Tech-Spring Report 1
EFFECT OF END LOOP SIZE ON FATIGUE LIFE

Introduction

Two batches of round wire extension springs, one made from BS EN 10270-1 Patented Carbon quality with D Loop end type and the other made from BS EN 10270-3 Austenitic Stainless Steel with Crossover Loop end type, were obtained from Metalpol of Poland. In each batch of springs, there were three different end loop sizes, namely S for Small (smaller than body diameter), R for Regular (equal to body diameter), and L for Large (larger than body diameter). The springs had been shot peened.

The springs were fatigue tested at corrected stress levels suitable to cause the springs to fail by fatigue up to 10^6 (1 million) cycles. These corrected stress levels were calculated using IST Spring Design & Validation software as shown in Figures 1 and 2 for Patented Carbon and Austenitic Stainless Steel spring batches, respectively. Further fatigue testing was carried out using larger diameter pins to establish whether the size of pin onto which the end loops are hooked has an effect on the fatigue performance. The fatigue test results were as shown in Tables 1 and 2.

Batch – Patented Carbon, D Loop End Type, Pin Size 3.53mm diameter (Small Pin)

Sample No.	End Loop Size	Corrected Stress Range (MPa)	Life to Failure
C-S-1	Small	236 – 736	93,900
C-S-2	Small	236 – 736	37,510
C-S-3	Small	236 – 736	55,730
C-S-4	Small	236 – 736	49,790
C-R-1	Regular	236 – 736	44,630
C-R-2	Regular	236 – 736	43,450
C-R-3	Regular	236 – 736	38,200
C-R-4	Regular	236 – 736	38,200
C-L-1	Large	236 – 736	34,980
C-L-2	Large	236 – 736	35,180
C-L-3	Large	236 – 736	22,190
C-L-4	Large	236 – 736	26,100

Batch – Patented Carbon, D Loop End Type, Pin Size 5.85mm diameter (Large Pin)

Sample No.	End Loop Size	Corrected Stress Range (MPa)	Life to Failure
C-S-5	Small	236 – 736	50,880
C-S-6	Small	236 – 736	47,470
C-R-5	Regular	236 – 736	53,680
C-R-6	Regular	236 – 736	48,360
C-L-5	Large	236 – 736	64,630
C-L-6	Large	236 – 736	23,290

Note: all the springs tested broke at body-to-end loop transition

Table 1 Fatigue test results for Patented Carbon extension springs batch

Batch – Austenitic Stainless Steel, Crossover Loop End Type, Pin Size 3.53mm diameter (Small Pin)

Sample No.	End Loop Size	Corrected Stress Range (MPa)	Life to Failure
S-S-1A	Small	200 – 600	$>10^6$
S-S-2A	Small	200 – 600	$>10^6$
S-S-1B	Small	200 – 750 (retest of 1A)	86,770 #
S-S-2B	Small	200 – 750 (retest of 2A)	42,150 *
S-R-1A	Regular	200 – 600	$>10^6$
S-R-2A	Regular	200 – 600	$>10^6$
S-R-1B	Regular	200 – 650 (retest of 1A)	$>10^6$
S-R-2B	Regular	200 – 650 (retest of 2A)	$>10^6$
S-R-1C	Regular	200 – 700 (retest of 1B)	$>10^6$
S-R-2C	Regular	200 – 700 (retest of 2B)	$>10^6$
S-R-1D	Regular	200 – 750 (retest of 1C)	$>10^6$
S-R-2D	Regular	200 – 750 (retest of 2C)	130,120 #
S-L-1A	Large	200 – 600	$>10^6$
S-L-2A	Large	200 – 600	$>10^6$
S-L-1B	Large	200 – 650 (retest of 1A)	$>10^6$
S-L-2B	Large	200 – 650 (retest of 2A)	$>10^6$
S-L-1C	Large	200 – 700 (retest of 1B)	72,030 *
S-L-2C	Large	200 – 700 (retest of 2B)	50,160 *
S-L-3	Large	200 – 750	23,030 *
S-L-4	Large	200 – 750	18,510 *

Batch – Austenitic Stainless Steel, Crossover Loop End Type, Pin Size 5.85mm diameter (Large Pin)

Sample No.	End Loop Size	Corrected Stress Range (MPa)	Life to Failure
S-S-3	Small	200 – 750	56,080 #
S-S-4	Small	200 – 750	66,790 #
S-R-3	Regular	200 – 750	30,920 #
S-R-4	Regular	200 – 750	69,610 *
S-L-5	Large	200 – 750	37,260 *

Note: * = spring broke in hook at the anticipated location of highest stress
= spring broke at sharp bend transition from body to end loop

Table 2 Fatigue test results for Austenitic Stainless Steel extension springs batch

Conclusion

Extension springs with D Loop end type which had smaller end loop diameter than the body diameter appeared to have, on average, a relatively better fatigue life at equivalent stress range than those which had end loop diameter equal to or larger than the body diameter, the order of fatigue performance being S>R>L. On the other hand, extension springs with Crossover Loop end type which had end loop diameter equal to the body diameter appeared to have, on average, a relatively better fatigue life at equivalent stress range than those which had smaller or larger end loop diameter than the body diameter, the order of

fatigue performance being R>S>L. It can be seen that regardless of end loop type, extension springs with larger end loop diameter than the body diameter had the worst fatigue performance. Furthermore, in all cases, the pin diameter did not seem to have a notable effect on the fatigue performance of the extension springs.

INSTITUTE OF SPRING TECHNOLOGY Date: 25/05/2007 11:24:45

Identifier:	Metalpol
Part No.:	Extension Spring - Effect of End Loop Size
Details:	810 TECHSPRING PROJECT
Contact:	Mr Victor Sowa

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:	D Loop	
Loop Selection	Equal to Body Dia.	
Loop Outside Diameter:	13.08	mm

Calculated Data

Estimated Free Length:	26.92	mm
Initial Tension Stress:	147.25	N/mm^2
Body Length:	18.74	mm
Body Length (Max):	18.93	mm
Stress Factor:	1.35	
Spring Index:	4.34	
Inside Diameter:	8.18	mm
Mean Coil Dia.	10.63	mm
Loop Inside Diameter:	8.18	mm
Wire Length:	257.85	mm
Weight / 100:	0.954	Kg
Natural Freq:	70938	RPM

Design Parameters

Wire Diameter:	2.45	mm	
Outside Diameter:	13.08	mm	
Total Coils:	6.65		
Spring Rate:	45.95	N/mm	(Calculated)
Initial Tension:	80.00	N	
Free Length:	28.70	mm	

Stress Data

			Operating Positions % Tensile			
	Lower Tensile	I. T.	1	2	3	4
SL	1460	10 U	18 U	32 U	16 U	50 O
SM	1690	9 U	15 U	28 U	14 U	44 U
DM	1690	9 U	15 U	28 U	14 U	44 U
SH	1900	8 U	14 U	25 U	12 U	39 U
DH	1900	8 U	14 U	25 U	12 U	39 U

Specified

Operating Data

	Operating Positions 1	2	3	4
Length	30.00	32.50	29.75	35.66
Load	139.74	254.62	128.25	399.83
Deflection	1.30	3.80	1.05	6.96
Body Stress	257	469	236	736
Loop Stress	650.74	1185.7	597.25	1862.0
Load Tol. Grade 1	32.14	33.22	32.03	34.59
Load Tol. Grade 2	51.01	52.73	50.84	54.91
Load Tol. Grade 3	81.62	84.37	81.34	87.86

Figure 1 Spring Design for Patented Carbon extension springs batch

INSTITUTE OF SPRING TECHNOLOGY Date: 29/05/2007 10:58:10

Identifier:	Metalpol
Part No.:	Extension Spring - Effect of End Loop Size
Details:	810 TECHSPRING PROJECT
Contact:	Mr Victor Sowa

Spring Type Round Wire Extension

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

Material

EN 10270 Pt3 Aust. Stainless

Youngs Mod (E):	185000	N/mm^2
Rigidity Mod (G):	73000	N/mm^2
Density:	.00000790	Kg/mm^3
Unprestress:	0-45	%
End Type:	Crossover Loop	
Loop Selection	Specified	
Loop Outside Diameter:	12.36	mm

Calculated Data

Estimated Free Length:	33.78	mm
Initial Tension Stress:	108.27	N/mm^2
Body Length:	13.86	mm
Body Length (Max):	14.03	mm
Stress Factor:	1.19	
Spring Index:	7.47	
Inside Diameter:	7.76	mm
Mean Coil Dia.	8.96	mm
Loop Inside Diameter:	9.96	mm
Wire Length:	367.46	mm
Weight / 100:	0.328	Kg
Natural Freq:	29082	RPM

Design Parameters

Wire Diameter:	1.20	mm	
Outside Diameter:	10.16	mm	
Total Coils:	10.55		
Spring Rate:	2.49	N/mm	(Calculated)
Initial Tension:	8.20	N	
Free Length:	33.88	mm	

Stress Data

			Operating Positions % Tensile						
	Lower Tensile	I. T.	1	2	3	4	5	6	7
NS	1850	6 U	11 U	14 U	11 U	32 U	35 U	38 U	41 U
HS	2000	5 U	11 U	13 U	10 U	30 U	33 U	35 U	37 U
Specified									

Operating Data

	Operating Positions 1	2	3	4	5	6	7
Length	37.00	38.50	36.67	48.80	50.35	51.85	53.37
Load	15.98	19.72	15.16	45.40	49.27	53.01	56.80
Deflection	3.12	4.62	2.79	14.92	16.47	17.97	19.49
Body Stress	211	260	200	599	650	700	750
Loop Stress	585.51	722.55	555.36	1663.6	1805.2	1942.2	2081.1
Load Tol. Grade 1	2.61	2.65	2.60	2.89	2.93	2.96	3.00
Load Tol. Grade 2	4.15	4.20	4.13	4.59	4.64	4.70	4.76
Load Tol. Grade 3	6.63	6.72	6.61	7.34	7.43	7.52	7.61

Figure 2 Spring Design for Austenitic Stainless Steel extension springs batch