Digital Inspection of Cutting and Machining Based on Manufacturing Quality for Shop Floor

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Keywords: Digital inspection, Manufacturing quality, Digital measuring equipment.

Abstract. In this paper, based on digital measuring equipment, data and information flow, and local network of inspection, two main aspects of digital inspection of cutting and machining are discussed in detail including: digital inspection of dimension, and digital inspection of shape and position. For digital inspection of dimension, we can fabricate special apparatus with digital indicator and directly synthesize old tester and new digital indicator to implement digital inspection of internal diameter, external diameter, depth and thickness. For digital inspection of shape and position, we should fabricate respective equipment to fulfill requirements of all kinds of parts and develop special inspection software. Then, this paper has also put forwards an actual example of manufacturing quality, and results show that digital inspection technology can be applied successfully in manufacturing factory.

Introduction

Standardization, automation, integration and digitalization have become main trends of quality testing for manufacturing factory. Among these aspects, digitalization is an update and new achievement for quality test because of the easiness of cooperation with computer processing, which decreases manual error and tiredness of manual labor. Digitalization technology have some advantages in quality testing, detail is shown in table 1. [1-3]

<table>
<thead>
<tr>
<th>Advantages of digital inspection</th>
<th>Application</th>
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<tbody>
<tr>
<td>Using property</td>
<td>Tolerance inspection, especially testing of shape and position</td>
</tr>
<tr>
<td>Digitalization performance</td>
<td>Error inspection in umbral place and open air</td>
</tr>
<tr>
<td>a. no indicating error because of its clear display, in which, light emitting diode is a typical application</td>
<td></td>
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<tr>
<td>b. accuracy of digital indicator is very higher, generally below 0.05%</td>
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<tr>
<td>c. sensitive to tiny signal, generally 0.1µV - 10µV</td>
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</tr>
<tr>
<td>d. rapid response, sampling velocity usually is 1 times/second to 1,000,000 times/second</td>
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<tr>
<td>Communication with computer</td>
<td>Quality monitoring and data saving in computer</td>
</tr>
<tr>
<td>easy to connect and data processing with computer and benefited to transmit for far distance</td>
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<tr>
<td>Calibration</td>
<td>easy to calibrate</td>
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<tr>
<td>easy to calibrate</td>
<td>Especially for micrometer</td>
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<tr>
<td>Maintenance</td>
<td>easy to maintain</td>
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Owing to rapid development of electronic technology, digital inspection technology and equipment have been studied deeply in research organization and instrumentation manufacturing factory. But digital inspection technology and application based on respective machining types and cooperated with actual manufacturing example are less investigated in the past. In this research, digital inspection technology of cutting and machining is analyzed in detail, and an actual example is discussed for manufacturing factory.
Digital Inspection of Dimension for Cutting and Machining [4-10]

Digital Inspection of Internal Diameter

Digital inspection of internal diameter is generally difficult than inspection of external diameter, and some measures should be adopted to solve the accuracy problem of inspection of internal diameter, for example reasonable choice of digital tester and familiar operational skill. In order to apply digital testing technology in inspection of internal diameter, we have synthesized digital indicator and internal measuring pole together. And it has been successfully applied in testing of internal diameter of thrust bearing, shown in figure 1.

![Figure 1. Digital inspection of internal diameter.](image)

Digital Inspection of External Diameter [8]

Digital inspection of external diameter generally use digital micrometer, and Shanghai measuring and cutting tool works have a series of digital micrometer, so user can choose according to accuracy and measuring range. We have produced a set-up seat for bar-shape part, such as lift-bar, in order to place conveniently the part when testing is done. The lift-bar and seat is shown in figure 2.

![Figure 2. Digital inspection of external diameter.](image)

Digital Inspection of Thickness [9]

Digital inspection of thickness is very popular in quality testing, especially in purchasing testing of manufacturing factory. We fabricated a thickness meter using the digital indicator of Shanghai measuring and cutting tool works, shown in figure 3. The measuring range of thickness meter is 0-10, and accuracy is 0.02. In figure 3, an applied examples are given, in which plane ring is in the right of figure.

![Figure 3. Digital inspection of thickness.](image)

Digital Inspection of Depth [4, 5]

In quality testing of manufacturing factory, depth inspection is also an usual working. To implement digital testing of depth, a digital depth meter is invented with the digital indicator of Shanghai measuring and cutting tool works.
Fabrication of Digital Depth Meter

**Fabrication of Apparatus of Digital Depth Meter.** The apparatus of digital depth meter is composed of four sections, including: (a) T type bench, (b) supporting section, (c) vertical pillar and lifting-lever section, and (d) base of instrument. Detail is shown in the left of figure 4. T type bench is used to position the work piece, and vertical pillar and lifting-lever section with a sleeve is supporting frame which set-up the digital indicator. And supporting section is the adjuster to fit the dimension of work piece.

![Figure 4](image)

**Fabrication of Measuring Probe of Digital Depth Meter.** In order to measure depth of all kinds of part, some measuring probes are fabricated to fit full requirement of shape of work piece. In the right of figure 4, it is a measuring probe with unusual shape.

**Error Analysis of Digital Depth Meter [3]**

**Mechanism Error of Apparatus.** For this digital depth meter, mechanism error of mechanical apparatus section mainly includes Abbe error. Abbe error of mechanical apparatus section is

\[
\delta_{me} = \delta_1 = a \cdot \tan \varphi = (2.5 + 2.25) \tan 1\varphi = 4.75 \times \left(\frac{1}{70} \times \frac{25}{180}\right) = 1.4 \times 10^{-3} \text{ mm}
\]

(1)

**Manufacturing Error of Apparatus.** Manufacturing error mainly includes manufacturing error of every part and assembly error of instrument.

a. Error from gap of measuring bar and sleeve

\[
\delta_2 = \frac{1}{2} (L \cdot \alpha consult) = \frac{1}{2} \left(\frac{1}{2} \cdot (L \cdot \alpha consult)^2\right) = 0.5 \times (100 \times \left(\frac{118}{60}\right)^2) = 0.0045 \times 10^{-3} \text{ mm}
\]

(2)

b. Error of measuring force

\[
\delta_3 = 0.45 \times \frac{2}{3} \times \sqrt{\frac{1}{P \cdot d}} \Delta p = 0.45 \times \frac{2}{3} \times \sqrt{\frac{1}{4 \times 4}} \times 0.8 = 0.096 \mu m
\]

(3)

We have,

\[
\delta_{ma} = \sqrt{\delta_2^2 + \delta_3^2} = \sqrt{0.0045^2 + 0.096^2} = \sqrt{0.009236} = 0.0961 \mu m \approx \delta_3
\]

(4)

Because \( \delta_{ma} \ll \delta_{me} \), \( \delta_{apparatus} = 1.4 \mu m \).

**Indicating Error of Digital Indicator Section.** According to product specification of Shanghai measuring and cutting tool works, indicating error of digital indicator section is

\( \delta_{indicator} = 0.02 \text{ mm} \).

Because \( \delta_{apparatus} \ll \delta_{indicator} \), the total error of digital depth meter is

\[
\delta_{total} = \sqrt{\delta_{apparatus}^2 + \delta_{indicator}^2} \approx \delta_{indicator} = 0.02
\]

(5)
Application of Digital Depth Meter

This digital depth meter can inspect all kinds of hole, grave, and groove, and its accuracy is 0.02, measuring range is 0-10. In figure 5, we have given an example of digital inspection of depth for length-plus lift bar, and the set-up seat is fabricated especially to position the testing part.

![Digital depth meter](image)

Accuracy: 0.02  
Measuring range: 0-10  
Tolerance: ±0.05  
Basic dimension: 2

Figure 5. Digital inspection of depth.

Digital Inspection of Shape and Position for Cutting and Machining

Measuring Method

Measuring method of shape and position error for rotational shape part is illustrated in figure 6.

![Measuring method](image)

Figure 6. Measuring method of shape and position error for rotational shape part.

Hardware Section

The hardware section of this new testing approach is based on digital test technology, which includes digital indicator and communication interface for computer.

All hardware of this testing approach is mainly bought from Shanghai measuring and cutting tool works, except which we designed and fabricated by ourselves.

Software Section

In digital inspection process of shape and position for rotational shape part, testing data should been gathered from indicators at movement of rotationing part, while the inspection pole touch the effective location of rotational shape part.

![Software](image)

Figure 7. Function diagram.  
Figure 8. Software of inspection of shape and position.
Using VC++ to program for data processing, can celebrate the speed of data processing and avoid the mistakes especially for tediousness, therefore, the error testing program is developed with VC++. The function diagram of computer processing is shown in figure 7.

The testing software of digital inspection of shape and position for rotational shape part is implemented visual technology, and actuality, consistency, stability, and easy-to-use are achieved. The interface of testing software is shown in figure 8.

**Example and Discussion [5, 6]**

Actual application of digital inspection for cutting and machining includes three aspects: (a) digital testing of general turning, milling and boring section, (b) digital testing of general grinding section, and (c) digital testing of free surface of machining. Detail is shown in figure 9. In this figure, some objective examples of part have been given, it would become references to execute of digital testing for product quality. [7, 8]

In application of digital inspection for cutting and machining, digital tester and instrument should be firstly applied for special operator of quality testing. Therefore, operators of producing should be gradually executed later.

Figure 9. Example of digital inspection of cutting and machining for manufactory factory.
Based on inspection accuracy, measuring method and easy-to-use, distinguished choice should be adopted in digital inspection of dimensional error for cutting and machining. Digital caliper and micrometer should be used for general turning, milling and boring. In this figure, digital caliper is used for inspection of part with lower accuracy between -0.10 and +0.10, and digital micrometer is used to test of part with higher accuracy between +0.036 and +0.018. Digital micrometer and internal indicator should be used for general grinding. In this figure, digital micrometer is used for inspection of grinding part with more stringent accuracy between +0.012 and +0.001, and digital internal indicator is used to test thrust bearing part with more high accuracy between +0.021 and +0.008. In digital inspection of shape and position error for cutting and machining, digital dial indicator can be used with testing apparatus to fit all kinds of requirement of workpiece. In this figure, a digital inspection equipment fabricated by ourselves is applied to test the rotational shape part with general accuracy blower than 0.02. In free surface measuring, coordinate measuring machine should be applied for requirement of high accuracy. [9]

Inspection local network can improve the efficiency of quality testing and control. computer will effectively lift responding speed, efficiency of disposing and safety of data for gathering, saving and transmitting of quality information. Set-up of inspection network should keep gradual procedure, and apply advanced technology of data communication such as advanced router technology. [10, 11]

Results and Conclusions

Digital testing is a new development and achievement for cutting and machining. Digital inspection can successfully and effectively applied in testing of dimension and shape and position for cutting and machining. For digital inspection of dimension, we can fabricate special apparatus with digital indicator to implement the digital inspection of depth and thickness, and directly synthesize old tester and new digital indicator sometimes. For digital inspection of shape and position, we should fabricate respective equipment to fulfill requirements of all kinds of parts and develop special inspection software. In detail, in digital inspection of turning, milling and boring, some digital tester can be adopted from instrument manufacturer for example Shanghai measuring and cutting tool works. In digital inspection of higher accuracy such as grinding process, precise measuring tester and instrument should be used. And for digital inspection of free surface of cutting and machining, the coordinate measuring machine should be applied. In order to improve efficiency of data and information flow, local network of quality inspection should been set up.

References


