THE SPRING RESEARCH ASSOCIATION

THE PRESTRESSING OF COMPRESSION SPRINGS MADE FROM OIL-HARDENED AND TEMPERED WIRE

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SUMMARY

An investigation has been carried out to examine the details of prestressing compression springs made of pre-hardened and tempered wire, with varying solid stresses.

To effectively stabilise a spring with a solid stress between 50% and 61% of the tensile strength, at least one prestressing operation was required. Between 62% and 70% two operations were needed, between 70% and 75% three operations were needed, and above 75% four operations were required to stabilise the spring.

Prestressing had little effect if the solid stress of the spring was below 50% of the tensile strength of the wire. The maximum solid stress to which a spring could be coiled was found to be equivalent to approximately 80% of the tensile strength of the wire.

CONTENTS

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1. INTRODUCTION

Prestressing, or scragging, is applied to compression springs in order to increase their load bearing capacity by improving the stress distribution. The operation consists of coiling the spring to a free length greater than that desired and then compressing the spring to solid, beyond the elastic limit, thus causing a reduction in the free length of the spring. Repeating the operation causes a diminishing amount of further set in the spring, until no further reduction in length is achieved by additional prestressing.

Previous work has been carried out by the Association on the prestressing of patented cold drawn wire to BS 1408 [1] and this report describes a similar investigation into the behaviour of springs made from oil-hardened and tempered wire.

In the previous work only one spring index was used, while in the work reported here springs with indices between 3 and 12 were investigated.

2. SPRING DESIGN

The material selected for the investigation was 3.66 mm diameter chromium-vanadium steel wire. Springs were made from wire in the pre-hardened and tempered condition, low temperature heat treated after coiling (370°C for half-an-hour), and identical wire hardened and tempered after coiling (quenched at 880°C; tempered at 415°C for half-an-hour) so that any residual coiling stresses would be eliminated. Springs were designed to four different indices (3, 5, 7.5 and 12) and, for each index, compression springs were coiled to give solid stresses after prestressing, of approximately 50%, 60%, 70% and 80% of the tensile strength. The spring ends were closed and ground. Details of the spring designs are shown in Table I.

3. PROCEDURE

The free length of each spring was measured before prestressing between two parallel plates, perpendicular to the axis of the spring and in contact with the end coils. One of the plates was adjustable and its position measured with a dial gauge. The springs were then closed to solid and released between the two plates, thus completing one prestressing operation, during which the load/deflection curve was measured. The free length of each spring was measured after one scragging operation and the procedure was repeated until the free length after two successive scragging operations was the same. After each operation the mean coil diameter was measured to determine any variation.

4. RESULTS

4.1 Prestressing of Compression Springs

For each design, the number of prestressing operations needed to stabilise a spring was recorded. In practice it may not be necessary to stabilise a spring fully, but merely to eliminate the greatest part of set which is likely to take place. For practical purposes, therefore, a spring can be considered to be satisfactorily scragged when further scragging will not reduce the free length by more than 50% of the free length tolerance specified in BS 1726.

On the basis of the results obtained a graph was drawn, showing the number of prestressing operations needed to stabilise a spring of any given solid stress (see Fig. 1). These same data have been re-plotted in Fig. 2, in which the corrected solid stress of the spring after prestressing has been expressed as a percentage of the ultimate tensile strength of the wire. This enables the results obtained with hardened and tempered wire to be directly compared with the data previously obtained with springs made from patented wire. In Fig. 3, the corrected stresses after coiling and prestressing are expressed as a percentage of the tensile strength of the material; a smooth curve has been drawn through the data for all the spring indices investigated.

4.2 Mechanical Testing

Two tensile and torsion tests were carried out on samples of the wire in each condition, the results being shown in Table II.

5. DISCUSSION OF RESULTS

For both wire conditions the number of prestressing operations required to produce stability ranges from none with a solid stress of about 875 N/mm^2 to four with a solid stress of about 1350 N/mm^2. The results obtained with stress relieved springs differ from those from hardened and tempered springs in that the latter give slightly higher solid stresses after prestressing (stresses corrected using Sopwith correction factor). The spring index does not seem to affect the prestressing results. This can be seen in Fig. 1 where there is no regular pattern to the plotted values for springs of the same index; the curves drawn show an average of the four indices. Below a solid stress equal to the torsional elastic limit there should be no setting of the spring during prestressing, as the stresses in the spring are completely within the elastic range of the material. From Table II the elastic limit values are 870 N/mm^2 and 840 N/mm^2 for stress relieved and hardened and tempered wire respectively, both values representing about 50% of the tensile strength. As can be seen from the curve in Fig. 4, prestressing has no effect where the solid stress is 50% of the tensile strength. Another factor that can be noted from Fig. 4 is that the maximum solid stress to which a spring can be designed, for practical reasons, is approximately 80% of the tensile strength of the wire. This represents the maximum solid stress, irrespective of the number of prestressing operations needed to stabilise the spring. Springs designed to higher values would be very difficult to stabilise, even after numerous pre-stressing operations.

In Fig. 4 the results for the number of prestressing operations to produce stability for the BS 1408 wire have been superimposed upon the data presented in Fig. 2 and it can be seen that the results are very similar.

In Fig. 5 the solid stress values before and after pre-stressing have been plotted for both the hardened and tempered and the patented wire. It can be seen that the loss of solid stress on prestressing is greater for the patented wire than for the oil-hardened and tempered material. This is consistent with the findings that the torsional elastic limit/tensile strength ratio is greater for the hardened and tempered material than for the patented wire. (See Table 3.)

6. CONCLUSIONS

1. There is an increase in the number of prestressing operations required to stabilise a spring, as the solid stress of the spring increases.

2. Prestressing has little effect if the solid stress of the spring is less than 50% of the tensile strength (Rm) of the wire.

3. There is a maximum solid stress to which a spring can be designed for practical reasons; this was found to be approximately 80% of the tensile strength.

4. The minimum numbers of prestressing operations required for compression springs made from pre-hardened and tempered chromium-vanadium steel wire are as follows:-

Solid Stress (% Rm)	Minimum Number of Scrags
Below 50	0
50 - 61	1
62 - 70	2
71 - 75	3
76 - 79	4

7. REFERENCE

1. BIRD G.C. "An Investigation into the Effects of Solid Stress on Prestressing Compression Springs". SRA Report No. 208

TABLE I SPRING DESIGNS

	DESIGN A	DESIGN B	DESIGN C	DESIGN D
Wire diameter (mm)	3.66	3.66	3.66	3.66
Mean coil diameter (mm)	10.97	18.3	27.4	43.9
Spring index	3	5	7.5	12
Active coils	12	7	3	1.5
Total coils	14	9	5	3.5
Spring rate (N/mm)	112	41.2	28.6	14.0
Type 1				
Free length (mm)	59.2	48.5	35.0	35.3
Solid stress after prestressing (N/mm^2)	800	800	800	800
Type 2				
Free length (mm)	60.7	52.8	39.1	40.9
Solid stress after prestressing (N/mm^2)	1000	1000	1000	1000
Type 3				
Free length (mm)	62.2	55.6	42.2	45.2
Solid stress after prestressing (N/mm^2)	1150	1150	1150	1150
Type 4				
Free length (mm)	63.7	58.4	45.5	49.3
Solid stress after prestressing (N/mm^2)	1300	1300	1300	1300

TABLE II MECHANICAL PROPERTIES OF WIRE

		PRE-HARDENED AND TEMPERED WIRE		
		As Received	Stress Relieved	Hardened and Tempered
Tensile Properties:				
Tensile Strength(Rm)	(N/mm^2)	1726	1726	1727
0.1% Proof Stress	(N/mm^2)	1703	1701	1654
0.2% Proof Stress	(N/mm^2)	1712	1715	1674
Elongation (A)	(%)	6.3	6.3	6.3
Reduction of Area (Z)	(%)	53.7	52.7	49.8
Torsional Properties:				
Max. Shear Strength	(N/mm^2)	1420	1375	1310
0.1% Proof Stress	(N/mm^2)	1047	1080	1042
0.2% Proof Stress	(N/mm^2)	1115	1136	1095
Twists to Failure		12	14	5
Elastic Limit	(N/mm^2)	720	870	840

TABLE III RATIO OF TORSIONAL ELASTIC LIMIT AND TENSILE STRENGTH

Material	Condition	Tensile Strength (N/mm^2)	Torsional Elastic Limit (N/mm^2)	Ratio (%)	
Oil-Hardened and Tempered Wire	Stress Relieved	1726	870	50.4	50.4
	Hardened and Tempered	1727	840	48.6	
Patented Wire to BS 1408	Range 1	1289	530	41.1	40.3
	Range 3	1792	710	39.6	

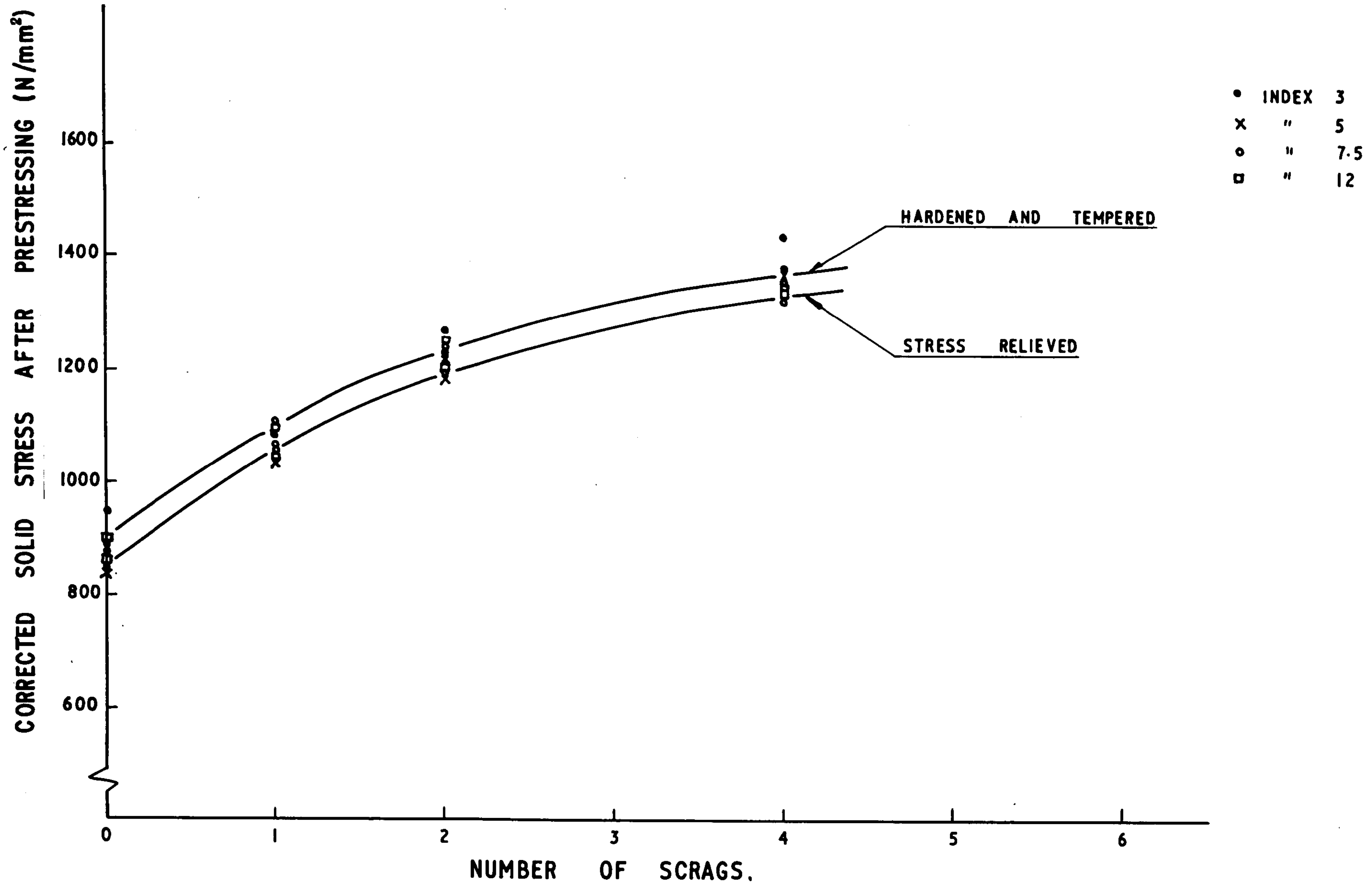

FIG. I NUMBER OF PRESTRESSING OPERATIONS REQUIRED TO STABILIZE SPRINGS.

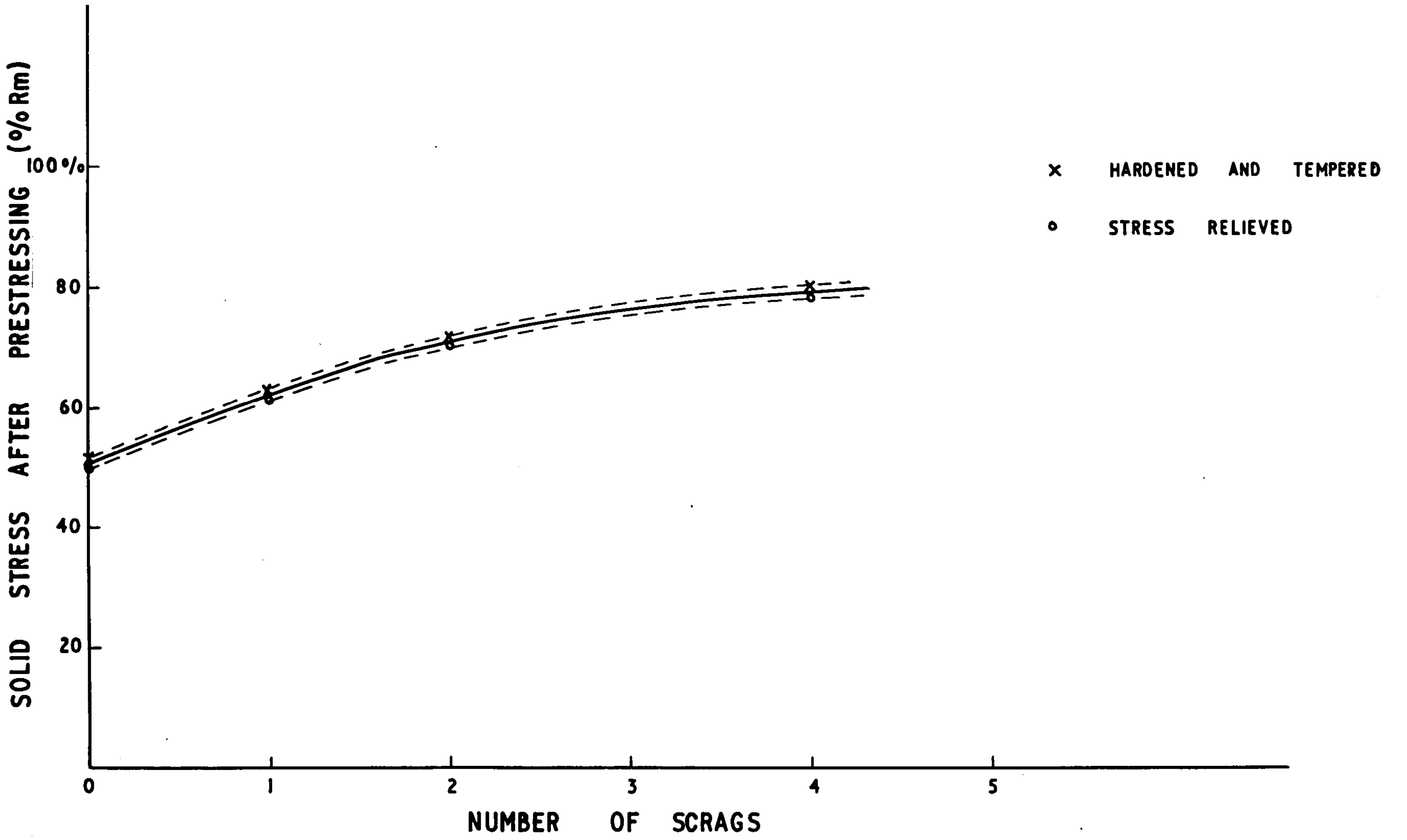

FIG. 2 NUMBER OF PRESTRESSING OPERATIONS REQUIRED FOR DESIRED SOLID STRESS AS PERCENTAGE OF TENSILE STRENGTH (Rm)

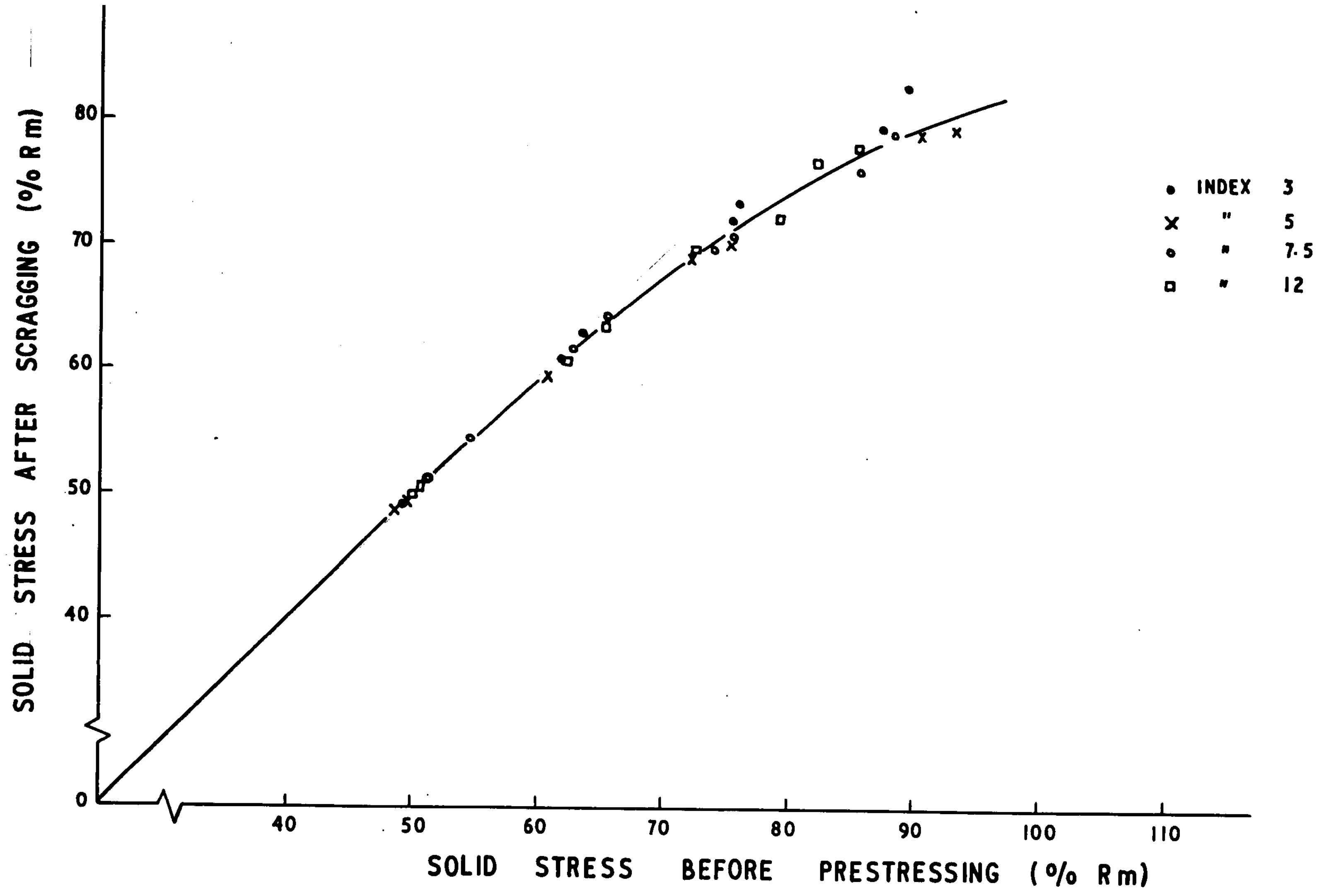

FIG. 3 STRESS BEFORE AND AFTER PRESTRESSING AS PERCENTAGE OF Rm

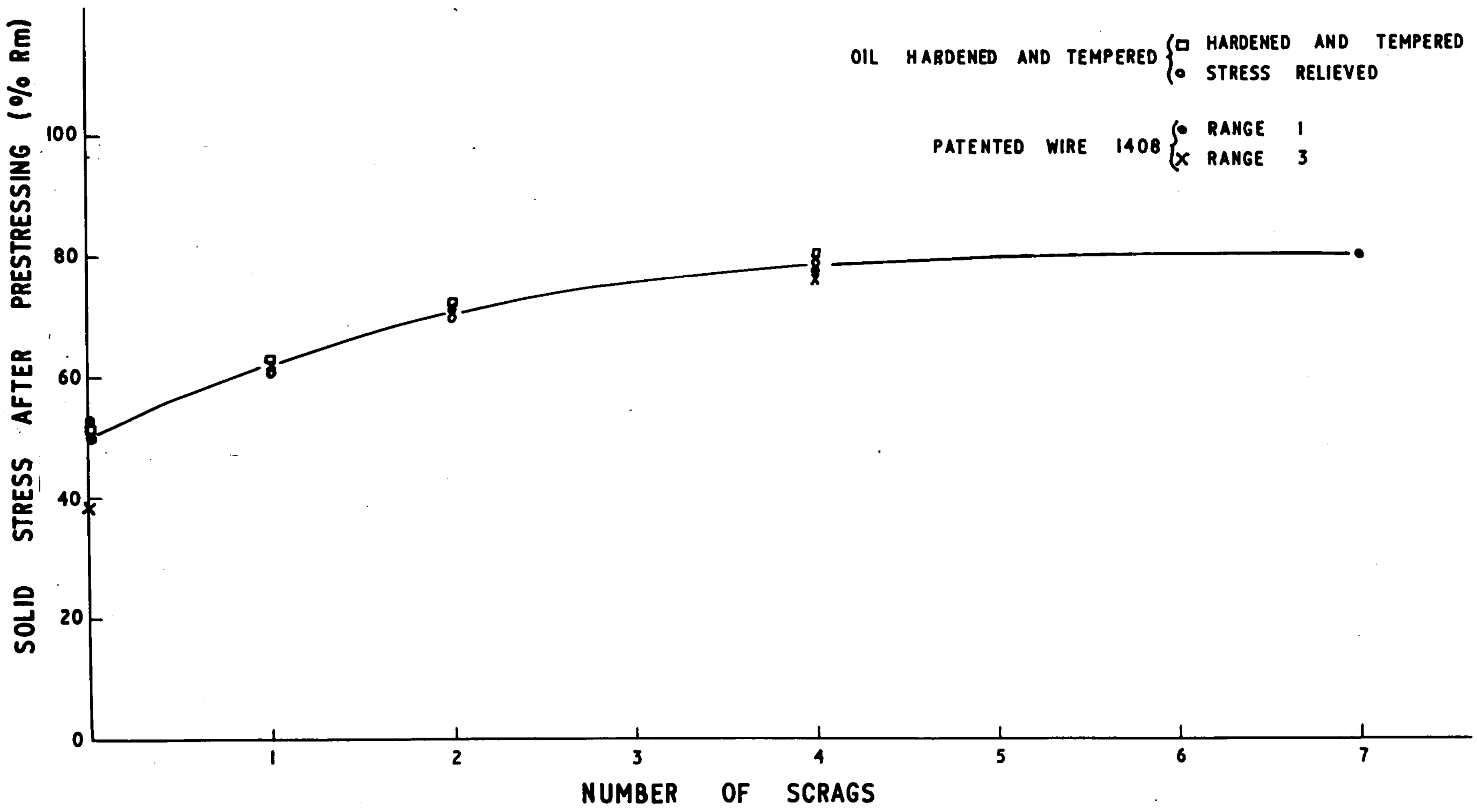

FIG. 4 NUMBER OF PRESTRESSING OPERATIONS REQUIRED FOR DESIRED SOLID STRESS AS PERCENTAGE OF TENSILE STRENGTH FOR PATENTED (BS 1408) AND OIL HARDENED AND

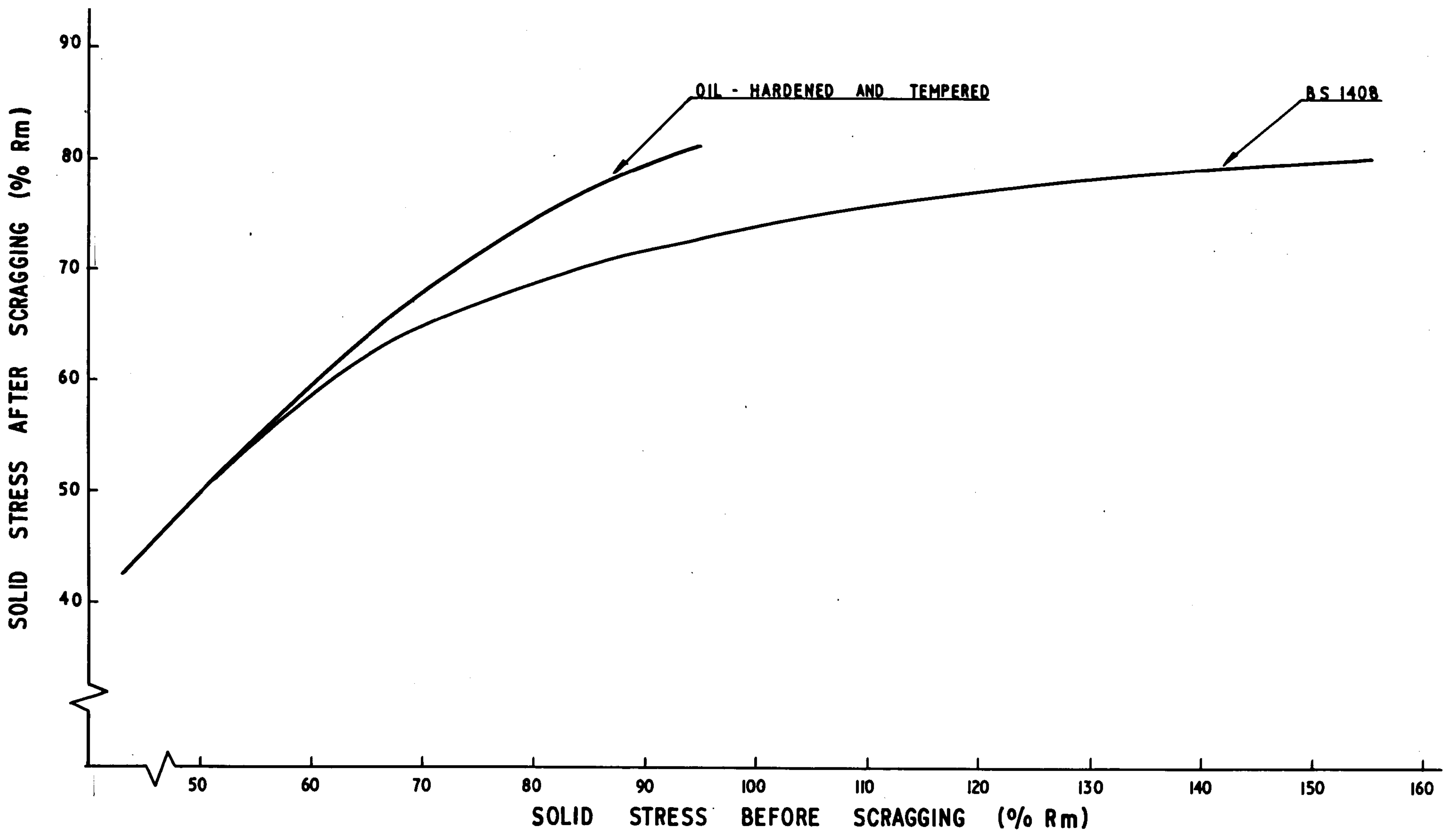

FIG. 5 STRESS BEFORE AND AFTER PRESTRESSING AS PERCENTAGE OF Rm FOR PATENTED WIRE (BS 1408) AND OIL-HARDENED AND TEMPERED WIRE.