THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

A NOTE ON THE RELATIONSHIP BETWEEN HARDNESS AND TENSILE STRENGTH FOR HARDENED AND TEMPERED SPRING WIRES

by

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INTRODUCTION

A hardness test is probably the most widely used of all the mechanical tests carried out on metals and can reveal a considerable amount of information to the trained technician. One attraction is that it is relatively simple to perform and being a non-destructive test it can, on many occasions, be used on finished components as a means of indicating the tensile strength of the material.

It should however be realised that the hardness test and the tensile test measure two distinctly different properties of metals and consequently the empirical relationship that exists in general terms can be influenced by residual stresses in the metal and variations in the elastic limit-ultimate tensile strength ratio of the materials under test.

In 1955 the Commission of the European Communities (ECSC) first published a Euronorm standard No. 8 covering the approximate conversion of hardness to tensile strength for steels. This original document did not however place sufficient emphasis on the scatter of the data in such conversions, consequently there was a tendency, both in the U.K. and abroad, for users of this standard and other similar conversion tables to convert from a measured hardness value to some fixed tensile strength value without recognising the scatter which can occur in practice.

Last year a discussion document was circulated to members of the European Coal & Steel Community on hardness to tensile strength conversions. The proposed conversion ranges for Brinell and Vickers scales of hardness had been established following testing

by the Iron and Steel Research Institute of France (IRSID) on a very large number and wide range of heat treated carbon and alloy steels.

A summary of the results obtained by IRSID is given below together with data produced by the Spring Research and Manufacturers' Association on the hardness-tensile strength relationship obtained from tests carried out on prehardened and tempered carbon and low alloy steel spring wires provided by member companies and also drawn from SRAMA own stocks of wire.

SUMMARY OF DRAFT EURONORM: BNS 1482

Tables and graphs relating the Brinell and Vickers hardness values to the median tensile strength together with scatter bands for 95% confidence are given. The conversion table and graph for the Brinell test cover a hardness range from 85 HB to 450 HB using a steel ball or a tungsten ball indentor and a range from 460 HB to 650 HB using a tungsten ball indentor only. In the case of the Vickers test the range covered is 85 HV to 650 HV.

Examples of the expected tensile strength values obtained by conversion from hardness are given in the following table:-

Hardness	Tensile Strength (R_m), N/mm^2		
	R_{min}	R_{median}*	R_{max}
200 HB	590	690	790
400 HB	1270	1370	1470
450 HB	1470	1570	1670
200 HV	540	650	750
300 HV	850	960	1070
400 HV	1190	1290	1400
450 HV	1360	1470	1570
500 HV	1540	1650	1750
550 HV	1720	1830	1940
600 HV	1910	2020	2130

* With the data under consideration, a normal distribution would be expected, thus the median and mean values would be similar.

The draft Euronorm also includes the following guide on the use of the conversion tables and graphs:-

"The tensile strength values obtained by conversion may not, under any circumstances, replace the values laid down in product standards and their use may not exempt them from the tensile test.

Nor may these values be regarded as grounds for complaint.

The conversion values as defined in this document may only be used to determine the approximate tensile strengths."

SRAMA DATA

To assess the applicability of the proposed conversion tables produced by ECSC to the specific field of prehardened and tempered spring wires, testing undertaken in the Association's own laboratories, has enabled a completely independent relationship between Vickers hardness and tensile strength to be developed.

This relationship is shown in Fig. 1, and like the ECSC document, illustrates the 95% confidence band placed in the experimental data.

Due to the limited strength range over which prehardened and tempered spring wires are produced the investigation was restricted to hardness values between 440 HV and 620 HV, using an indentation load of 30 kgf. Over such a range of hardness the relationship with tensile strength could be adequately described by the linear function

$$R_{mean} = (3.733 \times HV) - 205.6$$

with the high level of correlation of 0.96 and a 95% confidence band of ± 93 N/mm^2 on the regression line. In practice this means that from a hardness determination the estimate of the tensile strength will lay within the scatter bands indiciated in 95 cases out of 100.

Data calculated from the linear function is also presented in numerical form (Table 1) and allows easy comparisons to be made with the information contained in draft Euronorm BNS 1482.

It is emphasised that the conversions are only applicable to materials in the hardened and tempered condition. From experience it is known that the hardness-tensile strength relationship for cold drawn carbon and stainless wires is much more variable therefore not allowing a reliable conversion to be established.

CONCLUSIONS

1. It will be seen that the data generated by the Association is in very close agreement with that published in the draft Euronorm BNS 1482.

2. With the SRAMA data the scatter band to give 95% confidence is somewhat narrower at $\pm$93 N/mm^2 than that produced in the Euronorm draft BNS 1482 at about $\pm$100 N/mm^2 or $\pm$110 N/mm^2. This difference is in part due to rounding of numbers and also probably due to the wider range of hardness (e.g. 85 to 650 HV) over which the Euronorm relationship has been established.

3. This work supports the comment made in the draft Euronorm BNS 1482 concerning the dangers of using the hardness test as an accurate means of determining the tensile strength. Tensile strength values obtained by conversion from hardening determinations can only be used to give an approximate indication of tensile strength.

4. The relationship determined between hardness and tensile strength applies only to hardened and tempered carbon and low alloy steels within a range of hardness of 400 to 650 HV. On no account should this relationship be used to indicate the tensile strength of cold drawn carbon or stainless steel spring wires.

TABLE I CONVERSION TABLE FOR VICKERS HARDNESS TO MEAN TENSILE STRENGTH; ALSO THE SCATTER BAND FOR A CONFIDENCE LEVEL OF 95%

HV	R_{min} N/mm^2	R_{mean} N/mm^2	R_{max} N/mm^2
400	1195	1288	1381
410	1232	1325	1418
420	1269	1362	1455
430	1307	1400	1493
440	1344	1437	1530
450	1381	1474	1567
460	1419	1512	1605
470	1456	1549	1642
480	1493	1586	1679
490	1531	1624	1717
500	1568	1661	1754
510	1605	1698	1791
520	1643	1736	1829
530	1680	1773	1866
540	1717	1810	1903
550	1755	1848	1941
560	1792	1885	1978
570	1829	1922	2015
580	1867	1960	2053
590	1904	1997	2090
600	1941	2034	2127
610	1979	2072	2165
620	2016	2109	2202
630	2053	2146	2239
640	2091	2184	2277
650	2128	2221	2314

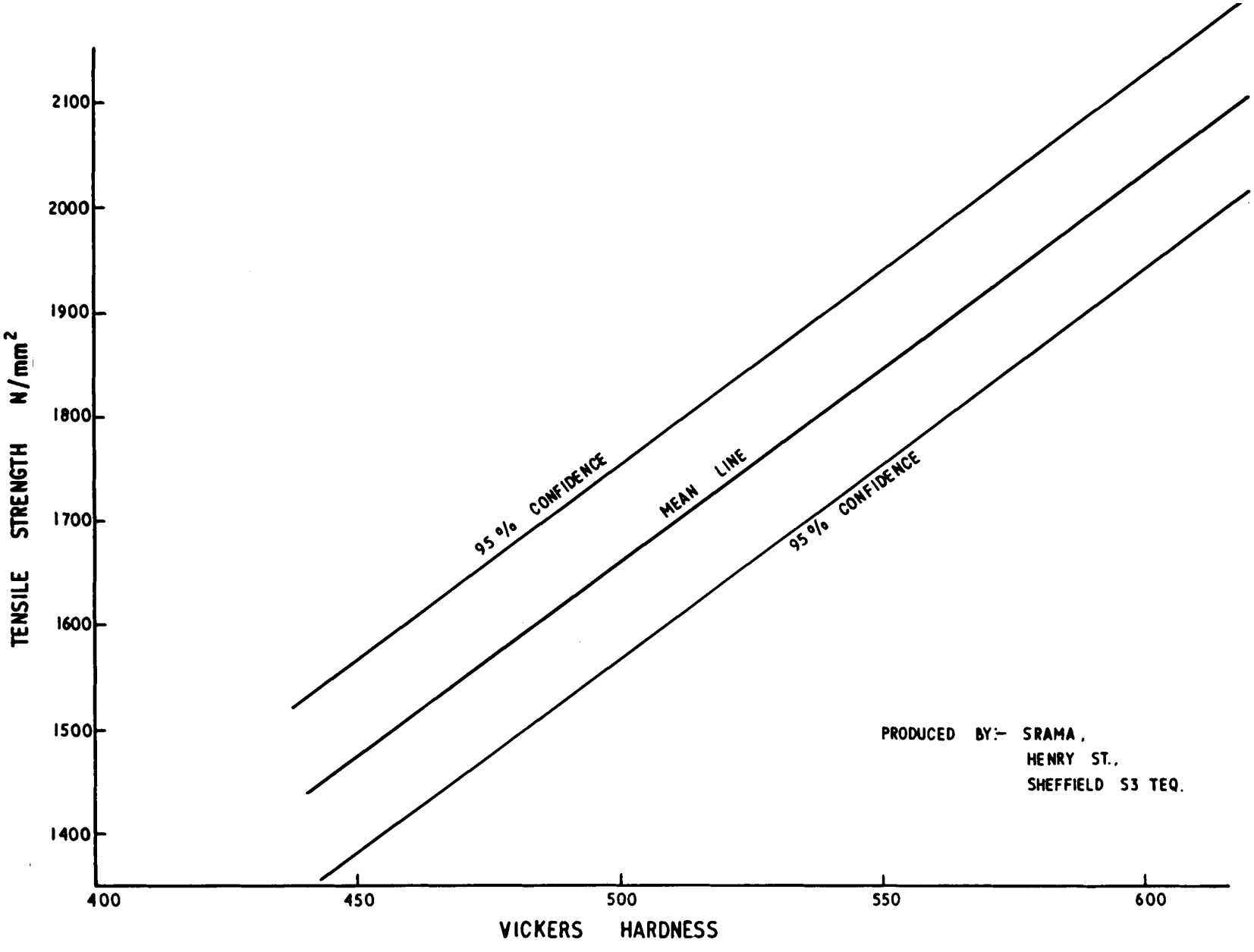

FIG. 1. HARDNESS – TENSILE STRENGTH RELATIONSHIP FOR CARBON AND LOW ALLOY STEEL PREHARDENED AND TEMPERED SPRING WIRE.