Tech-Spring Report 11
Extension Springs

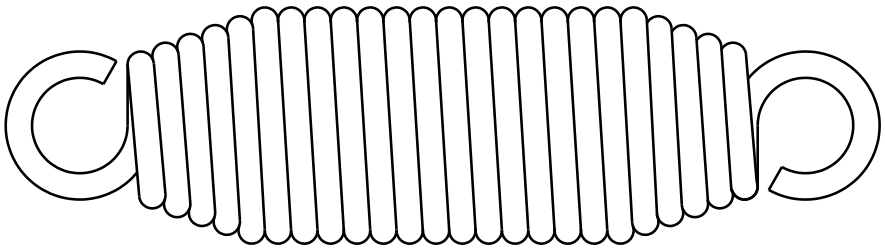
Introduction

Most extension springs have loops the same diameter as the body of the spring. For such springs, the loop is the position of maximum stress, and if failure is to occur, then it usually does so from the inside surface of the loop.

The European standard does not include the calculation of bending stresses in end loops, but the classical mechanics formulae for these loops are well known. Hence, an extension spring should have two stress values calculated – a torsional stress in the body coils, and a bending stress in the end loops. For both these stresses, spring manufacturers would be very interested to know whether there is a risk of fatigue failure. The Tech-Spring project has generated such data for the first time – see reports 1 – 3. The results in those reports have now been validated and refined in this further research by making springs with coned end coils and reduced diameter loops.

11.1 Reduced Diameter Loops

In order to validate the first version of the Tech-Spring Toolkit software two batches of extension springs were supplied by DSA. They had reduced diameter end loops and the last body coils before the hook were coned down, as shown below.



The spring designs were as shown in Table 1.

Table 1 Spring Designs

	d/ mm	Do/mm	Rate/ N/mm	Fo/ N	Loop inside dia./mm
1A	3.24	34.78	1.30	25	21.34
1B	3.24	34.66	1.38	25	18.31
1C	3.24	34.66	1.44	25	14.93
2A	2.80	29.83	0.98	13	18.75
2B	2.80	29.52	1.03	11	15.82
2C	2.80	29.50	1.10	11	13.41

These springs were fatigue tested at a speed of 200rpm and in each test the position of failure was noted. Failures in the end loop are designated L in table 2, and those in the body B. This data enables an assessment of whether the lines on the Goodman Diagrams

are in the correct place. The springs were made from 3.24mm (Batch 1) and 2.80mm carbon steel (Batch 2) to EN 10270-1 SH, but the surface quality was checked and conformed to DH.

The fatigue test results are given in table 2.:

Table 2 Fatigue test results

1A

Lengths	Body stress/ MPa	Loop stress/ MPa	Fatigue lives/k cycles
175 – 330	195 – 736	305 – 1152	76^{L} 92^{L} 154^{B} 169^{B}
175 – 320	195 – 701	305 – 1097	107^{L} 131^{L} 168^{L} 190^{L} All^{L}
190 – 320	247 – 701	387 – 1097	99^{L} 146^{B} $2@10^{6}$
190 – 350	247 – 666	387 – 1042	256^{L} 224^{B} $2 @ 10^{6}$
190 – 300	247 – 632	387 – 987	$4 @ 10^{6}$

1B

Lengths	Body stress/ MPa	Loop stress/ MPa	Fatigue lives/k cycles
166 – 321	199 – 772	279 – 1082	183^{L} 124^{B} 242^{B} 327^{B}
166 – 311	199 – 735	279 – 1031	129^{L} 131^{B} 161^{B} 242^{B}

1C

Lengths	Body stress/ MPa	Loop stress/ MPa	Fatigue lives/k cycles
158 – 311	182 – 772	222 – 940	113^{B} 113^{B} 121^{B} 133^{B}
158 – 301	182 – 733	222 – 893	157^{B} 166^{B} 184^{B} 204^{B}
168 – 311	221 – 772	269 – 940	138^{B} 192^{B} 214^{B} 355^{B}
178 – 311	259 – 772	316 – 940	162^{B} 661^{B} 751^{B} $1 @ 10^{6}$
188 – 311	298 – 772	363 – 940	$4 @ 10^{6}$

2A

Lengths	Body stress/ MPa	Loop stress/ MPa	Fatigue lives/k cycles
173 – 327	177 – 715	282 – 1142	91^{L} 94^{L} 119^{L} 10^{6}
173 – 348	177 – 789	282 – 1259	48^{L} 50^{L} 53^{L} 73^{L}

2B

Lengths	Body stress/ MPa	Loop stress/ MPa	Fatigue lives/k cycles
165 – 313	177 – 715	251 – 1017	141^{B} 143^{B} 193^{L} 10^{6}
165 – 334	177 – 792	251 – 1126	63^{L} 86^{B} 96^{B} 107^{B}

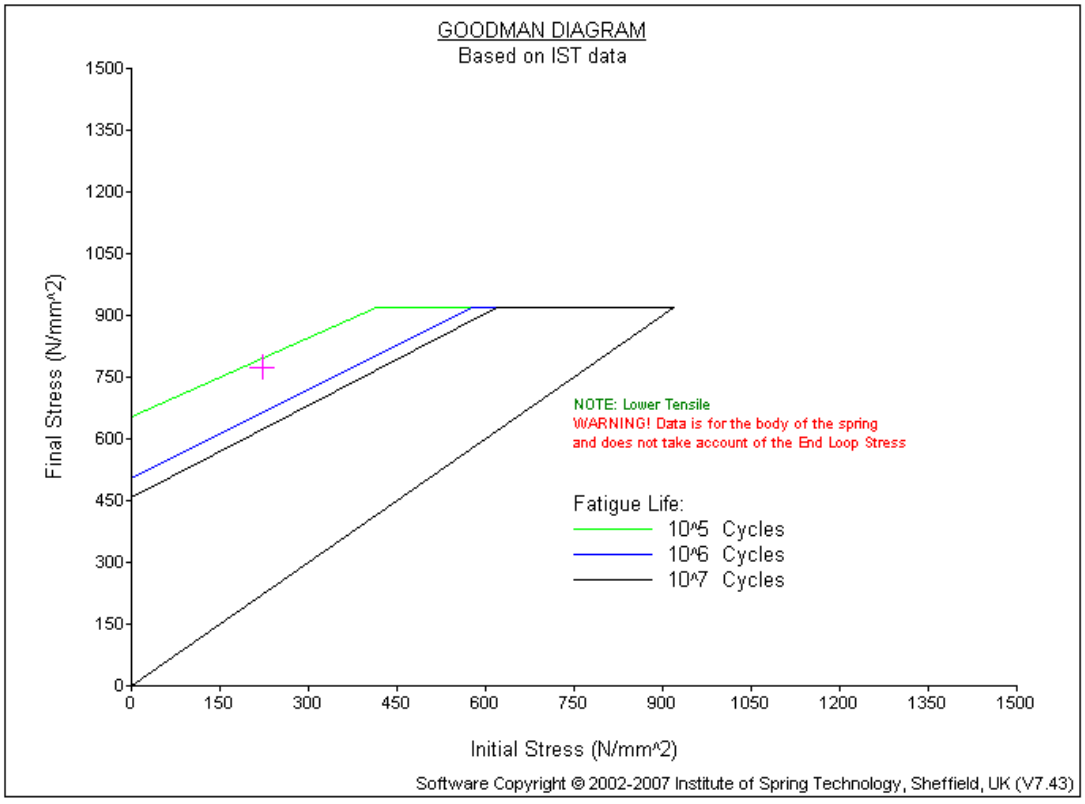
2C

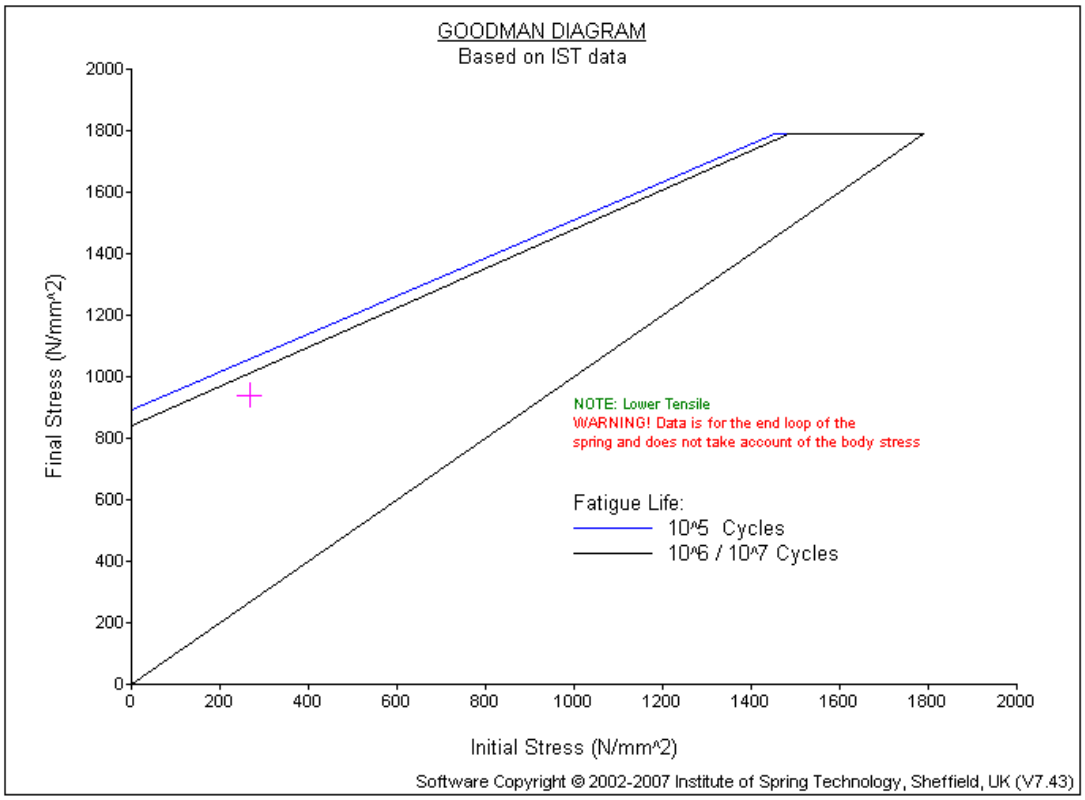
Lengths	Body stress/ MPa	Loop stress/ MPa	Fatigue lives/k cycles
160 – 300	178 – 722	226 – 916	149^{B} 189^{B} 2×10^{6}
160 – 320	178 – 800	226 – 1014	130^{B} 131^{B} 139^{B} 152^{B}

All the springs from batches 1C and 2C broke in the body, thus indicating the reduction in loop diameter that was effective in preventing fatigue failure in the loop – the usual position of fatigue failure in extension springs.

Goodman diagrams for batches 1C and 2C are shown below for both body and loop stresses.

	1	2
Length (mm):	168.00	311.00
Load (N):	82.60	288.52
Corrected Stress (N/mm^2):	221	774





11.2 Conclusions

a) In Toolkit 1, the Goodman Diagrams were approximately correct.

b) Slightly greater safety margins have been shown to be necessary in these results and so the Goodman Diagrams have been re0drawn in Tooklkit 2.

c) Fatigue data in the end loop is required for 3 x 10^4 cycles.

d) This report will provide a design guide for extension springs that is far superior to any previously published.

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