Tech-Spring Report 5A
THE STRESS PROFILE IN LARGER WIRES

Introduction

Three batches of compression springs were supplied to IST to investigate the effect of the stress profile in cold-coiled springs made from relatively large wire. The springs supplied and information from their respective wire test certificate were as follows:

Batch	Wire	Material	T.S.
VS	5.09mm	Oil hardened SiCr	1843MPa
VBlue	7.49mm	Oil hardened SiCr	1730MPa
VL	7.98mm	Induction hardened SiCr	1874MPa

IST fatigue tested these springs in order to compare their relative performance, and when we found significant differences, the springs were sent for evaluation of their residual stress profiles.

This interim report is supplied only to the supplier of the springs, but will be sent to all project partners once the residual stress data is available.

Fatigue Testing

Each batch of springs was accurately load tested so as to establish the relationship between load and stress. They were then fatigue tested to establish the stress conditions necessary to cause failure. They were tested on mechanically driven machines at 380rpm, a speed that would not result in dynamic stresses being additional to those calculated. The results were:

Batch	Load Range / N	Stress Range / MPa	Life to Failure
VS	111 - 1109	100 - 1000	2 survived one million
	55 - 1109	50 - 1000	Survived one million

This batch could not be failed by fatigue. The solid stress was 1,170MPa, and testing closer to solid than 1000MPa would have given unreliable results because of the risk of coil contact.

Batch	Load Range / N	Stress Range / MPa	Life to Failure
VBlue	253 - 2393	100 - 945	4 survived one million
	253 - 2532	100 - 1000	3 survived one million & 1 failed at 645k
	126 - 2532	50 - 1000	4 failed at 477k - 944k

The fatigue performance of this batch, like the VS batch was good - IST's software would predict a risk of failure after about 200k when tested between 100 - 1000MPa.

Batch	Load Range / N	Stress Range / MPa	Life to Failure
VL	235 - 2246	100 - 950	1 survived one million, 3 failed at 327k, 391k and 561k.

The fatigue performance of this batch was relatively poor - IST's software would predict a risk of fatigue failure after about 400k cycles when tested between 100 - 950MPa.

Hence the fatigue testing has shown that the fatigue performance can be ranked VS better than VBlue better than VL.

Optical Metallography

Transverse and longitudinal sections were prepared from a tested spring of each type. This was done to check whether there were metallurgical differences that could account for the fatigue life differences. The results were:

Batch	Microstructure	Defects / Decarb	Hv
VS	Tempered martensite	No defects, slight partial decarburisation, usual effect of shot peening	560 / 579
VBlue	Tempered martensite	No defects, slight partial decarburisation, shot peening very light.	525 / 525
VL	Tempered martensite	No defects, slight partial decarburisation, shot peening o.k., longitudinal oxidised crack (Figure 1)	554 / 592

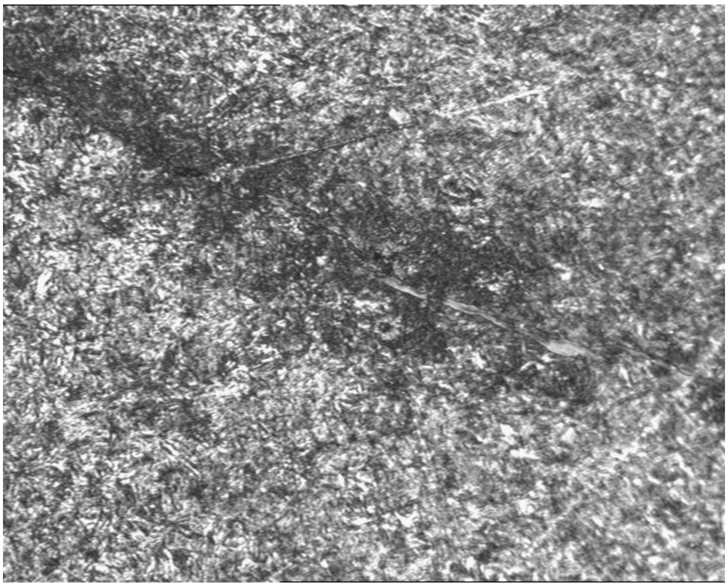


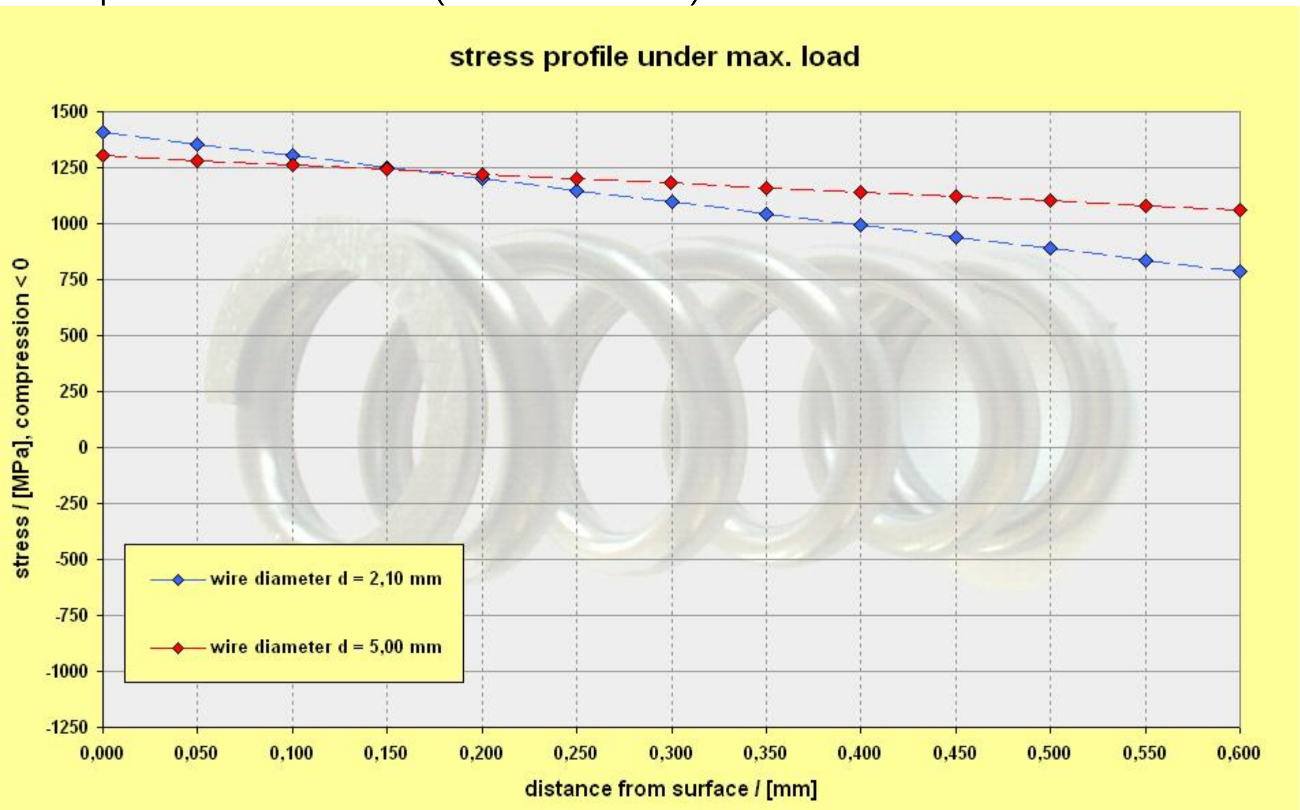
Figure 1 **x 430**

It would usually be expected that a higher hardness would bring better fatigue performance, hence VS better than VBlue. Shot peening is vital to give the higher fatigue performance observed here and the VBlue springs appear to have been peeened with very small shot compared with the other two. Nonetheless, the VBlue springs have given good performance.

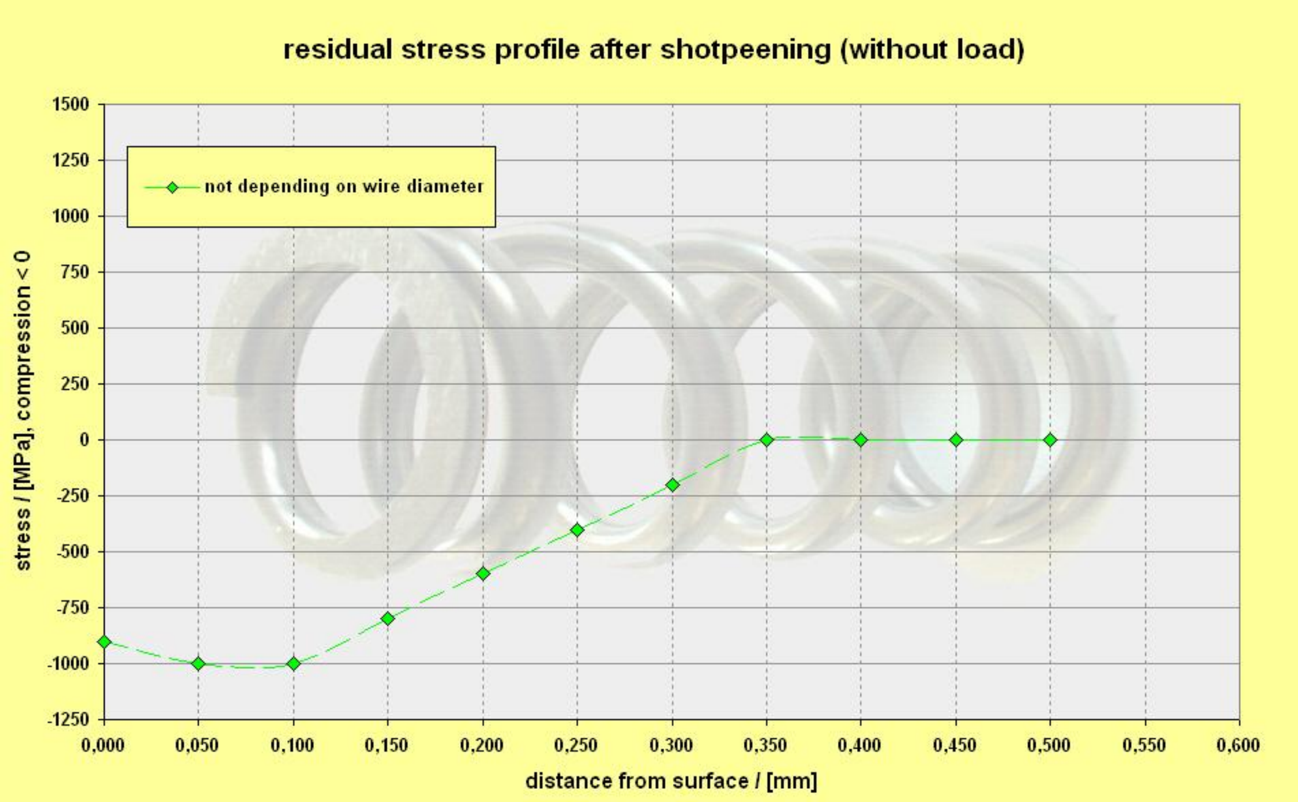
The larger longitudinal and oxidised crack in the VL spring maybe a full explanation for its relatively poor fatigue performance, but IST have not observed cracks of this type previously and are in the process of examining untested springs for evidence of similar cracks. With this type of crack the fatigue performance would have been expected to be very much worse than that observed, if the crack has been present before the start of the test. It is not clear why this spring should have developed a longitudinal crack during fatigue test, the crack and fatigue origin was at the outside surface of the spring which is unusual - springs of this type should have fatigue initiation at the inside surface, as was observed in the VBlue springs.

Residual Stress Results

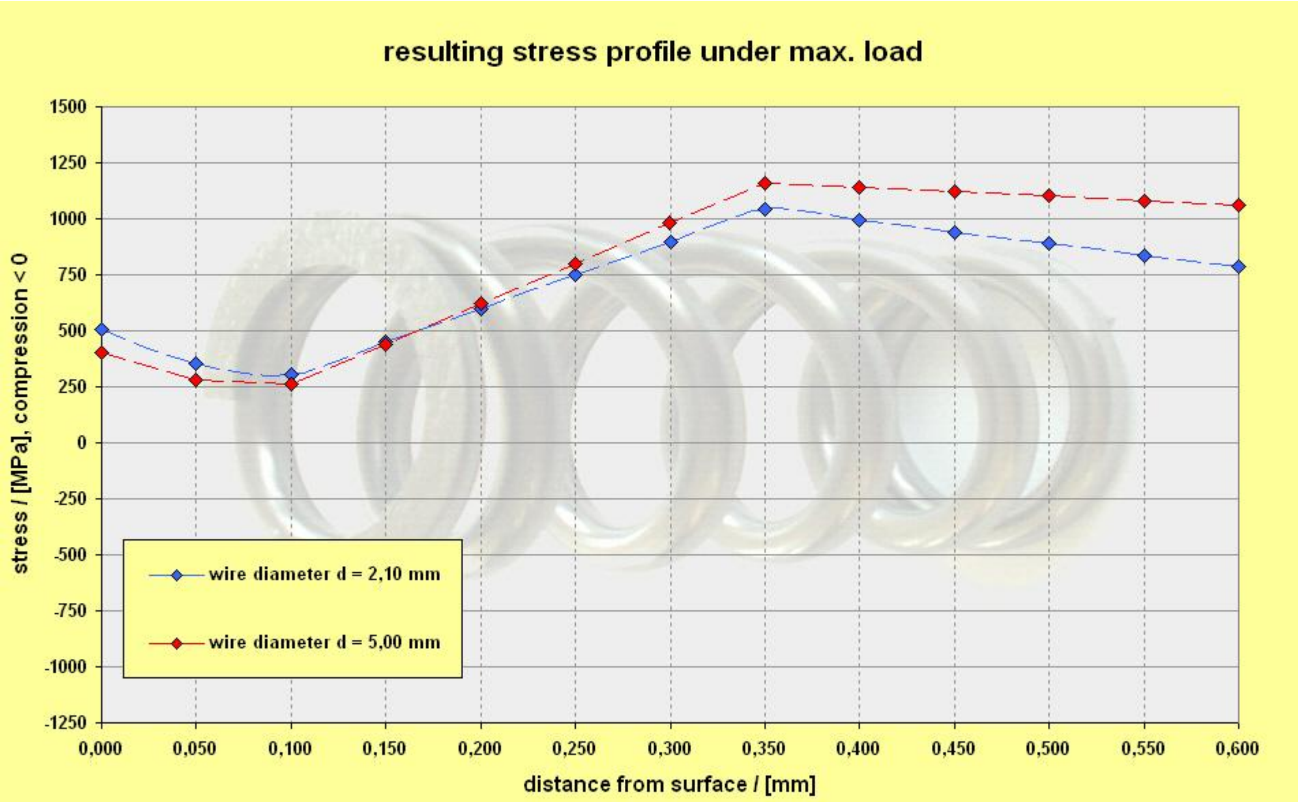
Stress profile under max. load (calculated values)



Residual stress profile after shot-pening without load (mean values of three measured springs)



Resulting stress profile under max. load (calculated values)



Additional batch of Stainless Steel Barrel shaped springs

These springs had been manufactured from EN 10270-3 1.4301 wire and had been shot peened, but the appearance of the shot peened finish, shown as figures 2 and 3 was variable, which curtailed this test programme. Innotech photographed the shot peened finish shown in figure 2 on the scanning electron microscope and expressed doubt that it was satisfactory, but the fatigue performance was good and so this topic was left for future exploration. The spring design enabled IST to illustrate the printout from their non-standard compression spring program for the first time in this project, as figure 4.

The fatigue test results on the well peened springs – figure 2
52 – 804 MPa stress range Two springs survived 10 million cycles
The fatigue test results for the springs –figure3.
52 – 804 MPa stress range Two springs failed at 82,820 and 292,370 cycles

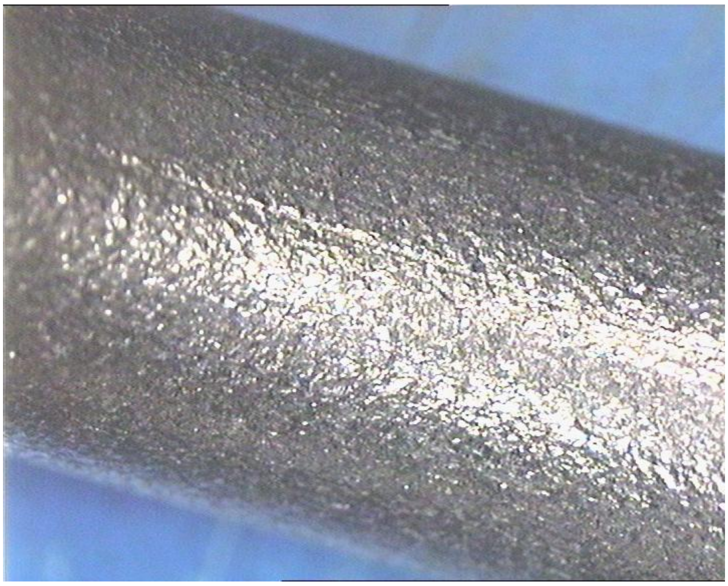


Figure 2 100% peening coverage x 11.5

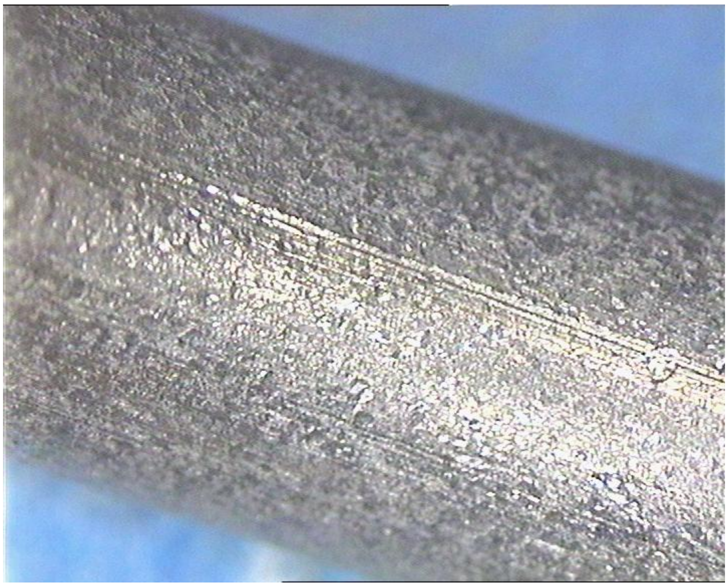


Figure 3 < 50% peening coverage x 11.5

These photographs show that peening has not obliterated the coiling scratches on the inside surface of these springs.

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Identifier: Barrel shaped
Details: 810

Spring Type Non-Standard Compression
Designed To: IST

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:	0-40	%
Prestress:	40-59	%

Tip Thickness:

End 1:	30.00	%
End 2:	20.00	%

Design Parameters

Total Coils:	5.30	
Wire Diameter:	5.90	mm

Outside Diameter:

Coil Position		Outside Diameter (mm)	
Start	End	Start	End
0	1.00	30.00	30.00
1.00	2.00	30.00	37.30
2.00	2.65	37.30	38.86
2.65	3.30	38.86	37.30
3.30	4.30	37.30	30.00
4.30	5.30	30.00	30.00

Spring Pitch

Coil Position		Axial distance between wire centres (mm)	
Start	End	Start	End
0	1.00	6.30	6.30
1.00	2.00	11.20	11.20
2.00	2.65	10.00	10.00
2.65	3.30	10.00	10.00
3.30	4.30	11.20	11.20
4.30	5.30	6.30	6.30

Calculated Data

Free Length:	52.05	mm
Solid Length:	26.52	mm
Solid Load:	4414.9	N
Solid Stress:	1832.4	N/mm^2
Outside Diameter Max.:	38.86	mm
Inside Diameter Min.:	18.20	mm
End 1: Outside Diam Max:	30.00	mm
End 1: Inside Diam Min:	18.20	mm
End 2: Outside Diam Max:	30.00	mm
End 2: Inside Diam Min:	18.20	mm
Spring Index Min.:	4.08	
Spring Index Max.:	5.59	
Stress Factor Min.:	1.26	
Stress Factor Max.:	1.39	
Wire Length:	460.69	mm
Weight / 100:	9.95	Kg

Stress Data

	Lower Tensile	Solid	% Tensile Operating Positions 1	2
NS	1400	131 O	4 U	57 P
HS	1500	122 O	3 U	54 P
Specified				

Operating Data

	Operating Positions 1	2
Length (mm)	51.00	39.00
Load (N)	101.12	1560.1
Deflection (mm)	1.05	13.05
Stress (N/mm^2)	52	804
Stress % Solid	3	44

Figure 4 Barrel shaped spring design