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Adaptive Robot Based Reworking System

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1. Introduction

Surface quality plays an important role for both components and products. Either are an exact form and a dimensional accuracy required to fulfil a certain function, e.g. in the case of turbine blades, or the visual impression of a surface must meet high demands, e.g. in sanitary fittings. In order to meet these high demands in material processing, processes such as grinding and polishing are often used (VDMA, 2000).

Nowadays the processes of grinding and polishing are automatised by industrial robots to release the operator and to grant an economical manufacturing. Presently known systems however face the problem that they can be adjusted to other part geometries and processing cycles only at high costs and therefore are used only in large batches (Schraft & Kaun, 1999). One reason are the work-intensive and time-consuming programming and optimisation of the movement paths, and another is that the handling systems do not recognize the existing defects on the surface resulting from grinding and polishing. As a defect-related adaptation to the subsequent processing steps is not possible, the reprocessing of the surfaces is done manually.

In this chapter a concept is presented which makes it possible to automatise the reworking of design surfaces of high-quality sanitary fittings with the help of industrial robots.

2. Analysis of the initial situation in the reworking of sanitary fittings

Design surfaces of sanitary fittings must meet high optical demands whereas a millimetre accuracy to size of the fittings is not required. The slightest defects in the surface, such as pores or cracks, and also slightly visible processing traces lead to fittings not being sold anymore. For this reason defective fittings must be reworked at high costs. Since current handling and robot systems are not flexible enough to react, the reworking is usually done manually.

The course of the manual reworking is the following:

First the operator checks the ground and subsequently high-polished fitting for possibly occurring defects in the surface. Frequently occurring defects in the manufacturing process are, for example pores, cracks or gas pockets.

When the operator thinks that the defects are small and can be removed by reprocessing, he marks the area, and passes the fitting on to the reworking station. If the defects are too big, he will reject the fitting. In the reworking station the defective area is first ground and then polished.

When analysing the manual reworking more closely, one sees that it is an iterative process. The operator first grinds a little area in the centre of which the defect is to be removed and then he checks the result. If the defect has not been removed completely, he repeats grinding it, but this time he will work on a bigger area. This is repeated until the defect is removed. Upon removal of the defect the operator tries to clear the traces of the processing by further grinding paths, finally he polishes the reworked surface largely.

The most important aspects of the manual reworking can be summarized as follows:

- Every high-polished fitting is checked for surface defects.
- Big defects are scrapped, little ones are reworked.
- If possibly, only little areas are reworked.
- There are two types of grinding paths:
 1. Paths to remove the defect.
 2. Paths to remove the processing traces.
- The result of the previous processing step is directly checked.
- The processing strategy is adapted to the result of the previous grinding step.

Fig. 1. Example for manual rework strategies.

3. Analysis of the transferability of manual rework to a robot-aided solution

If you try to automatise the above mentioned reworking process with the help of an industrial robot system, you will face various problems which make an adaptation to the abilities of a robot necessary.

When reworking, the robot system must take over the following tasks:

- To handle the sanitary fitting during the checking and reworking process.
- To check the sanitary fitting for surface defects.
- To make a decision if a defective fitting is to be reworked or scrapped.
- To select an appropriate strategy for the reprocessing and generating of the robot paths necessary for reworking.

- To process the defective fittings with the means of surface processing, such as grinding and polishing.

An image processing system is used for checking the surface quality (see also Kuhlenkötter, et al, 2004). This image processing system has an illumination especially developed for checking high-polished components to detect defects up to a minimum size of 0.3 mm and to classify them into different defect and polluting groups. For further information about the classification system see (Zhang, et al., 2006).

Due to the time needed for the checking of the complete surface (up to 25 seconds) it is economically not advisable to recheck the fitting each time after a processing step what makes a steady adaptation of the processing strategy - as it is done in manual rework - impossible.

Therefore the robot system must select a suited strategy for the whole reworking process and generate processing paths as to the strategy and adapt them to the previous case of defect already before the reworking process starts.

This reason entails another change in comparison to the manual process. The fact that it is not possible to check after each grinding or polishing process in which condition the surface is in and which defects and processing traces are still visible or have occurred newly, leads in most cases to an enlargement of the area to be processed. By that, it is granted that both the defect and the processing traces are actually removed and no further reworking will become necessary.

The division of the processing paths into groups of defect removal and groups of processing trace removal has been modified in comparison to the manual reworking. In the robot-aided reworking the paths for the removal of processing traces are subdivided into paths which border the paths to the outside and paths which are in the vicinity of the defects to be removed. This additional division helps to better adapt the paths to be generated to the respective location of the defect and the occurring type of defect.

4. Concept of a robot based reworking system

The robot based reworking system requires an intelligent link-up of the vision system for surface inspection, the selection of the right processing strategy and the following generation of the processing paths, which is based on the CAD-model of the handled sanitary fitting. In order to realise this link-up, some important questions need to be answered. One question is, how to draw a conclusion from the 2D information about the location of the defect, which is given by the picture of the vision system, to the 3D location on the CAD-model in a sufficiently accurate way. Another question is, how to generate the paths before each reworking process considering the requirements according to the requested station times. Or, if it is more practical to implement a database solution with stored processing strategies and appropriate paths and use a kernel function to select the elements out of the database which have the biggest similarity with the present case and interpolate between these elements.

Answers to these questions must be found to develop a reworking system which can be used under real production conditions.

In the application introduced here the 3D-position of the defect on the surface of the sanitary fitting and the CAD-model, respectively is determined by a projection of the defect-position on the 2D-picture of the vision system onto the surface of the CAD-model (see also Fig. 2).

Fig. 2. Projection of the defect position onto the 3D CAD model.

Such a projection is possible because all needed information like the focal point of the camera lens and the position of the inspected fitting is known, or can be determined. With this method it is possible to get the position of the defect with an accuracy of about two millimetres. A more accurate determination of the position without an additional complex sensor system is not possible. In nearly all cases the reached accuracy is sufficient, so that an additional sensor system is not needed.

The knowledge about the 3D defect position makes it possible to use the information about the position and the shape of the surface around the defect itself to generate geometry based processing strategies.

The shape of a workpiece and the required processing quality lead to high demands on the path planning process for industrial robots. The analysis of the manual rework and the transferability of the strategies of the manual rework to a robot based solution have shown that the loss of degrees of freedom leads to the necessity of developing a category of geometrical strategies for the defect removal that are suitable for industrial robots. Therefore the approach of a geometry value modification was used.

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This book covers a wide range of topics relating to advanced industrial robotics, sensors and automation technologies. Although being highly technical and complex in nature, the papers presented in this book represent some of the latest cutting edge technologies and advancements in industrial robotics technology. This book covers topics such as networking, properties of manipulators, forward and inverse robot arm kinematics, motion path-planning, machine vision and many other practical topics too numerous to list here. The authors and editor of this book wish to inspire people, especially young ones, to get involved with robotic and mechatronic engineering technology and to develop new and exciting practical applications, perhaps using the ideas and concepts presented herein.

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