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Analysis of Axially Symmetric Non-Standard Compression Springs

INTRODUCTION

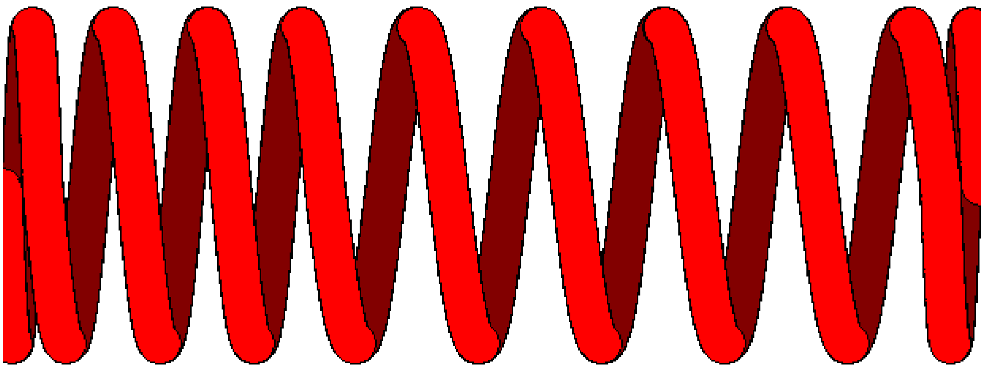
Lowest possible weight, maximum volumetric efficiency, and load-deflection characteristic for maximum functionality will be the objectives of a designer of compression springs today. This applies whether the spring is used in a car, train, boat, plane, washing machine or whatever. Downsizing for environmental, fuel efficiency, competitiveness or other worthy cause has to be within the scope of the designer.

In former times it was sufficient that compression springs be designed to store energy within a given space envelope. EN 13906-1 provides the formulae to enable constant pitch parallel sided compression springs to be designed. The formulae are based upon classical mechanics and contain some known approximations. The dominant discrepancy between theory and practice is always the estimation of the number of active coils, making other approximations irrelevant.

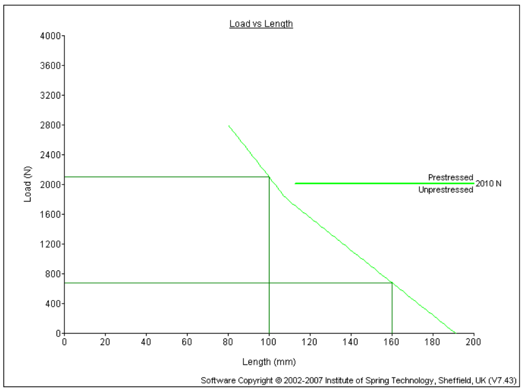
To design a compression spring with one or two sudden changes of pitch is possible using the same formulae and some intelligence. However, if the wire diameter, outside diameter or pitch changes along the spring, how then do you design or check such a spring? Until recently, the only answer was – 'Use Finite Element Analysis (FEA)'. Now there are CAD programs available, still based upon classical mechanics, that will design such springs providing that the spring is axially symmetric, and do so in minutes rather than the hours or days required for FEA. Such programs come with spring performance data, always absent from FEA programs.

VARIABLE PITCH SPRINGS

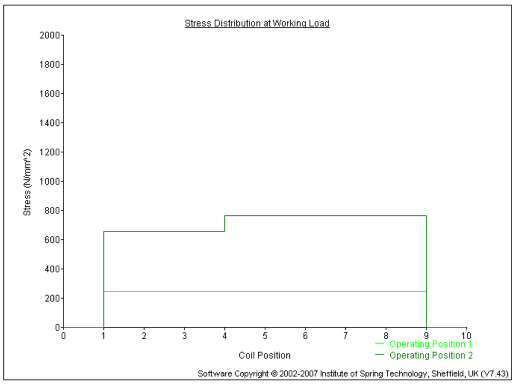
Motor cycle suspension springs are of this type, having two distinct pitches giving a low rate to improve comfort as one sits, and a higher rate to improve handling at speed. Such a spring might look like this on a CAD program



Spring with a smaller pitch in the first four coils on the left.

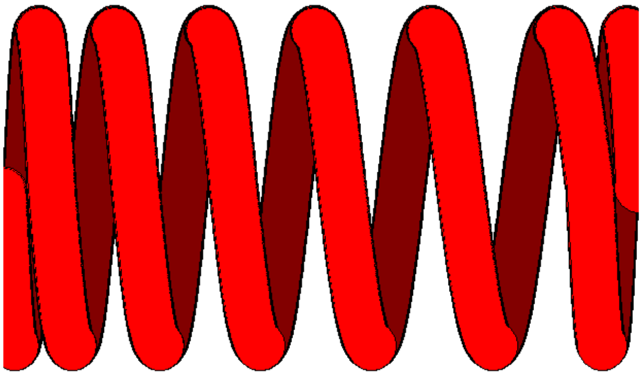


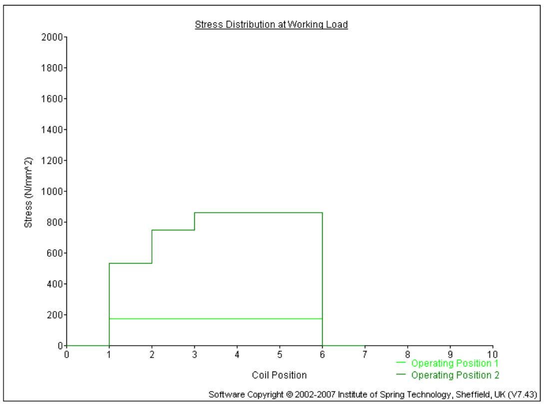
Load – deflection characteristic



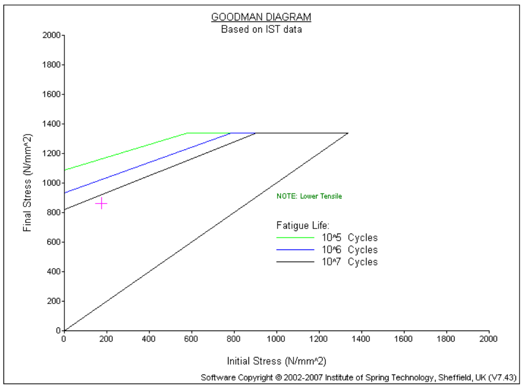
Stress distribution at two lengths

Some engine valve springs are of this type too, except that they have progressively changing pitch





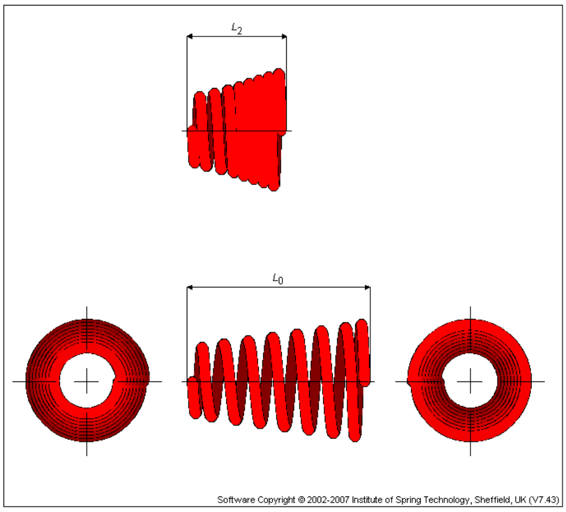
Stress distribution at position 1 (light green) and at position 2 (darker green)



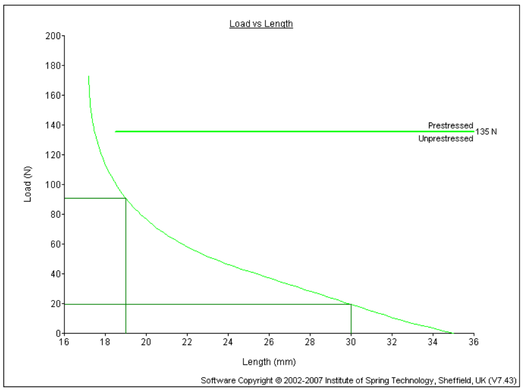
Goodman diagram that shows spring will survive >10 million cycles if peened and prestressed

VARIABLE OUTSIDE DIAMETER

Conical springs are one example. The classical mechanics formulae for these are well known, although not published in spring design standards. This type of spring is more difficult to calculate both in terms of rate and stress because the coils contact each other progressively.

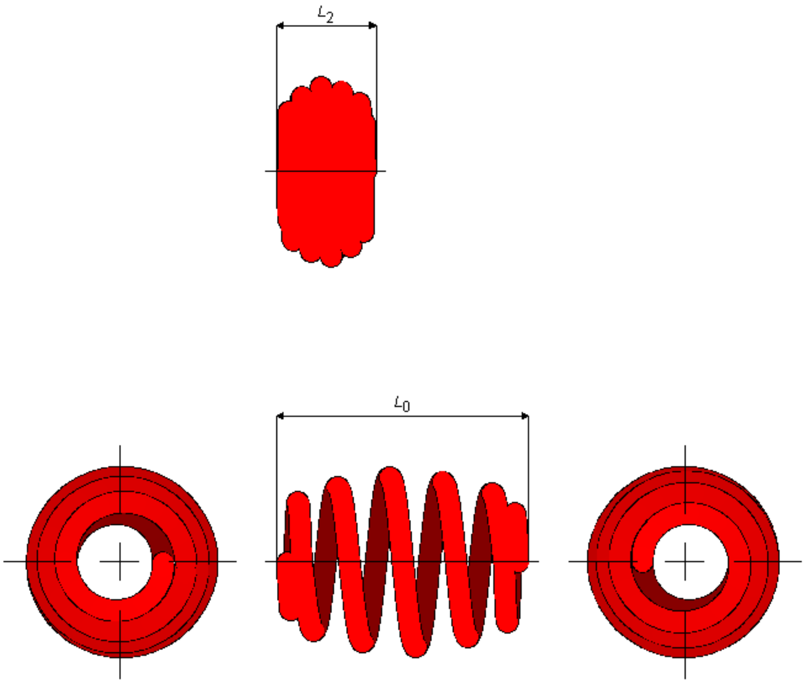


Drawing at free length and at position 2



Load – deflection curve

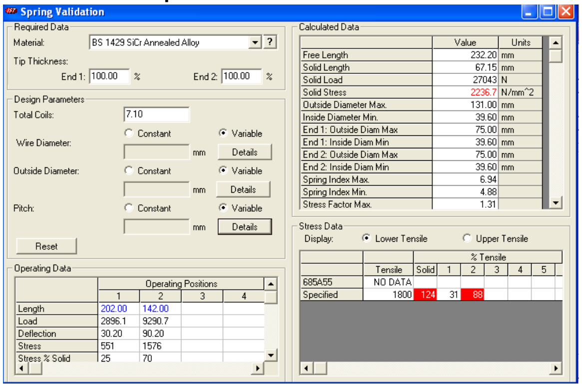
Barrel shaped springs, such as brake springs, present one further degree of difficulty in that these might close such that the end coil tucks inside the first active coil leaving a very short block length. These also have variable pitch.



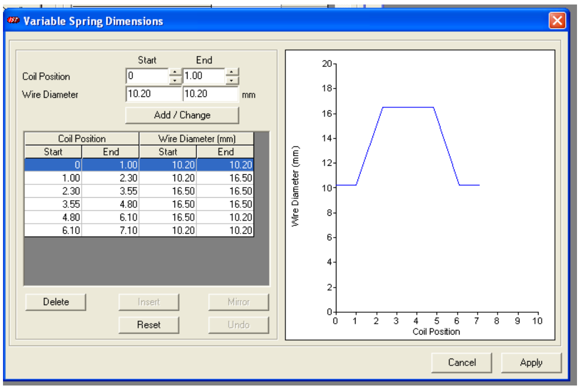
VARIABLE WIRE DIAMETER

One would only resort to machining the wire before coiling in order to attain a particular rate and stress characteristic, usually without coils contacting each other, as happens in mini-bloc suspension springs. In these springs the wire diameter is variable, as is the pitch and outside diameter. Algorithms have been worked out so that even springs with this degree of complexity can be calculated.

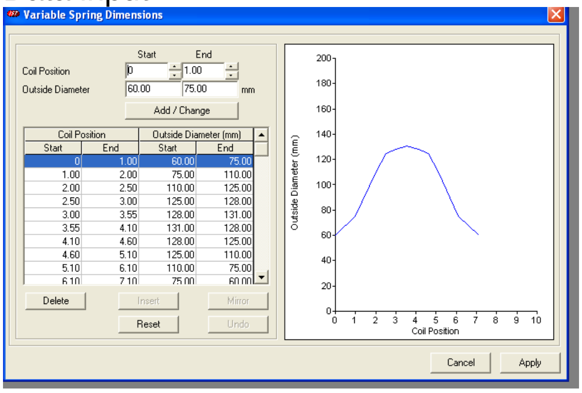
The data input looks like this



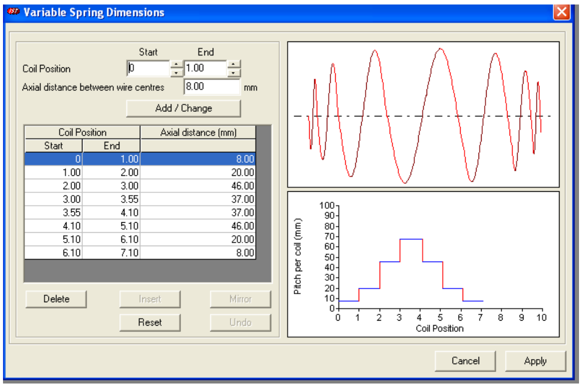
Data input



Wire diameter

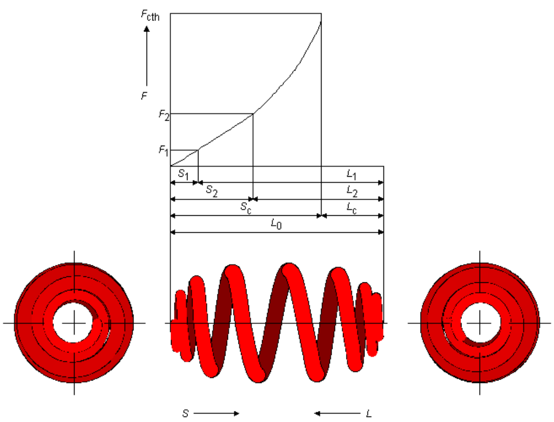


Outside diameter

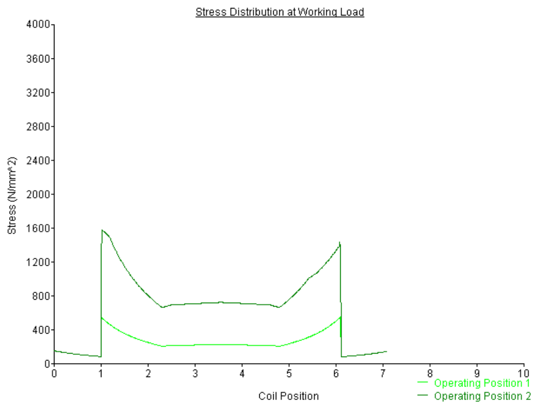


Pitch

Resulting in



Drawing with load/ deflection curve



Stress distribution in coils

To see this spring animated you will have to watch my presentation, but this is a real suspension spring that failed by stress corrosion cracking at 1.1 – 1.2 coils from the lower end where the software indicated that the stress was a maximum.

CONCLUSION

The possibilities to increase the scope for use of CAD programs based upon classical mechanics has been described. There is still a need to use Finite Element Analysis for compression springs that are not axially symmetric, but most springs are manufactured by small companies who are unlikely to have expertise in FEA, but could use the type of analysis shown here to ensure that the stresses in the non standard springs that they manufacture are within acceptable limits.

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