With a human touch

How robots have learned to polish

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An apparently simple operation to polish a work piece is in fact highly complex. A skilled person with a long experience in this process can do it very well and most of the handling is based on "feeling."

China has developed into an industry for which polishing is an important step in production. The housings of mobile phones, computers, video cameras and similar consumer goods all need polishing before they can be used and China is a global center for the manufacturing of these parts.

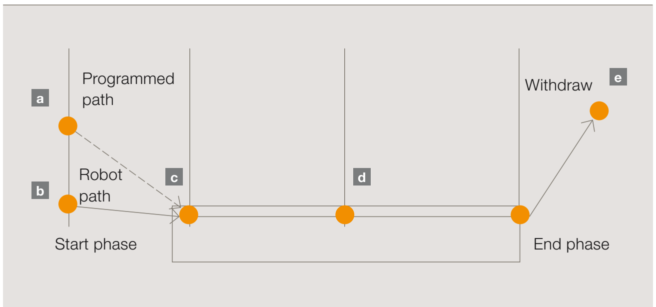
When we talk about almost one billion of those parts manufactured in China every year it is clear that even skilled workers cannot manage this huge amount of polishing.

With ABB's new software tools, robots can learn this "feeling" required for high-quality polishing. Their flexibility and constant optimal performance make robots an irre-placeable tool for the computer, communication and consumer electronics (3C) industry.

In recent years, the 3C industry has grown continuously and China's mobile phone industry is a good example of that. The total shipment in 2007 reached more than 636 million units, up 24 percent over 2006. Similar growth is expected in 2008. With this rapid growth, polishing as a part of mechanical finishing in die-casted light alloys gains more and more attention. Polishing can be, and traditionally is done by manual work or by dedicated polishing machines. Now, robotic polishing is also being introduced as a new technology, which offers higher flexibility compared with manual polishing, and better economics than the use of dedicated machines. Replacing the manual work and dedicated polishing machines with robotic polishing can give the operators reprieve from the harsh environment and improve quality and efficiency while reducing cost.

Manual polishing requires highly skilled and experienced workers, increasingly difficult to find, as fewer people are interested in the "dirty" polishing environment. To reach consistent quality when shifts are changing and workers' skills are varying is very demanding. The introduction of robotic automation to such processes not only alleviates the stress on workers but also guarantees high quality throughout the whole manufacturing process.

1 Phases for the Controlled Contact Force model



In the 3C industry, aluminum and magnesium alloys are the most common materials for the decorative parts that do not require dimensional accuracy, such as mobile phone covers, laptop covers or mp3 covers. Factories face the challenge of frequently changing parts, which raises the request for high flexibility, a clear advantage of robotic polishing.

But before robots can do this work with the "human touch," they must learn a number of techniques, which, in the language of robots, result in offline as well as online programming, now developed by ABB.

Sensitive robots need force control

The key issue for a good finishing quality is to control the material removal rate in the polishing process. With a given polishing fixture, the material removal rate can be controlled by the speed and contact force of the polishing tool. Controlling the speed is relatively easy but traditional robot position control is not sufficient to guarantee a stable contact force.

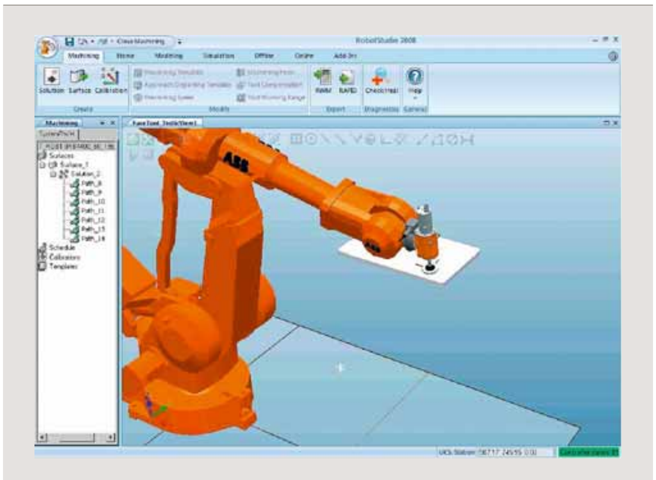
In the 3C industry, the most commonly used light alloys have a low surface rigidity. In this case, to obtain fine quality requires an accurately controlled contact force of the robotic surface finishing system. ABB's new Controlled Contact Force model makes robots sensitive to contact forces; the polishing pressure can be "felt" by the robot and the surface of the processed part can be followed to obtain the required pressure on the object.

The total shipment of parts from the 3C industry in China reached 636 million in 2006.

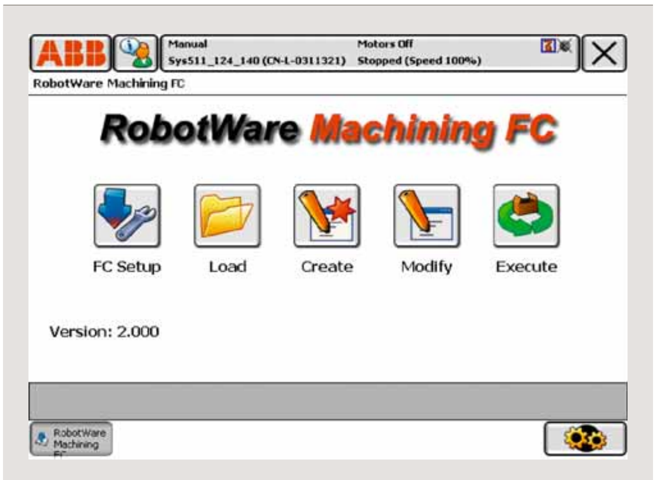
This means that the position of the robot will be adjusted to apply a constant force/pressure on the surface, even if the exact position of the surface is unknown. Since pressure is obtained by moving the robot path, this parameter is suited for polishing, grinding and cleaning, where a surface should be made even and smooth. The removed material and the subsequent changes of the surface topology are dependent on a number of process parameters like tooling, applied pressure or robot speed, for example.

The phases for the Controlled Contact Force model are described in 1.

2 RSMPP graphic user interface based on ABB RobotStudio



3 RWMFC graphic user interface on the Flex-Pendant of IRC5 controller



During the start phase, the robot is switched to the force control mode and moves in the direction of the reference force in order to get in contact with the work piece 1b. Once a contact is achieved the robot will start the movement towards the programmed position 1c. During the process of moving along the surface, the robot will still be kept in force control mode. After the last process movement, the robot is removed from the work piece and switched to position control mode when moving to the end position 1e. With a controlled contact force, the material removal rate can be kept constant during the polishing process and the required finishing quality is obtained.

Offline and online programming

ABB's force-control technology provides a well-defined value of the force applied to the work piece, but as a force is characterized by its magnitude and direction, the robot path needs a control as well. Most abrasive tools have a specific abrasive working surface, so that a different contact tilt leads to different polishing effects. To obtain the best quality, the abrasive tool has to keep both a stable contact with the work piece and the correct tilting angle along the polishing path.

In the 3C industry, a lot of decorative parts that need polishing have very complex shapes. To program a robot to follow these paths is a big challenge. Traditionally the path is programmed by hand when the coordinates of the path are determined by a worker. But an accurate polishing path on complex curvature surfaces requires hundreds of coordinates for the contact point, the tool orientation and the tilt of the tool.

ABB has developed two dedicated software applications for robotic machining to solve this complex problem. The CAD-model-based offline programming environment called RSMPP (RobotStudio Machining PowerPac) is a module within ABB RobotStudio 2. RobotStudio is a PC-based software, which provides virtual robot system support, offline programming and simulation in a 3-D environment. Based on this platform, RSMPP develops key functions as CAD-based path generation, machining-process template based programming, and exporting of the generated programs.

The online software product called RWMFC (RobotWare Machining Force Control) is based on the ABB IRC5 robot controller, and is a special option to support force-control-based robot machining applications. The key functions of RWMFC are online teaching, auto-path learning and exporting the program with its defined path parameters 3.

Robot polishing provides more stable finishing with increased productivity.

With the combination of CAD-model-based offline programming and online auto-path learning, accurate polishing can be provided. Based on the CAD model, by choosing the right polishing template, RSMPP generates the paths. The result can be tested in both a 3-D simulation or the real robot system.

If no CAD model is available, the user can use RWMFC to define rough outline points by leading-through with force control. Auto-path learning can then be performed by the robot system itself. With high accuracy, missing coordinates can then be added to the generated path. It is also very common that the CAD model shows small differences compared with the real part. When these differences affect the polishing quality from an offline-generated path on the real part, online auto-path learning can be applied based on the outline points generated by the offline RSMPP. 4 illustrates the functionalities of these software solutions.

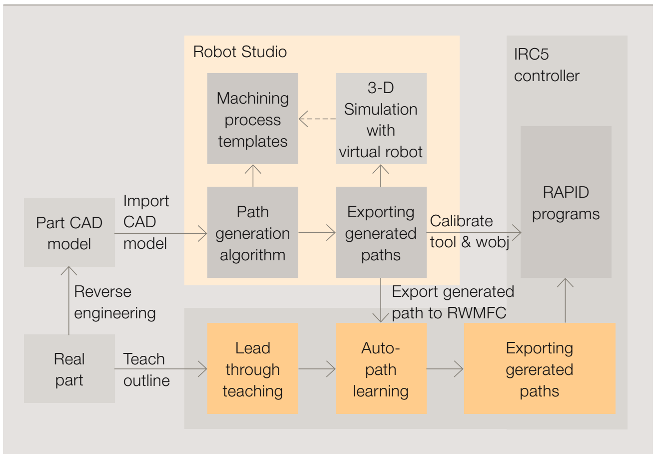
The ABB software solutions for automatically generating polishing paths not only improve the processing accuracy, but also introduce great flexibility for robotic polishing applications. When parts change, which happens very often in the 3-C industry, the time spent in re-programming robot can be shortened significantly.

Aluminum alloy LCD back panels

A typical case for a polishing work in the 3C industry is an aluminum alloy LCD back panel. The surface is a spherical area (marked in green in 5) on top of a square frame. Some scratches on the surface, probably generated in previous process steps, have to be removed before sandblasting and plating. In this typical mechanical finishing operation, a widely used medium-hard non-woven disc can be used to provide a proper material removal rate and surface finish. A CAD model and several test pieces are available to develop the applications.

As by position-control only at medium speed, a stable contact cannot be guaranteed, force-control is the right choice in this case. It is too time consuming to define the accurate polishing paths on this large part by hand; up to thousands of coordinates have to be defined. To provide a consistent surface finish for each part of the spherical area, the abrasive tool must contact the surface everywhere with a particular angle, which requires the tool orientation to change along the paths. Based on the CAD model, offline programming can be used to generate the machining paths for the pol-

4 Using RSMPP and RWMFC to automatically generate the polishing path



ishing process using the cutting plane method. 6 shows a 3-D simulation of the extracted polishing paths in RobotStudio, with different tool orientation depending on the surface curvature.

The generated coordinates are downloaded to the IRC5 controller. Now the path can be tested in a real environment. In this test, one may find that some polishing areas between the scratch gaps on the panel are not polished as well as the other areas.

This is a result of the die-casting process, which has introduced more deformation on this area than described in the CAD model. To overcome this deficiency, the online path learning based on the offline generated paths are applied to improve the contact stability. The corrected and fine adjusted path is now used as a reference for the auto-path learning function. With this new path, the test is repeated and leads to an acceptable finish quality of the work piece. With the combined effort of both offline programming and online path learning, the best fit process with several hundred coordinates is obtained in a short time.

After generating the accurate polishing paths, additional tests must be carried out to determine the factors that will influence the cycle time, tool wear and final finishing quality. These factors include the abrasive grain size, media hardness, abrasive tool diameter, spindle tilt angle and contact area. The result after these tests is a compromise between the final surface finishing quality, the polishing cycle time, the material removal and the abrasive tool-wear rate.

In comparison with the replaced manual polishing for this LCD back panel, robotic polishing provides more stable finishing quality with increased productivity.

The way forward

Robotic polishing in the 3C industry is a new application area for industrial robots, which so far seemed too challenging to enter. ABB, after developing the key required technologies – force control, CAD-model-based offline programming and online auto path learning – has paved the way to a broad implementation of robot polishing.

ABB is dedicated to further developing this attractive application by modeling the process parameters that, in addition to the robot performance, have an influence on the polishing task. A better understanding of these parameters will lead to a further increase in automation of a flexible robot polishing process, reduce engineering time, lift the quality and reduce the cost.

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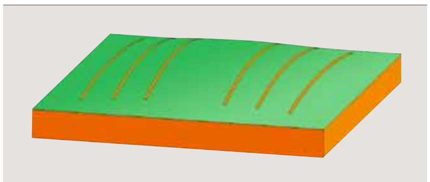
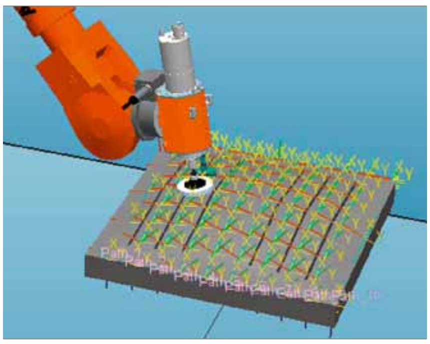
5 The CAD model of an LCD back panel



6 Generated paths in RobotStudio 3-D simulation



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