Tech-Spring Report 2
THE EFFECT OF INITIAL TENSION STRESS ON EXTENSION SPRING ELASTIC LIMIT AND FATIGUE PERFORMANCE

Introduction

Extension springs are usually made with initial tension. Initial tension is achieved by twisting the wire in the opposite direction to the applied twisting when the spring is loaded. It is logical therefore to assume that the initial tension stress should be subtracted from the applied stress when estimating both the elastic limit and fatigue performance. None of the international standards for extension spring design do this - the stress is calculated directly from the applied load.

To establish whether initial tension stress has any influence on either elastic limit or fatigue performance springs were made to the same nominal design with

a) Maximum initial tension 28.7 N
b) Minimum initial tension 5.0 N
c) Slightly open coiled O N

The design of the maximum initial tension spring is shown as Figure 1.

INSTITUTE OF SPRING TECHNOLOGY Date: 04/09/2007 11:32:44

Identifier: Max i.it.
Details: 810

Spring Type Round Wire Extension

Designed To:	EN 13906-2: 2001	
Tolerance Standard:	DIN 2097: 1973	

Material

EN 10270 Pt1 Patented Carbon

Youngs Mod (E):	206000	N/mm^2
Rigidity Mod (G):	81500	N/mm^2
Density:	.00000785	Kg/mm^3
Unprestress:	0-45	%
End Type:	Machine Loop	
Loop Selection	Equal to Body Dia.	
Loop Outside Diameter:	15.26	mm

Calculated Data

Estimated Free Length:	125.54	mm
Initial Tension Stress:	103.85	N/mm^2
Body Length:	103.42	mm
Body Length (Max):	104.66	mm
Stress Factor:	1.23	
Spring Index:	6.27	
Inside Diameter:	11.06	mm
Mean Coil Dia.	13.16	mm
Loop Inside Diameter:	11.06	mm
Wire Length:	2068.3	mm
Weight / 100:	5.62	Kg
Natural Freq:	5467.8	RPM

Design Parameters

Wire Diameter:	2.10	mm	
Outside Diameter:	15.26	mm	
Total Coils:	48.25		
Spring Rate:	1.80	N/mm	(Calculated)
Initial Tension:	28.70	N	
Free Length:	134.42	mm	

Stress Data

			Operating Positions % Tensile	
	Lower Tensile	I. T.	1	2
SL	1510	7 U	10 U	42 U
SM	1740	6 U	9 U	37 U
DM	1740	6 U	9 U	37 U
SH	1970	5 U	8 U	33 U
DH	1970	5 U	8 U	33 U

Specified

Operating Data

	Operating Positions 1	2
Length (mm)	141.80	216.80
Load (N)	42.00	177.12
Deflection (mm)	7.38	82.38
Body Stress (N/mm^2)	152	641
Loop Stress (N/mm^2)	357.04	1505.8
Load Tol. Grade 1 (N)	6.17	7.45
Load Tol. Grade 2 (N)	9.80	11.83
Load Tol. Grade 3 (N)	15.68	18.92

Figure 1

Load Testing

One spring of each type was load tested until each had been plastically deformed (either initial tension reduced or had become longer in its free position). Graphs drawn of the load / deflection curves are shown here as Figures 2 - 4. It is clear from these graphs that the load at which the springs started to deform plastically was 175N for the open coiled 190N for the minimum initial tension and 200N for the maximum initial tension springs.

Figure 2

Figure 3

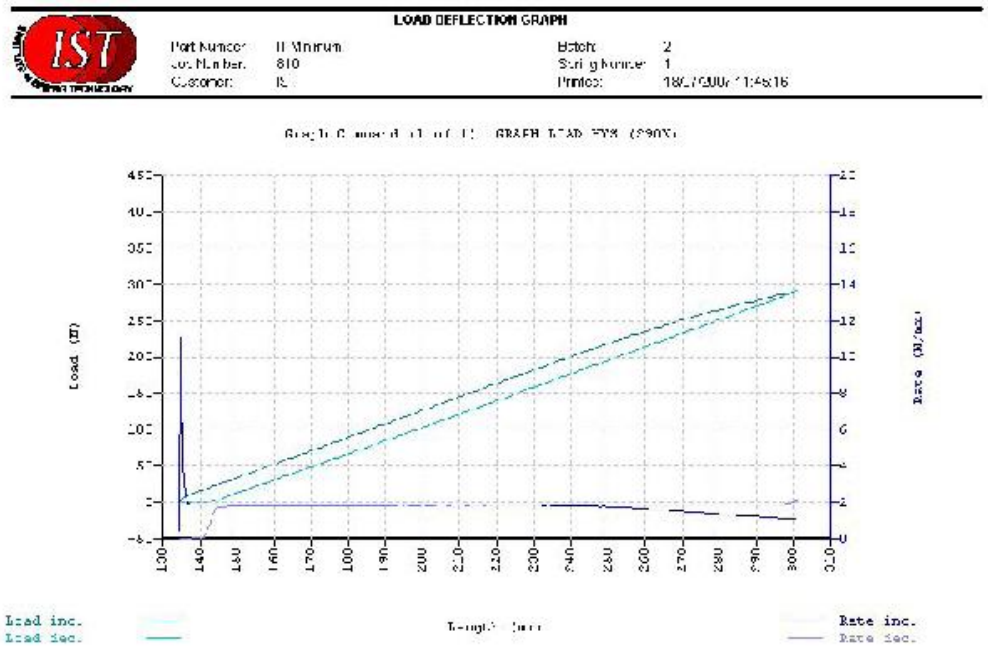
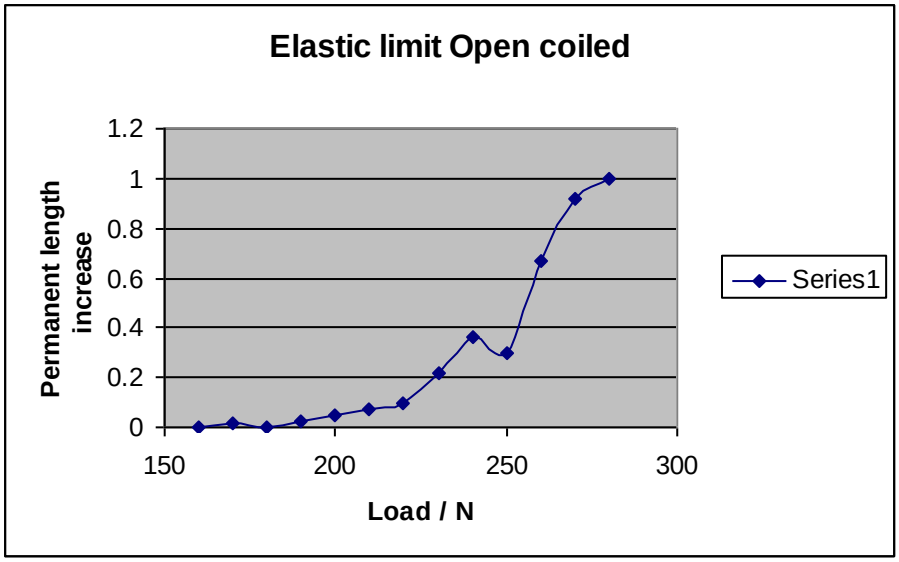


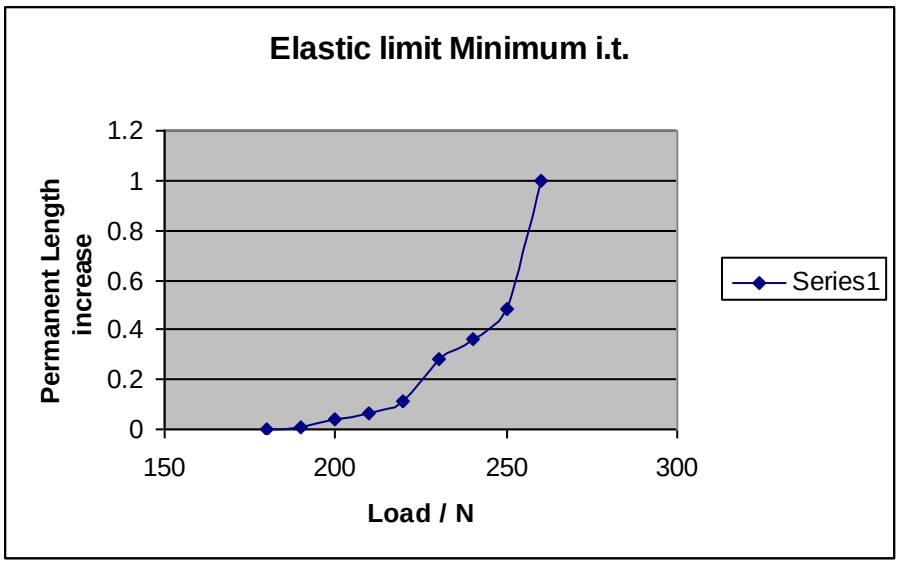
Figure 4

A second load test on one spring of each type was undertaken in which the springs were loaded progressively to identify the length and load at which they became plastically deformed. In this test the springs were loaded, unloaded, re-loaded to the last load, loaded a little further, unloaded etc.

The results of these tests are shown on Figure 5. The load at which plastic deformation started was

Open Coiled	Minimum Initial Tension	Maximum Initial Tension
180N	190N	230N


Elastic limit Open coiled
Permanent length increase
1.2
1
0.8
0.6
0.4
0.2
0
150
200
250
300
Load / N
Series1


Elastic limit Minimum i.t.
Permanent Length increase
1.2
1
0.8
0.6
0.4
0.2
0
150
200
250
300
Load / N
Series1

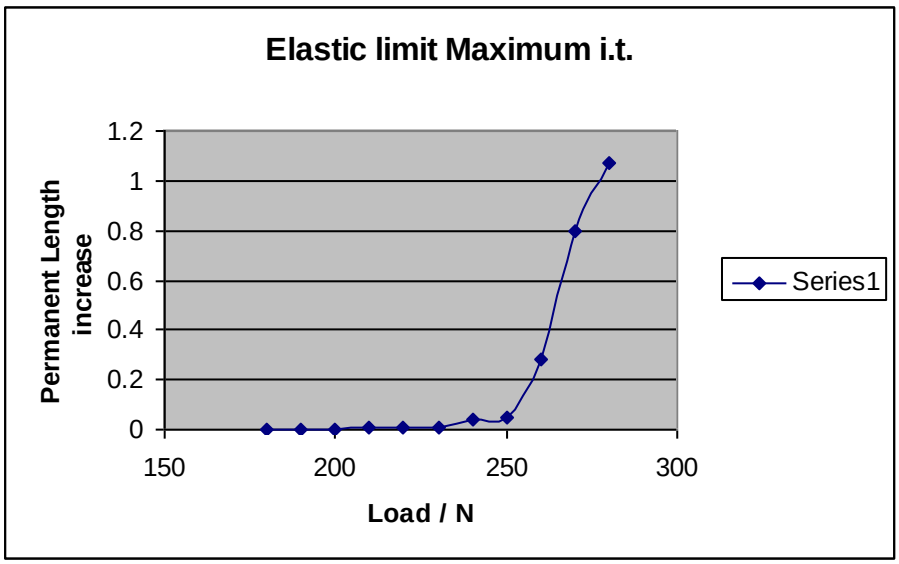

Elastic limit Maximum i.t.
Permanent Length increase
1.2
1
0.8
0.6
0.4
0.2
0
150
200
250
300
Load / N
Series1

Figure 5.

Fatigue Testing

Springs of each type were fatigue tested on a forced motion tester between an initial load of 45N and an applied stroke of 75mm to failure or one million cycles. In this way, the stress range, calculated according to EN 3706-2 or BS 1726 Part 2 was nominally the same when taking no account of the other subtle differences in the design of these springs. The results of the fatigue tests were as shown in Table 1.

Maximum Initial Tension

111,489	143,108	10^6	10^6	10^6	10^6	78,297	-

Minimum Initial Tension

93,382	96,095	298,215	125,448	191,199*	116,418	10^6	139,479

Slightly Open Coiled

75,737	89,330	98,455	114,164	166,420*	392,811	636,395	10^6

*Springs so marked failed in a central coil, typical of wire flaw shown as Figure 6. All others failed within the end loop, mostly at the end that was moving, but some also failed at the static end.

Figure 6

Conclusion

These results suggest that both the elastic limit and the fatigue performance are affected by the initial tension, and the current way of calculating in spring design standards and CAD programs may be incorrect. Much greater precision is required to verify this result and so it is recommended that this program of work be repeated.