In Process Visualization of Micro Manufacturing Operations

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Abstract

In general micro manufacturing operations are done by specialized machine tools. These tools are able to manufacture micro workpieces with a very low tolerance. For guaranteeing this high precision new machine tools are developed, which are able to execute the whole production process in one workspace. But for every quality check the workpiece has to be removed out of the workspace and that means also leaving the coordinate system and the references in relation to the machine tool. In this article a new optical measurement system for in process measurement is presented. The system can be used in two modes: first to reference the workpiece in the coordinate system of the machine tools and second as a measurement system for quality checking.

Introduction

The production of hybrid micro systems often takes place in process chains in the workspace of one production unit. In many cases the integration of various technologies for generating parts geometry or joining different parts is solved.[1,2] But the visualization of the workpiece in the workspace is still not satisfying even there is a strong demand for imaging processes. To improve the precision of positioning and clamping procedures the actual values of position (axial) and pose (rotational) of the workpiece has to be detected. Also its geometrical quality after machining has to be detected. Today available systems have still problems with the surroundings conditions in the workspace of machine tools like temperature or vibrations.

Experimental

To solve this problem a new imaging device based on a rod lens system [3,4], which is equiped by a micro objective, is developed at the Institute of Production Engineering at the Helmut-Schmidt-University. The system can be easily mounted very close to the workpiece, caused by its small diameter and so the picture of the workpiece can be transformed from the micro room to the macro room. Here the image is digitised by a CMOS camera and can be analysed with conventional image processing algorithms. By using this method, it is possible to analyse or to measure the workpiece without taking it out of its reference system.

The main specification for an optical system which should be include into the workspace of a machine are the geometrical dates like a small diameter of the system and also the optical dates like the distance between object and optic system (working distance of the system).

By using a rod lens system it is possible to fulfil the request of a small diameter. As a result of this small diameter it will be possible to mount the optical system close to the spindle. This is the reason why the optical system can be easily positioned above the workpiece by a simple offset movement.

Regarding the selection of the systems focus point inside the rod lens system, attention should be paid to the following constraints:
The optical system must be mounted high enough above the workpiece because it should not be damaged during the working process, but it must be also mounted in a position with enough distance between the workpiece and the tool when the workpiece will be in the focus of the system. Another important factor is that the focus distance of the rod lens system is fix. That means it is not possible to focus the system like a camera objective, it can just be focused by adjust the correct distance or by building a new lens system with another focus point, but this will be a very expensive way. For the aperture angle of the optical system it is also important to define the maximum object size which should be imaged, because the angle is also not variable. Figure 1 shows the system in principle with the defined values for the working distance and for the maximum object size.

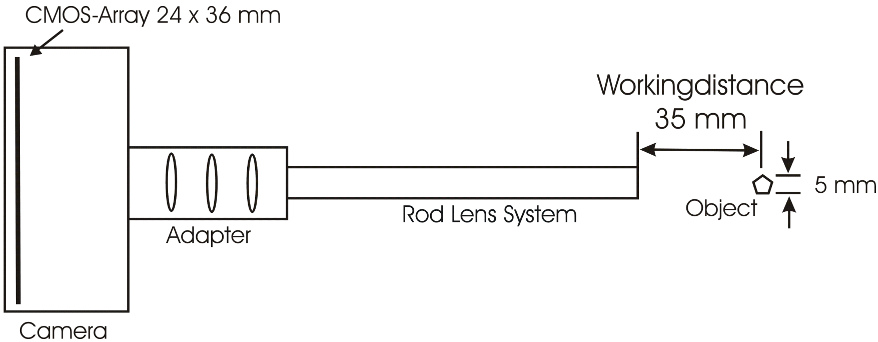

Fig.1: Main principle of the optical system

By integrating the system directly into the machine tool an image of the workpiece can be taken without changing the position of the workpiece, so it will be possible to control the quality of the workpiece after every production step. If it will be necessary to take the workpiece out of the reference system, e.g. for changing the machine tool, it will be possible to find out the current attitude by analysing the image of the object. When the optical axes are exactly in line with the machine axes, it will be simple to find out the angle of rotation relative to the machine tool axes by using a commercial image processing software. By knowing the angle the coordinate system of the machine can be rotated or the NC program for producing the workpiece can be adapted. This method can be used for reducing the number of failed workpieces.

Results and Analysis

Figure 2 shows the image of a partly manufactured workpiece. By using the image processing toolbox of Mathwork's MATLAB some typical geometrical characteristics of the workpiece are identified. Typical geometrical characteristics are e.g. edges or drill-holes and there centres. Before using the image processing toolbox the picture has to be changed to a black and white image because the toolbox can not work on colour pictures.

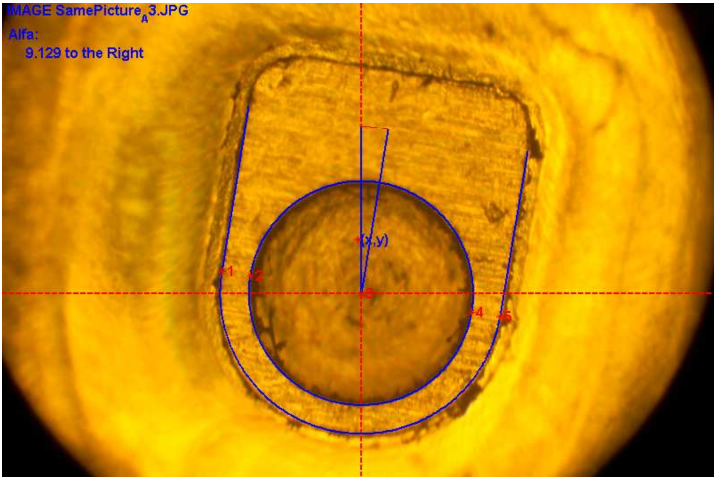

Fig.2: Analysed image of a workpiece, rotated for 9,129° relative to the tool axes (red lines)

The first step by analysing the picture is to find the centre of the drill-hole. In the second step the edges of the workpiece and of the drill-hole are detected. And finally the angle of rotation in terms of the tool axes (red lines) was established. Based on the geometric properties it is possible to conclude that the point of origin of the workpiece is also rotated to the angle. This information is needed to correct the parameters of the machine tool or the NC program for producing the workpiece.

Conclusion

The first done experiments have shown, that the concept of the optical system is working in general. As shown in figure 2 it is possible to find out a rotation in the xy-plain, which is e.g. one reason for an incorrect workpiece. The next step will be to integrate the system in that way into the machine, that the rotation relative to the tool axes will be transmitted to the machine controller where it can be considered in the next machining step.

Another point is to analyse the optical system concerning the optical resolution. It has to be checked, if the optical resolution is sufficient for the problem or if it has to be higher. Therefore it must be proved if it is possible to get a higher optical resolution in general or if there is limitation by the physic of optic.

Furthermore it has to be discussed how it is possible to update the system from a 2D-system to a 3D-system. Today only a rotation in the xy-plain can be detected by the system, that means it is not possible to detect a dumping of the workpiece.

In general the described optical system offers the opportunity to measure the workpiece in process. That means that it is theoretical possible to measure the workpiece after every machining step. By using the optical system as a measurement system a faulty workpiece can be located in the process early. That offers the opportunity to correct a mistake (if it is possible) before starting the next process step. Otherwise the incorrect workpiece can be taken out of the machining process, so that the machine can start to produce the next (hopefully correct) workpiece. In both case the production costs will go down. In the first case a incorrect workpiece will be corrected and so the number of useless workpieses will go down. In the second case the machine will not be blocked by machining a useless workpiece and the life time of the tools are not reduced by an unless process.

References

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