IMEKO 2010 TC3, TC5 and TC22 Conferences
Metrology in Modern Context
November 22–25, 2010, Pattaya, Chonburi, Thailand

Upgrading of the Rockwell Hardness Primary Standard Machine

He Li[1] Zhang Feng[1] Ye Ming[1] Liu Lianqiu[1] Wang Beiping[2]
(1 National Institute of Metrology , Beijing, China, hel@nim.ac.cn,
2 Wuzhong Material Tester Limited Company, Wuzhong , China)

Abstract: According to the new definition of Rockwell hardness given by the international working group on hardness, the Rockwell hardness primary standard machine has been upgraded. As the new loading system, loading monitor system, PLC control system and laser measuring system have been developed, the function of the new primary standard machine can now meet the requirements of the new definition and its measuring uncertainty can reach the expected values.

Key Words: new definition for Rockwell hardness , toothed-belt drive, hydraulic transmission, loading monitor system.

1. A NEW DEFINITION

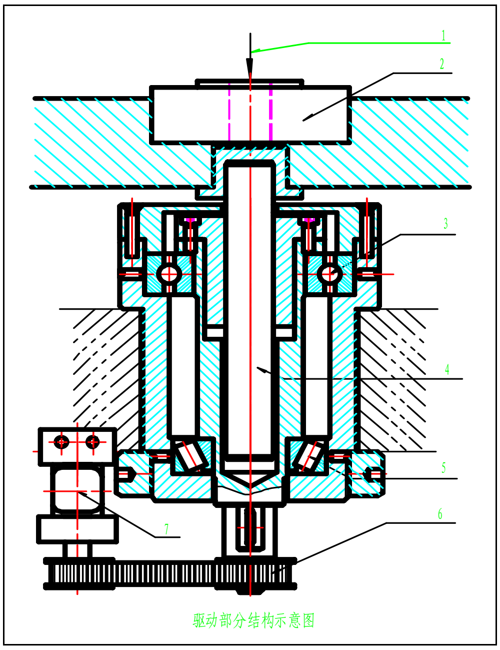
In the 8th working meeting of the International Working Group on Hardness in 2006, the Working Group approved the adoption of a new definition of the Rockwell C scale, uncertainty calculation and sensitivity coefficients.

2. RESEARCH AND DEVELOPMENT

The International Working Group requested of Member States to adopt the new definition on their Rockwell hardness primary standard machines and perform a key international comparison on Rockwell hardness of C scale in 2010- 2011. In this regard, we carried out research on the upgrading of the Rockwell hardness primary standard machine. The research is outlined as follows:

2.1 Developing the loading and unloading system

(1) Abort the hydraulic loading and unloading system and, according to the new definition, use a motor transmission system with a reduced vibration structure (the synchronous toothed belt drive) which can be precisely controlled, with a software for precise control of motor speed, to control the loading and unloading speed and loading time in the new definition. Structure of the driven part is shown in Figure 1.



1. Loading 2. Force sensor 3.Radial ball bearing
4.Ball screw 5.Cone bearing 6..Synchronous toothed belt
7.Servo motor

Figure 1 Driven part

(2) PLC (Programable Logic Controller) controlled motor loading and unloading system

The newly developed loading and unloading system uses PLC and a serving motor. It can quantitatively control the loading and unloading speed and is easy to operate, programmable and provide a high level of controlling precision.

Scheme of PLC controlled motor loading and unloading system unit is shown in Figure 2:

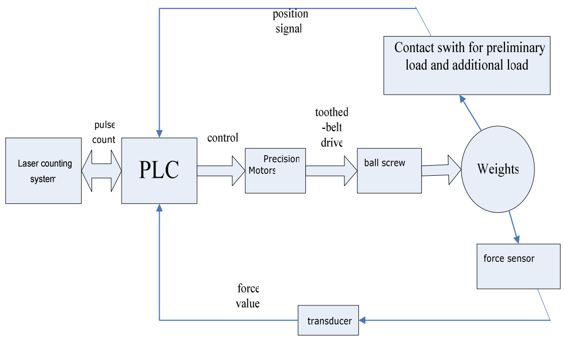


Figure 2　PLC controlled motor loading and unloading system

2.2 Developing a system to monitor the loading and unloading process

Under the new definition, the loading speed is required to change at 80%　of　required testing force. This requires that the hardness machine be equipped with a force sensor to monitor the entire loading process. To meet this requirement, we developed a specialized force sensor and the measuring and controlling system tailored to the structure of the host machine.

Using this system, the sensor gives the signal when the measurement of HRC scale reaches 80% loading and the loading speed is changed. The end loading speed is 30 µm / s, Figure 3 is a computer display of the FT curve of the actual loading.

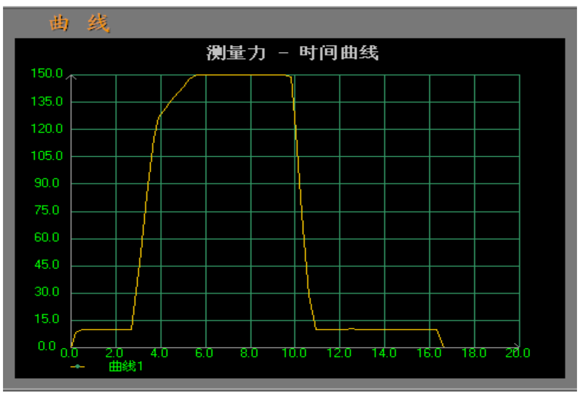


Figure 3　Actual loading F-T curve

2.3 PLC hardware control circuit and the software control system

The system uses PLC as controller for motor operation and data processing. And the hardness machine can be operated in two ways: basic operations can be performed via man-to-machine interface independently operations, including display, data storage and processing, can also be carried out with a computer.

2.4 Laser Measuring System

Rockwell indentation depth is measured with laser, which has the merit of high efficiency and high precision. The proposed system adopts a new laser light path design with fewer optical components and simple optical path, thus giving it a strong anti-interference ability. The laser light path is shown in Figure 4.

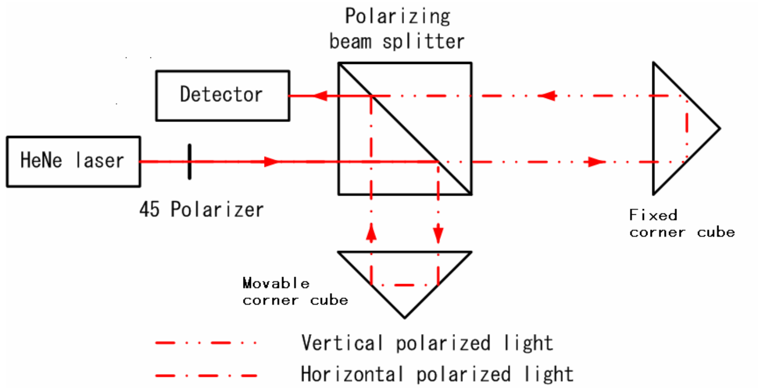
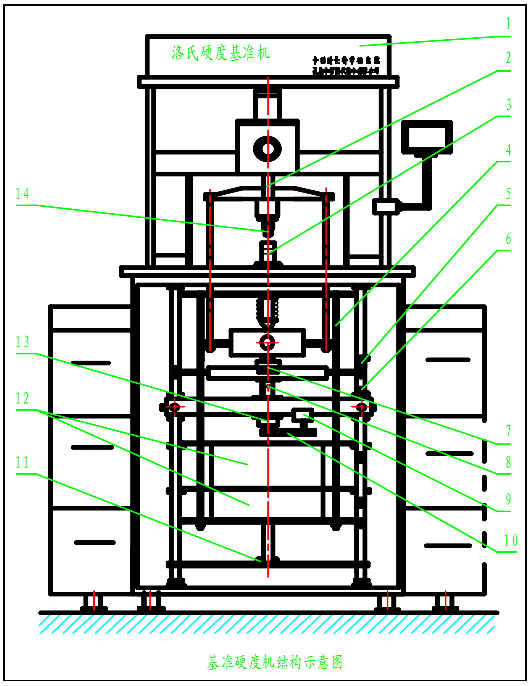


Figure 4 laser light path

Figure 5 and Figure 6 shows the structural drawing and the picture of the new Rockwell hardness primary standard machine after the transformation.



1. Laser interferometer 2.Principal axis 3.Working table 4.Weights holder 5.Up limit switch 6. Down limit switch 7. Force sensor 8.Ball screw 9.Servo motor 10.Synchronous toothed belt 11.Pilat bearing 12.Weights 13.Driven part 14.Indenter

Figure 5 The structural drawing of the improved primary standard machine

Figure 6 the picture of the new Rockwell hardness primary standard machine

3. UNCERTAINTY ANALYSIS

As the international working group has unified the uncertainty analysis procedure and method, we have estimated the expanded uncertainties based on the actual value of each component :

Measuring values of the parameters:

Parameter/ Units	deviation of parameter	Standard deviation of parameter
F_0/N	0. 01	0. 006
F/N	0. 01	0. 04
R_a/ μ m	0	0. 50
α_m/°	-0. 03	0. 015
T_p/s	0	0. 3
T_{df}/s	0	0. 2
V_{fis}/(μm/s)	-1. 7	0. 16
l/(μm)	0. 03	0. 016

(20-25) HRC hardness level

Parameter/ Units	Ci	ΔH	$U^2(yi)$
F_0/N	0. 12	0. 0012	5. 18E-07
F/N	-0. 04	-0. 0004	2. 56E-06
R_a/ μ m	0. 015	0	5. 63E-05
α_m/°	1. 3	-0. 039	3. 80E-04
T_p/s	0. 010	0	9. 00E-06
T_{df}/s	-0. 07	0	1. 96E-04
V_{fis}/(μm/s)	-0. 02	0. 034	1. 02E-05
l/(μm)	-0. 5	-0. 015	6. 40E-05
Total		-0. 0192	7. 19E-04
Combined standard uncertainty u(H)			2. 68E-02
Expanded standard uncertainty U(H)，k=2			5. 36E-02
Expanded standard uncertainty U(H)+|ΔH|			0. 07HRC

(40-45) HRC hardness level

Parameter/ Units	Ci	ΔH	$U^2(yi)$
F_0/N	0. 07	0. 0007	1. 76E-07
F/N	-0. 03	-0. 0003	1. 44E-06
R_a/ μ m	0. 030	0	2. 25E-04
α_m/°	0. 8	-0. 024	1. 44E-04
T_p/s	0. 005	0	2. 25E-06
T_{df}/s	-0. 04	0	6. 40E-05
V_{fis}/(μm/s)	0. 00	0	0. 00E+00
l/(μm)	-0. 5	-0. 015	6. 40E-05
Total		0. 0386	5. 01E-04
Combined standard uncertainty u(H)			2. 24E-02
Expanded standard uncertainty U(H)，k=2			4. 48E-02
Expanded standard uncertainty U(H)+|ΔH|			0. 08HRC

(60-65) HRC hardness level

Parameter/ Units	Ci	ΔH	$U^2(yi)$
F_0/N	0. 05	0. 0005	9. 00E-08
F/N	-0. 02	-0. 0002	6. 40E-07
R_a/μm	0. 050	0	6. 25E-04
α_m/°	0. 4	-0. 012	3. 60E-05
T_p/s	0. 004	0	1. 44E-06
T_{df}/s	-0. 03	0	3. 60E-05
V_{fis}/(μm/s)	0. 03	-0. 051	2. 30E-05
l/(μm)	-0. 5	-0. 015	6. 40E-05
Total		-0. 0777	7. 86E-04
Combined standard uncertainty u(H)			2. 80E-02
Expanded standard uncertainty U(H)，k=2			5. 61E-02
Expanded standard uncertainty U(H)+|ΔH|			0. 13HRC

4. CONCLUSION

This research has upgraded the original Rockwell primary standard hardness machine with the new definition of Rockwell hardness requirements so that it can successfully realize the functions in the new definition. With the uncertainty U < 0.2HRC (k = 2) is obtained, the new machine meets the expectation of new definition by the International Working Group.

REFERENCES

[1] A. Germark, S. Low: Summary report of the working Group on hardness(WGH)8th meeting — 16 and 21. 9. 2006, Rio de Janeiro, Brazil.

[2] ISO6508-1,2005：Metallic material –Rockwell hardness test-part 1: Testing Method

[3] ISO6508-2,2005：Metallic material –Rockwell hardness test-part 2: Verification and Calibration of the testing machine

[4] ISO6508-3,2005：Metallic material –Rockwell hardness test-part 3: Calibration of reference blocks

[5] EURAMET/cg-16/v.01:Guidelines on the estimation of uncertainty in hardness measurement July, 2007