

NOTE ON BRINELL AND SCRATCH TESTS FOR HARDENED STEEL.

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[Selected for Publication only.]

It is well-known that the Brinell method of testing hardness is unsatisfactory, if applied to very hard substances, such as hardened steel. One source of error is that due to the deformation of the ball. A series of experiments was therefore undertaken with the object of ascertaining how far a modified form of scratch test is applicable to hardened steel. In view of Professor Thomas Turner's established reputation in connexion with scratch testing, the results were submitted to him, and in his opinion are worthy of publication. The Authors are much indebted to him for help in the drafting of this Note, and also for useful suggestions regarding further work.

The instrument employed, which is a modification of Professor Turner's sclerometer, is shown in Fig. 1 (page 582). It was manufactured by Messrs. W. and T. Avery of Birmingham, from a design prepared by Mr. W. E. Alkins, B.Sc., in consultation with Professor Turner. The experiments were conducted in the Research Department of Hadfields Ltd., of Sheffield. The apparatus was

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FIG. 1.—Scratch Testing Apparatus.

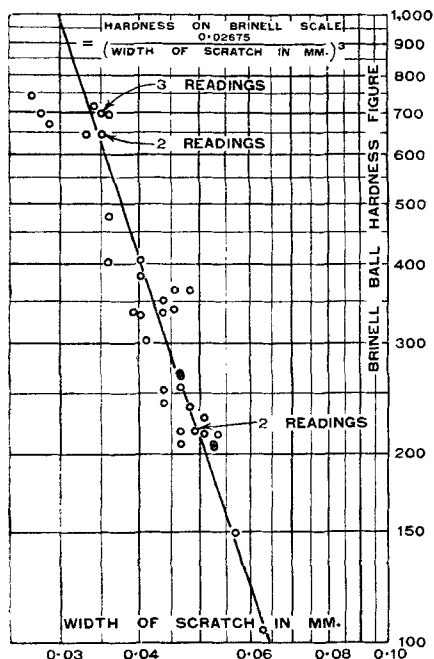
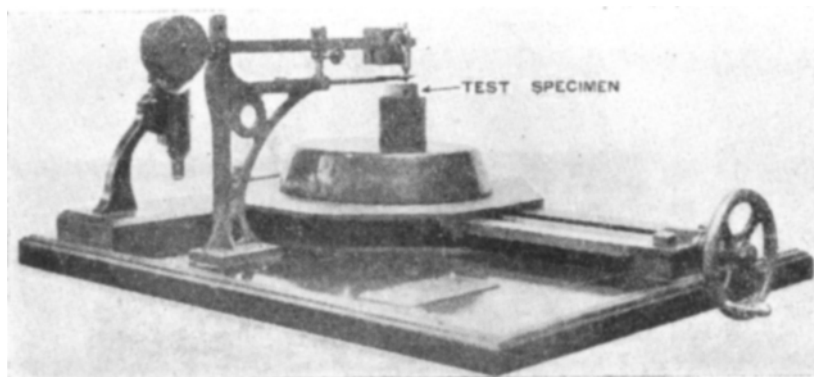
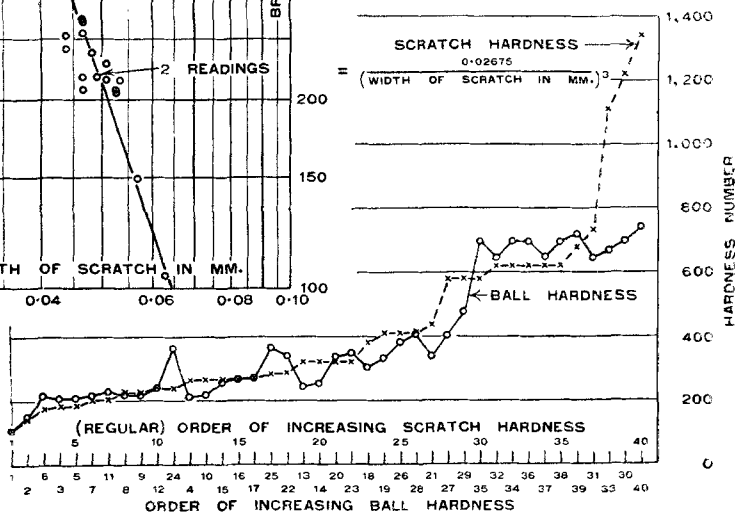


FIG. 2.—Brinell Hardness and Width of Scratch with Uniform Load.

FIG. 3.—Comparison of Scratch and Ball Hardness on forty Steel Specimens of varying Hardness.



originally designed for testing the hardness of steel helmets, and would need some modification in order to be suitable for research work, or other purposes.

It will be seen that the apparatus is of a simple character, consisting of a balanced-lever arm, fitted with jockey-weight, and carrying at its end a diamond point. The diamond is drawn along the surface of the metal to be tested, thus making a scratch. In each case the surface of the piece was polished before testing. The test-piece was placed under the weighted diamond point, and was held firmly by hand. A turn was then given to the small wheel, which is connected with a threaded screw, and moves the table and test-piece. A constant weight of about 6 oz. was employed, and the width of the scratch was measured by means of a special measuring microscope, supplied by Watson, which is part of the equipment. The scale on the eye-piece was arbitrary, and was not calibrated to represent inches or millimetres. It was, therefore, calibrated by means of an engine-divided scale, when it was found that one division on the microscope was equal to 0.0175 mm.

A series of test-pieces were prepared, and these varied in hardness from soft to glass-scratching hardness, so as to give a considerable range. After the scratch test had been completed, a Brinell hardness test was performed on each piece, close to the scratch, so as to obtain a definite comparison by the two methods. The results of the experiments are given in the Table (page 585), and are graphically represented in Figs. 2 and 3. The diamond points used in such tests are usually pyramidal in shape, having four flat sides, and it is advisable that the diamond shall always be so placed that two edges shall be in the line of scratch. Unfortunately, in the present experiments the orientation of the diamond was not noted, though it remained the same throughout the whole series.

From an examination of the results, it would appear that the scratch hardness obtained by the method above described, bears a general relation to the Brinell hardness, which can be represented approximately by the formula

$$\text{Brinell Hardness} = \frac{0.02675}{(\text{width of the scratch in mm.})^2}$$

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This would appear to show that the two methods measure somewhat similar properties in the metal to be tested, and it may be possible to establish a scratch test giving hardness figures corresponding generally with the Brinell scale but not subject to the disabilities of the Brinell. It may be observed, however, that as the two methods must to some extent register different properties, it cannot be expected that uniform results will be obtained. In examining Fig. 3 it will be observed that the scratch hardness figures, when taken in accordance with the above formula, have been plotted against the Brinell figures, and though the general agreement is satisfactory, having regard to experimental errors, there are some important exceptions.

The tests of particular interest are the last four on the diagram. In these there is a wide divergence between ball and scratch hardness tests, the scratch figures being 730, 1,110, 1,220, and 1,345 respectively, as against ball-hardness figures of 645, 670, 696, and 741. The hardness of these specimens, which are all in the very high range, is therefore considerably greater when measured by the scratch test than by the ball test, which confirms the breaking down of the Brinell method with increase in hardness.

Though only moderate accuracy can be claimed for the scratch tests in the present experiments, it can be said with confidence that the error in testing is not sufficient to account for the difference found. This may indicate that the scratch test does, in some cases, deal with a different aspect of hardness from that indicated by the Brinell test. For reasons above mentioned, it has not been possible to confirm the above figures by repeating experiments under exactly similar conditions, but the results obtained do appear to show that the ball-hardness method is unsatisfactory when dealing with very hard material. The hardness of very hard steel as measured by the scratch test is much higher than is indicated by the ball-hardness method.

On the other hand the lack of sensitiveness of the scratch method, which is a difficulty in its use, is rendered very apparent by the relationship found above. A slight difference in the width of the scratch on two specimens corresponds with a difference in

COMPARISON OF SCRATCH AND BRINELL HARDNESS OF STEEL
WITH UNIFORM LOAD.

Arranged in order of increasing scratch hardness.

SCRATCH TEST.			Brinell Ball Hardness Figure.
Width of Scratch.		Scratch Hardness Figure taken as 0.02675 (width of scratch in mm.) ³ .	
Divisions on Watson Microscope scale. 1 div.=0.0175 mm.	Mm.		
3.6	0.0630	107	104
3.25	0.0569	145	149
3.05	0.0534	175	214
3.0	0.0525	185	205
3.0	0.0525	185	207
2.9	0.0507	205	215
2.9	0.0507	205	228
2.8	0.0490	227	217
2.8	0.0490	227	217
2.75	0.0481	239	238
2.75	0.0481	239	364
2.7	0.0465	265	207
2.7	0.0465	265	217
2.7	0.0465	265	255
2.7	0.0465	265	267
2.7	0.0465	265	269
2.6	0.0455	284	364
2.45	0.0454	286	340
2.5	0.0437	321	241
2.5	0.0437	321	353
2.5	0.0437	321	337
2.5	0.0437	321	351
2.35	0.0411	379	302
2.3	0.0402	412	332
2.3	0.0402	412	382
2.3	0.0402	412	405
2.25	0.0394	437	337
2.05	0.0359	578	402
2.05	0.0359	578	477
2.05	0.0359	578	690
2.0	0.0350	622	645
2.0	0.0350	622	696
2.0	0.0350	622	696
2.0	0.0350	622	645
2.0	0.0350	622	696
1.95	0.0341	675	718
1.9	0.0332	730	645
1.65	0.0289	1,110	670
1.6	0.0280	1,220	696
1.55	0.0271	1,345	741

hardness proportional to the cube; or, expressed in another way, the probable error in the hardness figure is approximately three times the probable error in measuring the scratch. This difficulty, however, unlike that in the Brinell test, is amenable to refinement of method and skill in manipulation.

The series of experiments above described are not presented as being in any sense complete or conclusive, but rather as one step in the endeavour to ascertain the best method of hardness testing for very hard materials, and the relationship which may exist between the results obtained when employing different methods of testing.

The formula derived should be regarded as a quite tentative and empirical relationship between Brinell and scratch hardness of steel. The establishment of a satisfactory and rational hardness scale for the scratch method will involve further work, including the determination of the relation between pressure and width of scratch.

The Authors have pleasure in acknowledging the assistance of Mr. A. Stevenson in carrying out the experiments.

The Paper is illustrated by 3 Figs. in the letterpress.
