STRESS ANALYSIS FOR COLD FORMED SPRINGS
SPANNUNGSANALYSEMETHODEN FÜR KALTGEFORMTEN FEDERN

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ZUSAMMENFASSUNG: Dieses Manuskript bescheibt die Vorteile von die folgenden Spannungsanalysemethoden für Kaltgeformte Federn.
Finite – Elemente – Methode
Multi – Koerper Systeme
Benutzung von Dehnungsmeßgeräte
Eigenspannungsanalysen
Benutzung von eine Hochgeschwindigkeit Kamera
Benutzung von CAD Programme
Es wird gezeigt, dass die letzte dieser Methoden werden technisch und wirtschaftlich sehr viel Nutzen für die Federn-Hersteller. Die angemessene Interpretation der Ergebnisse von den anderen Methoden werden gezeigt.

ABSTRACT: The relative merits of the following stress analysis methods will be described so as to inform spring manufacturers when each gives reliable and useful information should be used.
Finite Element Analysis
MKS
Strain Gauging
Residual Stress Analysis
High Speed Camera Filming
Advanced spring CAD Programs
It will be shown that the last of these methods will be technically and commercially of much benefit to spring manufacturers. The appropriate interpretation of results from the other methods will be revealed.

KEYWORDS: Finite Element Analysis, MKS, Strain Gauging, Residual Stress Analysis, High Speed Camera Filming, Advanced Spring CAD Programs, Techspring, Stress Analysis Methods, Boundary Conditions, www.spring-tech.eu, Cold Formed Springs, Residual Stress, Prestressing, Residual Compressive Stress.

1. INTRODUCTION

The European Collective Project, Techspring, has investigated a number of stress analysis methods for springs with a view to identifying when each provides good technical information about springs. Within the project the partners have studied Finite Element Analysis, MKS, Strain Gauging, Residual Stress Analysis, High Speed Filming, Advanced CAD Programs, and have come to a number of conclusions that would be of technical and commercial interest to spring manufacturers. Each method will be discussed here to clarify the benefits each bring.

A spring manufacturer's view of these technologies will depend upon how reliable results are from each method and on how to interpret them. The vast majority of springs in

Europe (and the rest of the world) are made by relatively small companies who seldom have expertise in stress analysis. Indeed the usual supply situation is:

A) Large Company X designs a widget for cleaning, washing, diving, sowing, digging, delivering, actuating,…….. and as the design evolves the space for the spring gets squeezed, and the spring is designed last.

B) Small springmakers A, B and C receive a drawing for a compression spring made from spring steel that has free length, rate and two working lengths, all toleranced, but no mention of function or performance requirements.

C) i) Springmaker A offers springs to drawing
ii) Springmaker B offers springs from spring wire to BS EN … with 2 of the 4 parameters toleranced
iii) Springmaker C offers springs from spring wire to BS EN …. With 2 of 4 parameters toleranced and requests information about relaxation, fatigue and corrosion requirements, together with assessment of the design in terms of stress analysis.

D) Buyer from Company X likes offer i) – cheaper, no hassle answering questions, and order is placed. The springs are supplied, but don't work properly, and much time is wasted correcting the malfunction, and even then long term reliability is not assured.

The evaluation of stress analysis methods is written with scenarios, such as the one described, in mind. Naturally, many springs are well designed, and it is the spring manufacturer's job to realise that design accurately and no design advice is required. However, successful springmakers contribute to the design process for the mutual benefit of themselves and their customers.

The stress analysis methods available are now discussed individually.

2. FINITE ELEMENT ANALYSIS

FEA has the potential to calculate applied stress accurately and to estimate residual stress profiles to arrive at the net stress operating in a spring. However, two further inputs are necessary for this analysis method to be accurate. The boundary conditions need to be defined accurately, and this isn't easy to accomplish for springs. In addition, the material property input has to be done with great care because the processes of stress relieving, shot peening and prestressing frequently affect the elastic limit. Hence the mechanical property input for the surface of the spring will need to be different from that below the surface. Few, if any, finite element analysts get all these parameters correct, and so this method nearly always gives an imprecise net stress. Despite this, the method should identify the position of maximum net stress correctly. So, the FE analyst arrives at the conclusion that this net stress range is 180-540 MPa at the position of maximum stress – what does this mean? Will the spring be safe, will it work? Other data resources are required to answer these questions.

The Techspring Project acknowledges that FEA is the only method for non-axially symmetric springs, and those subjected to both torsional and bending stresses, when classical mechanical formulae have not been rigorously devised. However, where classical mechanical formulae are available, build them into a CAD program and use that in preference. A design can be analysed in several hours / days using FEA, or a few minutes using a CAD program –

and this latter is likely to give the more accurate and practically useful answer.

Spring manufacturers need to be able to understand FEA results produced by their customers. The Techspring project has provided examples to help this process with examples where FEA gave both believable and unbelievable results.

3. MKS

MKS is a stress analysis method for determining dynamic stresses and resonance risk. It has been used successfully for engine valve springs driven by a cam. The Techspring Project used MKS for regular compression springs that were sinusoidally loaded. Its answers were incomplete, and so Techspring partners identified that using a strain gauge would identify the resonant frequencies of a spring accurately. A high speed camera was used to confirm this and to quantify the additional stresses at resonance – see www.spring-tech.eu for a film of this. Furthermore, magnetic sensors have been used successfully to determine axial and transverse resonance. MKS is useful under clearly defined conditions, but not for the general case of most springs – there are better ways that will be much more easily understood by springmakers.

4. STRAIN GAUGING

The use of strain gauges is a method within the scope of the understanding of most spring manufacturers. Gauges may be stuck to springs of section > 3mm for the determination of applied stresses. If applied at the correct orientation at the position of maximum stress, the results obtained are accurate and repeatable, and confirm the stresses calculated by CAD programs. This method is not suitable for very small springs, and only gives results of the stress applied with no information about residual stress.

5. RESIDUAL STRESS ANALYSIS

Residual stresses can measured by drilling a hole in the middle of a rosette of strain gauges in large springs like leaf springs, but for smaller cold formed wire springs may be accomplished by means of X-Ray methods. Again, the method is not suitable for very small springs because of the doubly curved surfaces being analysed and the need to be able to collect sufficient diffracted X-Rays, but springs of 3mm wire were tested successfully. The method measures residual stresses at the inside surface of a spring and below that surface after electopolishing. It will quantify the magnitude, direction and depth of residual stresses after stress relief heat treatment, shot peening and prestressing.

The method is specified for engine valve springs to verify that the required residual stress from manufacture has been achieved, but is rarely required for other spring types. It is also used for research purposes, as in this project and on a sub-contract basis to help explain failure analysis results. It is too expensive for use on less demanding spring applications, or for springmaker’s shot peening process control.

An example of its use within the Techspring Project was in the measurement of residual stress due to prestressing- such results had not previously been published. A typical result being shown in Figure 1, which shows the way the wire has been permanently twisted during prestressing (1).

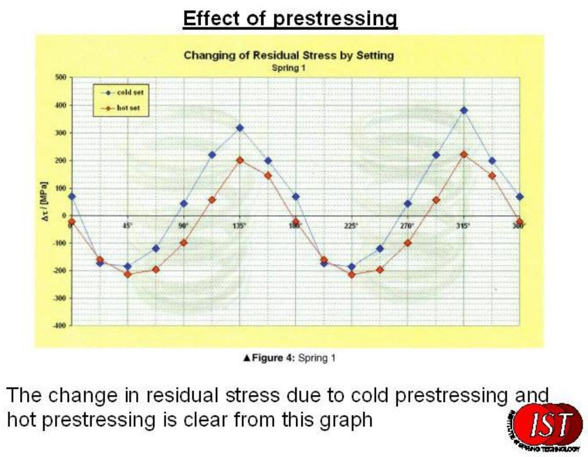

Figure 1: Measurement of Residual Stress due to Prestressing.

It was identified that the residual compressive stress arising from the prestressing process in a compression spring is about 25-33% of that due to shot peening. It follows logically then that the benefit to fatigue performance would be 25-30% of that due to shot peening – and that is exactly what was concluded within Techspring..

6. HIGH SPEED FILMING

Making amovie of the motion of springs was applied successfully in the project. Often springs move too quickly to see their deflection exactly, but filmed at normal speed with a high speed camera, it was easy to slow the film down and to observe the precise movement. This was used for springs in service, springs on test and springs in manufacture. The cameras are expensive to buy, but may be hired, and good lighting is required, but they can be set up witin minutes if there is a line of sight to the spring. This technology will help the spring industry to explain problems that arise with springs.

7. ADVANCED CAD PROGRAMS

CAD programs utilise classical mechanics formulae. Many of these were thoroughly tested within Techspring. It was found that the formulae used to calculate stress in international spring standards are accurate. The only type of spring that for which the accepted formulae were found to be in doubt was for dynamically loaded torsion springs. For these no curvature correction factor was required. In all other respects CAD programs give an accurate calculation of stress even for non-standard shaped compression springs.

When coupled with a good database of relaxation and fatigue performance, very useful data is obtained quickly and easily, which will be readily understood by small spring manufacturing companies. The programs commercially available in Europe work for all springs that are axially symmetric (2). To one of these programs the Techspring Project has added data – three typical examples being: for the effect of prestressing on compression springs; for the fatigue of extension spring hooks (Figure 2); for the effect of leg type on torsion springs fatigue. Each of these results will be published at the end of the Techspring project in www.spring-tech.eu at the end of 2009 (3).

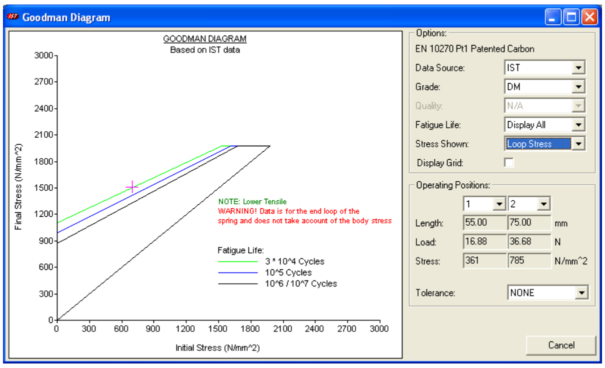

Figure 2: Fatigue Extension Spring Hooks

8. CONCLUSION

The relative merits of the stress analysis methods available to spring manufacturers have been described. Use of CAD programs is likely to be the first resort of all spring manufacturers, who will be very well served by the data provided, especially if their functionality and data resources are continually improved. The other methods all have their place, but will be used significantly less often.

WORD OF THANKS

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