

DOES THE WEARING POWER OF STEEL RAILS INCREASE WITH THE HARDNESS OF THE STEEL? *

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While working, during the summer of 1877, upon the "Chemical Composition and Physical Properties of Steel Rails," the results of which are given in my report † with this title, I was struck with the surprising wear which some of the rails, which would ordinarily be called soft rails, had endured. At that time I knew of no chemical measure of softness except low carbon, and I found that a number of rails with low carbon had endured as high or higher tonnage, with apparently as little loss of metal by wear, as those with higher carbon. My own work on steel rails that summer did not embrace any definite experiments as to the amount of metal worn off the rail per million tons which had passed over it; and so I could get no more definite answer from that work, to the question at the head of this paper, than was given by comparing the appearance of the worn section of the rail with its tonnage. This comparison, however, served to arouse in my mind the query, whether the commonly received opinion as to the relation between the hardness and wearing power of steel, is correct, as applied to steel rails. This opinion, if I am right, is: the harder the steel, the better will be the wear, and the limit of hardness is simply one of safety; hard, brittle steel being, of course, more liable to break than soft, tough steel. The query, although aroused, did not bear any immediate fruit, and, as will be evident to any one reading it, the report above referred to was written with the commonly received opinion in mind. Since that time I have collected a little information upon this subject, which I should be glad to submit to the Institute, if for no other purpose, for the sake of arousing attention, and directing study to the question of hardness *versus* wear in steel rails.

Before making known the information, however, permit me a few words in reference to hardness. How shall we measure the hardness of steel? Of the various ways of getting indications as to the hard-

* A paper read before the Institute of Mining Engineers, October 15th, 1878.

† See vol. cvi, page 361.

ness of steel, which are known, three will serve our present purpose. These are: 1st. High carbon. It is generally agreed, I think, that at least within proper limits, the greater the amount of combined carbon in a piece of steel, the harder the steel, and I need not do more than mention this fact to obtain your assent to it. 2d. The physical test of punching, measures the hardness of steel. Data in regard to the wearing power of hard and soft rails, determined in this way, will be given below. 3d. The sum of the phosphorus units in a piece of steel measures its hardness. Phosphorus units, as is fully described in my report above referred to, are an attempt to measure the hardness of steel by estimating the combined hardening power of the phosphorus, silicon, carbon and manganese in a piece of steel, in terms of the phosphorus. Now, by measuring hardness in these three ways, I have been able to collect the following information with regard to the relation between the hardness and wearing power of steel rails.

1. Some two years ago the Penna. R. R. Co., in view of the unsatisfactory wear it was obtaining from its steel rails, asked to have more carbon put into its rails, with a view of making them harder, to resist wear. Before the increase, the limits of carbon for rails to be used on Penna. R. R., was from 0.30 to 0.50 per cent. After the increase, the limits were from 0.40 to 0.50 per cent., thus securing on the average perhaps, about a tenth of a per cent. more carbon in the steel. Now, Mr. W. H. Brown, Chief Engineer, Maintenance of Way, Penna. R. R., informs me that these rails of higher carbon are giving poorer wear than before the lower limit of carbon was raised. This opinion of Mr. Brown is based on his observation of the wear of these higher carbon rails, and on the number of renewals of these rails, rendered necessary by the condition of the track.

2. Mr. J. T. Smith, General Manager of the Barrow Hæmatite Steel Works, England, read a paper on "Bessemer Steel Rails," before the Institution of Civil Engineers, in 1875.* The object of the paper was to show that Bessemer steel may be produced constant in quality, and that certain inexpensive tests may be applied, which shall determine the quality of the metal for railway purposes. The test proposed by Mr. Smith was to punch the fish-plate holes with a registering-press, the quality of the metal being judged of by the

* Proceedings Inst. Civil Eng., vol. xlii, p. 69.

force required to punch the holes. This would render it possible to inspect and judge of the quality of every single rail. I must refer you to Mr. Smith's paper for further information upon this point.

The point which is of especial interest to us now is that Mr. Smith examined thirty rails which had been eight years in service on the main line of the Furness Railway. The rails were divided into two classes, on the basis of the force required to punch a hole $\frac{7}{8}$ of an inch in diameter, through the web $\frac{3}{4}$ of an inch thick. Twenty of the rails required for this purpose a force varying from $46\frac{1}{4}$ tons to $52\frac{1}{2}$ tons, and were therefore called soft rails; while the remaining ten rails required for the same purpose a force varying from $56\frac{3}{4}$ tons to $82\frac{1}{2}$ tons, and were therefore called hard rails. The average force required to punch the soft rails was about 49 tons, while for the hard rails this average force was about $64\frac{3}{4}$ tons. Mr. Smith likewise gives the determinations of the carbon in these rails. In the twenty soft rails the carbon varied from 0.28 to 0.32 per cent., or an average of 0.30 per cent., while in the hard rails the carbon varied from 0.36 to 0.57 per cent., with an average of 0.44 per cent. Now as to the wear of these rails. The wear seems to have been determined by taking the difference between the original weight of the rail per yard, and the weight per yard of the worn rail, and then reducing this to the percentage of the metal worn off. Now in the twenty soft rails, this percentage of wear varied from 10.38 to 16.24 per cent., with an average wear of 13.54 per cent., while in the ten hard rails the percentage of wear varied from 12 to 20.53 per cent., with an average of 15.18 per cent. These figures seem to me very significant, and to warrant Mr. Smith in the conclusion which he expresses, viz.: "Contrary to what might have been anticipated, greater hardness has not conduced to the longevity of the rails, and the softer ones show the minimum of wear."

3. With regard to the wear of rails, in which the hardness is measured in phosphorus units. On May 23d, 1876, Mr. R. Price Williams read a paper before the Institution of Civil Engineers, on "The Permanent Way of Railways." * In his investigation into the subject of steel rails, Mr. Williams found such a surprising difference in the wear of certain rails which were side by side, and therefore subjected to the same traffic, that he had seven of these rails from the Great Northern Railway analyzed by Mr. Edward Riley. The

* Proceedings Inst. Civil Eng., vol. xlvi, p. 147.

results as to wear are given in number of million tons traffic per $\frac{1}{16}$ inch worn off the rail. Four of these seven rails, measured in phosphorus units, sum up 31, 30, 32 and 25, and may, therefore, be called, in comparison with the others, soft rails. The remaining three rails sum up, in phosphorus units, 38, 40 and 47, and may be called hard rails. The rails are numbered, in Mr. Williams' series, Nos. 9, 17, 18, 21, 22, 23 and 24. Nos. 17 and 18 were side by side, and subjected to the same traffic. The phosphorus units in No. 17 are 38, and in No. 18, 30, one hard and one soft, as is seen. The hard rail withstood 5,251,000 tons per $\frac{1}{16}$ inch wear, while the soft one withstood 8,402,000 tons per $\frac{1}{16}$ inch wear. Again, Nos. 23 and 24 were side by side. The phosphorus units in No. 23 were 47, and in No. 24, 25, one hard and one soft, as before. The hard rail withstood 15,531,000 tons per $\frac{1}{16}$ inch wear, while the soft rail withstood 31,061,000 tons per $\frac{1}{16}$ inch wear. In Nos. 21 and 22, which were side by side, the hard rail shows a little the best wear, the figures being 9,283,000 tons per $\frac{1}{16}$ inch wear, for the hard rail, and 7,676,000 tons per $\frac{1}{16}$ inch wear for the soft rail. If now we take the average of the tonnage per $\frac{1}{16}$ inch wear for the three hard rails and the four soft ones, the result becomes quite striking. The four soft rails withstood an average tonnage of 15,567,000 tons per $\frac{1}{16}$ inch wear, while the three hard rails withstood, on the average, only 10,055,000 tons per $\frac{1}{16}$ inch of the metal worn off. The chemical composition of the one rail of this series, which withstood the highest tonnage, viz., 31,061,000 tons per $\frac{1}{16}$ inch wear, is so remarkable that I cannot forbear quoting the full analysis. This rail sums up 25 in phosphorus units, and contains: carbon, 0.270 per cent.; phosphorus, 0.100 per cent.; silicon, 0.020 per cent.; manganese, 0.259 per cent.; sulphur, 0.051 per cent.; copper, 0.025 per cent.; and iron, 99.475 per cent.

If enough has been said upon this subject to direct attention to it, my object will have been accomplished. It is perhaps too soon to venture conclusions. The indications would seem to be, however, that under the conditions of wear to which a steel rail is subjected, viz., rolling friction, unlubricated surfaces, and great weight with small bearing surface, the quality of the metal necessary to most successfully withstand the disintegrating forces, is best expressed by the word toughness, and not by hardness.

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