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STRESS EQUALIZED COIL SPRING

Filed May 18, 1959

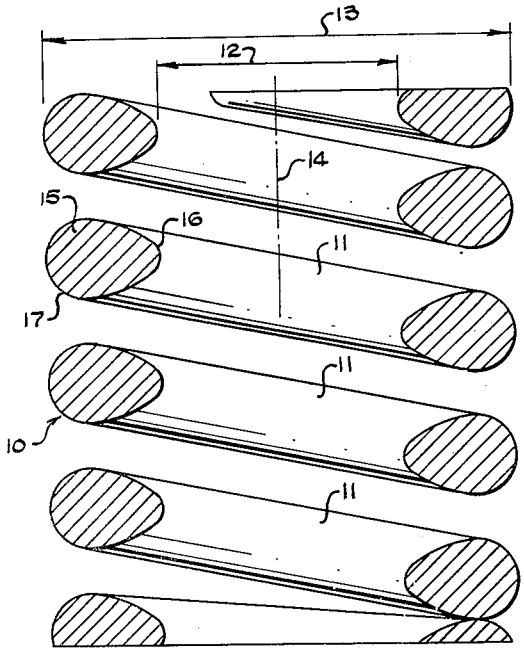


Fig. 1

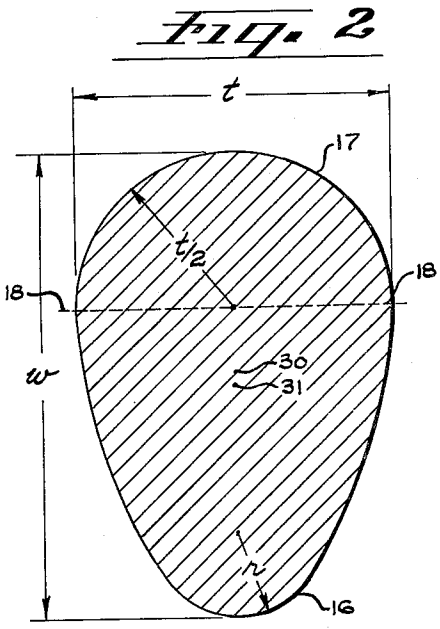


Fig. 2

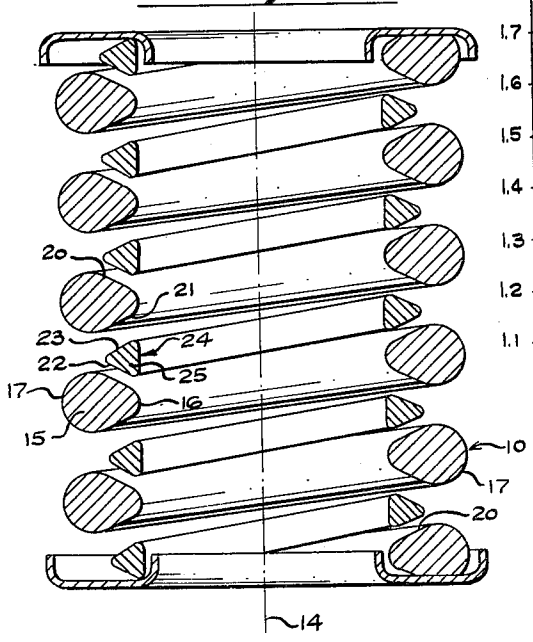


Fig. 3

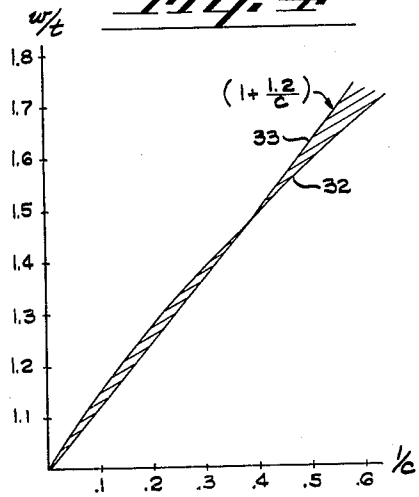


Fig. 4

JOHN G. SCHWARZBECK
HENRY O. FUCHS
INVENTORS

BY White & Haefliger

ATTORNEYS

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STRESS EQUALIZED COIL SPRING

John G. Schwarzbeck, 2610 Illinois Ave., South Gate, Calif., and Henry O. Fuchs, 2323 Pinecrest Drive, Altadena, Calif.

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This invention relates generally to improvements in coil springs, and more particularly concerns the provision of a coil spring having a novel turn cross section giving the spring improved performance in terms of load and deflection capacity, or alternatively permitting savings in space and weight.

Normally, coil springs having circular cross sections have their efficiency curtailed by stress peaks on parts of the surface of the coil turn during coil deflection. For example, at the inside of the coil the direct shearing stresses add to the torsional stresses and the shorter fibers at the inside of the coil are twisted through the same angle as the longer fibers at the outside of the turn. Both these factors produce higher total stresses than exist at the outside of the coil. For a round wire, the increased stress at the inside of the turn is approximately $1.6/c$ times the average surface stress, where c is the spring index equal to the mean coil diameter divided by the wire diameter. For a spring index of 5, there exists about 30% greater peak stress at the inside of the coil turn, over and above the average surface stress. Since the spring efficiency is proportional to the square of the permissible stress, the efficiency of such a spring in fatigue loading, where the maximum stress range is the determining factor, is only 60% of the efficiency of the same spring in static loading where the average stress is the determining factor.

The present invention has for its major object the provision of a coil spring having turns the cross sections of which in axial radial planes are such that the highest stress is more nearly equal to the average stress in order that the problems and difficulties associated with coil springs having round cross section turns may be overcome. Accordingly, the invention contemplates a turn cross section characterized in that the section curvature presented inwardly toward the coil axis is substantially greater than the section curvature presented outwardly away from the coil axis, the difference between the inwardly and outwardly presented curvatures being such that the stresses produced on the surface of the coil during coil axial deflection are substantially equal from the point of greatest thickness to the inside of the coil. The centroid of the cross section is located towards the outside of the coil from the midpoint between the inner and outer sides of a turn cross section.

In conformance with this major object, the spring turn cross section outline is most desirably oval in shape, the section over-all width and length dimensions and the curvatures at the inside and outside of the turn being optimally related by mathematical expressions which will be later set forth. The section oval outline may typically comprise a half circle and a half ellipse substantially tangent to the half circle, the latter being convex in a direction away from the coil axis and the half ellipse being convex toward the coil axis.

As a result of these considerations the spring is made more efficient. This means that more elastic energy can be stored in the same space, that less weight of spring is required to absorb or store a given amount of energy, and that for equal performance in terms of load capacity, stresses and deflections, the spring will have a higher resonant frequency and be less subject to flutter than is characteristic of a coil spring having circular cross section turns. For equal performance in terms of load and deflection capacity, the spring may take up less space, weigh less, have a higher resonant frequency, and at the same time have less maximum stress than a coil spring having circular cross sectional turns.

The same type of cross section, with a greater ratio of width to thickness, can also serve to store more spring energy in a small space, thereby increasing the space efficiency as well as the weight efficiency of such springs.

The invention is also concerned with the provision of an additional or auxiliary coil spring, the turns of which extend within the spaces between the first or larger coil turns, for engagement therewith during axial compression of the first coil. Thus, the second or smaller spring turns fit loosely into the spaces between the typically flat sides of the egg shaped turns of the larger spring, without requiring any additional space. Such an auxiliary or bumper spring frictionally engages the turns of the larger coil that move together when the coil is compressed. Being more flexible, the auxiliary or smaller spring will then contract as a whole and its coils will also bend to a slightly smaller radius, fractionally increasing the number of coils of the auxiliary spring. Such a bumper spring is useful in applications where it is desired to reduce or eliminate surging of the larger spring, the sliding contact of the two springs resulting in surge energy absorption by friction. Also, the smaller spring limits the stroke of the main spring, thus providing a margin between pre-setting load and maximum service load.

When an auxiliary spring is so used, it is desirable to keep the sides of the oval shaped main spring cross section flattened instead of convex, thereby decreasing the bearing stress between the main spring and the auxiliary spring. The latter typically has a triangular cross section with rounded corners, the cross section being considerably smaller than the turn cross section of the main spring. Consequently, the auxiliary spring carries relatively little load and is subject to relatively low stress until it is contacted by the flattened surfaces of the main spring turns.

These and other objects and advantages of the present invention, as well as the details of an illustrative embodiment, will be more fully understood from the following detailed description of the drawings, in which:

FIG. 1 is an axial cross section through a coil spring having oval turn cross sectional shape;

FIG. 2 is an enlarged view of the oval cross section characteristic of the spring turns;

FIG. 3 is an axial section taken through the combination of the main spring having oval turn cross sections with an auxiliary spring having triangular spring cross sections; and

FIG. 4 is a graph which will be described.

In FIG. 1 the coil spring designated generally at **10** has turns indicated at **11**, the inner and outer diameters of which are shown at **12** and **13**. The axis of the spring coil is shown at **14** and the turn cross sections **15** are seen to be oval shaped, with the section curvature **16** presented inwardly toward axis **14** being greater than the section curvature **17** presented outwardly away from axis **14**. As mentioned in the introduction the difference between the inwardly and outwardly presented curvatures is such that the stresses produced during coil axial deflection are substantially equal on the curved surface **16** and at the points **18** as seen in FIG. 2, defined as the points between which the overall thickness dimension "t" of the section is measured.

Typically, and in reference to FIG. 2, the oval section over-all length and width dimensions are approximately related to the coil inner and outer diameters by the expression:

$$\frac{w}{t}=1+\frac{1.2}{c}$$

where

w=the over-all length of the section in a radial direction normal to the coil axis

t=the over-all width thickness of the section in a direction parallel to the coil axis

$$c=\frac{Do+Di}{2w}$$

Do=outer diameter of coil
Di=inner diameter of coil

As is shown in FIG. 2, the length and width dimensions are indicated by the letters "w" and "t" associated with the dimensional arrows. The exact relationship between w/t and $1/c$ is shown by the curve **32** in FIG. 4, the line **33** being a plot of the relationship between w/t and

$$1+\frac{1.2}{c}$$

The shaded area between curve **32** and line **33** indicates the small error between the exact relationship of w/t to c as indicated by curve **32** and the approximate relationship of w/t to c as indicated by line **33**.

The above expression interrelating the length and width dimensions of the oval may be further related to radii of curvature at the inwardly and outwardly presented sides of the oval section through the expression:

$$\frac{t}{2r}-1=2\left(\frac{w}{t}-1\right)$$

where

$$\frac{t}{2r}-1$$

defines the "egginess" of the oval section **15**.

The letter r designates the radius of curvature at the small end of the oval, and "t" and "w" refer to the over-all width and length dimensions of the oval as before. Accordingly, when these dimensions are interrelated as given by these expressions, the cross section shape is optimized for stress equalization. In FIG. 2, the cross section has radial curvature at the large end of the oval, the radius being equal to

$$\frac{t}{2}$$

Typically, the section oval outline may comprise a half circle at the large end of the oval, together with a half ellipse substantially tangent to the half circle at points **18** between which the dimension "t" is measured. Thus it is clear that the half ellipse has a minor axis the ends of which are at points **18**, and a major axis normal to the coil axis. The centroid **30** of the cross section is located toward the outside of the coil from the mid-point **31** between the inner and outer sides of the cross section.

The particular cross section shown in FIG. 2 is characterized by the following expression:

$$t=.6 \qquad r=.15 \qquad w=.9$$

Elongation:

$$\frac{w}{t}-1=\frac{.9}{.6}-1=.5$$

"Egginess"

$$\frac{t}{2r}-1=\frac{.6}{.3}-1=1$$

Referring to FIG. 3, the larger spring **10** is the same as discussed in connection with FIGS. 1 and 2 with the exception that the coil turns have spaced apart upper and lower flat sides indicated at **20** and **21**. These sides are adapted to move toward and engage the lower and upper flat sides **22** and **23** of a smaller coil spring generally indicated at **24**, the turns **25** of which extend within the spaces between the larger coil turns **15**, for interengagement therewith during axial compression of the larger coil. As shown, the flat sides **21** and **23** are substantially parallel and also the flat sides **20** and **22** are substantially parallel, and extend at substantial acute angles to radii from the coil axis **14**.

The smaller spring has a triangular cross section with rounded corners, and it carries relatively little loading and is subject to relatively low stress until contacted by the flat surfaces **20** and **21** of the large spring. The latter will try to push the smaller spring inward whereas the smaller spring will try to push the main spring outward. Since the auxiliary spring is the more flexible, the pushing will produce relatively little increased deflection and stress in the main or larger spring, which is already stressed highly in torsion, but such pushing will produce relatively higher stress in the smaller spring which is only slightly stressed in torsion. The stresses produced by the mutual pushing are tension and compression.

To comply with the pushing action, the smaller spring will contract as a whole, and its turns will also bend to a smaller radius which will increase fractionally the number of turns in the smaller spring. The compression involves radial sliding, and the bending involves both radial and helical sliding between the two contacting faces in such sliding. Energy is absorbed by friction so that flexure or surging of the larger spring is eliminated frictionally by energy absorption.

We claim:

1. An improved coil spring the turns of which have oval cross-sections in axial radial planes and characterized in that the section curvature presented inwardly toward the coil axis has substantially the outline shape of half an ellipse bisected by the ellipse minor axis and the major axis of which extends substantially normal to the coil axis, the section curvature presented outwardly away from the coil axis having substantially the outline shape of a half-circle the diametrically opposite sides of which extend substantially tangent to the opposite sides of said half elliptical section curvature.

2. The invention as defined in claim 1, including a second and coaxial coil spring the turns of which extend within the spaces between the first mentioned coil turns for interengagement therewith during axial compression of the first mentioned coil.

3. The invention as defined in claim 1 wherein the section over-all length and width dimensions, the curvature at the inside of the turn, and the spring index "c" are approximately related by the expressions:

$$\frac{w}{t}=1+\frac{1.2}{c}$$

and

$$\frac{t}{2r}-1=2\left(\frac{w}{t}-1\right)$$

where

w=the over-all length of the section in a radial direction normal to the coil axis

t=the over-all thickness of the section in a direction parallel to the coil axis

r=the radius of curvature at the inside of the turn section and in an axial radial plane

$$c=\frac{Do+Di}{2w}$$

Do=outer diameter of coil
Di=inner diameter of coil.

4. The invention as defined in claim 2 in which the first and second coil turns have interengageable and spaced apart flats.

5. The invention as defined in claim 4 in which the second coil turns have triangular cross sections in axial radial planes.

6. The invention as defined in claim 5 in which said triangular cross sections have rounded corners and a flat side of the triangular section is presented toward the first coil axis.

7. The invention as defined in claim 5 in which the inside diameter of the second coil spring turns is at least as large as the inside diameter of the first coil spring turns.

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