, if the robot sander is applied to other different materials, desirable parameters (i.e., semi-optimized parameters) should be found again. Because the desirable parameters tend to largely depend on the species of wooden material.

Liao, et al. [1] has developed a system for modeling and control of an automated polishing process that utilizes a dual-purpose compliant toolhead. This toolhead has a pneumatic spindle that can be extended and retracted by three pneumatic actuators to provide tool compliance. By integrating a pressure sensor and a linear encoder, this toolhead can be used for polishing. For the polishing control, the tool pressure is pre-planned based on the given part geometry, For the polishing control, a PID controller is applied for pressure tracking though pressure sensing. The experiment results show that this control scheme can effectively control the tool pressure to follow the planned tool pressure under the constant contact stress condition.

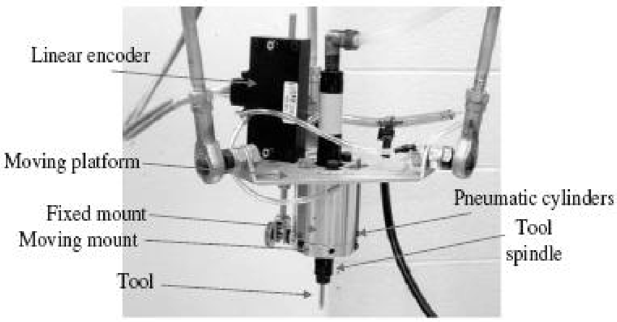

Fig.4. Prototype of the dual purpose toolhead

The surface roughness measurement in the polished area has proven the uniform polishing along the part geometry with varying curvatures.For the polishing control, another PID controller is applied to maintain the desired tool length through tool extension sensing. The experiment results show that this control scheme can effectively control the tool length with or without the occurrence of burrs. The part profile measurement has proven the uniform polishing along the part geometry with varying burr geometry.

C. Ultrasonic Vibration

Zhao, et al. [8] built ultrasonic machining system and methodology by which a robot polishes on free-form surfaces at an oblique angle with an elastic tool. On the basis of the theories of reflection of elastic waves and dynamic stress concentration, the conception is brought forward that ultrasonic elastic contact is not continuous, the physical process of the oblique ultrasonic polishing is studied and the cutting mechanism of the abrasive finish machining methods driven by ultrasonic vibration is ascribed to the joint action of the machining operation and shot blasting. Experimental results verify that the new oblique ultrasonic polishing method by robot is an effective machining method for free-form surfaces.

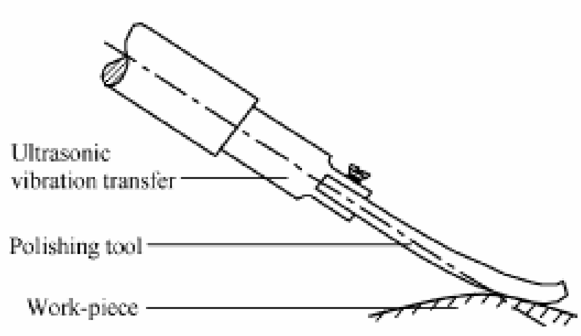

Fig.5. Polishing tool of compliant EDM

D. Touch Trigger Probe & Laser Scanner

Yang [9] deals with a new shape adaptive motion control system that integrates part measurement with motion control using Ryerson robot. The key technology used in surface measurement and surface reconstruction is the spatial spectral analysis. In the surface measurement block, a new spectral spectrum comparison method is proposed to determine an optimal digitizing frequency. The task of surface measurement is to drive a digitizer to digitize the surface. The digitizer could be a contact probe, such as touch trigger probe (TTP) as shown in Fig.6, or a non-contact probe, such as laser scanner as shown in Fig.7.

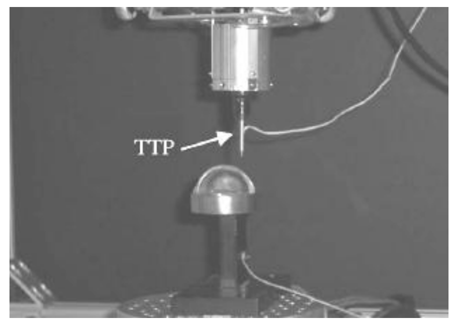

Fig.6. Touch trigger probe on the robot

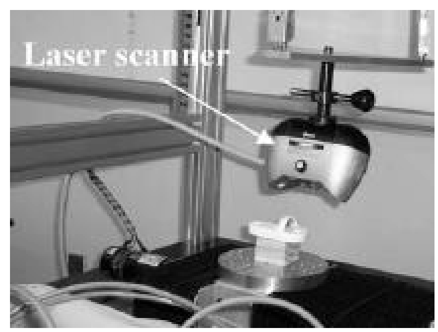

Fig.7. Laser scanner on the robot

The relation between the geometry and the digitization is most important for a good coverage of the part. The contact measurement is non-continuous, in which the probe moves point to point at the digitizing step size. At each point, the probe will stop to perform the measurement. The non-contact measurement is continuous, in which the scanner moves along the contour of the part without stopping to perform the measurement.

A software package is developed and implemented on the polishing robot. The effectiveness of the proposed system has been demonstrated by the experiment on edge polishing. In this experiment, the shape of the part edges is measured first, and then constructed as a wire-frame CAD model, based on which the tool trajectory is planned to control the tool to polish the edges.

E. Optical Sensor

Yiu and Tam [10] have developed computer controlled optical surfacing (CCOS) has been developed mainly for the fabrication of spherical and a spherical optics. The surface is repeatedly measured and corrected using abrasives until the target accuracy is attained. In principle, sub-micron accuracy is achievable. The accuracy is limited by surface measurement, and not by the processing equipment. The current research investigates the adoption of CCOS for the fabrication of free-form steel surfaces.

The surface is prepared by CNC surface machining with the initial maximum error over 50 um. The positioning accuracy of the motion system is estimated to be no better than 0.1 mm. Through surface measurement and correction, the surface accuracy is significantly improved.

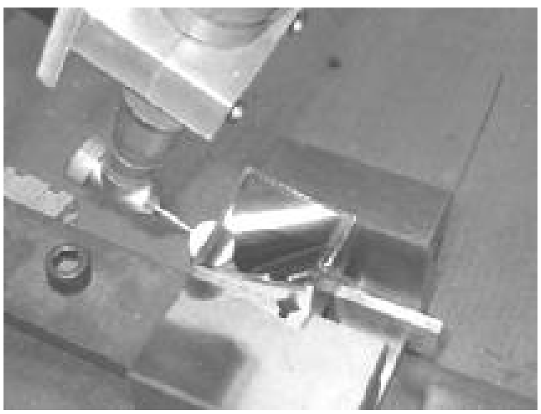

Fig.8. Close-up view of the spindle and the specimen.

In view that the initial surface error is quite large. An heuristic method was adopted that focused on: (1) removing material at locations where the error was large; and (2) avoiding removal at locations where the error was very small. This was motivated by the fact that CCOS could be used in optics manufacturing to produce mirrors and lenses of remarkable precision. The experiment demonstrated that the maximum error of the DF2 steel specimen was reduced from over 50 μm to slightly about 20 μm in a small number of iterations. The amount of material removed from the surface co-related well with the planned removal.

F. Vision Sensor

The non-contact methods may present an alternative to allow the surface roughness to be measured rapidly and with an acceptable accuracy. One of the most promising of the non-contact methods in terms of speed and accuracy is the computer vision technique [11]. The surface roughness of turned parts measured by computer vision system over a wide range of turning conditions could be got with a reasonable accuracy compared with those measured by traditional stylus method. Comparing with the stylus method, the constructed computer vision system is a useful method for measuring the surface roughness with faster, lower price, and lower environment noise in manufacturing process [12].

Kiran et al. [13] deals with the possibility of doing using a vision system in higher levels of automation in the shop floor for evaluating surfaces of medium finished parts. He conclude that the direct imaging approach is quick and easy to apply in the shop floor level.

Kindi and Shirinzadeh [14] has developed feasibility assessment of acquiring vision-based surface roughness parameters for specimens produced by different machining type processes. The overall results assure that vision data have great inheritance of the surface profile, thus encourage the modification of these models to enable them achieve more complying results of the roughness parameters.

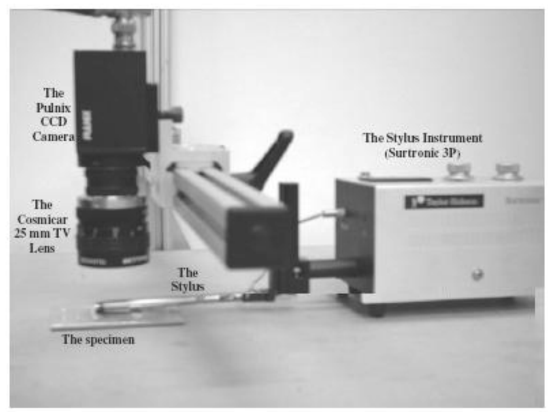

Fig.9. Surface roughness inspection by Kindi and Shirinzadeh.

Lee et al. [13] has been built vision system to capture images for surfaces to be characterized and a software has been developed to analyze the captured images based on the gray level co-occurrence matrix (GLCM). 3D plots of the GLCM and some statistical parameters have been employed to characterize surface roughness. Therefore, the SDM is considered the most suitable parameter for both smooth and rough surfaces.

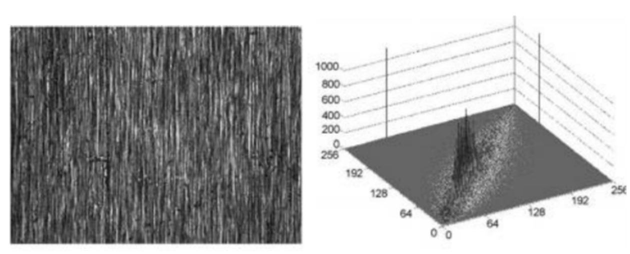

Fig.10. The captured images and the corresponding GLCM for the lapped specimens.

III. DISCUSSION AND FUTURE WORK

The sensor that has been explained above can be devided into *contact methods* (force sensor; ultrasonic vibration) *non-contact methods* (optical sensor; vision sensor) and *combining both methods* (CAD/CAM based; touch trigger probe and laser scanner). Many experiments develop contact-methods that simpler than the other because it gives direct sensing to polishing robot system. Contradictory with contact methods, non-contact methods rarely used for polishing robot. It often used for surface roughness inspecting for evaluation in final polishing process. Whereas, the combining both method fill a gap in non-contact method comparing with contact method. The non-contact methods may present an alternative to allow the surface roughness to be measured rapidly and with an acceptable accuracy. One of the most promising of the non-contact methods in terms of speed and accuracy is the computer vision technique

IV. CONCLUSION

We have reported the continuous research project aimed to identify a novel sensing techniques for automatic polishing robot system. The research is developed with identifying the appropriate literature from several published journal. The results have shown the trends that related in the fields area. Next, those trends will be definitely giving benefit for assist the research project team to develop the system. In future works, we plan to design computer vision technique that represent non-contact methods in surface roughness inspection that rarely used for polishing robot.

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