Tech-Spring Report 13
Fatigue testing of torsion springs
FIRST PROGRESS REPORT

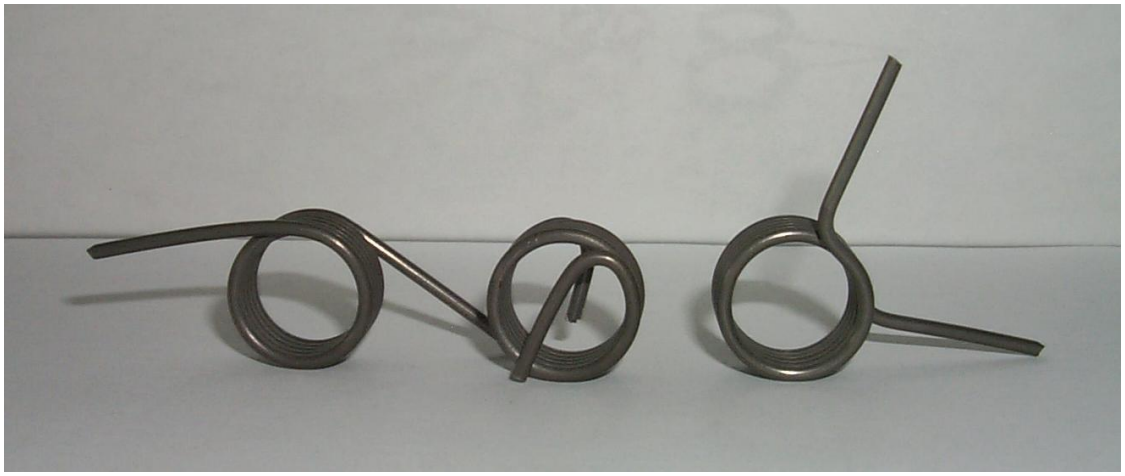
Introduction

This programme of work is designed to enable the fatigue performance to be quantified for torsion springs with various leg types. Both carbon steel and stainless steel springs were supplied, but only the 302 stainless steel springs have been tested to date. Necessarily test speeds for this type of spring are low and IST's capacity is limited, and so it will take some time to complete all testing. Results to date are very interesting, and so have been complied into this interim report.

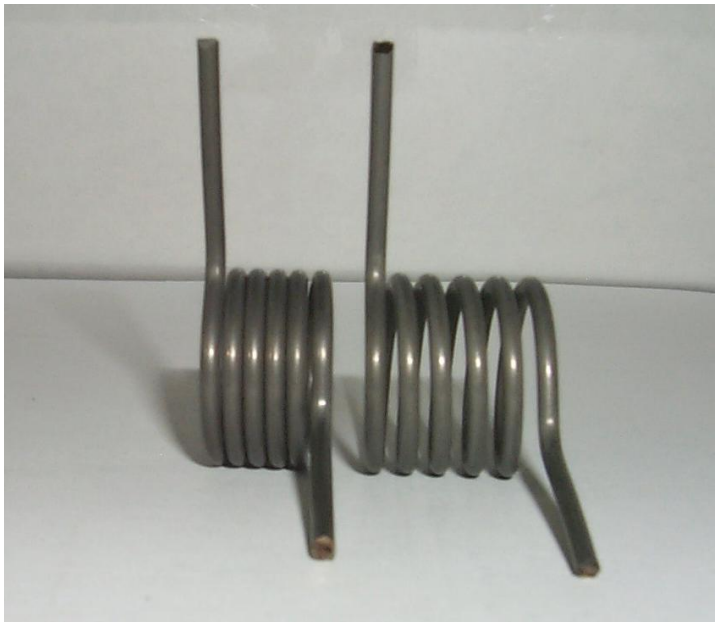
All the springs 5A-5D were manufactured from 2.75mm diameter EN 10270-3 1.4301 NS grade wire, that has been checked by IST to be free from significant surface defects. The springs had the appearance of having been stress relieved after coiling. Springs with internal radial legs were tested at 500rpm and springs with tangential or external radial legs were tested at approximately 40rpm.

The spring designs were as follows:

Design	Do/mm	Coils	Leg	Coiling
5A	26.95	5.27	Internal radial	Closed coiled
5B	26.95	5.27	Internal radial	Open coiled
5C	26.95	5.42	External radial	Close coiled
5D	26.95	5.42	Tangential	Close coiled
6 (d = 3mm)	24.3	5.68	Tangential	Open coiled



Spring designs – tangential legs, internal radial legs and external radial legs



Close coiled and open coiled

A typical printout from IST's CAD program is shown below utilising the EN 13906-3 design methodology.

INSTITUTE OF SPRING TECHNOLOGY Date: 23/07/2008 16:54:37

Identifier: 5C
Part No.: External radial legs
Details: 810j)

Spring Type Round / Rect Wire Torsion
Designed To: EN 13906-3: 2002
Tolerance Standard: DIN 2194: 2002

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:	0-70	%
Prestress:	70-100	%

Wire Section: Round Wire
Leg Type: Radial Leg
Length Leg 1: 17.00 mm
Length Leg 2: 35.00 mm

Design Parameters
Wire Diameter: 2.74 mm
Outside Diameter: 26.95 mm
Total Coils: 5.58
Spring Rate: 20.22 Nmm/Deg (Calculated)

Calculated Data

Body Length:	18.03	mm
Body Length (Max):	19.54	mm
Partial Angle (Free):	208.80	Deg
Stress Factor:	1.10	
Spring Index:	8.84	
Inside Diameter:	21.47	mm
Mean Coil Dia.	24.21	mm
Wire Length:	476.68	mm
Weight / 100:	2.22	Kg
Natural Freq:	9662.9	RPM

Stress Data

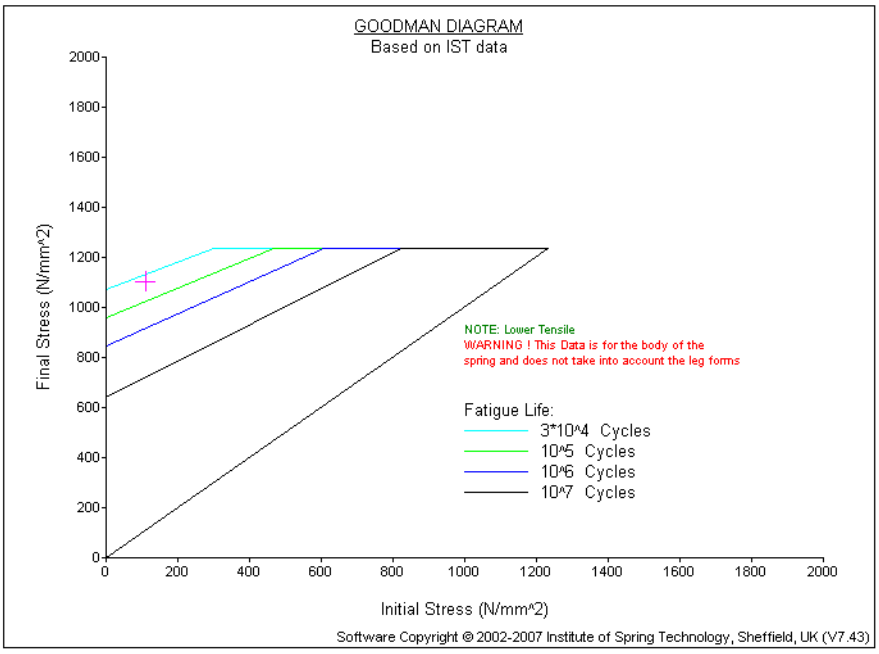
	Lower Tensile	Operating Positions % Tensile 1	2	3
NS	1600	13 U	25 U	75 P
HS	1700	12 U	24 U	71 P
Specified				

Operating Data

	Operating Positions 1	2	3
Torque (Nmm)	404.47	808.94	2426.8
Deflection (Deg)	20.00	40.00	120.00
Partial Angle (Deg)	228.80	248.80	328.80
Stress (Deg)	200	401	1202
Inside Diameter (N/mm^2)	21.23	21.00	20.11
Body Length (Max) (mm)	19.69	19.85	20.46
Load Tol. Grade 1 (mm)	337.65	337.65	337.65
Load Tol. Grade 2 (Nmm)	535.95	535.95	535.95
Load Tol. Grade 3 (Nmm)	857.52	857.52	857.52

Operating Positions

	1	3
Deflection: (Deg):	10.00	100.00
Torque: (Nmm):	202.24	2022.4
Corrected Stress (N/mm^2):	110	1103



The corrected stress shown is higher than the uncorrected stress – do partners agree that this is correct? I suspect that it should be lower.

Load Test results:

Design	**Angle**						
	Torque/Nm						
	20°	**40°**	**60°**	**80°**	**100°**	**120°**	**140°**
5A close IR	0.44	0.91	1.33	1.76	2.16	2.53	2.85
5B open IR	0.44	0.86	1.28	1.71	2.13	2.51	2.88
5C close ER	0.39	0.85	1.26	1.64	2.05	2.45	2.86
	with L_1 = 17mm and L_2 = 35mm						
	0.43	0.91	1.33	1.76	2.14		
	with L_1 = L_2 = 0mm						
5D close T	0.36	0.70	0.99	1.44	1.82	2.22	2.60
	with L_1 = 30mm and L_2 = 25mm						
6 open T	0.44	0.92	1.45	1.95	2.54	3.08	3.60
	with L_1 = 50mm and L_2 = 28mm						

Fatigue Test results:

Batch	**Test Range**	**Lives**
5A close IR	10°-130° (no mandrel)	39,4630 ~ 45,000
5B open IR	10°-100° (no mandrel)	3 million U/B
5B open IR	10°-130° (no mandrel)	225,740, 106,470. 107,760, 149,350

Batch	Test Range	Lives
5C (L_1 17, L_2 35)	10°-100°	23,416, 21,871, 25,520, 21,557
open ER	10°-90°	16,738, 19,111, 19,568, 15,569
	10°-70°	36,679, 48,520, 54,650, 46,526
	10°-50°	132,590, 131,477, 133,171, 125,302
5C (L_1 = L_2 = 0)	10°-66° (Ξ 10°-70°)	251,440 U/B
close ER	10°-86° (Ξ 10°-90°)	224,501 U/B
	10°-105° (Ξ 10°-110°)	205,405 U/B
	10°-125° (Ξ 10°130°)	93,239
5D	10°-90°	802, 165, (4) U/B
close T	10°-110°	71,737, 87,534, 114,854, 152,545
	10°-130°	37,582, 47,138, 58,117, 77,044
	10°-150°	23,756, 25,424, 27,238, 33,249
6	10°-80°	600, 148 (4) U/B
open T	10°-90°	77,787, 102,123, 114,757, 172,014
	10°-100°	61,337, 69,287, 70,675, 98,281
	10°-110°	30,535
	10°-120°	29,488

The applied stress can be calculated for each of the above tests so that Goodman Diagrams for each leg type can be drawn, but the calculation of the corrected stress requires clarification.

Conclusion

Internal radial legs are best if the springs are open coiled. Tangential legs and close coiled internal radial legs are next best. External radial legs are much worse, but if the leg length is reduced to zero, the fatigue performance is much better.

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