Several methods for improving the accuracy of Rockwell hardness testing

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Abstract: In order to reduce the testing errors in Rockwell hardness of metal specimens and improve the accuracy of hardness testing, several methods had been tried out and examined based on GB/T 230 and other relevant inspection specifications, firstly, correct the hardness of testing pieces directly by using the hardness reference blocks to calibrate the hardness tester; secondly, correct the hardness of testing pieces by linear calculation of the errors in different hardness values to calibrate the hardness tester; for a great deal of testing pieces, check the hardness twice and the second time in a reverse order. The result shows that the applied methods are effective to further improve the accuracy of Rockwell hardness testing.

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1 The basis for reducing and eliminating testing errors of Rockwell hardness testing is to follow the requirements in some standard(s) strictly.

In order to reduce and eliminate testing errors of Rockwell hardness testing, it is quite necessary to detect the hardness of specimens by strictly following GB/T 230 and relevant inspection specifications.

2 Necessity for further reducing testing errors

In the heat treatment workshop, strictly according to the requirements of standard(s) mentioned above and the relevant inspection specifications, the measured error for specimens is not large, meeting demands of production and inspection. But if more accurate readings are needed for some military specimens, the accuracy of data sometimes is not satisfactory only according to the standard.

In order to reduce testing errors, following measures should be taken for those specimens needed higher accuracy.

3 Directly correct the measured value of the hardness tester according to the standard hardness block..

Before inspecting the hardness of the specimen, use the standard Rockwell hardness block to calibrate the hardness tester, and record the error. After inspecting the hardness of specimen, calibrate the hardness tester with standard Rockwell hardness block and record its error again. Take the average error before and after the inspection as the corrected value, and the hardness value will be got through correction calculation on the measured value of the specimen.

This method is suitable for the hardness value of the specimen which is the same or similar hardness value with the standard block.

4 According to the error of the hardness tester, use the method of linear calculation to correct the measured value

The hardness of specimen is often quite different from that of the standard Rockwell hardness block, and it is not suitable to correct the measured value directly according to the hardness tester of standard hardness block. In this case, the hardness tester is checked by several standard blocks with different hardness, and the error of the hardness test is measured. Then take the higher and the lower testing error values of standard hardness block compared with the hardness of the specimen, and then according to the following linear calculation formula to correct the measured value of the specimen.

4.1 Calculation formula

$$y = \frac{B_2-B_1}{x_2-x_1}x + B_2 - \frac{B_2-B_1}{1-x_1/x_2}$$

Among them:

Y——The actual hardness value of workpiece through correction.

B_1——Label hardness value of standard hardness block 1.

B_2——Label hardness value of standard hardness block 2.

x——Hardness reading of the work piece on the measured spot (mean value)

x_1——Calibration hardness reading of standard hardness block 1 (mean value)

x_2——Calibration hardness reading of standard hardness block 2 (mean value)

Because the hardness values of different locations on the same work piece are often different, sometimes quite different, "x" in the formula refers to the direct reading or the mean value obtained from the average readings on a tested portion, rather than the mean value from the average readings on different locations on the work piece.

The above formula can be used to correct the average reading of several hardness measurement spots in a location; "x" takes the mean value of readings of several testing locations respectively. It is also possible to correct the measured values of each measuring spot respectively. At this time,"x" takes the readings of each testing location respectively.

4.2 Formula derivation process

The derivation process of the formula above is as follows:

The mean value of the direct hardness reading of specimen on a certain spot is regarded as"x", the hardness value for the standard hardness block 1 is B_1; the mean value of the calibration hardness reading of standard hardness block 1 is x_1; the hardness value for the standard hardness block 2 is B_2; the mean value of the calibration hardness reading of standard hardness block 2 is x_2; the actual hardness value of specimens is y.

The testing error of the hardness tester reading x_1 and x_2 interval is regarded as a linear relationship.

$$Y=kx+b$$

Where the coefficient k is the slope and the coefficient b is the intercept.

Because:

When y = B1, x = x1.

When y = B2, x = x2.

So:

$$B_1=kx_1+b \quad ①$$

$$B_2=kx_2+b \quad ②$$

We can solve this system:

$$k= \frac{B_2-B_1}{x_2-x_1} \qquad b= B_2 - \frac{B_2-B_1}{1-x_1/x_2}$$

So:

$$y = \frac{B_2-B_1}{x_2-x_1}x + B_2 - \frac{B_2-B_1}{1-x_1/x_2}$$

4.3 Application examples

Before the heat treatment experiment of a kind of T250 steel parts, the hardness of the specimen in the material supply state (solid solution state) should be tested. the mean value "x" of four specimens, No. 1~4, is 35.7 HRC, 34.9 HRC, 35.5 HRC, 35.4HRC respectively. Because there were no standard hardness blocks whose hardness were close to the hardness of the four specimens on the production site, only blocks with a greater difference compared with the specimens. The mean value of the standard hardness block 26.2HRC calibrated by the hardness tester is 27.2 HRC, the mean value of the standard hardness block 45.1 HRC calibrated by the hardness tester is 45.2 HRC.

The above calculation formula is applied to calculate the data as follows:

$$B_2-B_1=45.1-27.2=17.9$$

$$x_2-x_1=45.2-27.2=18$$

$$1- x_1/x_2=1-27.2/45.2 =0.398$$

$$(B_2-B_1)/(x_2-x_1)=17.9/18=0.944$$

$$(B_2-B_1)/(1-x_1/x_2)=17.9/0.398=44.975$$

The hardness value of the specimen No.1 is corrected as:

$$y_1=0.944x+B_2-44.975=0.944\times 35.7+45.1-44.975\approx 33.8 \text{ (HRC)}$$

The hardness value of the specimen No. 2 is corrected as:

$$y_2=0.944x+B_2-44.975=0.944\times 34.9+45.1-44.975\approx 33.1 \text{ (HRC)}$$

The hardness value of the specimen No. 3 is corrected as:

$$y_3=0.944x+B_2-44.975=0.944\times 35.5+45.1-44.975\approx 33.6 \text{ (HRC)}$$

The hardness value of the specimen No. 4 is corrected as:

$$y_4=0.944x+B_2-44.975=0.944\times 35.4+45.1-44.975\approx 33.5 \text{ (HRC)}$$

5 Repeated inspection method in positive and negative orders

5.1 Method

Firstly, check the hardness of the specimens in positive order, then in negative order, take the hardness according to the data from two times.

5.2 Application examples

After quenching respectively on 13 heat treatment specimens (No. 0 ~No. 12) with local carburizing by deferent processes, first check the hardness from No.0 to No.12, then from No.12 to No.0, see the measured value in table 1. The standard block is also calibrated by the same repeated method.

Ser. No. of specimens Hardness of Standard block	Locations	Check in positive order 1	Check in positive order 2	Mean value in positive order	Check in inverted order 1	Check in inverted order 2	Mean value in inverted order	Total mean value
46.3HRC standard block		44.1	45.5	44.8	46.8	46.0	46.40	45.6
63.8HRC standard block		62.6	63.4	63.0	63.5	63.5	63.50	63.3
0	Non-Carburizing location	43.5	44.0	43.8	45.8	44.6	45.20	44.5
1		42.3	42.8	42.6	43.4	43.8	43.60	43.1
2		42.8	42.6	42.7	44.0	43.7	43.85	43.3
3		42.1	42.1	42.1	43.0	43.3	43.15	42.6
4		42.5	42.2	42.4	43.5	43.5	43.50	42.9
5		44.6	43.9	44.3	45.6	45.6	45.60	44.9
6		43.6	44.2	43.9	45.3	45.4	45.35	44.6
7		43.5	43.5	43.5	45.4	44.7	45.05	44.3
8		44.0	44.7	44.4	45.3	45.4	45.35	44.9
9		45.0	44.9	45.0	45.6	45.9	45.75	45.4
10		44.7	44.8	44.8	45.8	45.6	45.70	45.2
11		45.5	45.0	45.3	45.8	45.8	45.80	45.5
12		44.7	45.0	44.9	45.7	45.9	45.80	45.3
0	Carburizing location	61.0	61.3	61.2				61.2
1		60.5	60.5	60.5				60.5
2		56.2	55.5	55.9				55.9
3		48.7	48.5	48.6				48.6
4		45.5	45.9	45.7				45.7
5		63.0	64.0	63.5				63.5
6		61.1	61.4	61.3				61.3
7		56.7	56.0	56.4				56.4
8		52.2	53.5	52.9				52.9
9		63.2	63.6	63.4				63.4
10		62.8	62.8	62.8				62.8
11		61.8	62.9	62.4				62.4
12		61.0	60.6	60.8				60.8

Table 1 Hardness data of local-carburizing specimens after quenching by repeated inspection method in positive and negative orders.

Table 1 shows the mean value on the non-carburizing locations in negative order is higher than that in positive order, the standard hardness block also has similar situation. This indicates that the measured value gradually increases during inspections due to the hardness tester.

In order to reduce testing errors, take the mean value using the repeated inspection method in positive and negative orders when the measure value gradually increases because of the hardness tester. In this case, according to the measured value data of the standard block from two times, take the measured value in negative order but not in positive order for locations of specimens with non-carburizing.

6 Conclusions

The methods mentioned above have been applied in some military enterprises for years, e.g. the heat treatment process and the hardness inspection for some important products; it makes good effect on reducing Rockwell hardness testing errors and guarantees the accuracy and reliability of heat treatment tests and hardness inspection of products. The result of the trial application shows that the inspection method and data correction method mentioned above are effective ways to further improve the accuracy of Rockwell hardness test.