DEVELOPMENT OF INTELLIGENT HARDNESS MEASUREMENT MACHINE

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ABSTRACT
This paper describes the development of lever-type Vickers hardness standard machine according to the requirements of ISO6507-3 by NIMT (National Institute of Metrology Thailand). According to ISO6507-3[1], the standard machine must pass both direct verification and indirect verification. The direct verification requires checking four parameters: test force, testing cycle, indenter shape, and diagonal measuring device. The most difficult parameter to control is the testing cycle. In testing cycle verification, there are three parameters concerned: approach velocity of the indenter shall be 50 \( \mu \text{m/s} \) to 1 mm/s, the duration of application of the test force shall be 13 s to 15 s, and time for application of the test force shall be 6 s to 8 s. The uncertainty of time shall be within \( \pm 0.5 \) s of each parameter. After the machine was modified, the testing cycle of machine can be automatically and precisely controlled by PC with well-designed interface software. The behavior of testing cycle of NIMT Vickers hardness standard machine was detected by using force sensing element and displacement sensor. We can successfully control the approach velocity in 5 \( \mu \text{m/s} \) resolutions, the duration of application of the test force and time for application of the test force in 0.1 s resolutions with \( \pm 0.5 \) s uncertainty of measurement.

1. INTRODUCTION
The Vickers hardness standard machine of NIMT, which is a lever-type machine, had been developed from Rockwell hardness machine. This machine operates under the regular force (5, 10, 20, 30, and 50 kgf) by automatic control through the lever of magnification ratio about 20 times of hanging weight. For direct verification, NIMT can select the indenter, adjust testing force, and improve diagonal measuring device to meet the requirements of ISO6507-3. However, the testing cycle of this machine still follows the Rockwell hardness test method, which is two-step force application. To meet the requirements of ISO6507-3 the two-step force application must be modified to one-step. Originally, approach velocity of the indenter and time for application of the test force\( (t_{0.1}) \) were controlled by same hydraulic damping. With this system, it is hard to precisely control the testing cycle, and the approach velocity and \( t_{0.1} \) are not independent parameters. Moreover, the indentation depth during the \( t_{0.1} \) is ranging from 10 to 100 \( \mu \text{m} \). To control \( t_{0.1} \) to be 7 to 8 seconds for 10 \( \mu \text{m} \) distance, the speed of indenter must be control in order of 0.1 \( \mu \text{m/sec} \). Thus with hydraulic damping, it is impossible to get the testing cycle in accordance to ISO6507-3.

2. PRINCIPLE OF DEVELOPMENT
According to ISO6507-3, new behavior of testing cycle after development should be able to control approach speed of indenter and duration of application of the test force separately from each other. Therefore, the set of new weight had developed. One weight represent to one force value. This method is easy to control and maintain testing force in control limit. The weight pan for carrying each weight is hung on the other side of the lever.

![New development of weight support for Primary Vickers hardness machine.](image-url)
When the tip of indenter just touch on surface of work piece, load cell A that have high sensitivity with small force will be perform with this touch. The just touch point is the beginning of the duration of application of the test force. When force on work piece over than 20g, load cell A will be obsolete action. Next stage is the operation of load cell B. This load cell will indicate actual force on work piece. It is the control point of the duration of application of the test force (14±1s). The speed of indenter in this stage will be slower than velocity in air. When the weight supports go down to the lowest position, 100% weight of weight pan will be applied to lever. The load cell B will be show that weight support and weight pan touch each other or not. The duration time from just touch point until 100% force applied is the time for application of the test force (7±1s). And the duration time from 100% force applied until unloads called the duration of application of the test force (14±1s). When this time reach 14s the weight support and weight pan will lift up, it’s mean that the indenter will be unload form work piece, at this stage is the end of make and indentation operation.

3. CONTROLLER AND PROGRAM

The high speed data acquisition card from NI is used for acquire digital data from depth measuring. In section of stepping motor control and force sensing element, another digital data acquisition was used. The operation of both DAQ card is obviously distinct. The monitoring program composing of control button, time and speed indicator and depth behavior graph. This software can indicate and control all of time parameter (approach velocity of indenter, \(t_0\), \(t_1\)) independently. The resolution of controller program is 0.01s time resolution.

4. TESTING CYCLE CALIBRATION

The real time hardware clock DAQ is used as data acquisition. Data from depth measuring device was acquiring follow time base of DAQ card. By using high precision function generator to generate high precision square pulse 5, 10, 15 and 20 s time period. DAQ card will acquire pulse signal by using same as operation sampling rate. The accuracy of time base of this system is better than ±0.05 s. The depth measuring device is calibrated by using ceramic gauge block with ±0.01µm accuracy. The accuracy of depth measuring device is better than ±0.15 µm. The speed of indenter is calculated from depth measurement and time measurement. After combine accuracy of time and depth together, the accuracy of speed is better than ±0.8 µm/s.

5. EVALUATION

To verify performance of machine, the 900HV5 and 200HV50 was used as artifact. Testing cycle behavior shown in Fig. 2. The result of testing cycle measurement shown in Table 1.

Fig. 2 Testing cycle of 200HV50 and 900HV5

<table>
<thead>
<tr>
<th>Hardness block</th>
<th>(v_{\text{indenter}}) (µm/s)</th>
<th>(t_0) (s)</th>
<th>(t_1) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200HV50</td>
<td>99.2</td>
<td>7.005</td>
<td>14.13</td>
</tr>
<tr>
<td>900HV5</td>
<td>97.53</td>
<td>7.465</td>
<td>14.01</td>
</tr>
</tbody>
</table>

The indentation depth on 900HV5 and 200HV50 are 3.65 µm and 66.56 µm respectively. The speed of indenter inside material is limited by \(t_0\). This operation is monitor by load cell B and control by stepping motor. Even softest block was indented by largest force (200HV50) and hardest block was indented by lowest force (900HV5), but from the experiment result in Table.1 shown that all time parameter according to ISO 6507-3.

9. CONCLUSION

This research has shown that NIMT was carrying lever type primary Vickers hardness machine. We succeed in development of primary Vickers hardness machine from Rockwell hardness machine. Two steps Rockwell hardness test force applied was changed to one step Vickers hardness test force applied. The behavior of testing force was monitor by using two load cell. The controller program is make operator easy to control and judgment. All of time parameter in testing cycle was control by PC with 0.01s time resolutions. Finally, the testing cycle of this machine can meet the requirement of ISO6507-3 with ±0.05s accuracy of time measurement and ±0.8 µm/s accuracy of speed measurement.

Future work, the judgment of testing cycle in this research is used low cost commercial type load cell as a force sensing element. This load cell can not provide precise force measurement, due to accuracy and repeatability of load cell. It should be replace by precision load cell to increase the accuracy of judgment.

REFERENCES