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.

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.
The load test results were:

<table>
<thead>
<tr>
<th></th>
<th>No Prestress</th>
<th>Prestress to 33mm</th>
<th>Prestress to 32mm</th>
<th>Prestress to 30mm</th>
<th>Prestress to 28mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_0$</td>
<td>39.68mm</td>
<td>39.67mm</td>
<td>39.53mm</td>
<td>39.15mm</td>
<td>38.51mm</td>
</tr>
<tr>
<td>$P_1$ @ 38mm</td>
<td>99.0N</td>
<td>99.5N</td>
<td>89.0N</td>
<td>63.5N</td>
<td>24.0N</td>
</tr>
<tr>
<td>$P_2$ @ 33mm</td>
<td>412.0N</td>
<td>411.5N</td>
<td>404.0N</td>
<td>375.5N</td>
<td>329.5N</td>
</tr>
</tbody>
</table>

(Reasonably straight)

The results calculated from these load test results.

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

* 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.

![Graph showing shortening of carbon steel due to prestressing](image)

**Shortening of Carbon steel due to Prestressing**

- **Solid stress before**
- **Solid stress after**
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.

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