THE SPRING RESEARCH ASSOCIATION

THE FATIGUE PROPERTIES OF HELICAL COMPRESSION SPRINGS MANUFACTURED FROM SHOT PEENED PATENTED AND COLD DRAWN SPRING STEEL WIRE

by

S. D. Gray, A.P. (Sheff.)

Report No. 195

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SUMMARY

Maximum increase in fatigue life of shot peened springs is only achieved if the total surface is treated by the peening media. In the case of close coiled extension springs shot peening would not be possible, and consequently the use of wire which has been shot peened prior to coiling might be advantageous.

Straight lengths of 2 mm diameter wire to specification B.S. 1408C Range 2 were shot peened prior to spring coiling and subsequently fatigue tested. Additional fatigue data have also been obtained on springs made from shot peened and subsequently dry-honed wire.

Springs manufactured from shot peened wire had an identical fatigue strength to those made from untreated wire.

Springs manufactured from shot peened and dry honed wire had a somewhat lower fatigue strength than springs made from untreated wire.

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1. INTRODUCTION

The beneficial effects arising from shot peening of springs are well known, and in most cases result in an approximate 20% increase in fatigue strength. However, peening is only fully effective if the total surface is treated, and practicable only when the wire diameter is greater than about 2 mm, otherwise excessive distortion is likely.

In previous work undertaken by the SRA, dry honing and vapour blasting techniques were shown to give the same elevation of fatigue limit as can be obtained by shot peening (1) (2). By using these techniques it is possible to treat wires having a diameter of less than 2 mm. It should also be possible to treat close coiled springs providing they are extended during surface treatment, thus allowing the abrasive to come in contact with the entire spring surface. If it were possible to shot peen wire prior to coiling, and for the beneficial effects of the peening process not to be destroyed by the coiling process, this would be an ideal manufacturing process for the production of close coiled springs.

This report investigates the possibilities of increasing the fatigue strength of springs by pre-peening lengths of straight wire prior to coiling with the following media:-

(a) Cast steel shot.
(b) Cast steel shot followed by alumina particles.

2. MATERIALS

2.1 Wire

Patented and cold drawn spring steel wire of 2 mm diameter to B.S. 1408C Range 2 was used in this investigation.

3. EXPERIMENTAL PROCEDURE

3.1 Surface Treatments

Preparatory work for this investigation involved the shot peening of 24 straight lengths of wire using pneumatic plant. Two sizes of steel shot were used, CS 120 and CS 170, and the wires were processed with nozzle angles at 45^o and 90^o to the wire. Almen arc rises of 0.019 and 0.024 for CS 120 and CS 170 shot sizes, were recorded for nozzle angles of 90^o.

To ensure full surface coverage, each wire was peened along its length, turned through 45^o, and peened again. This process was repeated until adequate coverage was obtained.

From the results of these preliminary tests it was not clearly evident which combination of nozzle angle and shot size was the most effective. A comparison of the results obtained, discounting the few with unusually good fatigue lives, again revealed a close similarity.

It was decided therefore to select CS 120 shot with a nozzle angle at 90^o to the wire, as this combination would produce less distortion of the wire and allow greater ease of operation together with shorter peening times for equivalent Almen arc rises.

Following shot peening, a batch of shot peened wires was further treated with 180/220 Al_2O_3 abrasive.

3.2 Manufacture of Test Springs

Following surface treatment, springs were coiled to the design used in a previous research [1] (Table I). After coiling each spring was low temperature heat treated at 220°C for 30 minutes followed by end-grinding and prestressing.

3.3 Fatigue Testing

Load tests were carried out on the springs to establish the necessary fatigue machine strokes to give the required stress ranges. Springs were tested on forced motion multi-valve spring testing machines, designed to run at approximately 2000 r.p.m. Preliminary tests involved fatigue testing at an initial stress of 100 N/mm^2 (6.5 $tonf/in^2$) and a maximum stress of 900 N/mm^2 (58.3 $tonf/in^2$).

Having completed these preliminary tests, the remaining springs were tested at an initial stress of 100 N/mm^2, and by varying the stress range applied to the springs the endurance could be measured and used to construct S/N curves.

4. RESULTS

Table I gives the design data of the springs which were coiled from the treated wire.

Table II gives the preliminary fatigue data obtained when utilising two different shot sizes and nozzle angles. The fatigue data obtained from the selected nozzle angle and shot size (as indicated from the preliminary tests) are given in Table III.

Additional fatigue data obtained from springs made from shot peened and dry honed wire are given in Table IV.

The results of the fatigue tests are presented as S/N curves in Figs. 1 and 2.

The results from the broken springs were analysed statistically to provide the appropriate regression line and to determine whether the correlation coefficient provided a significance of at least 95%. In the case of data for both surface conditions, correlations were significant at the 99% level.

5. DISCUSSION

The results of the preliminary fatigue tests carried out on springs coiled from shot peened wire are given in Table II. As previously discussed, it was not possible to select directly the best process from the results obtained; however, CS 120 shot with a 90^o nozzle angle was used for the remaining work. In order to assess the response to surface treatments, fatigue data of identical unpeened springs previously obtained (1) were used to provide a datum S/N curve.

It can be seen from Fig. 1 that springs manufactured from shot peened wire had a fatigue limit of 725 N/mm^2 (47.0 $tonf/in^2$), which was identical to the fatigue limit of springs made from untreated wire.

From an examination of the results in Fig. 2 it can be seen that the influence of dry-honing after shot peening reduces the fatigue limit of springs from 725 N/mm^2 to 625 N/mm^2 (40.5 $tonf/in^2$).

The results obtained indicate that the residual tensile stress remaining on the inside of the wire after coiling was greater in magnitude than the compressive stress produced by the shot peening process.

As a result of shot peening straight wire prior to coiling, beneficial surface compressive stresses are produced and upon coiling the wire into springs these compressive stresses are either increased or decreased dependant upon their relative positions in any one coil. Immediately upon coiling the compressive stresses in the wire at the inside of the coil are increased; however, when the constraint applied by the coiling point is removed, then equalising of stresses occurs throughout the wire, allowing the spring to reach equilibrium, ultimately producing a tensile stress at the inside radius.

It can be concluded therefore that the lack of response to peening, i.e. the ineffectiveness of the compressive stresses, induced prior to coiling, was due to a nullifying of all stresses by those introduced in the final coiling process. Further treatments, such as dry-honing, would not affect the ultimate residual stress system but would be expected to produce a smoother wire surface and thereby increase fatigue life. This has not been the case and further work would be necessary to resolve this unexpected drop in fatigue resistance.

6. CONCLUSIONS

1. Springs manufactured from shot peened wire had an identical fatigue strength to springs made from untreated wire.

2. Springs manufactured from shot peened and dry-honed wire had a lower fatigue strength than springs made from untreated wire.

7. ACKNOWLEDGEMENT

The author wishes to thank Vacu-Blast Limited for their co-operation in this programme of work.

8. REFERENCES

(1) G. B. Graves and J. M. A. Heap. "The Influence of Dry Honing and Vapour Blasting on the Fatigue Properties of Springs made from Patented Cold Drawn Wire."
SRA Report No. 179

(2) G. B. Graves. "The Fatigue Properties of Springs and Spring Materials." The Spring Journal No. 87

TABLE I SPRING DESIGN DATA

	METRIC	IMPERIAL
Wire Diameter	2 mm	0.079 in
Mean Diameter	16 mm	0.63 in
Active Coils	3.5	3.5
Total Coils	5.5	5.5
Coiled Length	45 mm	1.77 in
Length after End-Grinding and Prestressing	30 mm	1.18 in
Approx. Solid Stress	1400 N/mm^2	90.6 $tonf/in^2$

TABLE II PRELIMINARY FATIGUE DATA

SHOT SIZE	NOZZLE ANGLE	CYCLES TO FAILURE $\times 10^5$ INITIAL STRESS 100 N/mm^2 MAXIMUM STRESS 900 N/mm^2
CS120	90^o	1.08, 15.5, 1.35, 15.1, 1.71, 1.35, 1.80
CS120	45^0	2.16, 2.25, 1.62, 1.44, 0.99
CS170	90^o	2.07, 16.0, 1.59, 1.44, 1.08
CS170	45^o	1.44, 2.25, 0.90, 21.6, 2.34

TABLE III FATIGUE DATA FOR SPRINGS MADE FROM SHOT PEENED WIRE

MAXIMUM TORSIONAL STRESS (Initial Stress 100 N/mm^2)		CYCLES TO FAILURE (N)	CONDITION
N/mm^2	tonf/in^2		
700	45.3	10 000 000	Unbroken
725	47.0	12 000 000	Unbroken
750	48.6	11 000 000	Unbroken
750	48.6	261 000	Broken
860	55.7	90 000	Broken
900	58.3	144 000	Broken
1000	64.8	72 000	Broken
1100	71.2	42 000	Broken
1220	79.0	40 000	Broken

TABLE IV FATIGUE DATA FOR SPRINGS MADE FROM SHOT PEENED AND DRY-HONED WIRE

MAXIMUM TORSIONAL STRESS (Initial Stress 100 N/mm^2)		CYCLES TO FAILURE (N)	CONDITION
N/mm^2	tonf/in^2		
550	35.6	11 000 000	Unbroken
600	38.9	13 000 000	Unbroken
625	40.5	10 000 000	Unbroken
650	42.0	234 000	Broken
675	43.7	216 000	Broken
750	48.6	144 000	Broken
800	51.8	162 000	Broken
900	58.3	108 000	Broken
1000	64.8	66 000	Broken
1100	79.0	99 000	Broken

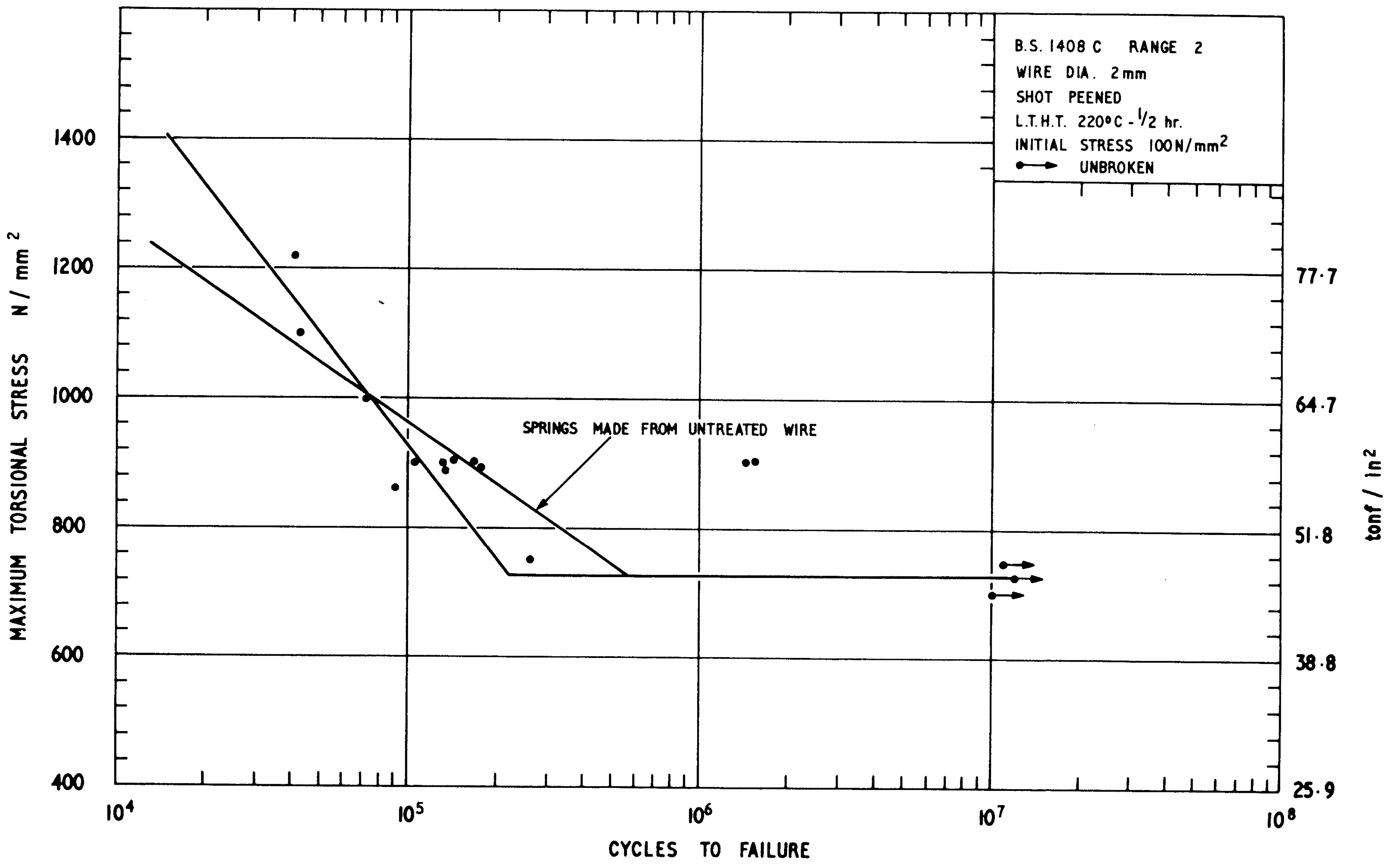

FIG. 1. S/N CURVE FOR SPRINGS MADE FROM SHOT-PEENED WIRE

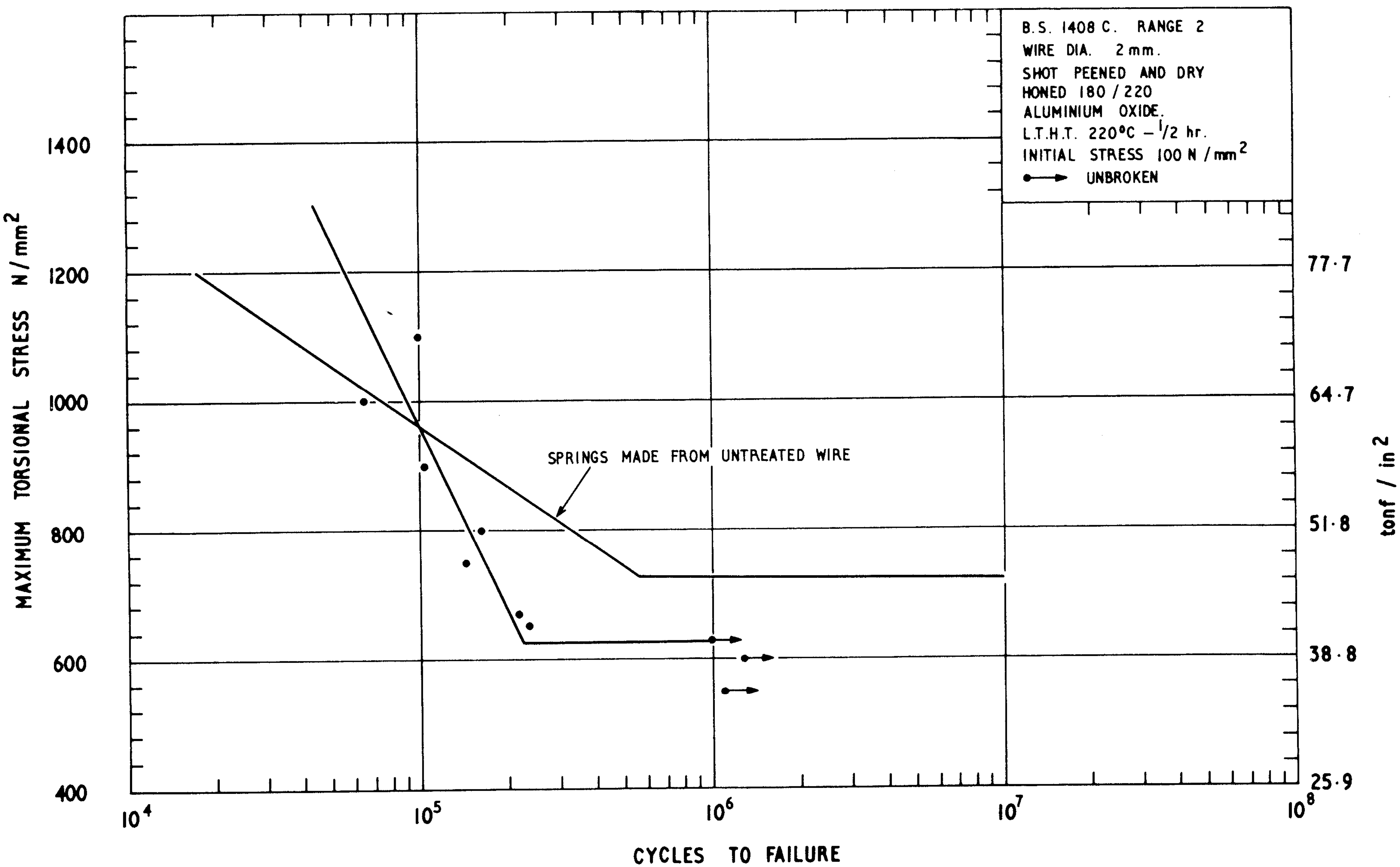

FIG.2. S/N CURVE FOR SPRINGS MADE FROM SHOT PEENED AND DRY-HONED WIRE