AUTOMATION OF ON-MACHINE MEASUREMENT BASED ON 3D CAD MODEL OF PRODUCT

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ABSTRACT

On-machine-Measurement (OMM) is the measuring on the machine tool and getting the result of machining instead of measuring on a measuring instrument. OMM doesn’t require the desperation and repositioning process, so the shortening the lead time for inspections is achieved. For execution of OMM the operator should set measurement strategy, such as measurement item, the number of measuring points and the position, to generate a NC program for the measurement.

In this study, our aim is the automation of those preparation tasks required time and effort, especially touch trigger probe which is introduced for NC machine tools is utilized. Our proposed system automatically recognize the machining feature from the Total Removal Volume (TRV) detected between the CAD models of product and material, and decide the measuring strategy. Therefore, the NC program for executing OMM with touch trigger probe is automatically generated. A case study was conducted to show the effectiveness of the developed OMM system.

Key words: On machine measurement, Measurement strategy, NC machine tool, Touch trigger probe, CAD

INTRODUCTION

High-precision machining can be realized by the latest modern machine tools. Several factors affect the machining accuracy, for example positioning accuracy and dynamic property of feed drive systems. Furthermore not only the accuracy of machine tools but also the cutting process itself during machining is also an important factor. However it is still difficult to suppress the machining error caused by the cutting process such as the tool deflection, the tool wear and the heat deformation during machining. Therefore, as one of the solutions for improving the machining accuracy, on-machine measurement (OMM) is introduced. In OMM, the work piece is measured on the machine tool. The advantage of OMM is that the measurement is conducted without desperation process and repositioning work piece, then the shortening the lead time is achieved. For these reasons, the necessity of OMM is increased to perform process and quality control during machining. However OMM requires to make a measurement strategy to decide measurement items and measuring points in detail.

In this study, our purpose is the automation of those preparation tasks required time and effort. In our proposed system, three process, the recognition of the product shape, setting the measurement strategy and the generation of NC program, are performed. For the recognition of product shape, the machining feature is extracted from the Total Removal Volume (TRV) between the CAD models of product and material. Then based on the machining feature, the measurement strategy can be set, and NC program can be generated. Our proposed system can eliminate the time for consuming preparation process by an operator and the autonomous OMM can be realized.

AUTOMATIC ON-MACHINE MEASUREMENT PLANNING SYSTEM BASED ON 3D CAD MODELS OF PRODUCT AND MATERIAL

In this study, the automatic on-machine measurement planning system is developed. In general, for executing on machine measurement, the NC program for the measurement is required same as in machining process on NC machine tools. In the NC program generation, the operator decides the measurement area in consideration of the design intention and the machining process, then decides the measurement items and positions of the measuring points, which is called teaching process. The measurement planning in this system has roughly three operations. The first operation is obtain of geometric information, second is decision of measurement strategy, and last is generation of an NC program for OMM.
Extraction and split of Total Removal Volume

In recognition of the measurement target shape, generally the machining shape is recognized from only the CAD model of product, however in OMM, the system should obtain the information where is machined or not. So this system is applied the method to extract and split the Total Removal Volume (TRV) which is proposed by our research group [6]. The TRV is extracted by Boolean operation between the CAD models of product and material. The advantage of this method is that the information of machining area which normally is recognized by the operator is easy to detect.

In the case the TRV has complicated shape, it is necessary to split into the simple shapes because computers can’t recognize the geometric features. So TRV is split by the planes into Split Removal Volumes (SRVs). The shape of SRV is a polygonal prism or a cylinder, and recognized easily for computers. The split plane is determined in consideration of actual machining, so the number of the split plane is reduced. Figure 1 shows the example of TRV extracted from the CAD models of product and material, and Figure 2 shows the example of the SRV. From the SRV, it is possible for this system to recognize the machining sequence, for example SRV1 is the face milling, SRV2 is slot milling, and SRV3, SRV4 and SRV5 are drilling, in this case.

Obtain of geometric information

Three kinds of geometric information obtained are machining feature, Open Face, and coordinate information. And geometric information is obtained based on SRV. At the beginning, it is necessary to get the shape information of SRV, so this system check the number of open face and the shape of tool approaching face, then recognize machining feature which is the basic form of machining. The open face means the face contacted with the atmosphere. In this study, 9 types of machining feature is considered and shown in Figure 3.

Measurement strategy based on machining feature

In this system, three measurement items, X-width, Y-width and Z-depth are set. This measurement is executed on the presupposition that the material flatness and degree of parallelization is accurate, so in measurement of 5 machining features (Open Slot, Step, Through Pocket, Through Hole and Face) some measurement is not activated, for example in the measurement of Through Pocket, the measurement of Z-depth is not activated.

In this paper, example of the position of measuring points in Open Pocket is described below. In the measurement of X-width, two measuring points are set on the two different planes, one is inside and another is outside of the removal volume. The detail position of measuring points for X-width are shown in the Figure 5(a), also measuring points for Y-width and Z-depth are shown in Figures 5(b) and 5(c), respectively.
The important consideration in path generation is the collision avoidance of the touch probe. In this study, the retracted point is set. The retracted point is set at a short distance from the measurement start point in Z-axis direction. The touch probe moves between the successive retracted points away from the product for the collision avoidance.

Figure 6 shows the example of touch probe path generated by this system. First, the touch probe is positioned at the retracted point, Point A, then the touch probe approach to the measurement start point, Point B, along Z axis. After the measurement, the touch probe return to the retracted point, Point A, and move to the next retracted point, Point C, for the next measurement and approach to the next measurement start point.

NC program is generated based on the measuring points and the touch probe paths described above. The NC program consists of three kinds of command for measurement, touch probe motion and measurement result output. The measurement results corrected by a computer can be compared with the design dimension, then the machining errors for each machining feature can be calculated and output for the product quality evaluation.

Case study

In order to validate the effectiveness of the proposed system, a case study was conducted. The CAD model used in this case study is shown in Figure 7(a). This model has several machining features, Open Pocket, Closed Pocket, Blind Hole, Open Slot, and Closed Slot. Firstly the model was machined by a vertical machining center NMV1500DCG (DMG MORI), then the on-machine measurement was executed using an NC program which is automatically generated by the proposed system under the same machine coordinate for the machining operation of this model. The touch trigger probe used is TC 52 (BLUM).
Table 1: The measurement result of case study

<table>
<thead>
<tr>
<th>Feature type</th>
<th>Item</th>
<th>CAD model (mm)</th>
<th>Measured (mm)</th>
<th>Error (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Slot</td>
<td>Y width</td>
<td>20.00</td>
<td>20.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Z depth</td>
<td>15.00</td>
<td>14.87</td>
<td>-0.13</td>
</tr>
<tr>
<td>Closed Pocket</td>
<td>X width</td>
<td>30.00</td>
<td>29.98</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>Y width</td>
<td>15.00</td>
<td>14.99</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>Z depth</td>
<td>15.00</td>
<td>14.86</td>
<td>-0.14</td>
</tr>
<tr>
<td>Blind Hole</td>
<td>X width</td>
<td>20.00</td>
<td>19.96</td>
<td>-0.04</td>
</tr>
<tr>
<td></td>
<td>Y width</td>
<td>20.00</td>
<td>19.98</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>Z depth</td>
<td>15.00</td>
<td>14.81</td>
<td>-0.19</td>
</tr>
</tbody>
</table>

The dimension of the test model is shown in Figure 8. In the measurement, no touch probe collision was occurred, and the measuring points matched the measuring point decided by our measuring strategy. In Table 1, the measuring results and the machining errors are summarized.

**CONCLUSIONS**

Our aim is the automation of the advance preparation for OMM with touch trigger probe, such as determination measuring item, the number and the positions of measuring points based on the shape of measuring target without any assistance of the operator. A case study showed the effectiveness of our proposed system.

(1) The geometric information about the measuring target is automatically obtained based on the extracted Total Removal Volume (TRV) form CAD models of material and product.

(2) The measurement strategy can be automatically determined based on the geometric information, and the NC program for the OMM with touch trigger probe also can be automatically generated.

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**REFERENCES**


