Design of a Helical Spring

Worked Example

A typical spring design problem:

- **(a)** List and discuss FOUR of the principal factors which a designer should consider in designing and specifying a close-coiled helical spring.
- **(b)** With reference to Figure Ex.1, determine the spring stiffness, wire diameter and number of active coils of a close-coiled helical spring which will maintain the follower in contact with the cam at all times.
- **(c)** Check the suitability of steel music wire, having a torsional yield strength of 720 MN/m^2, as a material for the spring.

Relevant data:

Mass of follower: 5.5 kg

Maximum acceptable axial load between the cam and the follower: 400N

Maximum displacement of follower: 20 mm

Spring index: 6

Maximum diametrical space available for spring: 46 mm

Modulus of rigidity of spring material: 83 GN/m^2

Other relevant data:

ISO R.10 Range of Preferred Sizes for Wire and Sheet Metal (diameters and thickness in mm)

0.020	0.100	0.500	2.500	12.500
0.025	0.125	0.630	3.150	16.000
0.032	0.160	0.800	4.000	20.000
0.040	0.200	1.000	5.000	25.000
0.050	0.250	1.250	6.300	
0.063	0.315	1.600	8.000	
0.080	0.400	2.000	10.000	

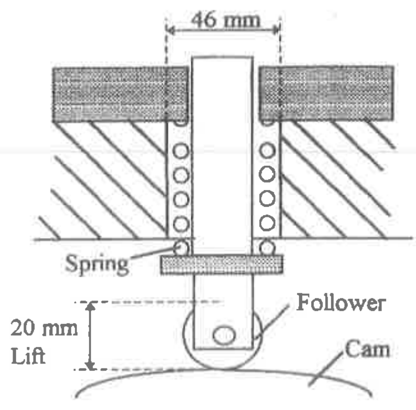

Figure Ex.1

Solution

(a) Some principle design factors include:

- Geometrical – space into which the spring must fit and operate.
- Physical – magnitudes and effects of working forces/loads and deformations.
- Environmental – type of service conditions such as temperature, atmosphere etc.
- Economic – cost of material and quantity for manufacture.
- Material – material properties such as E, G, σ, τ etc.

Other factors can include:

- Spring availability (standard stockist sizes).
- Spring material availability.
- Spring capability to absorb energy (stiffness/rate etc).
- Natural frequency.
- Nature of loading – *light service*: static loads up to 10000 cycles of loading with a low rate of loading without significant impact on spring.
  average service: typical machine design situations – moderate rate of loading and up to 10^6 cycles.
  severe service: rapid cycling for above 10^6 cycles; possibility of shock or impact loading, e.g. engine valve springs.

(b)

Spring Rate (or stiffness) S: $s = \frac{F}{\delta} = \frac{400}{20}$ = **20 N/mm**

Wire Diameter, d: From specification, max. diameter clearance = 46 mm $\therefore$ $46 > D + d$

Spring index, $C = D/d = 6$ $\therefore$ $D = 6d$

$\therefore$ $46 > 6d + d = 7d$ $\therefore$ $d = 6.57$mm

Hence from the wire diameter size data table, **d = 6.3 mm** is selected, giving a radial clearance of:

[46 – (7 x 6.3)]/2 = 0.95 mm.

Number spring coils (or turns), n: $s = \dfrac{Gd}{8C^3 n} \quad \therefore \quad n = \dfrac{Gd}{8C^3 s} = \dfrac{(83x10^3)x6.3}{8x6^3 x20}$ = 15.13

Hence, in the absence of spring end finish information, the number of active coils is taken as **16.**

(c)

Suitability of steel music wire:

Assume a Wahl factor given by: $K = \dfrac{4C-1}{4C-4} + \dfrac{0.615}{C} = \dfrac{(4x6)-1}{(4x6)-4} + \dfrac{0.615}{6}$ = 1.2525

Max. torsional shear stress: $\tau_{max} = \dfrac{8KFD}{\pi d^3} = \dfrac{8x1.2525x400x6x6.3}{\pi x6.3^3}$ = **192.86 MN/m^2**

Hence, since τ_{max} =192.86 MN/m^2 < 720 MN/m^2, then steel music wire is suitable for this application!