

Tech-Spring Report 12 Prediction of Shortening by Prestressing Compression Springs

Introduction

When a spring maker makes a compression spring that is to be prestressed in manufacture, there is no published guidance about the length to be aimed for at the coiler. At present the spring maker has to guess how much the spring will shorten during prestressing. The purpose of this programme of work is to provide a first estimate of the as-coiled length. It is certain to be approximate – there are too many variables for an accurate estimate. However, if the first sample is close to the required dimensions the number of iterative steps to produce the end customer's spring should be significantly reduced.

This program of work aims to provide a target free length at the coiler, as illustrated in Figure 1 below.



Figure 1 Customer requires length at coiler

Method Used

Prediction of Shortening by Prestressing Compression Springs

Many batches of springs of spring index between 4 and 12 have been tested. The method used is as follows:

1. Measure free length at a stress relieved spring.
2. Load test progressively to 50%, 60%, 70%, 80%, 90% and 100% of available deflection.
3. Measure reduction in free length after each prestress.
4. Calculate corrected stress before and after each prestress.
5. Plot graph of corrected stress before and after prestress.



6. Use this graph as a basis for predicting shortening.

The data obtained is widely scattered, but a typical example is as follows for batch ATVD, springs of index 4, which had a very high solid stress after they had been stress relieved. The springs were manufactured from EN 10270-1 HS wire – the design is given as table 1.

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Date: 23/07/2008 12:07:17

Identifier: ATVD
 Details: 810

Spring Type Round Wire Compression

Designed To: BS 1726-1: 1987
 Tolerance Standard: BS 1726-1: 2002

Calculated Data

Solid Length: 20.00 mm
 Solid Load: 1225.1 N
 Solid Stress: 2795.3 N/mm²
 Stress Factor: 1.40
 Active Coils: 6.36
 Spring Index: 4.00
 Helix Angle: 10.07 Deg
 Buckling Possible: STABLE
 Buckling Definite: STABLE
 Spring Pitch: 5.58 mm
 Inside Diameter: 7.50 mm
 Mean Coil Dia.: 10.00 mm
 Wire Length: 254.62 mm
 Weight / 100: 0.981 Kg
 Natural Freq: 85523 RPM
 As-Coiled Length: mm
 Max Test Speed: 6579 RPM

Material

EN 10270 Pt1 Patented Carbon
 Youngs Mod (E): 206000 N/mm²
 Rigidity Mod (G): 81500 N/mm²
 Density: .00000785 Kg/mm³
 Unprestress: 0-49 %
 Prestress: 49-70 %

End Type: Closed and Ground
 Dead Coils: 1.64
 Tip Thickness: 50.00 %
 End Fixation: Both Ends Fixed and Guided

Design Parameters

Wire Diameter: 2.50 mm
 Outside Diameter: 12.50 mm
 Total Coils: 8.00
 Spring Rate: 62.57 N/mm (Calculated)
 Free Length: 39.58 mm

Stress Data

	Lower Tensile	Solid	Operating Positions	
			% Tensile 1	2
SL	1460	191 O	15 U	64 P
SM	1690	165 O	13 U	56 P
DM	1690	165 O	13 U	56 P
SH	1900	147 O	12 U	49 U
DH	1900	147 O	12 U	49 U
Specified				

Operating Data

	Operating Positions	
	1	2
Length (mm)	38.00	33.00
Load (N)	98.86	411.71
Deflection (mm)	1.58	6.58
Stress (N/mm ²)	226	939
Stress % Solid	8	34
Load Tol. Grade 1 (N)	46.96	53.22
Load Tol. Grade 2 (N)	70.44	79.83
O.D. Expansion (N)	0.0151	0.0629

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The load test results were:

	No Prestress	Prestress to 33mm	Prestress to 32mm	Prestress to 30mm	Prestress to 28mm
L ₀	39.68mm	39.67mm	39.53mm	39.15mm	38.51mm
P ₁ @ 38mm	99.0N	99.5N	89.0N	63.5N	24.0N
P ₂ @ 33mm	412.0N	411.5N	404.0N	375.5N	329.5N

(reasonably straight)

	Prestress to 26mm	Prestress to 24mm (twice)	Prestress to solid 21.64mm (thrice)
L ₀	37.70mm	36.36mm	34.51mm
P ₁ @ 30mm	455.5N	367.0N	257.5N
P ₂ @ 26mm	681.0N	600.0N	491.5N

(significantly bent)

Results calculated from these load test results.

Prestress Length / mm	Shortening / mm	Corrected Stress before / MPa	Corrected Stress after / MPa
33	0.01	50	49.9
32	0.15	57	56.1
30	0.53	72	67.9
28	1.17	87	78.3
26*	1.98	102	87.0
24*	3.32	117	93.0
Solid*	5.14	140	102.0

* Springs unacceptably distorted (not straight) after prestressing to these lengths.

Results for index 6 and index 8 springs were similar to those shown above, but the shortening was very slightly greater as the index increased.

The factors that will affect shortening during prestressing will be:

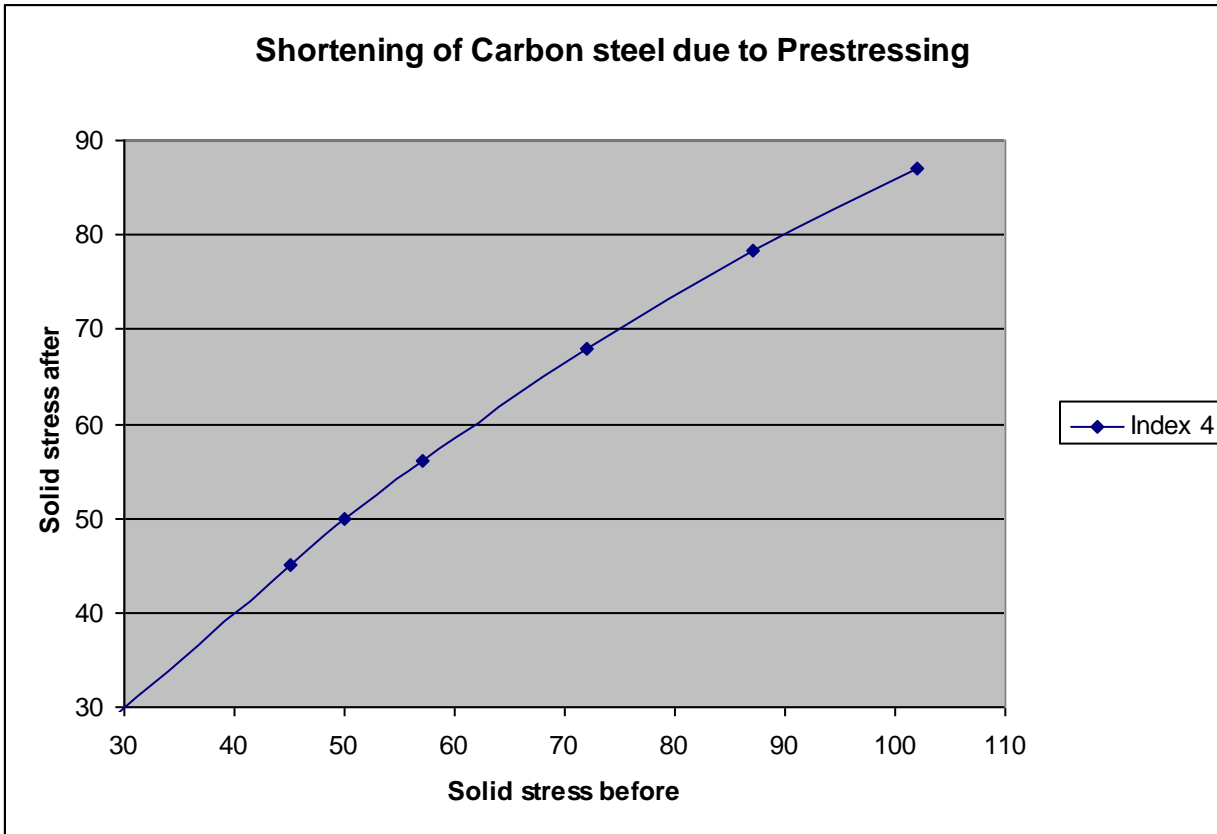
- a) how accurately springs are made (beyond the scope of prediction)
- b) the elastic limit of the material with oil tempered > drawn carbon > stainless steel
- c) the work hardening rate of the material.

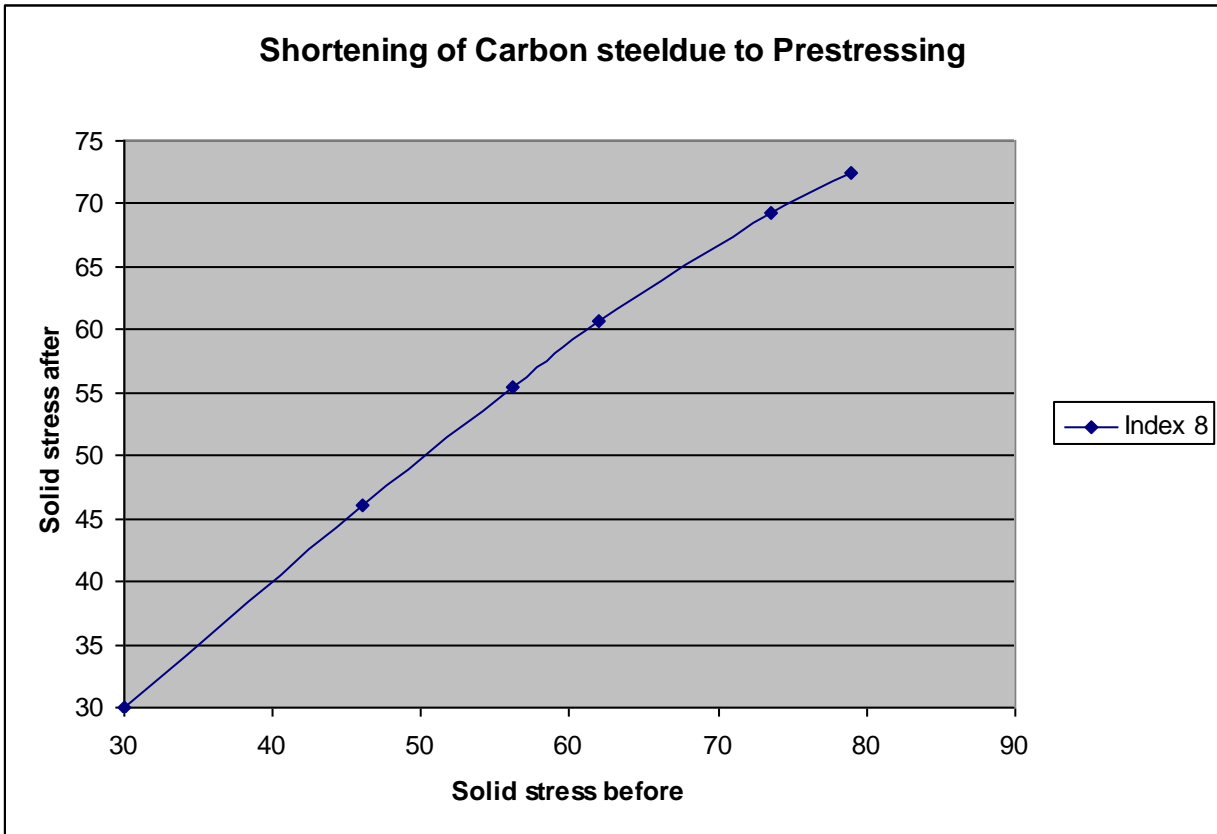
These last two will affect the distance that the prestressing front will progress – i.e. when the shortening is slight, a very small annulus of material will have been prestressed in a compression spring, and when the shortening is larger the annulus of prestress material will be greater, as shown below.

The results of IST’s test also shows that spring index has an effect with the curve being lower – i.e. shortening greater, and elastic limit lower particularly at spring index > 8. However, few springs of this design were available to test, and so more are requested.

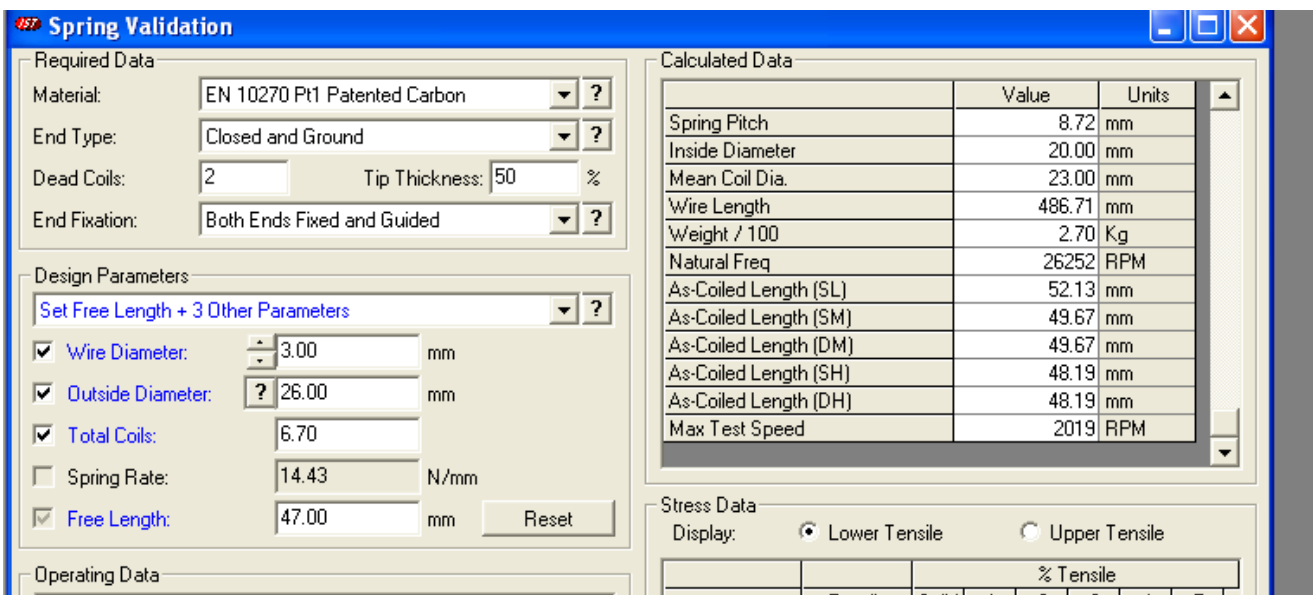


A summary of the results are shown on the graphs below for drawn carbon steel.





A first attempt has been made to input this data into the Tech-Spring 2 toolkit, and an example of the guidance provided is shown below. All partners are encouraged to check the accuracy of the prediction, and to supply springs where the prediction is more than 20% in error.



Spring Validation

Required Data

- Material: EN 10270 Pt1 Patented Carbon
- End Type: Closed and Ground
- Dead Coils: 2 Tip Thickness: 50 %
- End Fixation: Both Ends Fixed and Guided

Design Parameters

- Set Free Length + 3 Other Parameters
- Wire Diameter: 3.00 mm
- Outside Diameter: 26.00 mm
- Total Coils: 6.70
- Spring Rate: 14.43 N/mm
- Free Length: 47.00 mm

Calculated Data

Parameter	Value	Units
Spring Pitch	8.72	mm
Inside Diameter	20.00	mm
Mean Coil Dia.	23.00	mm
Wire Length	486.71	mm
Weight / 100	2.70	Kg
Natural Freq	26252	RPM
As-Coiled Length (SL)	52.13	mm
As-Coiled Length (SM)	49.67	mm
As-Coiled Length (DM)	49.67	mm
As-Coiled Length (SH)	48.19	mm
As-Coiled Length (DH)	48.19	mm
Max Test Speed	2019	RPM

Stress Data

Display: Lower Tensile Upper Tensile

Author Mark Hayes, IST.