A Novel Approach to Hardness Testing

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Key Words: Hardness, rebound, scleroscope, coefficient of restitution

Prerequisite Knowledge: Knowledge of physical testing of metallic materials

Objective: To demonstrate a simple rebound hardness measuring device and explore its applications and limitations.

Equipment:

1. Rebound hardness tester as outlined in Reference 1.
2. Several metallic samples of various compositions and harnesses.

Introduction:

This paper gives a description of the application of a simple rebound time measuring device and relates the deterrniniition of relative hardness of a variety of common engineering metals. A relation between rebound time and hardness will be sought; hardness is the ability of a material to resist permanent deformation and is typically quantified by relating the geometry of an indentor and normal force applied to the depth of penetration. The effect of specimen geometry and surface condition will also be discussed in order to acquaint the student with the problems associated with rebound hardness testing.

Procedure:

A complete description of the construction of the apparatus is contained in Reference 1. This device, constructed for under $100, is designed to repeatedly drop a 5.59 mm (0.220 in.) diameter ball from a fixed height of 9.0 cm (3.54 in.) onto a metal specimen clamped to a rigid base. A microphone coupled through an operational amplifier precisely relays the initial contact and subsequent rebound contact. A timing circuit is used to measure the interval between these events and calculates the rebound time, relatable to the coefficient of restitution of materials, a dimensionless quantity which is the negative of the relative velocity of two objects after a collision, divided by their relative velocity before the collision.

Results and Discussion:

As shown in Table 1, there is a general trend for the materials with lower hardness to exhibit lower rebound times. Figure 1 shows that a linear relationship exists for Shore Scleroscope hardness numbers with Brinell hardness numbers over the entire range of steel samples tested. Figure 2 indicates that a linear relationship between rebound time and Brinell hardness can be established for steels having harnesses measurable on the Rockwell C scale (Brinell hardness 300-500). The hardness relationship, unfortunate y, does not extrapolate well into the Rockwell B range for steels. As also observed in Table 1 and Figure 3, there exists a relatively linear relationship for aluminum with hardness measurable on the Rockwell F scale.

Like the apparatus described in Reference 1, the Shore Scleroscope is designed to drop a steel ball or diamond indentor from a fixed height onto a test specimen placed on a clamping stand; the rebound height is either visually noted or recorded on a dial and used to indicate relative hardness. With the test apparatus described in this paper, the time interval is measured by digital circuitry, giving this method an enhanced degree of precision over the scleroscope. With both of these devices, the portability, ease of use, and relative non-destructive interaction with the material, are significant with respect to Brinell testing in the field as well as in the undergraduate laboratory.

While cost, convenience, simplicity, and apparent correlation with conventional hardness tests are advantages of this devised testing method, sample geometry and surface condition can appreciable y affect the precision of the device. As reported in Table 1, four copper specimens, all with the same hardness as measured by the Rockwell F test, did not give the same rebound time. The difference in each of these was either geometric or in the condition of the test surface. However, it should be possible to explain the results in terms of energy absorption mechanisms and/or sample-base coupling. For instance, on the oxidized surface, the interaction with the surface layer (fracture, dissipation of rebound energy at the layer interface) could reduce the rebounding. A bent specimen (even with concave side up) could lower the rebound by inefficient y reflecting the stress wave moving through the test piece. The reduced rebound time with the thinner specimen suggests that, as in static indentation tests, there could be a minimum specimen size necessary to characterize the hardness of the bulk material.

Notes to the Instructor:

The above results give rise to many thought-provoking, yet simple experiments for the students. They could investigate rebound time vs. sample thickness (for the same material hardness). Would a stack of thin specimens give the same result as one thick specimen? What is the effect of surface finish on rebound time?

Acknowledgment:

The authors would like to express their appreciation to Stamos Courpas, graduate assistant in the Department of Physics and Computer Science at Loyola College for his efforts in the design and construction of this testing device.

References:

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2. Small, Louis. *Hardness: Theory and Practice, Part I, Practice, Abridged Edition,* Service Diamond Tool Co., Ferndale, Michigan, pp. 291-309.

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Sample Material	Thickness (in.)	Rockwell Hardness	Scleroscope Hardness	Brinell Hardness*	Rebound Time (0.001 seconds)					Ave.	Std. Dev.
					1	2	3	4	5		
018 Steel											
	3/32	C48	64	451	156	157	161	156	155	157.0	2.3
	3/32	C48	64	451	155	162	168	159	165	161.8	5.1
	3/32	C43	57	400	150	148	150	144	151	148.6	2.8
	3/32	C38	51	353	137	145	135	144	142	140.6	4.4
	3/32	C33	46	311	131	131	136	135	132	133.0	2.3
	3/32	B80	23	150	130	126	130	123	129	127.6	3.0
	3/32	B80	23	150	129	130	129	126	128	128.4	1.5
	3/32	B57	17	103	108	111	106	112	118	111.0	4.6
luminum											
	1/8	F9			46	46	55	53	44	48.8	4.9
	1/8	F70			83	78	75	88	91	83.0	6.7
	1/8	F90			97	101	105	103	108	102.8	4.1
opper											
Oxidized	3/16	F85			128	132	129	131	126	129.2	2.4
Clean	3/16	F85			144	144	144	146	147	145.0	1.4
Bent	3/16	F85			126	133	129	137	128	130.6	4.4
	1/8	F85			95	90	95	89	95	92.8	3.0

*3,000 kg load, 10 mm standard ball

Table 1: Hardness Values vs. Rebound Times

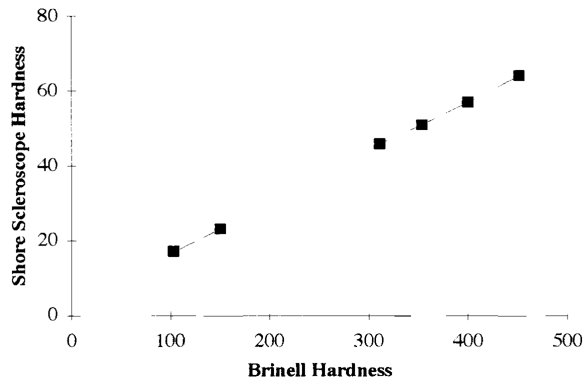

Figure 1
Scleroscope vs. Brinell
(Steel)

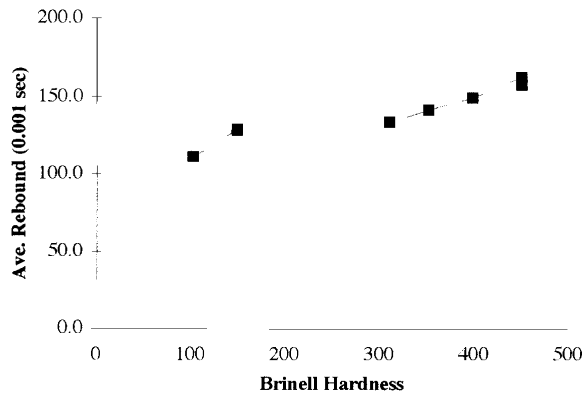

Figure 2
Rebound vs. Brinell
(Steel)

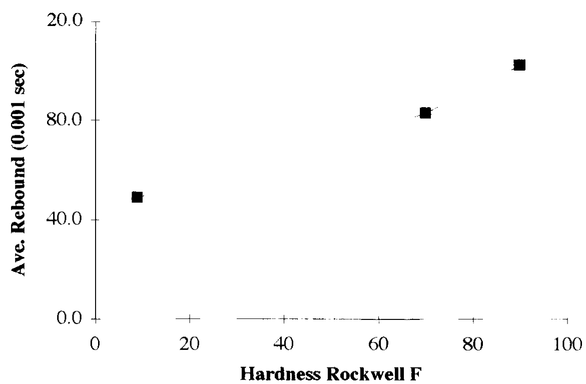

Figure 3
Rebound vs. Rockwell F
(Aluminum)