Helical Extension Springs

Extension springs must necessarily have some means of transferring the load from the support to the body of the spring, so one of the methods shown in figure 4.19 is usually employed. In designing the spring with a hook end, the stress concentration effect must be considered as failure, predominantly occurs here. Tests as well as analysis show that the stress-concentration factor is given approximately by which holds good for bending stress and occurs when the hook is off set, and for torsional stress.

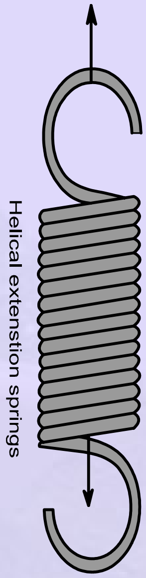

Figure 4.18

In designing the spring with a hook end, the stress concentration effect must be considered as failure, predominantly occurs here. Further as the spring elongates when loaded, no built in safety is available, as in coil compression springs and very often spring fails or loses its resilience when the extension exceeds a limit.

To mitigate this problem, the springs are initially wound with certain pre-stressing and consequently will have closed coils. The initial pre stress and the stress due to external loading should not exceed the permissible strength. The stress concentration effect further limits the useful load range for a given size. The stresses in the coils are found from the same formulas used for compression springs. However the standard hooks or loops have two locations of high stresses as shown in the figure below.

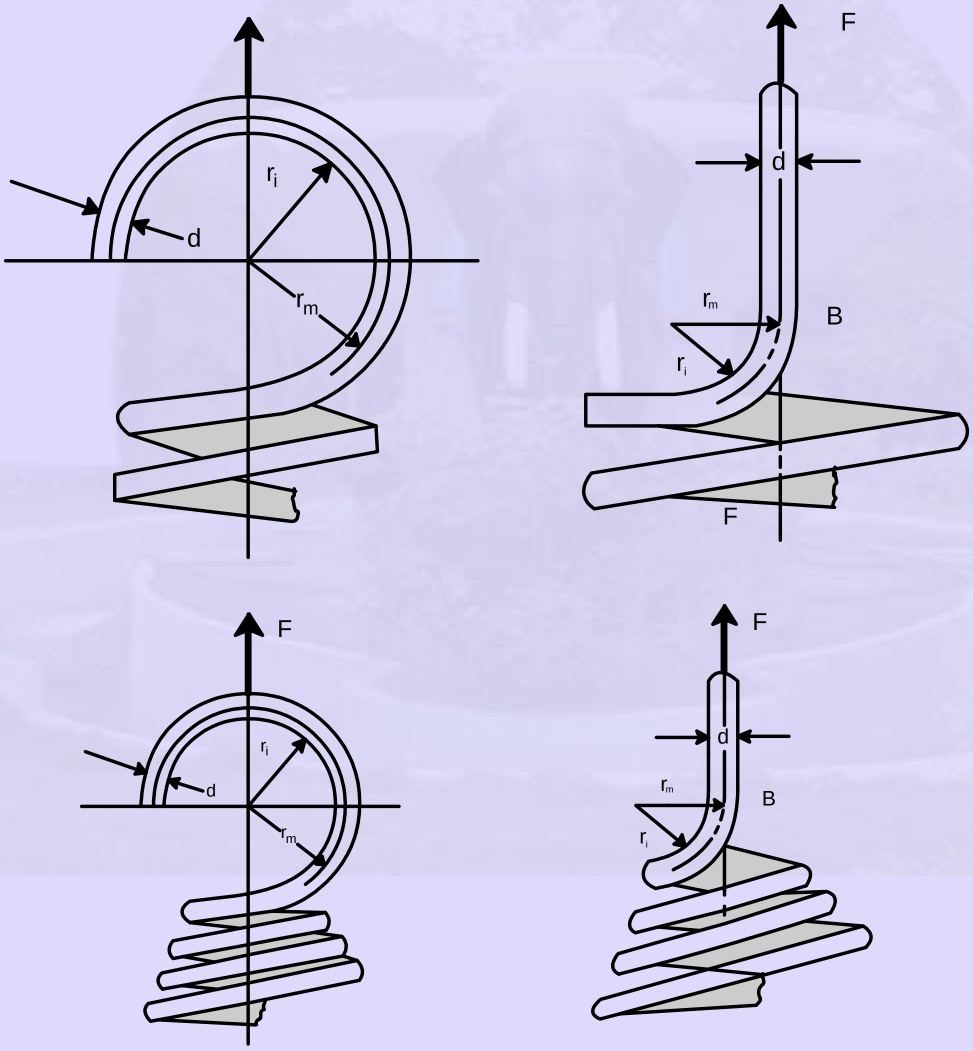

Figure 4.19

The maximum torsional stress occurs at point B where the bend radius is smallest.

There is also bending stress in the hook or loop at point A

$$\sigma_A = K_b \frac{16DF}{\pi d^3} + \frac{4F}{\pi d^2}$$

$$K_b = \frac{4C_1^2 - C_1 - 1}{4C_1\left(C_1 - 1\right)}$$

$$C_1 = \frac{2r_m}{d}$$

The torsional stress point B is

$$\tau_B = K_{w_2} \frac{8DF}{\pi d^3}$$

$$K_{w_2} = \frac{4C_2 - 1}{4C_2 - 4}$$

$$C_2 = \frac{2r_i}{d}$$

Tests as well as analysis show that the stress-concentration factor is given approximately by

$$K = \frac{r_m}{r_i}$$

The springs are designed such that the maximum stresses at these points are well below the permissible limits.

All coils in the body are considered to be active coils, but one is typically added to obtain the body length.

The free length is measured from the inside of one loop to the other end, and can be varied by changing the end configuration without changing the number of coils. While deciding the number of coils needed, the spring rate for a known magnitude of deflection is to be determined and number of active coils needed is calculated.

This is because the preload in the coils must be overcome to separate them as they are closely wound by pre stressing

i.e $$k = \frac{F - F_i}{y} = \frac{d^4 G}{8D^3 N_a}$$

Spring Materials

A great variety of spring materials are available to the designer, including plain carbon steels, alloy steels, and corrosion resisting steels, as well as non-ferrous materials such as phosphor bronze, spring brass, beryllium copper, and various nickel alloys.

Commonly used spring steel materials are listed in Table 4.1. For designing hot-worked, heavy coil springs as well as flat springs, leaf springs, and torsion bar springs. The UNS steels listed in Appendix should be used.

The materials and its processing, also, of course have an effect on tensile strength. It turns out that the graph of tensile strength versus wire diameter is almost a straight line for some materials when plotted on the log-log paper. Hence their tensile strength can be determined, writing the equation of this line as,

$$S_{ut} = \frac{A}{d^{m}}$$

Constants for computing their minimum tensile strengths are given in Table 10-5Springs are manufactured by hot or cold-working process, depending upon the size of the material, the spring index, and the properties desired.

NAME OF MATERIAL	SIMILAR SPECIFICATION	DESCRIPTION
Music wire,	UNS G10850 AISI 1085 ASTM A228-51	This is the best, toughest, and most widely used of all spring materials for small springs. It has the highest tensile strength and can withstand higher stresses under repeated loading than any other spring material. Available in diameters 0.12 to 3mm(0.005 to 0.125 in). Do not use above 120 C (250 F) or at subzero temperature
Oil-tempered wire, 0.60-0.70C	UNS G10650 AISI 1065 ASTM 229-41	This general-purpose spring steel is used for many types of coil springs where the cost of music wire is prohibitive and in sizes larger thena available in music wire. Not for shock or impact loading. Available in diameters 3 to 12 mm (0.125 to 0.5000 in),but larger and smaller sizes may be obtained. Not for use above 180 C (350 F) or at sub-zero temperatures
Hard-drawn wire, 0.60-0.70	UNS G10660 AISI 1066 ASTM 227-47	This is the cheapest general purpose spring steel and should be used only where life, accuracy, and deflection are not too important. Available in diametes 0.8 to 12 mm (0.031 to 0.500 in). Not for use above 120 C (250 F) or at subzero temperatures
Chrome Vanadium	UNS G61500 AISI 6150 ASTM 231-41	This is the most popular allowy spring steel for conditions involving higher stresses than cn be used with the high- carbon steels and for use wherefatigue resistanceand long endureance are needed. Aslo good for shock and impact loads. Widely used iforaircraft engine valve springs and for temperaturesto 220 C (425 F) Available in annealed or pretemperedsizes 0.r to 12mm(0.031 to 0.500 in) in diameter
Chrome silicon	UNS G92540 AISI 9254	This alloy is an excellent material for highly stressed springs that requrire long lfe and are subjected to shock loading. Rockwell hardnesses of C50 to C53 are quite common, and the material may be used up to 250 C(475 F). Available form 0.8 to 12 mim (0.031 to 0.500 in) in diameter

Table 4.1

Material	ASTM NO.	EXPONENT m	INTERCEPT A, kpsi	A,MPa
Music wire	A228	0.163	186	2060
Oil tempered wire	A229	0.193	146	1610
Hard-drawn wire	A227	0.201	137	1510
Chrome vanadium	A232	0.155	173	1790
Chrome silicon	A401	0.091	218	1960

Table 4.2

Hard and Soft Springs

Soft springs are pre-hardened wires and are cold wound, have better finish and strength. In general, pre-hardened wires should not be used if C (D/d) <4 or id d>1/4 inches. Such hard springs are hot wound, then hardened are tempered and normalized. Winding of the spring induces residual stresses through bending, but these are normal to the direction of the torsional working stresses in a coil spring. Quite frequently in spring manufacture they are relieved, after winding, by a mild thermal treatment.

Helical Torsion Springs

The torsion springs illustrated in Fig.4.19 is used in door hinges and automobile starters and in fact, for any application where torque is required. There is wound in the same manner as extension or compression springs but have the ends shaped to transmit torque.

Belleville Springs

The inset of Fig-4.7 shows a coned-disc spring, commonly called a Belleville spring. Although the mathematical treatment is beyond the scope, one should at least be familiar with the remarkable characteristics of these springs.

Miscellaneous springs

Flat stocks are used for a great variety of springs, such as clock springs, power springs, torsion springs, cantilever springs and hair springs; frequently is specially shaped to create certain spring actions for fuse chips, relay springs, spring washers, snap rings and retainers. They may be analyzed and designed by using the above and the other fundamental concepts discussed earlier.