Cautionary Tale

Torsion Spring Stresses; Part 1

During the Techspring project, IST had reason to question whether the classical mechanics formulae for calculating stresses in springs were correct. For compression and extension springs we found that the formulae were sufficiently accurate, but for torsion springs further investigation was required.

This was done by making open coiled torsion springs with tangential legs using 4mm square spring steel wire, and applying strain gauges with a grid size of 2 x 1mm, as shown in figure 1. To ensure the test spring was not subject to plastic deformation the maximum deflection was limited to 45 deg / 9.3Nm, equating to a theoretical uncorrected stress of 870MPa, or 52% of the wire UTS.

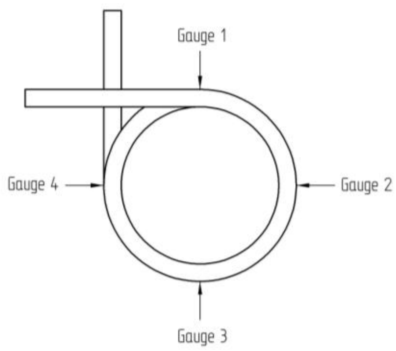

Fig 1 Gauge locations

During testing the spring was supported on interchangeable mandrels of Ø32, 30, 25mm diameter. The spring legs were loaded using Ø9mm pins at a radius of 40mm from the jig centre.

Effect of mandrel diameter on torque output

The spring was mounted onto the test mandrels and deflected from free to 45deg in increments of 5deg. The torque levels were recorded at each position, and results are shown in figure 2.

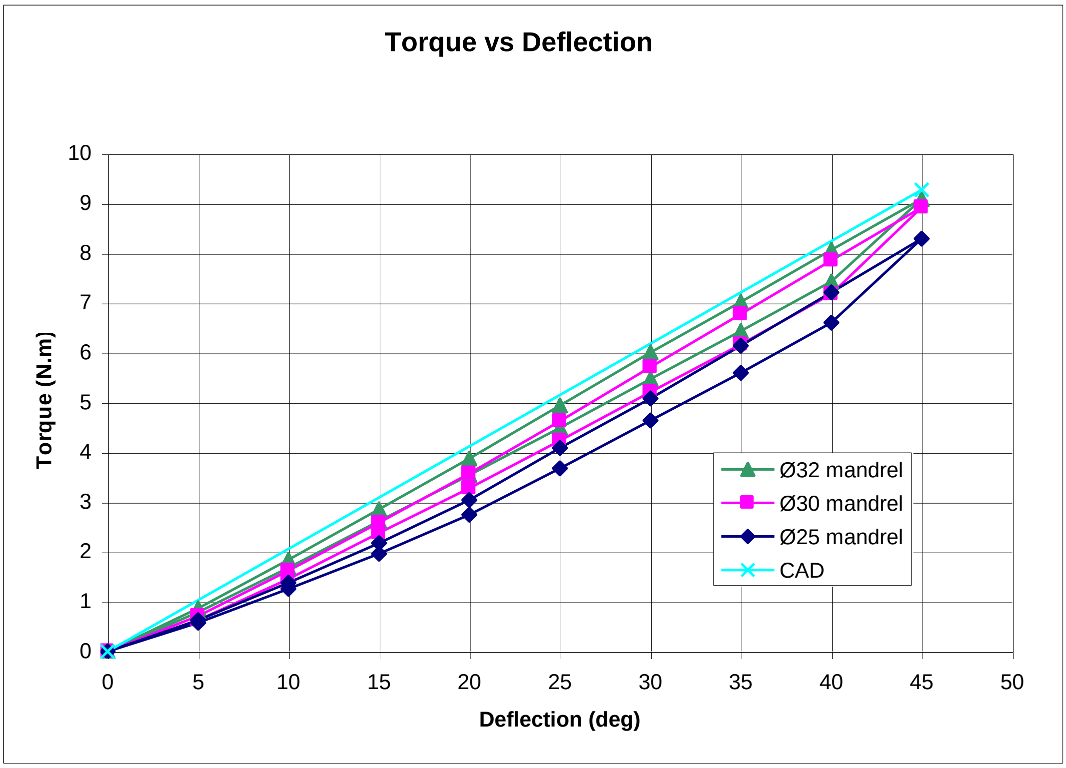

Fig 2 Effect of mandrel size on Torque output

It can be seen that the torque produced by the spring and hence spring rate is directly influenced by the supporting mandrel diameter.

Spring inside Diameter (mm)	Mandrel diameter (mm)	ID to mandrel % clearance	Max torque N.m
36	32	11.1	9.09
36	30	16.7	8.92
36	25	30.6	8.30

Table 1 Mandrel diameter and maximum torque output

Projecting the results back using a trend line indicates the torque with zero clearance is approximately 9.3N.m, which equates closely to the 9.27N.m calculated by the *IST* version 7.5 CAD software. When small mandrels are used, the shearing and tilting of the coils becomes significant, producing a reduction in the spring rate. This would mean that the stress was lower when using a smaller mandrel, but the spring visibly sheared and so the stress will not be the same at each of the strain gauge locations. To a first approximation the max stress recorded with each mandrel was similar, but the difference in max and min was much greater with the small mandrel. The first moral of this cautionary tale is that the torque output of torsion springs working on a mandrel will depend on the mandrel diameter, but the stress may not. The stress data will be quantified in part 2 of this cautionary tale. It will be shown that the corrected stress calculation is approximately correct, but the calculation formulae are only right by accident.

A second moral of this cautionary tale is that the torque output of these springs was not the same in the wind up and unwind directions- the CAD program shows that it is, but inevitably there is frictional contact between the springs and mandrel and this leads to hysteresis or a difference in torque depending on the direction at loading, as shown in figure 2 in which the difference was about 10%- it can be greater than this, especially if not lubricated.

Readers are encouraged to contact Mark with comments about this cautionary tale, and with subjects that they would like to be addressed in future tales, by telephone at (011) 44 114 255 3349 or e-mail m.hayes@springexpert.co.uk.