# REDESIGN OF HELICAL COIL SPRING BY SPLINE SPRING

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## ABSTRACT

The objective of this research is to produce a new design of spring called as Spline Springs (Flat Wire Compression Springs) offer the unique advantage of space savings when used to replace coil springs. By reducing spring operating height, spline springs also produce a decrease in the spring cavity. With a smaller assembly size and less material used in the manufacturing process, a cost savings is realized. Spline springs operate as load bearing devices. They take up play and compensate for dimensional variations within assemblies. A virtually unlimited range of forces can be produced whereby loads build either gradually or abruptly to reach a predetermined working height. This establishes a precise spring rate in which load is proportional to deflection. Functional requirements are necessary for both dynamic and static spring applications. Special performance characteristics are individually built into each spring to satisfy a variety of precise operating conditions. Typically, a spline spring will occupy an extremely small area for the amount of work it performs. The use of this product is demanded, but not limited to tight axial and radial space constraints.

**Keywords:** Space savings,Reducing spring, operating height, cost savings.

## I. INTRODUCTION

A spline spring is a multiple annularly would spring comprises a spline portion in which peaks and troughs are alternatively formed in a windings peripheral direction and a ring like mounting portion is formed in the winding peripheral direction, with an inner or outer peripheral of the mounting portion being mounted upon engaging with an outer periphery or an inner periphery of an member to be mounted, wherein the outer periphery or the inner periphery of the mounting portion is provided with an engaging urging portion which engagement through elastic contact with respect to a radial direction.

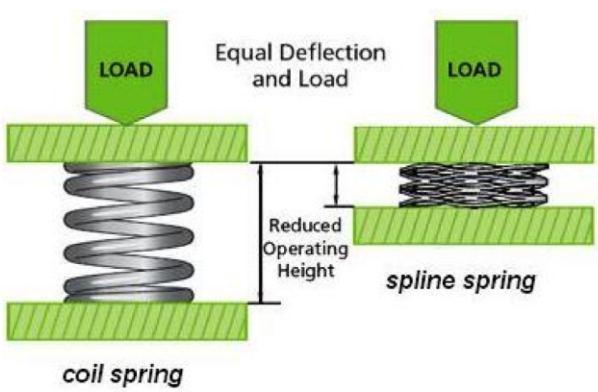


Fig. 1. Coil and Spline Springs at Loading Condition

### A. *Why we should use Spline Spring*

- Compact design reduces spline spring cavity by 50% with equal deflection and force as coil springs.
- No Tooling Charges for specially designed spline springs.
- Edge-wound spline springs have a circumferential grain structure that provides exceptional strength and dimensional stability.

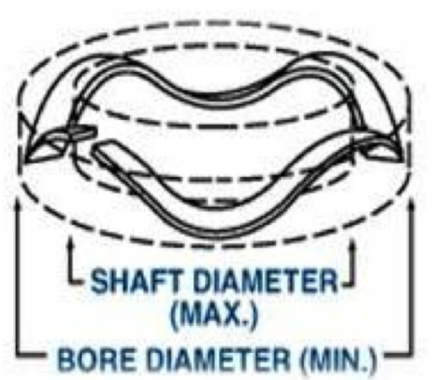


Fig. 2. Single Spline Coil

## II. WORKING PRINCIPLE OF SPRINGS

### *A. Hooke's law*

As long as they are not stretched or compressed beyond their elastic limit, most springs obey Hooke's law, which states that the force with which the spring pushes back is linearly proportional to the distance from its equilibrium length.

$$F = -kx \quad \text{... [1]}$$

where

- $X$ is the displacement vector – the distance and direction in which the spring is deformed
- $F$ is the resulting force vector – the magnitude and direction of the restoring force the spring exerts
- $K$ is the rate, spring constant or force constant of the spring, a constant that depends on the spring's material and construction.

In classical physics, a spring can be seen as a device that stores potential energy, specifically elastic potential energy, by straining the bonds between the atoms of an elastic material.

Hooke's law of elasticity states that the extension of an elastic rod (its distended length minus its relaxed length) is linearly proportional to its tension, the force used to stretch it. Similarly, the contraction (negative extension) is proportional to the compression (negative tension).

This law actually holds only approximately, and only when the deformation (extension or contraction) is small compared to the rod's overall length. For deformations beyond the elastic limit, atomic bonds get broken or rearranged, and a spring may snap, buckle or permanently deform. Many materials have no clearly defined elastic limit, and Hooke's law can not be meaningfully applied to these materials. Moreover, for the superelastic materials, the linear relationship between force and displacement is appropriate only in the low-strain region.

Hooke's law is a mathematical consequence of the fact that the potential energy of the rod is a minimum when it has its relaxed length. Any smooth function of one variable approximates a quadratic function when examined near enough to its minimum point; and therefore the force — which is the derivative of energy with respect to displacement — will approximate a linear function.

### *B. How to Choose a Spline Spring*

There are 6 critical factors when considering a spline spring:

- The constraints of the application: Pilot bore/ shaft, ID/OD, etc.
- The load (force).
- The working height at which the load is applied.
- The material desired.
- Whether it's dynamic or static.
- Number of splines.

#### *a. STATIC:*

This type of application implies that a spring never really moves once it is installed. This type of spring generally holds a load at a given height for the life of the assembly - There is no cycling of the part.

#### *b. DYNAMIC:*

This type of application indicates that a spring will constantly be moving up and down until the end of its life. This type of spline spring has 2 working heights and hence, 2 loads. Fatigue is critical in this type of spring. Generally, the higher the cycle life, the stronger the spring needs to be.

## III. SPRING DESIGN

### *A. Load Requirement*

The load requirement is defined by the amount of axial force the spring must produce when installed at its work height. Some applications require multiple working heights, where loads at 2 or more operating heights are critical and must be considered in the design. Often minimum and/or maximum loads are satisfactory solutions, particularly where tolerance stack-ups are inherent in the application.

### *B. Operating Environment*

High temperature, dynamic loading (fatigue), a corrosive media or other unusual operating conditions must be considered in spring applications.Solutions to various environmental conditions typically require selection of the optimal raw material and operating stress.

*C. STRESS*

*a. Operating Stress*

Compressing a spline spring creates bending stresses similar to a simple beam in bending. These compressive and tensile stresses limit the amount a spring can be compressed before it yields or "takes a set". Although spring set is sometimes not acceptable, load and deflection requirements will often drive the design to accept some set or "relaxation" over time.

*b. Maximum Design Stress*

**Static Applications:** Spline Spring utilizes the Minimum Tensile Strength found in this catalog's Materials section to approximate yield strength due to the minimal elongation of the hardened flat wire. When designing springs for static applications we recommend the calculated operating stress be no greater than 100% of the minimum tensile strength. However, depending on certain applications, operating stress can exceed the minimum tensile strength with allowances for yield strength. Typical factors to consider are permanent set, relaxation, loss of load and/or loss of free height.

**Dynamic Applications:** When designing spline springs for dynamic applications, calculation of operating stress not exceed 80% of the minimum tensile strength.

**Residual Stress/Pre-Setting**

Increasing the load capacity and/or fatigue life can be achieved by compressing a spring beyond its yield point or "presetting". Preset springs are manufactured to a higher than needed free height and load and then compressed solid. Both the free height and load are reduced and the material surfaces now exhibit residual stresses, which enhance spring performance.Spline springs are pre-stacked in series, decreasing the spring rate by a factor related to the number of turns.

## IV. DESIGN CALCULATIONS

*A. Calculation of Deflection*

- Deflection $= f = \frac{PKDm\hat{\ }32}{Ebt\hat{\ }3N\hat{\ }4} \times \frac{ID}{OD}$ ... [2]

*B. Calculation of Operating Stress*

- Operating Stress $= S = \frac{3\pi PDm}{4bt\hat{\ }2N\hat{\ }2}$ ... [3]

Note: $N$ must be in ½ spline increments.

$Z =$ Number of active turns.

*C. Calculation Of Free Height*

- Free Height $= \boldsymbol{H} = (\boldsymbol{W.H.} + \boldsymbol{f})$ .... [4]

Nomenclature

$b$ - Radial Width of Material, in $[(O.D. - I.D.)2]$

$Dm$ - Mean Diameter, in $[(O.D. + I.D.)2]$

$E$ - Modulus of Elasticity, psi

$f$ - Deflection,

$H$ - Free height,

$I.D.$ - Inside Diameter,

$K$ - Multiple Spline Factor,

$L$ - Length, Overall Linear,

$N$ - Number of Splines (per turn)

$O.D.$ - Outside Diameter,

$P$ - Load, lb

$S$ - Operating Stress, psi

$t$ - Thickness of Material,

$WH$ - Work Height, in $(H - f)$

$Z$ - Number of Turns.

*D. Fatigue Stress Ratio,* $\boldsymbol{X} = (\sigma - \boldsymbol{S1}) \div (\sigma - \boldsymbol{S2})$ ... [5]

Where,

$\sigma =$ Material tensile strength.

$S1 =$ Calculated operating stress at lower work height (must be less than $\sigma$).

$S2 =$ Calculated operating stress at upper work height.

**Table 1 Fatique stress value**

| X | Estimated Cycle Life |
|---|---|
| < .40 | Under 30,000 |
| .40 - .49 | 30,000 – 50,000 |
| .50 - .55 | 50,000 – 75,000 |
| .56 - .60 | 75,000 – 100,000 |
| .61 - .67 | 100,000 – 200,000 |
| .68 - .70 | 200,000 – 1,000,000 |
| > .70 | Over 1,000,000 |

## V. CALCULATIONS

By taking the below mentioned values as an example,

$P =$ 34 lb, $Dm =$ 1.835 in, $t =$ .024 in, $N =$ 4, $b =$ .150 in, $E =$ 30 $\times$ 106 psi, $O.D =$ 1.985 in, $K =$ 3.88 $I.D. =$ 1.685 in, $WH =$ .093 in

**Deflection**, $f =$ (34)(3.88)(1.835) *hat* 3/(30 $\times$ 10 *hat* 6) (.150 ) (.024) ^ 3(4) *hat* 4 $\times$ 1.685/1.985. .... [6]

= 0.43 inches.

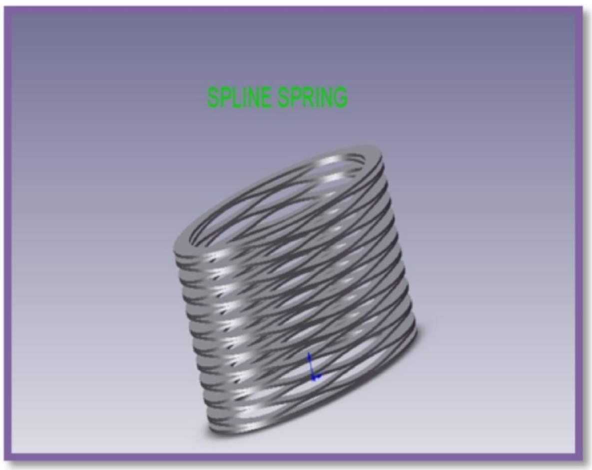


Fig. 3. CADD Model of Spline Spring

**Operating Stress**,

$S =$ (3) (*pi*) (34) (1.835) 4 (.150), 0.24^2 (4)^2 .... [7]

= 106,339 psi

**Free Height**, $H = (W.H. + f)$ .... [8]

$= 0.093 + 0.043$

$= 0.136$ inches

*Calculated free height may not be the same as the actual springs measure due to variations in raw material and manufacturing process.

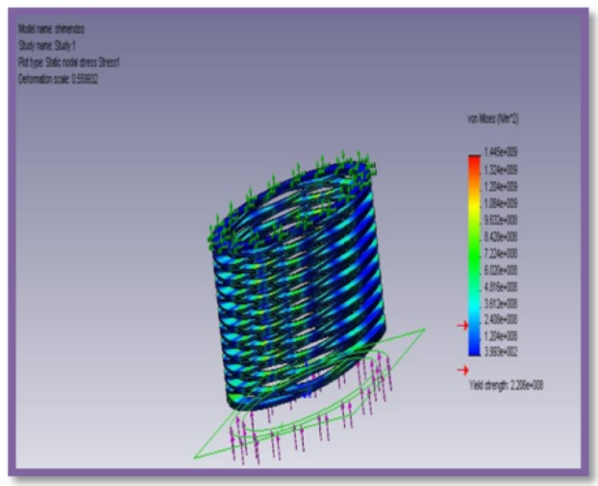

Fig. 4. Analysis of Spline Spring

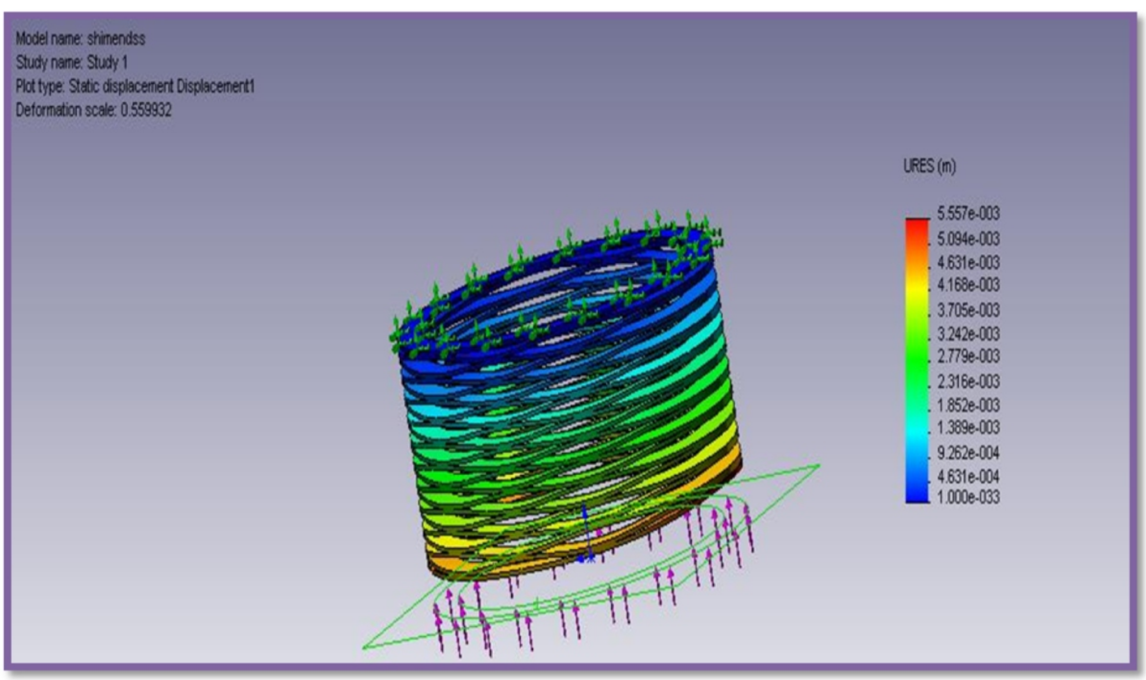


Fig. 5. Displacement Analysis

## VI. DIAMETER EXPANSION

Multiple Turn Spiral Splines expand in diameter when compressed. The formula shown below is used to predict the maximum fully compressed diameter.

Maximum outside diameter at 100% deflection (solid height) $= \mathbf{0.02222 \times R \times \theta + b}$ .... [9]

Where,

$R =$ Spline Radius $= (4Y2 + X2)\,8Y$ .... [10]

$N =$ Number of Splines

$\theta =$ Angle, degrees = ArcSin $(X2R)$ .... [11]

$b =$ Radial Wall

$X =$ ½ Spline Frequency $= Dm2N$ .... [12]

$Y =$ ½ Mean Free Height $= (H - t)\,2$, $H =$ Per Turn Free Height. .... [13]

## VII. ADVANTAGES OF SPLINE SPRING

- A spline spring is coiled flat wire with splines added to give it a spring effect.
- Spline springs are superior to coil springs in certain applications because they provide lower work heights with the same force.
- Spline springs can act as load bearing devices - compensating for accumulated tolerances in assemblies and providing end-play takeup.
- It has Smaller assemblies that use less materials.
- Space savings compared to coil spring.
- Lower production costs and also saves time.

## VIII. ACKNOWLEDGEMENT

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## IX. CONCLUSION

- Thus we had tried to produce a new design of spring by using cadd tools and also it worked well.
- This spring has various advantages and it could be used in many places where the coil spring is applied.
- We are sure that in future these type of spline springs would be used more than the other.

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