THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE FATIGUE PROPERTIES OF MEDIUM SIZED HELICAL COMPRESSION SPRINGS

by

K. Brummitt, B.Sc.

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SUMMARY AND CONCLUSIONS

This report presents the results of fatigue work on medium sized (10-15 mm bar dia) springs manufactured from three spring steels: a patented cold drawn wire to BS 1408 R2, a low alloy steel to En50 cold coiled and subsequently re-heat treated, and a low alloy steel, En48A, hot coiled into springs. The En48A quality was tested in both the unpeened and shot peened conditions, but the other qualities were tested in the shot peened condition only. The results are presented in the form of S/N curves and, in the case of the En48A springs, a Goodman diagram is also presented.

The main conclusions drawn from this work are:-

1. The fatigue properties of medium sized springs are related to the tensile strength of the material and are little affected by the specific chemical composition or metallurgical structure. Hardened and tempered low alloy steel springs are preferable to cold drawn ones for dynamic applications in this size range, because of the higher strengths available from the former materials.

2. The method of manufacture, whether hot coiled or cold coiled and subsequently hardened and tempered, does not appear to have a great effect on the fatigue properties of the springs.

3. Shot peening improved the infinite life fatigue properties of this particular sample of En48A springs by approximately 45%.

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1. INTRODUCTION

The work reported here is part of a comprehensive programme of work to determine the fatigue properties of helical compression springs manufactured from the most common spring materials for the size range 10 to 38 mm. This report covers work on the fatigue properties of medium sized compression springs manufactured from three materials. For the purpose of this investigation a medium sized spring is defined as one having a bar diameter in the range 10-15 mm, and this definition is applied to both hot and cold coiled springs.

2. MATERIAL

2.1 Composition

The materials used in this investigation were En50, En48A and drawn bar to BS 1408B R2. The actual chemical composition and the corresponding specifications are shown in Table I.

TABLE I CHEMICAL COMPOSITIONS

Material		%C	%Si	%Mn	%Cr	%S	%P	%V
BS 1408B R2	Specified	0.45-0.85	0.35 max	1.00 max	-	0.050 max	0.050 max	-
	Actual	0.53	0.17	0.63	-	0.035	0.015	-
En50	Specified	0.40-0.50	0.10-0.35	0.50 0.70	1.00-1.50	0.40 max	0.040 max	0.15 min
	Actual	0.45	0.27	0.61	1.40	0.010	0.012	0.15
En48A	Specified	0.50-0.60	1.35-1.65	0.60-0.90	0.55-0.85	0.050 max	0.050 max	-
	Actual	0.58	1.46	0.79	0.72	0.045	0.025	-

2.2 Spring Design and Manufacture

The spring designs used in this investigation are shown in Table II. All the springs used in this work were produced commercially by member firms.

TABLE II SPRING DESIGNS

	BS 1408B R2	En50	En48A
Wire Diameter mm	10.2	11.0	12.8
Mean Coil Diameter mm	78.9	93.5	100.0
Total Coils	8	7	5
Active Coils	6.5	5.5	3.5
Free Length after Prestressing mm	232.5	241.3	179.0
Solid Stress after Prestressing mm	830	1145	1226

Twenty springs, cold coiled from BS 1408B R2 wire to the design in Table II, were obtained, together with a similar number of springs cold coiled from En50 and subsequently hardened and tempered to a hardness of 500-520 HV. One hundred springs were hot coiled from normalised and ground En48A bar to the design shown in Table II, and subsequently hardened and tempered to a hardness of 500-520 HV. One hundred springs were hot coiled from normalised and ground En48A to the design shown in Table II, and subsequently hardened and tempered to a hardness of 500-520HV.

Some springs manufactured from En48A were tested in the unpeened state, the remaining springs were shot peened at SRAMA to an Almen arc rise of 0.45-0.55 mm A2 using S330 shot. In each case, the coverage was judged visually to be 100%.

3. FATIGUE TESTING

The springs were scragged until no further set down was observed with repeated loading, then individually load tested in order to determine the compressed heights needed to produce the required initial and maximum stresses. All the fatigue testing was carried out on a vertical resonance fatigue machine.

Cold coiled shot peened spring of both qualities were tested at an initial stress of 150 N/mm^2 to a series of maximum stresses ranging from 580 N/mm^2 to 820 N/mm^2 for material to BS 1408B and from 830 N/mm^2 to 1100 N/mm^2 for material to En 50, enabling an S/N curve to be established for each material. These are presented as Figs. 1 and 2 respectively.

The springs manufactured from En 48A bar were tested from a number of initial stresses in both the shot peened and unpeened conditions. The initial stresses used were 100, 300 and 500 N/mm^2 for the unpeened springs, and 100 and 300 N/mm^2 for the shot peened springs. From the data, S/N curves have been drawn and are shown in Figs 3 and 4.

4. RESULTS

4.1 Fatigue Testing

The results of the fatigue tests on the various springs are shown as S/N curves (Figs 1 to 4) and also as Goodman diagrams (Figs. 5 & 6). There is notably more scatter in the fatigue results obtained from springs which had subsequently been hardened and tempered than from springs which had been manufactured from cold drawn wire. More scatter is also evident in the results from shot peened springs in those from unpeened springs.

4.2 Metallographic Examination

Transverse microsections were taken from springs of each material. In the case of the results which showed a large degree of scatter, sections were taken from springs which exhibited relatively short and long endurances.

Microsections from springs manufactured from BS 1408B R2 material contained decarburisation to a total affected depth of 0.15 mm, and microsections from springs manufactured for En50 material showed a uniform structure of tempered martensite with decarburisation to a total affected depth of 0.25 mm. No oxide penetration or other surface defects were observed.

Examination of sections cut from springs manufactured from En48A material showed a uniform structure of tempered martensite with no decarburisation, oxide penetration or apparent defects at the surface.

TABLE III MISCELLANEOUS DATA

SPRING MATERIAL	GRAIN SIZE ASTM	MICROSTRUCTURE	COILING METHOD	DECARBURISATION mm
En 50	6 - 7	Uniform Tempered Martensite	Cold Coiled	0.275
En 48A	5 - 6	"	Hot Coiled	None
En 45	-	"	"	0.076
BS 1408B R2	-	Hard Drawn Pearlite	Cold Coiled	0.15

5. DISCUSSION

This report contains data obtained from springs manufactured from three types of material. These are En 50 bar cold coiled and subsequently hardened and tempered, En 48A hot coiled springs, and springs cold coiled from hard drawn material to BS 1408B R2. Previous work dealt with springs in the same size range which were hot coiled from En 45A bar. Direct comparison of the springs is not possible however, as they were manufactured to different designs. Also, the hardness (and hence the tensile strength) of the various materials was not identical. The first difficulty can be overcome by adapting a modified presentation of the fatigue data as suggested by Bird[2] (Fig. 7). This presentation shows that the En 48A springs had a maximum stress range for survival to 10^7 cycles 100 N/mm^2 greater than the springs manufactured from En 45 bar. The results for springs manufactured from En 50 bar are between these figures. The springs manufactured from the hard drawn BS 1408B R2 material had a much lower maximum stress range for survival to a life of 10^7 cycles.

The fatigue performance of these three material can be compared by examining the fatigue ratios, and as can be seen in Table IV these are very similar.

TABLE IV FATIGUE PROPERTIES OF SPRINGS

	R_m N/mm^2	Max. Stress for 10^7 Survival with 150 N/mm^2 Min. Stress	Fatigue Ratio
BS 1408B R2	1150	610	0.53
En 50	1690	830	0.49
En 48A	1690	880	0.52
En 45	1590	770	0.48

This suggests that for survival to 10^7 cycles the precise chemical composition of the steel and the metallographic structure do not critically affect fatigue strength, and that the most important factor is the strength of the material. Thus for fatigue applications in the size range under the higher strength levels obtainable from these material than from cold drawn material. With smaller sizes, higher tensile strengths are obtainable from hard drawn wires and hence these materials are more likely to find favour. In the size range considered here, all the low alloy steels have adequate hardenability, but as size increases steels will need to be chosen with hardenability in mind.

As data has been produced at a single intitial stress level of 150 N/mm^2 for material to BS 1408B and En 50 compression of limited life data must be made at this intitial stress level. This comparison is shown in fig 8. Data for shot peened En 48A springs has been derived from the data obtained at initial stress of 100 and 300 N/mm^2. Data presented for En 45 has been re-analysed from previous work to give mean life data comparable to that presented in this report.

6. CONCLUSIONS

1. From this work, it appears that the fatigue properties of medium sized springs are related to the tensile strength of the material and are little affected by the specific chemical composition or metallurgical structure. Hardened and tempered low alloy steel

springs seem to be preferable to cold drawn ones for dynamic applications in this size range, because of the higher strengths available from the former materials.

2. The method of manufacture, whether hot coiled or cold coiled and subsequently re-hardened and tempered, does not appear to have a great effect on the fatigue properties of springs.

3. Shot peening improves the infinite life fatigue properties of this particular sample of En 48A springs by approximately 45%.

7. REFERENCES

1. Owen, A.P. The Fatigue Properties of Heavy Helical Compression Springs. Progress Report No. 1: Phase I, En 45A. SRA Report No. 210, 1972.

2. Bird, G.C. The Effect of Solid Stress on the Fatigue Behaviour of Springs Manufactured from BS 1408C. SRA Report No. 219, 1973.

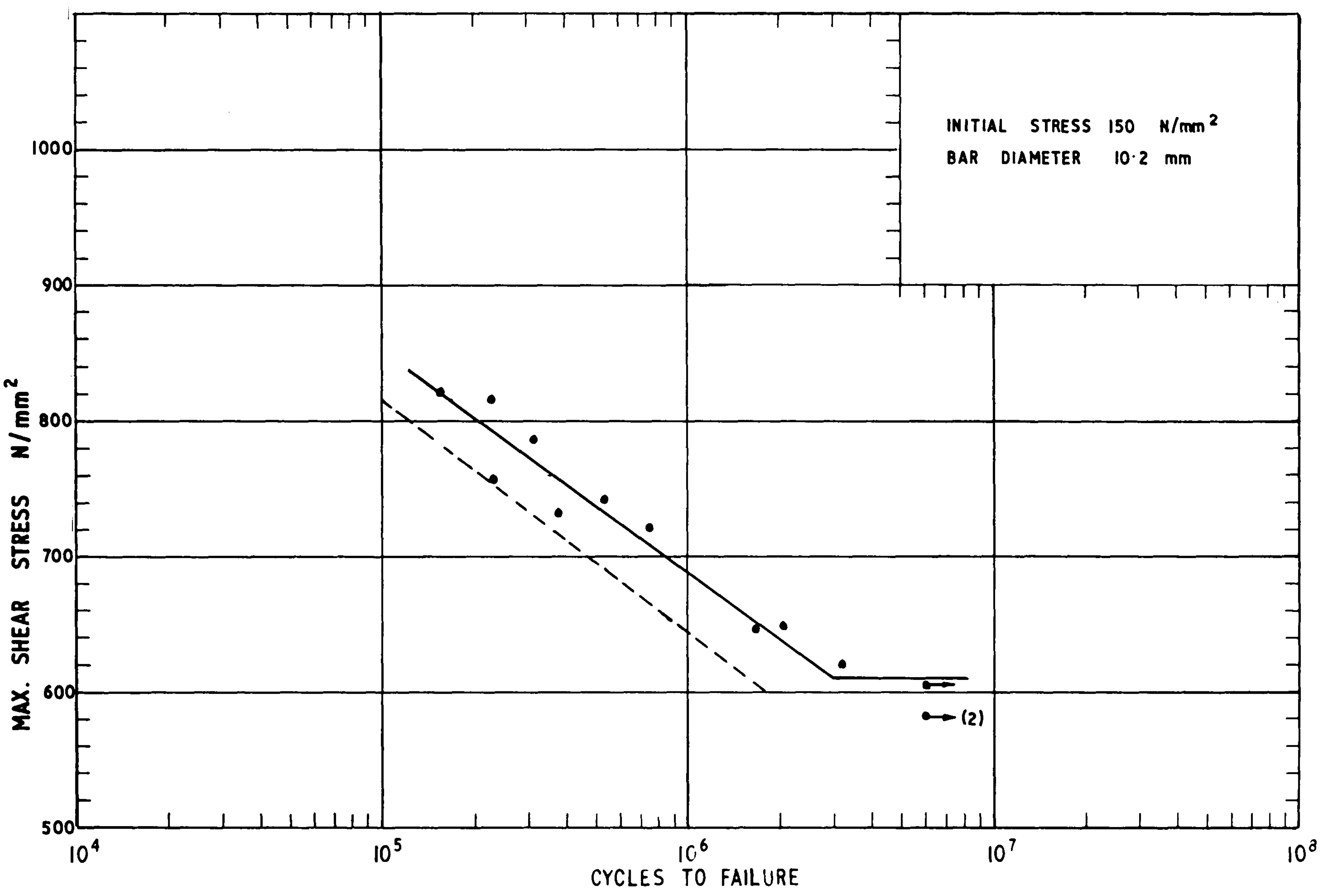

FIG.1 S/N CURVE FOR SHOT PEENED BS 1408 B R2 COLD COILED SPRINGS.

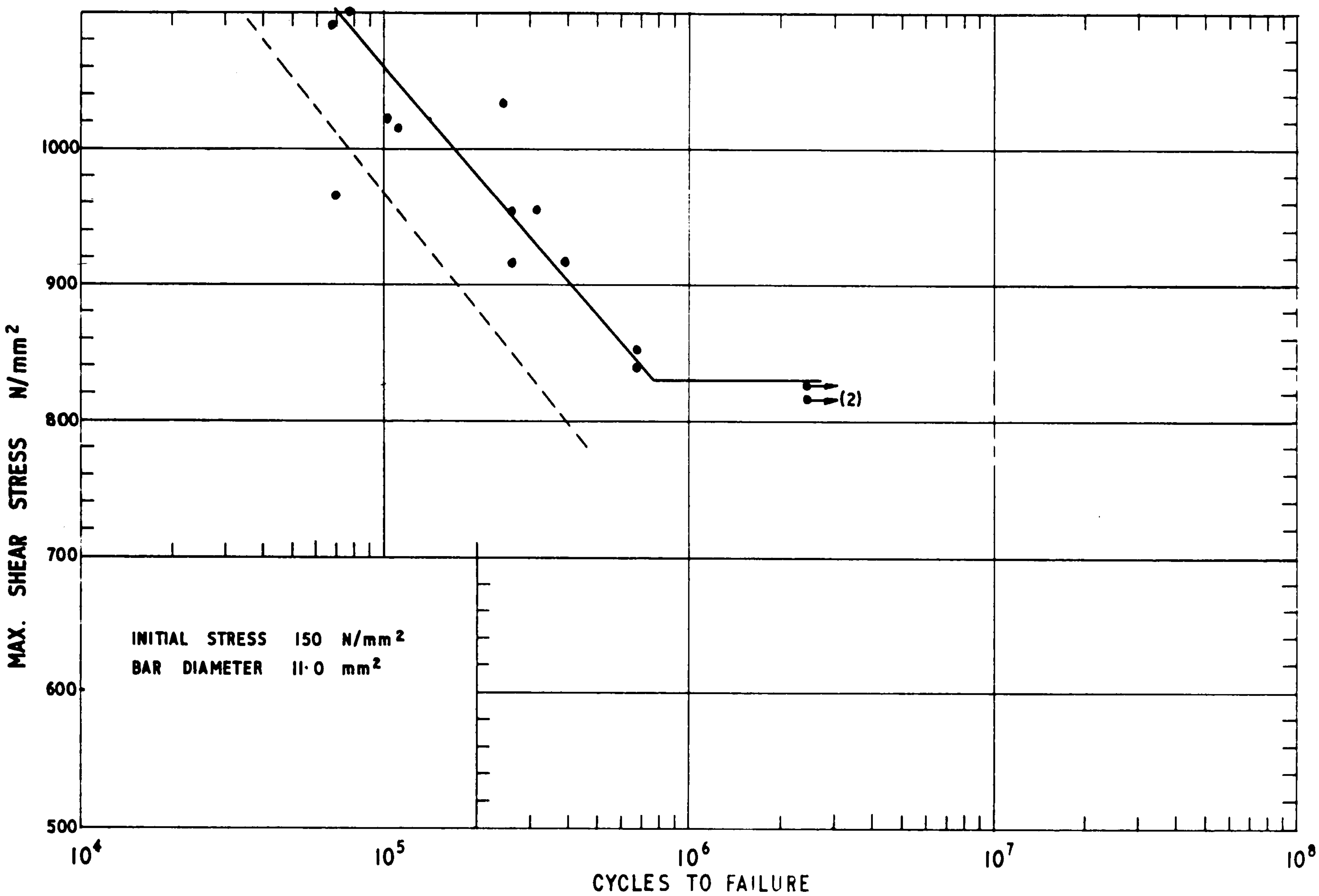

FIG. 2 S/N CURVE FOR SHOT PEENED EN 50 COLD COILED SPRINGS.

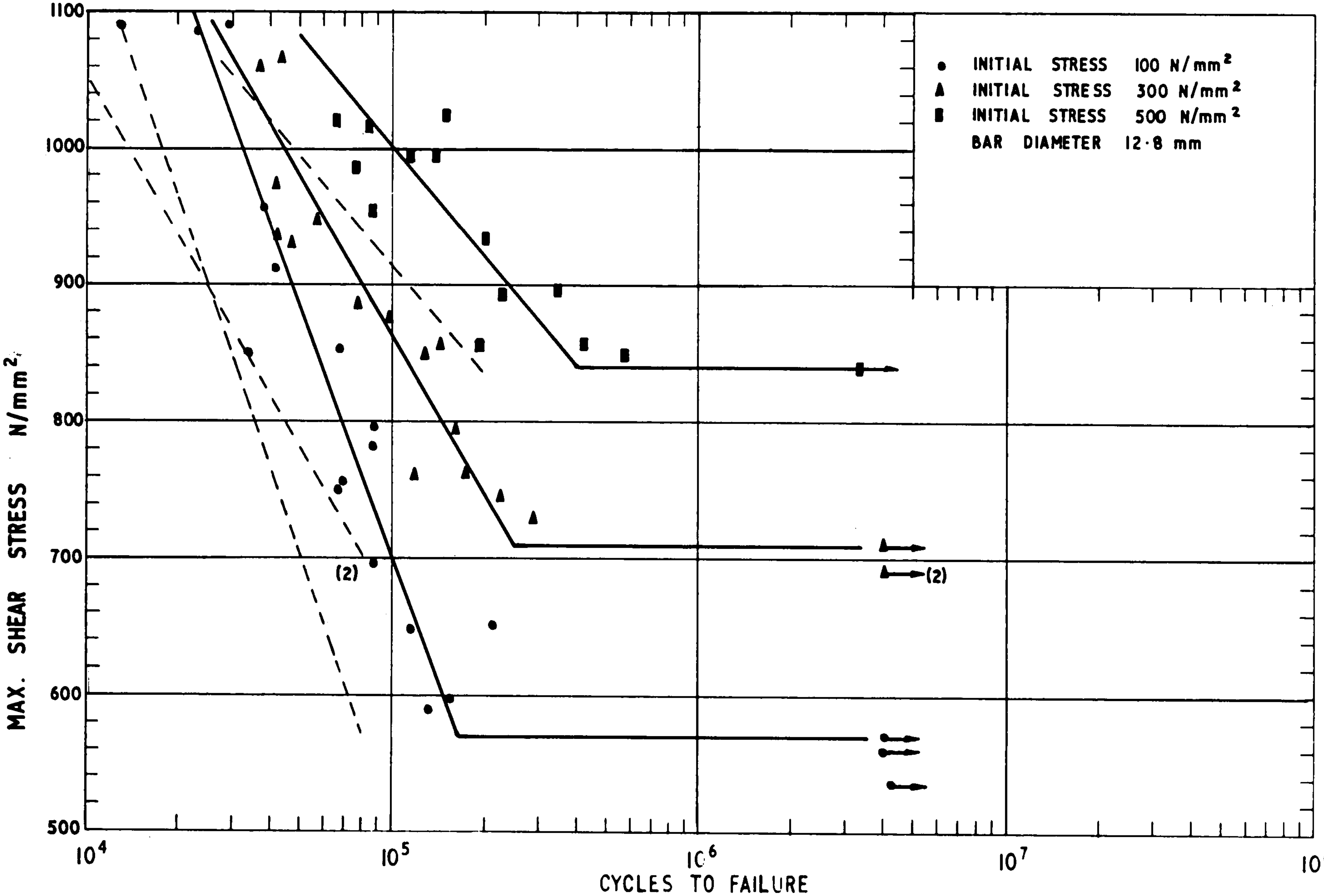

FIG. 3 S/N CURVES FOR UNPEENED En. 48 A HOT COILED SPRINGS.

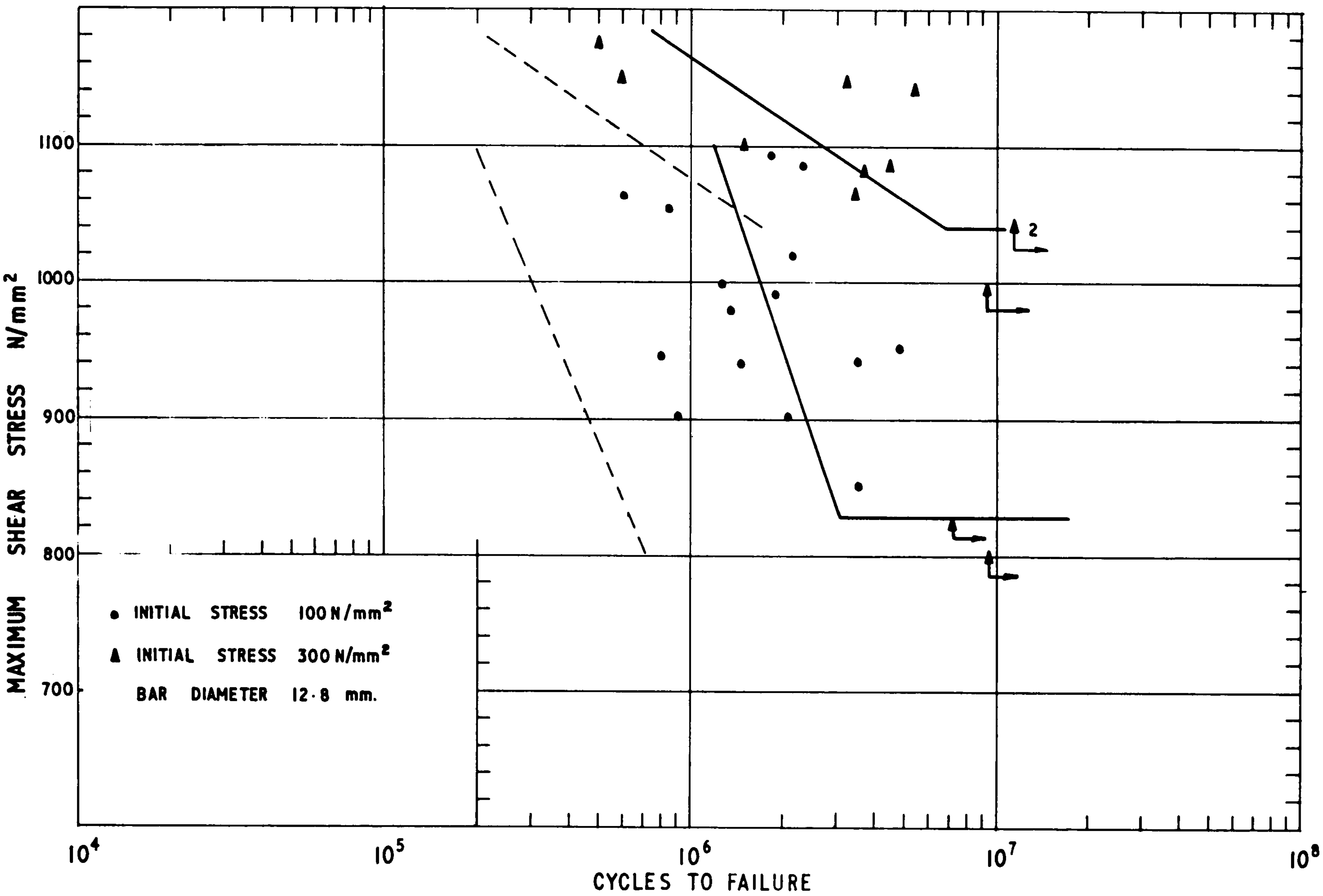

FIG. 4. S/N CURVES FOR SHOT PEENED EN 48 A HOT COILED SPRINGS.

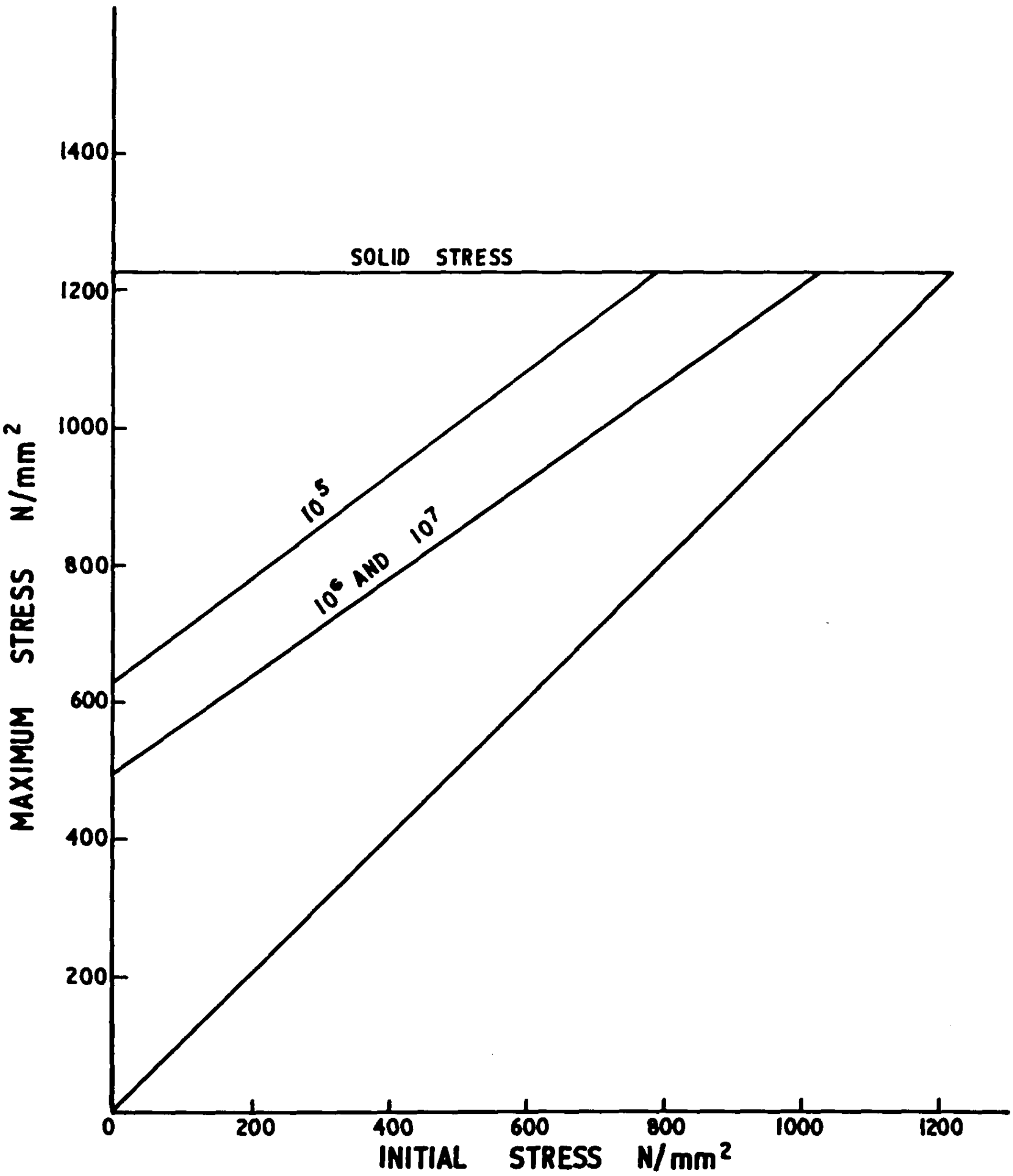

FIG. 5 MODIFIED GOODMAN DIAGRAM FOR UNPEENED EN 48 A HOT COILED SPRINGS. (MEAN LIFE DATA)

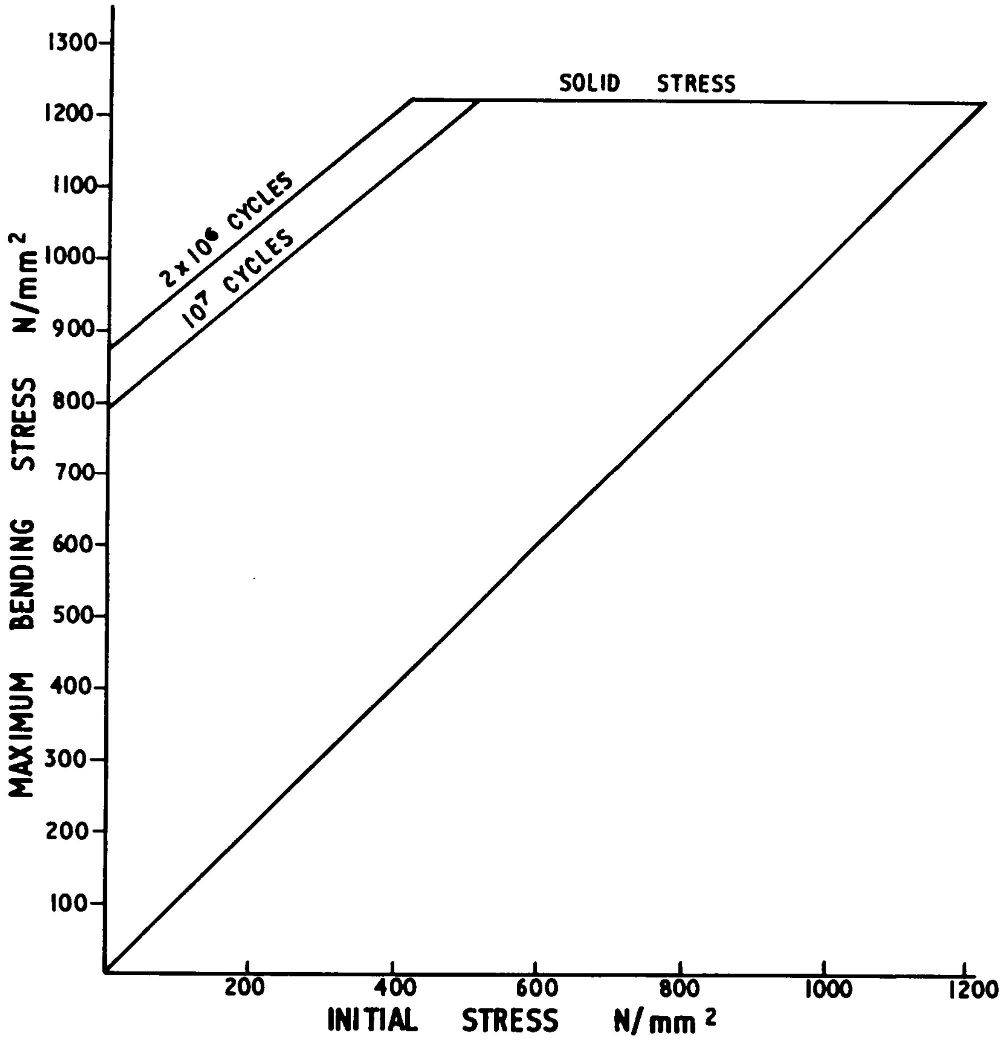

FIG. 6 MODIFIED GOODMAN DIAGRAM FOR SHOT PEENED EN 48A HOT COILED SPRINGS. (MEAN LIFE DATA)

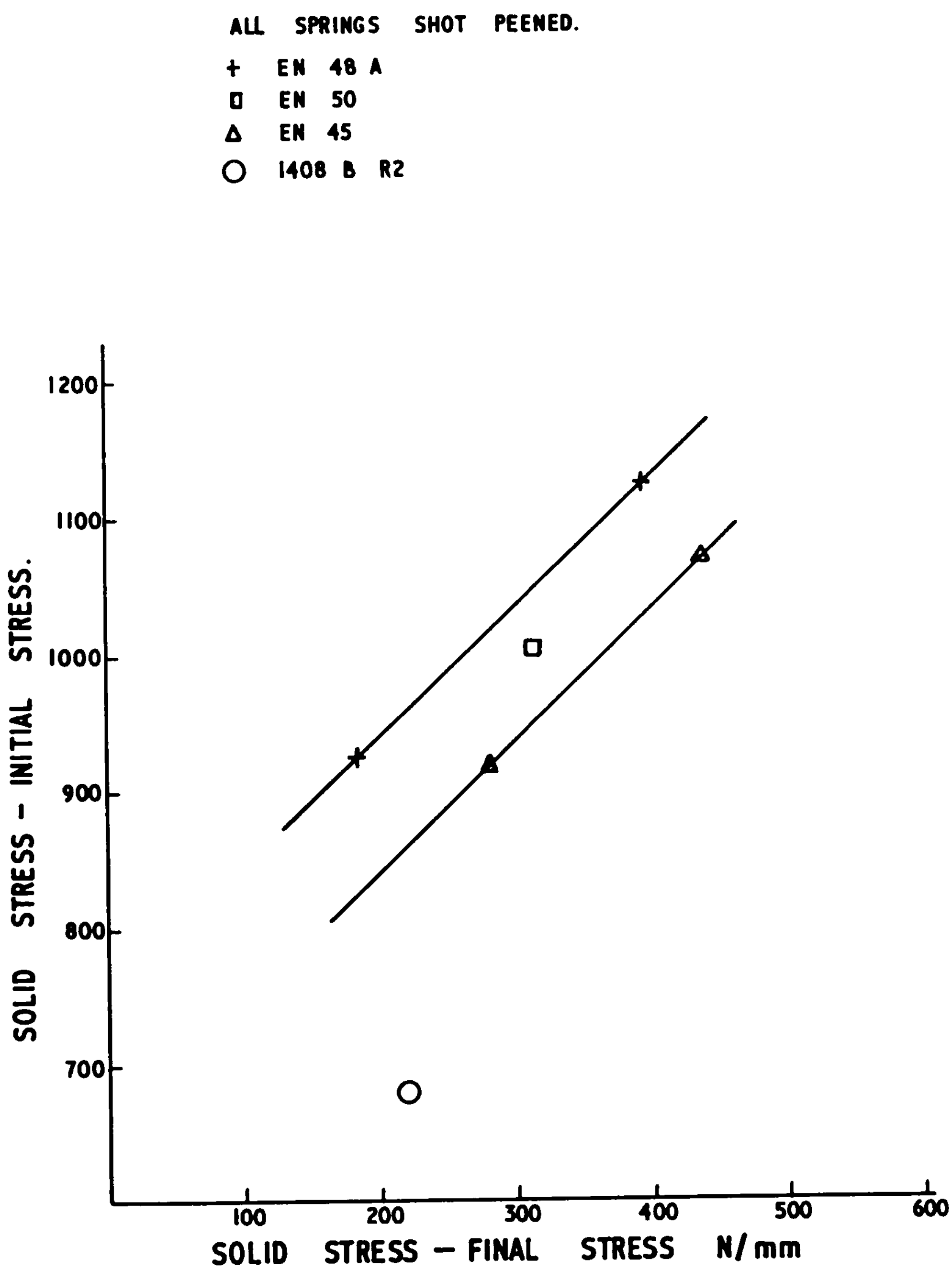

FIG. 7 MODIFIED PRESENTATION OF FATIGUE DATA FOR SHOT PEENED SPRINGS FOR 10^7 CYCLES SURVIVAL TO ALLOW COMPARISON OF FATIGUE PROPERTIES OF SPRINGS OF DIFFERING SOLID STRESS.

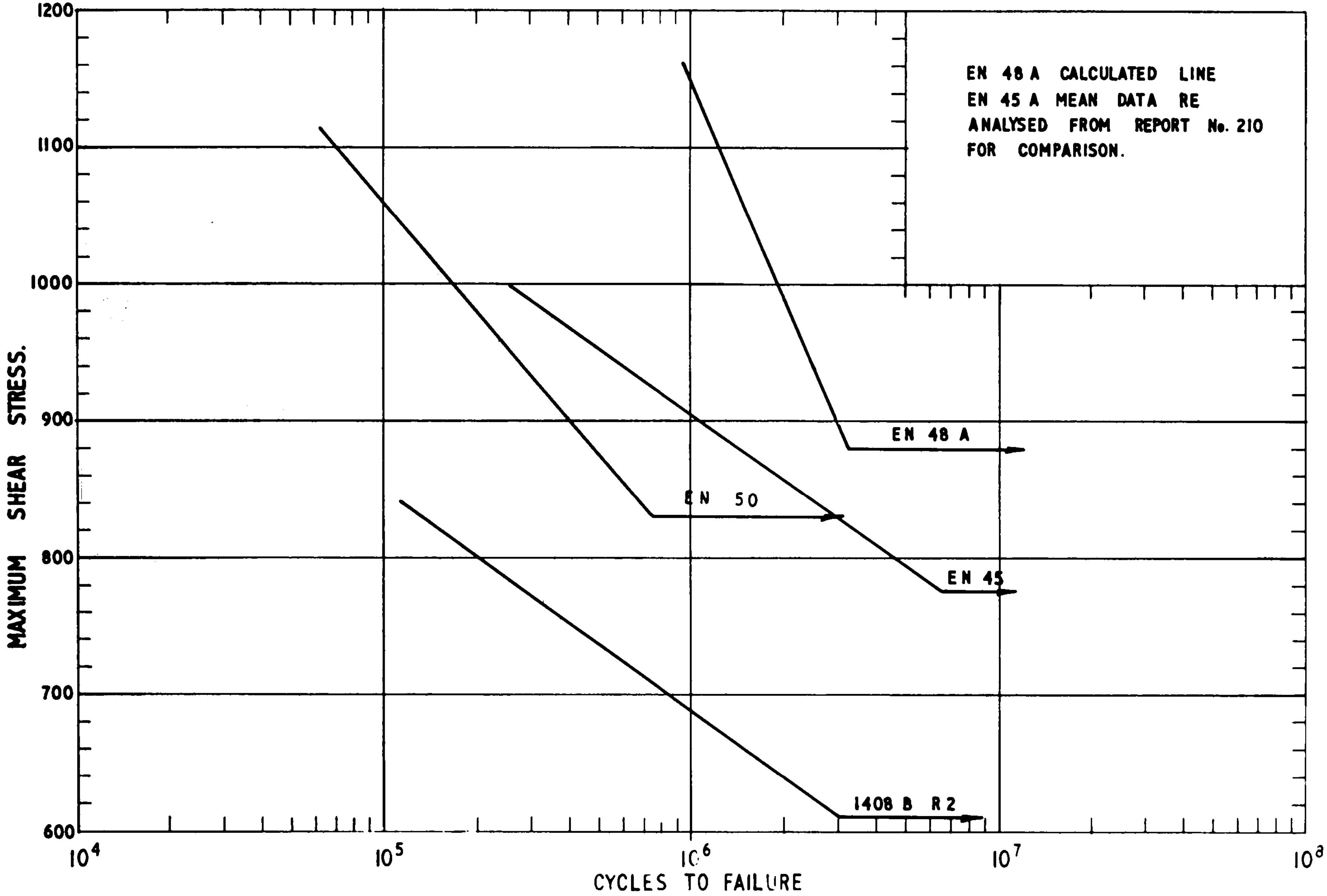

FIG. 8 COMPARISON OF FATIGUE PROPERTIES AT 150 N/mm² INITIAL STRESS SHOT PEENED SPRINGS.