GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 1999

Design
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

1. A parapodium is a device used to support toddlers born without any control over their lower bodies (generally, from the waist down). The device allows them to either stand erect without additional support or sit in a chair. Some manage to "walk" using crutches. Before trying to answer, please read through the entire question.

   a) In order to develop the design requirements and constraints for this problem, you need to determine, for the intended users, the parameters critical to the design. List these, defining each carefully. Numbers are not necessary but clearly indicate which parameters are single numbers and which are ranges of numbers.

   b) Determine the design requirements and constraints needed for a successful design. List these in two categories:
      - requirements or constraints that *must* be satisfied if you are to have a successful design
      - requirements or constraints that are *desirable* but not absolutely critical to a successful design

   c) The most marketable design is usable by the widest number of users over the longest period of time. Therefore, it is useful to quantify the coupling between your design requirements and constraints (part b) and your assumptions about the user population (part a). Develop a matrix for this purpose listing requirements and constraints versus patient parameters. Define a scale to measure the coupling and use it to populate the matrix.

Clutch Design Problem

In Figure 1 an automotive type clutch is shown, used with "standard" manual shift transmissions. The flywheel, clutch cover, and pressure plate rotate with the crankshaft. A series of circumferentially distributed springs force the pressure plate toward the flywheel, clamping the clutch plate (driven disk) between them. The hub of the clutch plate is spline-connected to the transmission input shaft. The clutch is disengaged by pressing the clutch pedal, which rotates the lever marked "To Release". This pushes the clutch release bearing against a series of radially oriented release levers that pull the pressure plate away from the flywheel. Note that the clutch release bearing is a thrust bearing. The right side bears against the release mechanism, which does not rotate; the left side bears against the release levers, which rotate with the crankshaft. You are now working for the Grob Renraw transmission company and checking the design of the clutch in Figure 1.

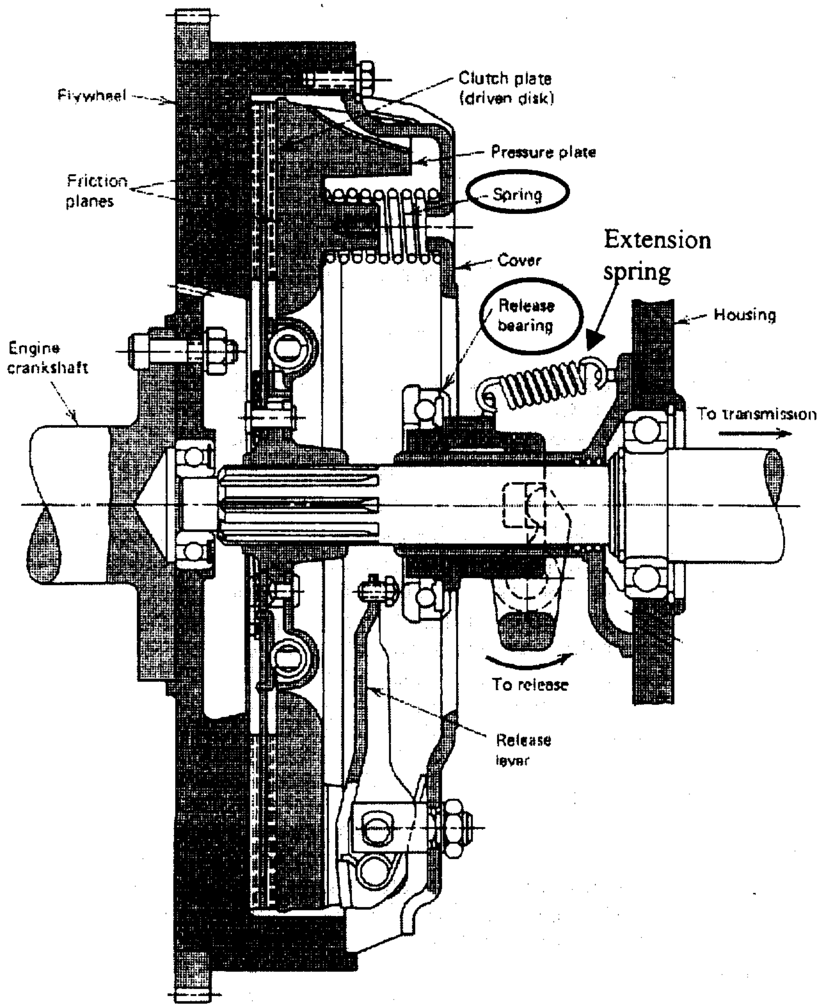

Figure 1 – Automotive Type Clutch Assembly

As shown in Figure 1, the clutch is equipped with compression springs that cause the clutch plate to press against the flywheel. Each spring takes a maximum load of 300 N at which is has a total deflection of 5 mm. Management wants to use a different compression springs with a spring index C of 6.5 and a mean coil diameter D of 2.5 cm. All springs have squared and ground ends. Assume that the spring material is hard drawn steel wire with a modulus of rigidity of 79.3 GPa and an ultimate tensile strength of 965 MPa.

a) What is the solid length of the new spring?

b) What is the absolute minimum free length the new spring should have? What free length would you recommend?

c) Instead of a straight compression spring, a conical shaped spring like shown in Figure 2 is used. Assume that the number of coils remains the same and that $D_{top} = 2$ cm and $D_{bottom} = 3$ cm. What is the minimum wire diameter needed for a maximum load of 300 N? Assume a constant wire thickness throughout the spring and focus on static loading only.

d) As shown in Figure 1, an extension spring is used to pull the release mechanism back to its original position once the driver has removed his/her foot from the clutch. Discuss the pros and cons for using an extension spring instead of a compression spring from technical and economical perspectives. Do not give general pros and cons, but relate your discussion to the clutch assembly.

e) In Figure 3, a coiled compression spring is shown that has been loaded against a support by means of a bolt and nut. After the nut has been tightened to the position shown, an external force F is applied to the bolt and the deflection of the spring is measured as F is increased. A plot of the deflection curve is also shown in Figure 3. Briefly explain why the curve changes at points A, B, and C.

f) What type of bearing is the release bearing? Be as precise as possible.

g) If the force on the bearing is 1000 N and the release bearing's basic load rating is 30000 N, what is the L_{10} life of the bearing? Is this life sufficient for an automobile clutch (why/why not)?

Some useful equations:

$k = d^4 G / (8D^3 Na)$ $C = D/d$ $Ks = (2C + 1) / 2C$ $G = 79.3$ GPa

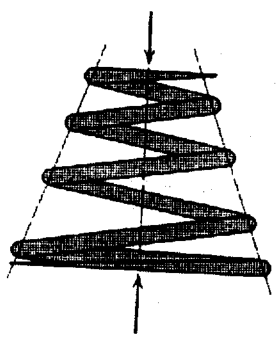

Figure 2 – Conical Spring

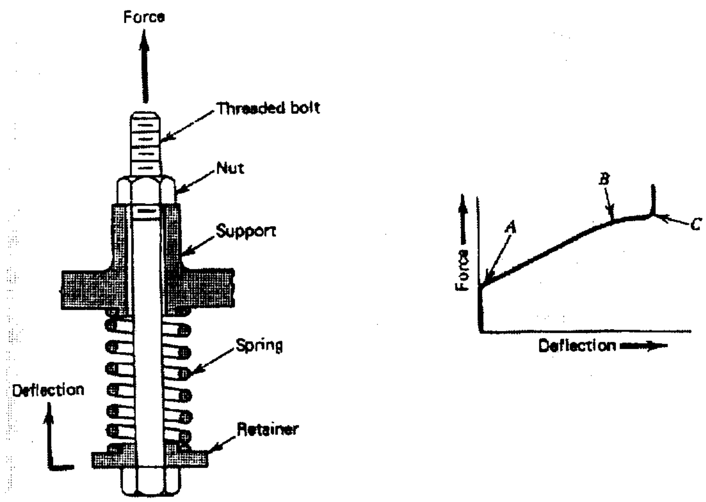

Figure 3 – Loaded Spring and Force-Deflection Curve

Solution

a) Total number of coils is

$k = d^4 G / (8D^3 Na)$
G = 79.3 GPa (Table A-5)
spring rate $k = \delta F/\delta y = 300 / 5 = 60$ N/mm

C = 6.5, D = 25 => d = 3.85 mm
$N_a = d G / (8C^3 k) = 3.85 \times 79300 / (8 \times 275 \times 60) = 305305/132000 = 2.31$ coils

Squared and ground Nt = Na + 2 (see Table 10-2)
Ls = Nt d = d(Na + 2) = 3.85 x 4.31 = 16.60 mm

b) Absolute minimum free length is Ls plus stroke = 16.60 + 5 = 21.6 mm
But take a 10% clash allowance into account, thus L0 = 21.6 + 0.1x16.6 = 23.26 mm

c) The minimum wire diameter is needed for the largest diameter, D = 3.0
$K_s = (2C+1) / (2C) = 1 + 0.5/C = 1 + 0.5/6.5 = 1.075$ (eq. 10-4) if spring is considered set.
Or $K_s = 1 + 0.615/6.5 = 1.095$

$\tau_m = K_s.(8.F_m.D)/(\pi d^3) = 1.08 \times 8 \times 300 \times 30 / \pi d^3 < Ssy$

Ssy = 0.56 Sut = 0.56 x 965 = 540 MPa.

Solve for d

d) Extension springs have disadvantages in the hook. If it fails, things will fly apart. Using a compression spring requires a modification of the release bearing mechanism.

e) A - contact is made and deflection starts to occur. B - spring starts to yield. C - spring solid condition

f) Roller thrust bearing

e) $L = (C / P)^a = (30000 / 1000)^a = 30^3 = 27000$ million revs.
If a car runs at 3000 rpm, then the bearing will last for 9 million minutes = 150,000 hours
This is more than enough.