

DEVELOPMENT OF THE STANDARD ROCKWELL HARDNESS MACHINE BASED ON FORCE LOADING USING MOTOR IN CLOSED LOOP METHOD

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Abstract: This paper mainly presents that one standard Rockwell hardness machine has been developed based on force loading using motor in closed-loop method without weight. The mechanical structure of the machine, design principle of the closed-loop force and the control method, are introduced. The results show that the precision of the preliminary and total force can respectively achieve to 0.2% and 0.1%, and the expand uncertainty is not more than 0.3HRC, $k=2$.

Keywords: Rockwell, standard machine, no weight, motor, force sensor, closed-loop force

1. INTRODUCTION

Usually, the force of the most standard Rockwell hardness machine gain by the weight, now, this paper presents that one standard Rockwell machine has been developed without weight, the force generates by the motor load and the feedback force sensor using closed-loop method. This machine has some advantage:

1. No weight, small volume
2. Many hardness scales can be achieved in one machine, for example, Rockwell, superficial Rockwell, plastics determination of hardness and so on.
3. The parameter in the loading process can be controlled accurately.

The machine generally consists of three parts: the mechanical structure, the closed-loop force loading system and PLC control system. Figure 1 show that the overall blocks diagram of the machine.

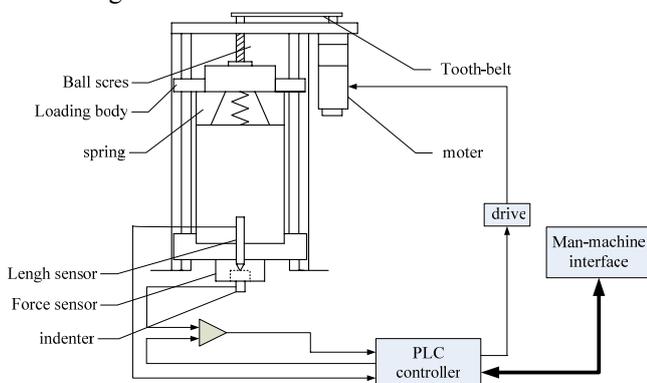


Figure 1 the overall blocks diagram

2. THE MECHANICAL STRUCTURE

Figure 2 shows that the mechanical structure of the hardness machine.

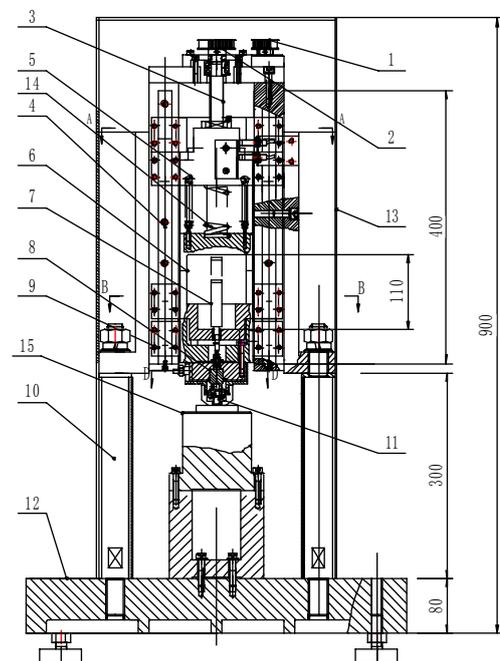


Figure 2 Mechanical structure

1 servo motor 2 tooth-belt 3 screw ball 4 linear bearings 5 secondary load body 6 primary load body 7 length sensor 8 force sensor 9 meter base 10 pillar 11 indenter 12 base 13 shell 14 spring 15 working table

The height of the new machine is only 90 cm, it's volume is smaller than other standard machines with weight. And the distance between screw and force sensor is 40 cm, this can be in favour of the precision of the test force control.

The depth of indentation is measured by length sensor and meter base which can be seen 7 and 9 in Figure 2, the measuring unit moves following the load body, so the meter spindle is always 6 cm which is adequately short, and the influence of machine hysteresis can be ignored.

Among the primary load body, secondary load body and meter base, using the linear bearing oriented, the orientation of linear bearing is accurate, so that the direction of test force loading and measurement is in the same straight line, to ensure the measurement accuracy.

Between the primary and secondary load body must have appropriate spring, to ensure the smooth transmission of test force and no impact.

3. THE CLOSED-LOOP FORCE LOADING SYSTEM

The best advantage of the machine is force loading without weight; the system loop diagram is shown in figure 3.

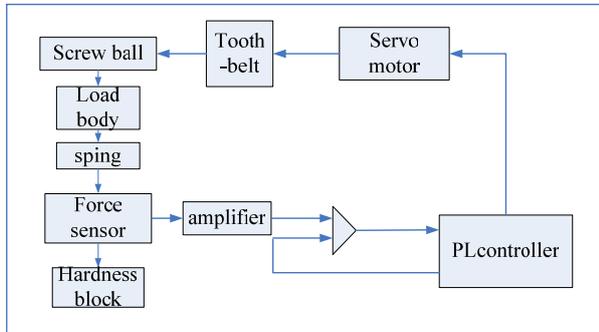


Figure 3 the closed-loop loading system

In this part, the important is the choice of the motor, force sensor and the spring.

Motor torque is calculated by:

$$T_L = k \cdot \frac{g \cdot P_B \cdot M_c}{2\pi \cdot n} \quad (1)$$

T_L - Motor rated torque

k - Transmission coefficient

g - Acceleration of gravity

P_B - Lead of screw

M_c - Mass of the weight

n - Mechanical efficiency

By calculating, the torque is not more than 0.3 NM.

The force sensor mainly considers two properties: static accuracy and dynamic performance. Table 1 shows the sensor's properties.

Table 1 Properties of force sensor

Zero error	0.025%
Combine error	0.0115%
Frequency response	1.6kHz

In the 3 kilogram of the force sensor, the performance will decline, but the stability and repeatability is not more than 0.2%.

The combine error of force sensor is less than 0.02%, but in the low load is about 0.2%.

Experiments show that the action of spring between loadings is important, by much experiments, can choose one appropriate spring.

4. PLC CONTROLLER SYSTEM

The system chooses PLC as controller, the Control algorithm can be described in Figure 4.

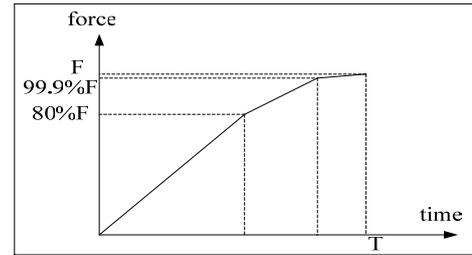


Figure 4 the control curve of force

F: the set force

T: the application time of the force

The loading process can be divided into three steps. Before 80%F, the motor run in a command velocity, when the force achieve to 80%, the velocity of motor change no more than 30μm/s, at the end of loading, in order to avoid overweight, after 99.9%F, the motor velocity will be more slow, with this method, experiments show have a good effect.

Using this new control type, the value of test force and the parameters, for example the velocity of load approach and time, can be controlled easily and accurately. Figure 5 is the setting interface of the test force, Figure 6 is the parameters.



Figure 5 setting interface of the test force



Figure 6 setting interface of the parameters

5. THE MEASUREMENT SYSTEM OF DEPTH

The schematic diagram of the measurement can be seen in Figure 7.

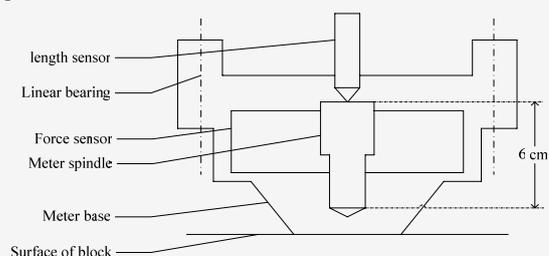


Figure 7 the measurement system

The measurement unit is one servo system, when the load body and force sensor moves, this unit follow it, so the meter spindle is only 6 cm, and in the measurement process,

there is no external force on the unit, the machine hysteresis almost no effect on the measurement.

The measurement instrument is one length sensor of Heidenhain, measurement resolution is not more than 0.004 μ m.

6. THE RESULT

We have much experiment, the machine can achieve the requirement of the precision, and table 2 is the result of the test force.

Table 2 the result of the force

Set force	Standard value	Test value	error
29.42 N	3.0023	3.009	0.22%
98.07 N	10.0035	10.0075	0.04%
147.1 N	15.01	15.01	0.00%
294.2 N	30.01	30.01	0.00%
441.3 N	45.00	45.01	0.02%
588.4 N	60.00	60.03	0.05%
980.7 N	100.00	100.02	0.02%
1471 N	150.02	150.03	0.01%

Table 3 is the stability of the hardness value among about three month.

Table 3 the stability of the machine

scales	Test result			stability
	1 st month	2 nd month	3 rd month	
HRC	63.51	63.50	63.51	0.01
HRC	46.20	46.34	46.34	0.14
HRC	26.46	26.43	26.30	0.16
HRA	83.75	83.74	83.76	0.02
HR45N	51.74	51.70	51.70	0.04
HR30N	80.19	80.21	80.23	0.04
HR15N	91.67	91.69	91.69	0.02

The expand uncertainty of the machine is evaluated not more than 0.3HRC, k=2.

7. CONCLUSION

The standard hardness machine using new type has good effect, because of its advantage: small volume, control easily and accurately, high precision of measurement, we think this type will has more and more application.

8. REFERENCES

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