**Tech-Spring Report 17A**
**High Tensile SiCr Wire**

This report is an update of the original report 17, and now includes a tensile range for the wire itself and a Goodman diagram for the new material type itself. This material will be added into the Tech-Spring toolkit as a specific material type (High strength Si Cr (Tech-Spring))
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## Introduction

Pengg made some superclean SiCrV wire that had a higher strength than regular SiCr. Project partners wanted to know the scope that higher strength wire gave them for designing higher stressed springs.

## Tensile Strength of the Wire

Tensile testing of the wire indicated that it had a tensile strength of 2236 – 2238 N/mm² at a diameter of 3.491 to 3.496 mm.

## Spring design

A quantity of 50 compression springs were manufactured from the supplied material. Approximately 30 of the springs were shot-peened (0.6mm conditioned cut steel wire shot, almen arc rise 0.25 – 0.33mm A2, followed by a 225°C / 30 minute low temperature heat treatment). By dimensional measurement and load test, the manufactured spring design was found to be as detailed in figure 1 below.

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**Spring Type** Round Wire Compression

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

**Material**

EN 10270 Pt2 Silicon -Cr

| | | |
|---|---|---|
| Youngs Mod (E): | 206000 | N/mm^2 |
| Rigidity Mod (G): | 79500 | N/mm^2 |
| Density: | .00000785 | Kg/mm^3 |
| Unprestress: | 0-53 | % |
| Prestress: | 53-70 | % |
| End Type: | Closed and Ground | |
| Dead Coils: | 2.35 | |
| Tip Thickness: | 40.00 | % |
| End Fixation: | Fixation not known | |

**Calculated Data**

| | | |
|---|---|---|
| Solid Length: | 19.72 | mm |
| Solid Load: | 754.08 | N |
| Solid Stress: | 1428.4 | N/mm^2 |
| Stress Factor: | 1.19 | |
| Active Coils: | 3.65 | |
| Spring Index: | 7.21 | |
| Helix Angle: | 8.68 | Deg |
| Buckling Possible: | Not Applicable | |
| Buckling Definite: | Not Applicable | |
| Spring Pitch: | 11.75 | mm |
| Inside Diameter: | 21.10 | mm |
| Mean Coil Dia.: | 24.50 | mm |
| Wire Length: | 465.25 | mm |
| Weight / 100: | 3.32 | Kg |
| Natural Freq: | 33347 | RPM |

**Design Parameters**

| | | | |
|---|---|---|---|
| Wire Diameter: | 3.40 | mm | |
| Outside Diameter: | 27.90 | mm | |
| Total Coils: | 6.00 | | |
| Spring Rate: | 24.74 | N/mm | (Calculated) |
| Free Length: | 50.20 | mm | |

**Stress Data**

| | Upper Tensile | Solid | Operating Positions % Tensile 1 | 2 | 3 |
|---|---|---|---|---|---|
| FDSiCr | 2060 | 69 P | 5 U | 51 U | 63 P |
| TDSiCr | 2010 | 71 O | 5 U | 52 U | 65 P |
| VDSiCr | 2010 | 71 O | 5 U | 52 U | 65 P |
| Specified | | | | | |

**Operating Data**

| | Operating Positions 1 | 2 | 3 |
|---|---|---|---|
| Length (mm) | 48.06 | 27.80 | 22.45 |
| Load (N) | 52.94 | 554.18 | 686.54 |
| Deflection (mm) | 2.14 | 22.40 | 27.75 |
| Stress (N/mm^2) | 100 | 1050 | 1300 |
| Stress % Solid | 7 | 73 | 91 |
| Load Tol. Grade 1 (N) | 25.04 | 35.07 | 37.71 |
| Load Tol. Grade 2 (N) | 37.56 | 52.60 | 56.57 |
| O.D. Expansion (N) | 0.0297 | 0.311 | 0.386 |



**Figure 1 – Manufactured spring design (after prestress)**

## Fatigue Testing

Sets of four springs were fatigue tested from an initial stress value of 100N/mm² to a range of maximum stress values to enable an S-N curve to be produced. To minimise the effects of manufacturing variation on the results obtained, each spring was individually load tested to determine the test lengths corresponding to the required stress level.

The fatigue test results are given in Table 1.

**Table 1**

| Stress (N/mm²) Initial | Final | Cycles completed | Broken | Unbroken |
|---|---|---|---|---|
| 100 | 1050 | 10,000,000 | | X |
| 100 | 1050 | 10,000,000 | | X |
| 100 | 1050 | 10,000,000 | | X |
| 100 | 1050 | 10,000,000 | | X |
| 100 | 1100 | 9,537,690 | X | |
| 100 | 1100 | 9,180,300 | X | |
| 100 | 1100 | 10,000,000 | | X |
| 100 | 1100 | 10,000,000 | | X |
| 100 | 1150 | <10,000,000 | X | |
| 100 | 1150 | 6,671,920 | X | |
| 100 | 1150 | 9,009,470 | X | |
| 100 | 1150 | 8,918,780 | X | |
| 100 | 1200 | 7,946,100 | X | |
| 100 | 1200 | 10,000,000 | | X |
| 100 | 1200 | 4,479,360 | X | |
| 100 | 1200 | 7,417,790 | X | |
| 100 | 1250 | 4,485,120 | X | |
| 100 | 1250 | 5,638,210 | X | |
| 100 | 1250 | 4,690,380 | X | |
| 100 | 1250 | 7,708,850 | X | |
| 100 | 1300 | 1,864,390 | X | |
| 100 | 1300 | 2,558,670 | X | |
| 100 | 1300 | 2,203,590 | X | |
| 100 | 1300 | 2,275,570 | X | |

The S-N curve generated from these results is included below as figure 4.

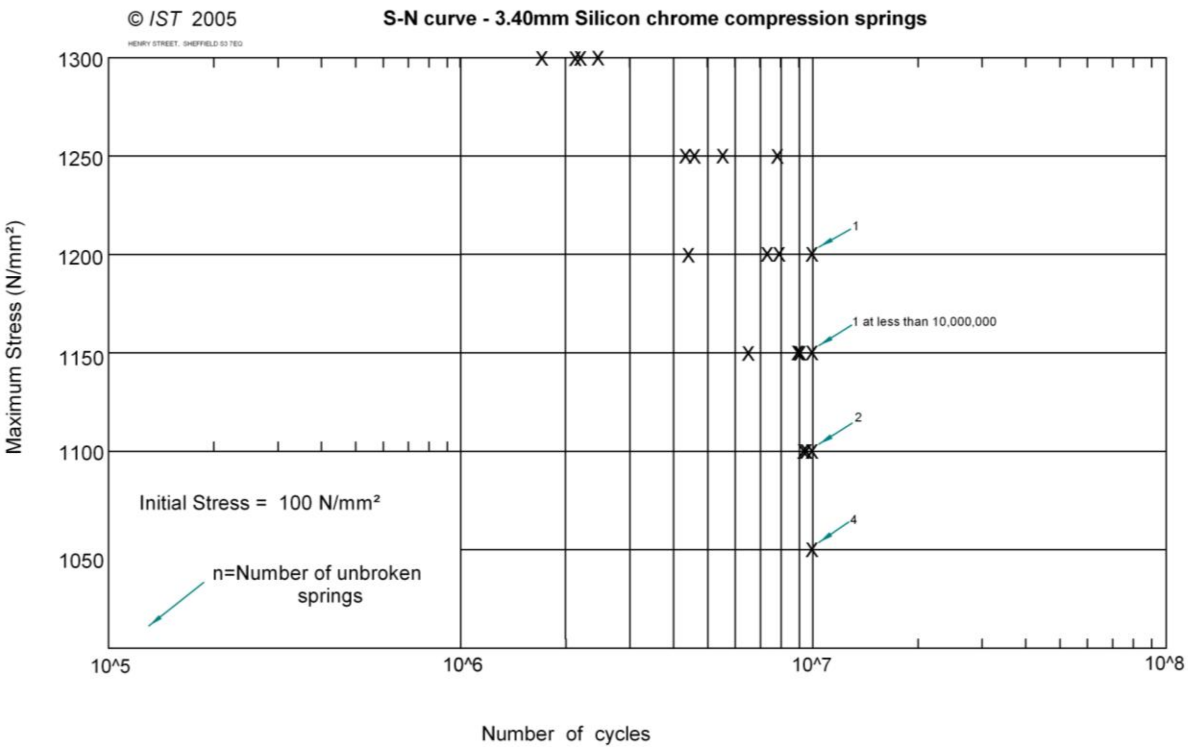


**Figure 4 – S-N curve**

## Discussion

Goodman diagrams are included below (figures 2 and 3) showing the performance of silicon chrome material compression springs which would be predicted, using currently available IST data, for the lowest and highest stress values used in this investigation.

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**Goodman Diagram**

| | |
|---|---|
| Material: | EN 10270 Pt2 Silicon -Cr |
| Grade: | VDSiCr |
| Shot Peened: | Yes |
| Pre-Stressed: | Yes |

**Operating Positions**

| | 1 | 2 |
|---|---|---|
| Length (mm): | 48.06 | 27.80 |
| Load (N): | 52.94 | 554.18 |
| Stress (N/mm^2): | 100 | 1050 |

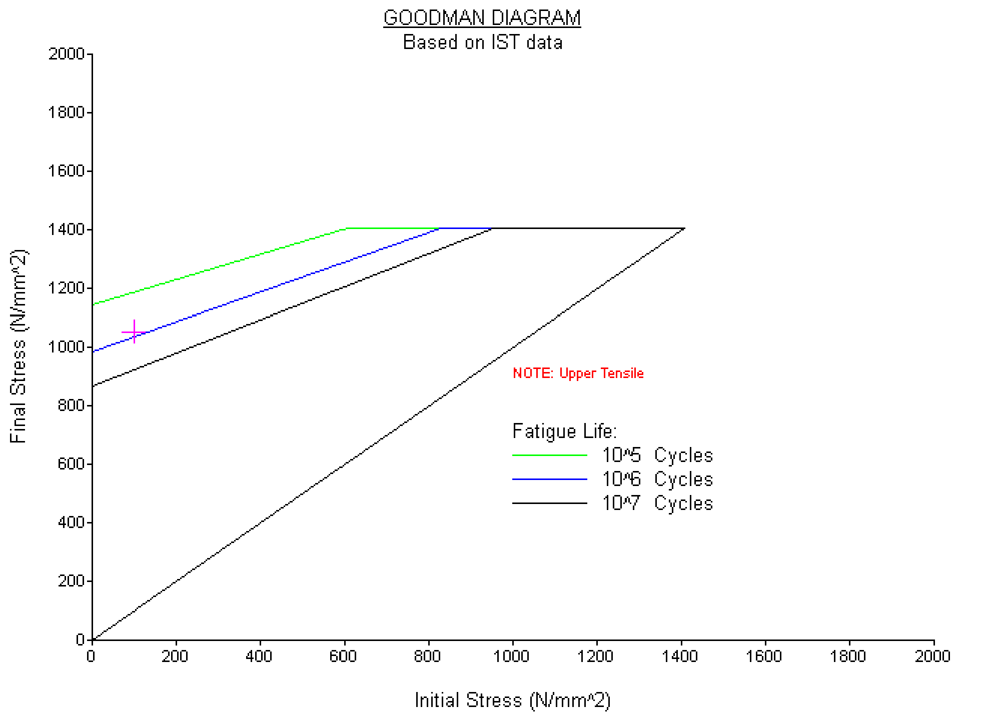




**Figure 2 – Fatigue prediction, 100 – 1050N/mm²**

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**Goodman Diagram**

| | |
|---|---|
| Material: | EN 10270 Pt2 Silicon -Cr |
| Grade: | VDSiCr |
| Shot Peened: | Yes |
| Pre-Stressed: | Yes |

**Operating Positions**

| | 1 | 3 |
|---|---|---|
| Length (mm): | 48.06 | 22.45 |
| Load (N): | 52.94 | 686.54 |
| Stress (N/mm^2): | 100 | 1300 |

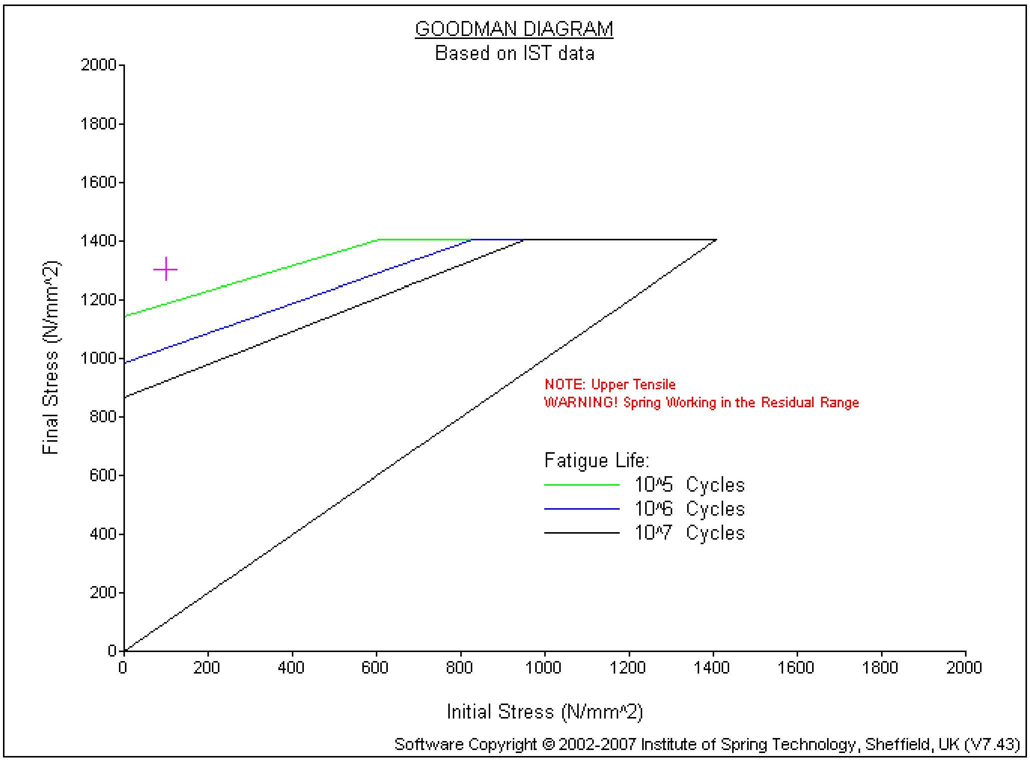



**Figure 3 – Fatigue prediction, 100 – 1300N/mm²**

It can be seen from figure 2 (100 – 1050N/mm²) that a fatigue life of just less than 1,000,000 cycles is predicted, whereas the Pengg wire springs have achieved a life in excess of 10,000,000 cycles. From figure 3 (100 – 1300N/mm²) a fatigue life of less than 100,000 cycles is predicted, whereas the earliest recorded Pengg wire spring failure was at 1,864,390 cycles.

## Data Incorporated into the Tech-Spring Toolkit 3

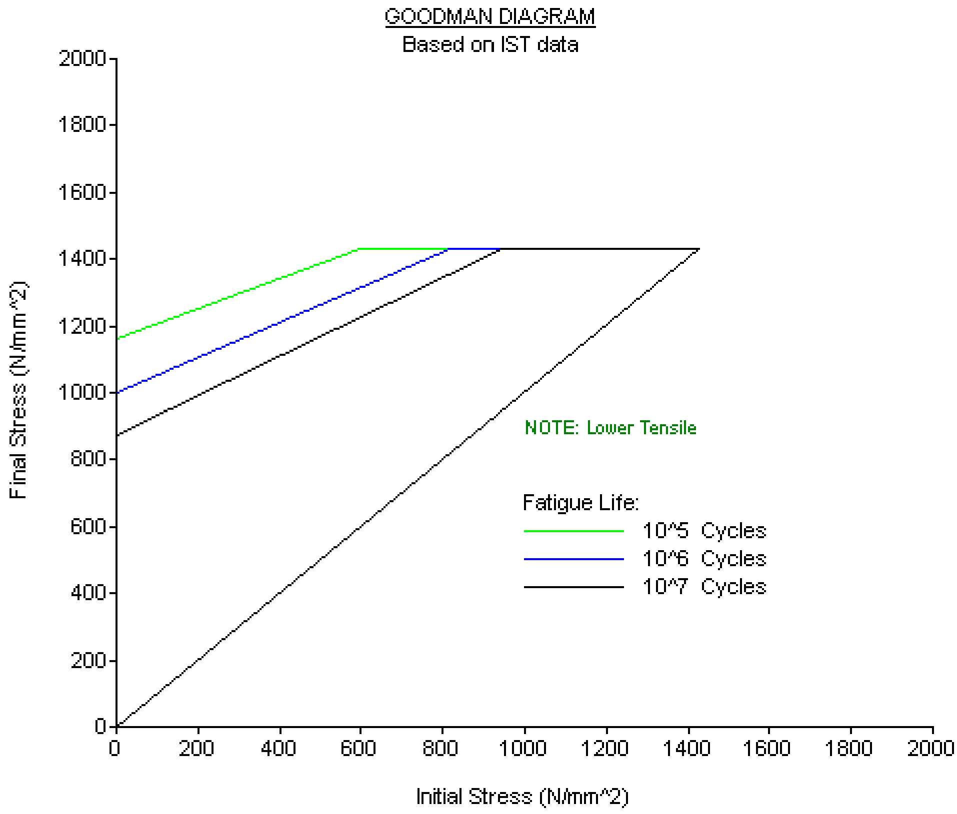
As a result of the above testing the following data has been agreed and incorporated into the Tech-Spring toolkit 3:-

Material name: High strength Si Cr (Tech-Spring)

Size Range 2.5 – 5 mm diameter

Tensile Range: 2100 – 2300 N/mm²

Goodman Diagram:




## Conclusions

1) The higher strength enables higher stressed spring designs, and yet the wire still has sufficient ductility for spring manufacturers.

2) The fatigue performance achieved by the Pengg silicon chrome wire compression springs exceeds that which would currently be predicted based on IST data.

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