Evaluation of mass effect in small ball rebound hardness test

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1. Introduction

Conventional rebound hardness test methods, such as the Shore hardness test and the Leeb hardness test, have the potential problem of "mass effect," in which a smaller and lighter specimen results in a lower measured value than the true rebound hardness.

Therefore, when measuring small, lightweight specimens in the Shore hardness test or the Leeb hardness test, it is necessary to take measures such as placing them on a heavy specimen table.

This is the biggest disadvantage of the conventional rebound hardness test method because it does not take advantage of the test's simplicity and the fact that the testing machine is small and portable.

A hardness test method that improves this problem is the small ball rebound hardness test [1].

The small ball rebound hardness test has an excellent feature in that, in principle, the hardness similarity law holds true regardless of the size of the ball, as long as balls of the same material are launched and tested at the same speed.

Therefore, the coefficient of restitution obtained from the small ball rebound hardness test is theoretically the same regardless of the ball diameter, so it can be expected that the effect of mass effect can be improved as the ball diameter is reduced [2].

It is also possible to directly compare the results of tests with balls of different diameters with each other.

This report describes the results of an investigation into the influence of mass effects on rebound hardness testing by measuring hardness reference blocks on several types of small ball rebound hardness testers, each with different ball sizes.

2. Experimental procedure

2.1 Small ball rebound hardness test

The small ball rebound hardness test is a test method in which a hard ball is impacted onto a specimen and the hardness of the specimen is evaluated by the ratio of the impact velocity V_1 to the rebound velocity V_2, or the coefficient of restitution $e = V_2/V_1$ [1][3].

A small ball rebound hardness tester that uses a 3 mm diameter alumina ceramic ball and a launch velocity of V_1 = 10 m/s (hereafter referred to as a 3 mm ball tester) has already been put into practical use and is currently being standardized.

In the small ball rebound hardness test, balls of the same material are launched at the same speed, and the same hardness values are obtained regardless of the size of the balls.

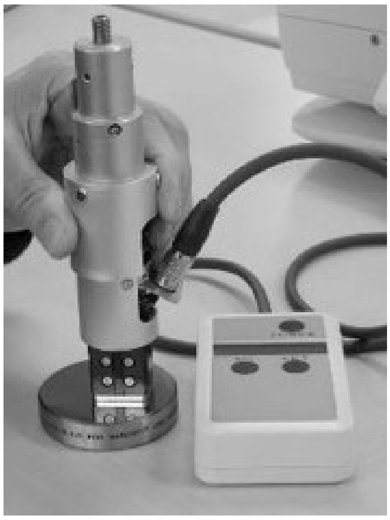

Figure 1 Small ball rebound tester.

Thus, test results obtained using balls smaller than 3 mm in diameter can be directly compared with those obtained using 3 mm diameter balls.

In this study, a testing machine capable of launching 1 mm alumina ceramic balls at V_1 = 10 m/s (hereafter referred to as the 1 mm ball testing machine) as well as a 3 mm ball testing machine was prepared, and hardness reference blocks were compared and measured in each testing machine. The appearance of the testing machine used is shown in Figure 1.

2.2 Material

Three types of samples were used: two types of steel hardness reference blocks (φ=64 mm × t 15 mm, mass 380 g) of approximately 300 HV and 700 HV, and a pure copper hardness reference block (φ=64 mm × t 10 mm, mass 270 g) of approximately 40 HV, as shown in Figure 2 and Table 1.

The specifications of these specimens were in accordance with JIS and ISO reference block standards, and the measurement surfaces were mirror-finished.

2.3 Test conditions

As mentioned above, a 3 mm ball tester and a 1 mm ball tester were prepared, and each sample was measured comparatively on each tester.

The test is conducted on a common worktable as shown in Figure 1, without specimen fixation.

First, 10 points were measured using a 3 mm ball tester, and the average value was used as the reference value in

Figure 2 Hardness reference blocks e = 0.87, 0.63 and 0.19

Table 1 Test results of hardness reference block with 3 mm ball tester (n=10)

Specimen No.	Vickers Hardness	Material	COR*, e (Avg.)
1	40	Copper	0.192
2	300	Steel	0.635
3	700	Steel	0.865

*COR : Coefficient of restitution

Table 2 Test results of hardness reference block using 1mm ball tester.

Specimen No.		COR*, e	
		Avg. (n=20)	CV%
1	(1)	0.193	1.19
	(2)	0.192	1.26
	(3)	0.192	1.74
	Avg.	**0.192**	1.39
2	(1)	0.638	0.32
	(2)	0.640	0.67
	(3)	0.638	0.44
	Avg.	**0.639**	0.48
3	(1)	0.862	0.36
	(2)	0.862	0.32
	(3)	0.864	0.36
	Avg.	**0.863**	0.35

*COR : Coefficient of restitution

this comparison experiment (see Table 1). The same reference block was then measured at 20 points using a 1 mm ball tester, and this was repeated three times, for a total of 60 points for each reference block. The coefficient of restitution was then measured and compared with the reference values.

3. Results and Discussions

The test results with the 1 mm ball tester are shown in Table 2, and the difference in the average value of coefficient of restitution e was less than 0.002. The difference from the test results with the 3 mm ball tester, which was used as the reference value, was less than 0.004, which is in very good agreement, indicating that the above-mentioned similarity raw of hardness is valid.

Figure 2 shows an example of the results of comparing the diameter of the indentation made by a 1 mm ball tester with that made by a 3 mm ball tester. The diameter of the indentation is in proportion to the diameter of the ball used, which confirms that the hardness similarity law is valid.

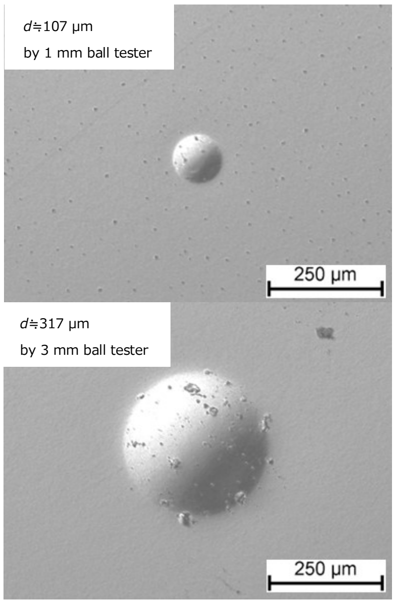

Figure 3 Indentations made by the small ball rebound hardness test on the e = 0.865 reference block (Nomarski differential interferogram image).

4. Conclusions

Even when the diameter of the balls used in the small ball rebound hardness tester was changed from 3 mm to 1 mm, the hardness values obtained were equivalent, and the variation was confirmed to be at a level that is acceptable for practical use as a hardness tester.

In addition, by reducing the diameter of the ball by 1/3, the minimum specimen thickness can be reduced to 1/3.

This is equivalent to reducing the test force to 1/9.

Thus, it was demonstrated that the use of a smaller diameter ball does not affect hardness values and reduces the mass effect that is a problem in conventional rebound hardness testing.

References

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