THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

SOLID STRESS OF HOT PRESTRESSED COMPRESSION SPRINGS

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SUMMARY

Shot peened compression springs made from Cr.V. wire were prestressed at 20°C, 250°C and 300°C from as coiled free lengths between 45 mm and 70 mm.

Measurement of the prestressed free length showed that springs could be prestressed at 20°C without excessive distortion to give a solid stress of 75% tensile strength.

Prestressing at 250°C and 300°C gave a solid stress of 68-69% tensile without excessive distortion.

A relationship was established permitting estimation of the coiled free length necessary for particular values of prestressed solid stress.

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1 INTRODUCTION

Past SRAMA reports have concerned fatigue and relaxation data produced for shot peened and hot prestressed compression springs.[1-6] However, there has been no singular effort devoted to predicting the "as coiled" solid stress and hence free length, required to obtain the highest practicable solid stress in shot peened and hot prestressed springs.

The present programme of work fills this information gap and thus allows estimation of the "as coiled" free length required to obtain selected solid stresses in shot peened and hot prestressed compression springs. The "as coiled" free length is here understood to be the length after stress relieving and end grinding.

2 MATERIALS AND SPRING MANUFACTURE

Compression springs were coiled from 3.54 mm diameter Cr.V. wire to BS 2803: 1980: 735A50: ND, with a tensile strength in the range 1620-1770 N/mm^2.

Tensile tests carried out on the wire confirmed that the material had a tensile strength of 1630 N/mm^2.

Microscopical examination revealed partial decarburization and occasional surface intrusions to a maximum depth of 0.01 mm, confirming that the wire conformed to the ND specification.

Six batches of 50 springs were coiled to the following nominal design:

Wire diameter	=	3.54 mm
Outside diameter of active coils	=	26.20 mm
Total coils	=	6.50
Theoretical solid length	=	23.01 mm

The nominal free length of the spring batches was varied in 5 mm steps from 45 mm to 70 mm, representing theoretical solid stresses between approximately 65% and 135% of the tensile strength as can be seen in Table I.

Ends: Closed and ground
Stress Relieved: 425°C/30 minutes.

From each batch of 50 "as coiled" springs, 10 were selected at random for measurement of the free length and the outside diameter using a height gauge and a surface plate.[6]

All the remaining springs were shot peened simultaneously using S230 shot, after which they were stress relieved at 220°C for 30 minutes.

3 HOT PRESTRESSING

Load tests on sample springs showed that coil to coil contact began at a loaded length of approximately 26.5/27 mm, despite a theoretical solid length of 23.01 mm.

To avoid excessive distortion, all prestressing was therefore carried out to a fixed length of 27.15 mm.

At this length, the springs were deflected through 81-91% of the total deflection from nominal "as coiled" free lengths between 45 mm and 70 mm.

For each "as coiled" nominal free length, 10 springs were prestressed once at 20°C, 250°C and 300°C.

All prestressing was carried out using the SRAMA hot prestressing machine, which has been fully described in earlier reports.[7]

The free length, outside diameter, bow and end squareness of the prestressed springs were measured as recommended by a recent SRAMA report.[6]

4 RESULTS

The measured values of wire diameter, mean free length and mean outside diameter of the springs were used to calculate the theoretical solid stress before and after hot prestressing.

The results of the dimensional measurements are shown in Tables II and III.

The solid stress before and after prestressing is shown in Figure 1, expressed as a percentage of the measured tensile strength. Expressed in this way, the results can be used to estimate the "as coiled" and ground free length required for a given hot prestressed solid stress, as shown in the Appendix.

The results of the bow and end squareness measurements are shown in Table IV.

All the springs met the specified requirements for bow laid down in BS 1726: Part 1: 1987 and hence this measurement was inappropriate for realistic assessment of spring distortion. However, the end squareness of the springs was clearly related to the initial free length, and this measure of spring distortion was therefore adopted in the present work. The end squareness results are more clearly expressed as a function of solid stress and tensile strength in Figure 2.

5 DISCUSSION

From the results given in Figure 1, it is clear that in principle at least, springs could be prestressed at 20°C to give theoretical solid stresses which were 90-95% of the

tensile strength. Similarly, solid stresses of the order of 80-85% of the tensile strength could be achieved after hot prestressing at 250-300°C.

However, in practice, the prestressed solid stress achieved will be limited by spring distortion and free length variability.

For example, BS 1726: Part 1: 1987 stipulates that, to meet grade 1 tolerance, the end squareness of the springs shall not exceed a value of 0.03 mm per mm of nominal free length. At all three prestressing temperatures investigated, the Grade 1 tolerance on end squareness was exceeded when springs were made with free lengths corresponding to "as coiled" solid stresses in excess of 92-95% Rm, as shown in Figure 2. Similarly the measurements shown in Table II suggest that all the prestressed springs exceeded the free length tolerance when coiled with free lengths over 50 mm, corresponding to "as coiled" solid stresses of approximately 80% Rm.

The prestressed solid stresses corresponding to the required "as coiled" solid stress, can be obtained from Figure 1. The "as coiled" and ground free length necessary for a given hot prestressed solid stress can then be estimated as shown in the Appendix.

6 CONCLUSIONS

1. Shot peened springs made from 735A50 wire can be hot prestressed without significant bow distortion at 250°C and

300°C to give theoretical solid stresses of 75% Rm and 73% Rm respectively. However, theoretical solid stresses over 68-69% Rm may result in springs which exceed the free length tolerance.

2. Cold prestressed springs can be made without significant bow distortion to give a theoretical solid stress of 82% Rm after one prestressing operation. This is reduced to approximately 75% Rm when the free length tolerance is considered.

7 RECOMMENDATIONS

The fatigue and relaxation properties of shot-peened/hot prestressed springs with varying levels of prestress may merit closer examination in the future to establish optimum spring properties.

8 REFERENCES

1. Bird, G.C., "An investigation into the effects of solid stress on the prestressing of compression springs". SRAMA Report 208, October 1972.

2. Gray, S.D., "The effect of hot prestressing on the relaxation properties of helical springs manufactured from Cr-V wire". SRAMA Report 215, May 1973.

3. Gray, S.D., "The effect of hot prestressing on the fatigue and relaxation properties of helical compression springs manufactured from low alloy steel wire". SRAMA Report 234, October 1974.

4. Heyes, P.F., "The effects of hot and cold prestressing on the fatigue and relaxation properties of compression springs made fom Cr-V steel wire". SRAMA Report 248, June 1975.

5. O'Malley, M., "The dynamic relaxation behaviour of shot peened and hot prestressed helical compression springs at elevated temperatures". SRAMA Report 412, August 1987.

6. Rushton, C.J., "Standard inspection techniques for springs". SRAMA Report 409, April 1987.

7. Brummitt, K., "Hot prestressing of springs for ambient temperature service". SRAMA Report 340, October 1980.

9. APPENDIX: Estimation of "as coiled" and ground free length

The data given in Figure 1 can be used as follows to estimate the "as coiled" and ground free length required to obtain a given hot prestressed solid stress:

i) Decide upon the solid stress required after hot prestressing.

ii) Calculate as % of tensile strength.

iii) Read off from the graph the corresponding "as coiled" and ground solid stress as % of tensile strength.

iv) Using the tensile strength value of the wire, calculate theoretical solid stress of the "as coiled" and ground spring.

v) Use this value of solid stress in the design calculations.

TABLE I AS COILED SPRING PROPERTIES

FREE LENGTH mm	CALCULATED SOLID STRESS, N/mm^2	SOLID STRESS/WIRE UTS %
45	1039	64
50	1276	78
55	1512	93
60	1748	107
65	1985	122
70	2221	136

TABLE II RESULTS OF FREE LENGTH MEASUREMENTS ON PRESTRESSED SPRINGS

SPRING DIMENSIONS, mm (MEAN OF 10)*				
NOMINAL AS COILED FREE LENGTH	MEASURED AS COILED FREE LENGTH		SHOTPEENED AND STRESS RELIEVED FREE LENGTH	
	MEAN	3xSD	MEAN	3xSD
45	45.32	0.63	44.98	0.87
50	50.15	0.45	49.73	0.66
55	55.13	0.63	+ 54.96	1.17
60	60.74	1.05	■ 60.82	1.80
65	65.36	0.75	65.16	0.69
70	70.40	0.84	70.16	0.87

FREE LENGTH AFTER PRESTRESSING AT					
20°C		250°C		300°C	
Mean	3xSD	Mean	3xSD	Mean	3xSD
44.68	0.90	44.05	0.87	43.58	0.81
48.72	0.87	47.50	0.84	46.41	0.87
■ 52.27	■ 1.47	■ 49.76	■ 1.50	■ 48.89	1.53
■ 54.99	■ 1.65	■ 51.35	■ 1.68	■ 50.59	1.44
■ 56.45	■ 1.68	■ 52.67	■ 1.80	■ 51.83	1.89
■ 57.47	■ 3.39	■ 53.46	■ 1.35	■ 52.35	1.83

* Springs met Grade A tolerance specified in BS 1726: Part 1: 1987 unless otherwise stated.

\+ Springs met Grade B tolerance specified in BS 1726: Part 1: 1987.

■ Springs did not meet free length tolerance specified in BS 1726: Part 1: 1987.

TABLE III RESULTS OF OUTSIDE DIAMETER MEASUREMENTS ON PRESTRESSED SPRINGS

SPRING DIMENSIONS, mm (MEAN OF 10)*			
MEASURED AS COILED FREE LENGTH	OUTSIDE DIAMETER AFTER PRESTRESSING AT		
	20°C	250°C	300°C
45.32	26.43	26.37	26.36
50.15	26.50	26.44	26.37
55.13	26.50	26.49	26.37
60.74	26.51	26.63	26.47
65.36	26.64	26.60	26.63
70.40	26.77	26.64	26.64

* As coiled outside diameter = 26.20 mm.

TABLE IV RESULTS OF BOW AND END SQUARENESS MEASUREMENTS FOR SHOT PEENED/PRESTRESSED SPRINGS

AS COILED FREE LENGTH mm	PRESTRESSING TEMPERATURE					
	MEAN BOW * +			MEAN END SQUARENESS * ■		
	20°C	250°C	300°C	20°C	250°C	300°C
45,32	0.002	0.003	0.003	0.008	0.009	0.015
50.15	0.004	0.006	0.006	0.015	0.016	0.020
55.13	0.005	0.010	0.009	0.026	0.034	0.031
60.74	0.013	0.013	0.009	0.042	0.041	0.041
65.36	0.017	0.014	0.014	0.057	0.050	0.045
70.40	0.018	0.018	0.024	0.069	0.057	0.060

* Results expressed as mm per mm

\+ BS 1726: Part 1: 1987. The maximum tolerance on bow is 0.025 mm per mm

■ BS 1726: Part 1: 1987. The end squareness tolerances are as follows:-

Grade 1: 0.03 mm per mm of the nominal free length.

Grade 2: 0.05 mm per mm of the nominal free length.

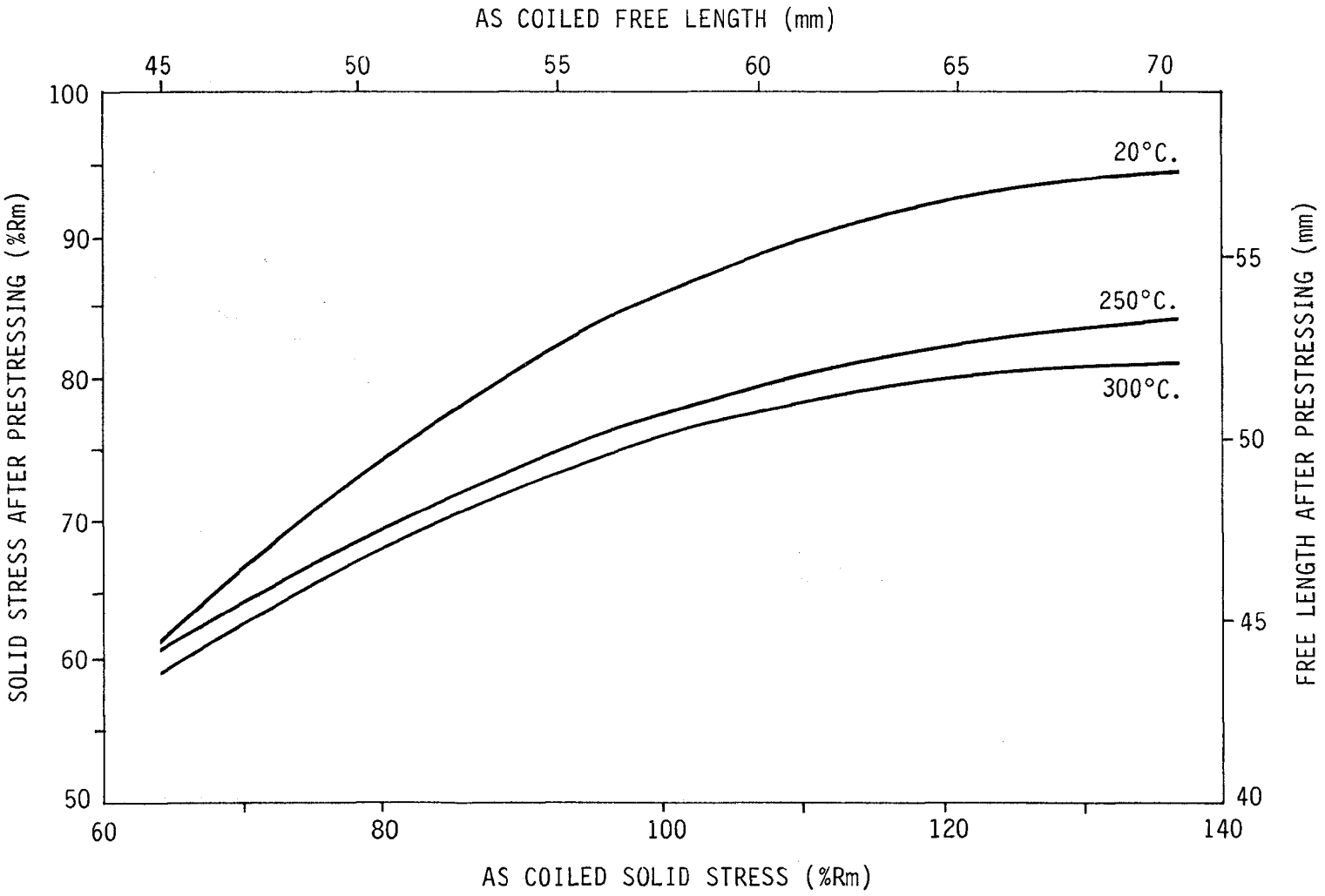

FIG.1. THEORETICAL SOLID STRESS OF SPRINGS BEFORE AND AFTER PRESTRESSING.

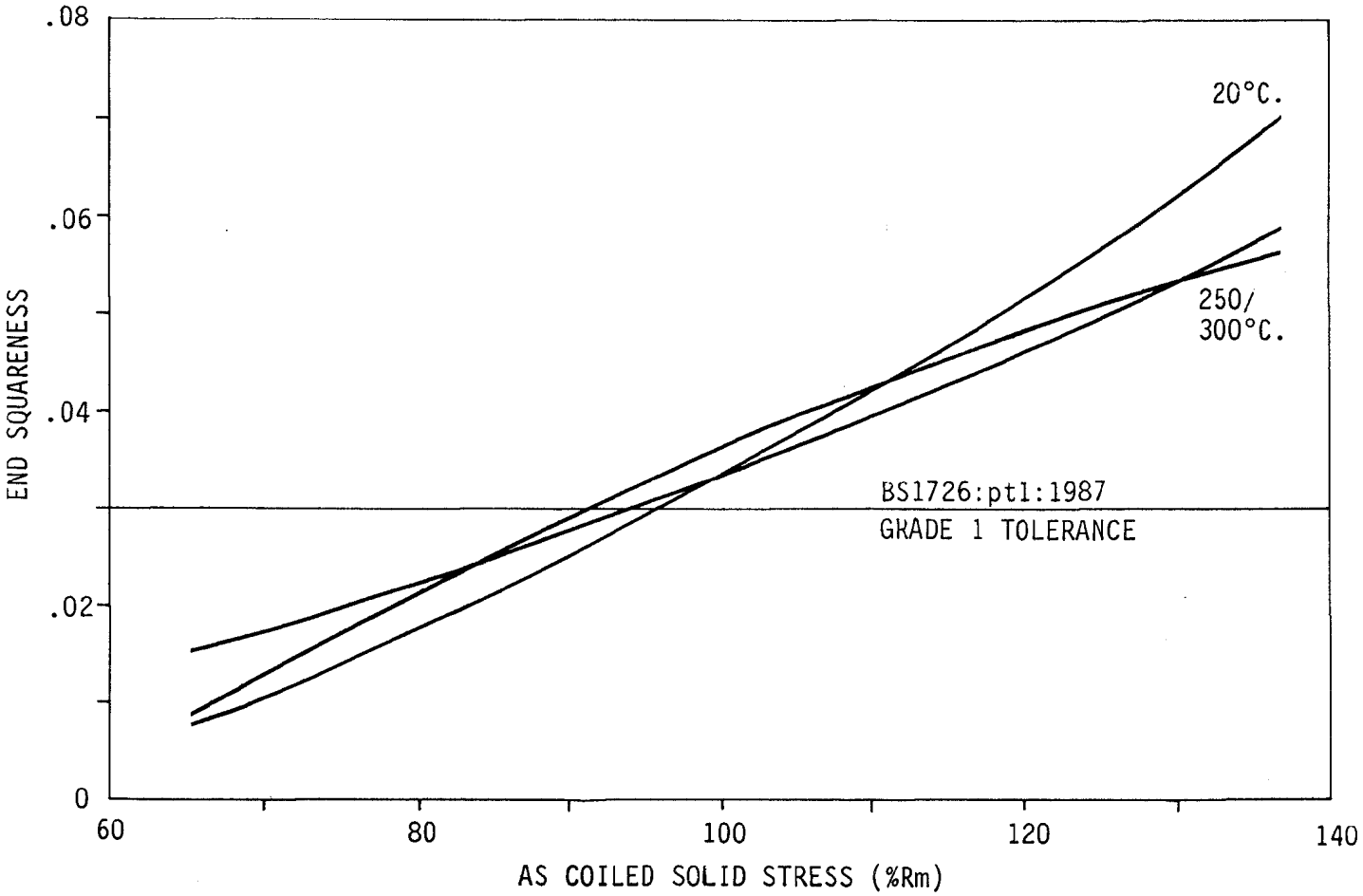

FIG.2. END SQUARENESS OF PRESTRESSED SPRINGS