MAINSPRING ASSEMBLY CALCULATIONS

GROUP 3

ME251

1 Introduction

The mainspring that powers the watch, a spiral ribbon of spring steel, is inside a cylindrical barrel, with the outer end of the mainspring attached to the barrel. The force of the mainspring turns the barrel. The barrel has gear teeth around the outside that turn the center wheel once per hour — this wheel has a shaft that goes through the dial.

The duration of power reserve of a mechanical watch is mainly depending on the size of the mainspring used, which is, in turn, a question of how much power is needed and how much space is available.

Most mechanical watch movements have a duration of run between 36 and 72 hours. Some mechanical watch movements are able to run for a week.

2 Concept

2.1 Duration Of Run Of A Watch

The exact duration of run for a mechanical movement is calculated with this formula:

$$n2 = \frac{n1 \times z1}{z2} \qquad (1)$$

where
z1 = Number of barrel teeth(C67).
z2 = Number of center pinion leaves(C18).
n1 = Number of revolutions of the barrel.
n2 = Number of revolutions of the center pinion (duration of run).

2.2 Output Torque Of The MainSpring

The number of turns of the mainspring serving as a power source of such a driving mechanism and the output torque are in a proportional relationship. When the output torque of the mainspring is T, the number of winding runs (number of turns) of the mainspring is N, Young's modulus is E, the total length of the mainspring is L, and the mainspring is assumed to have a rectangular cross-section having a thickness t and a width b, it is known that T can be expressed by:
$T = (Et^3 b\pi/6L)N$ (2)

On the other hand, the total length L, the thickness t and the width b of the mainspring are dependent on the size of the barrel drum housing the mainspring. If the barrel drum has an inside radius R and a barrel arbor radius r, the total length L of the mainspring is determinable from the following formula:
$L = \pi(R^2 - r^2)/2t$ (3)

2.3 LOSSES IN A MECHANICAL WATCH

Most of the moving parts of a mechanical watch are powered by the mainspring which is wound manually. Since losses are inevitable, the watch can only run for a given number of hours once reloaded. Main sources of energy losses can be due to friction between surfaces, viscous drag between hands of the watch

We analyse each component and came up with the following conclusion with respect to the energy losses in the overall watch mechanism:

a. The Shaft and Pinion gear will incur losses due to friction. However the normal reactions being small and coefficient of friction negligible too, we can ignore the energy losses in them.

b. While doing our calculations we assume the losses in the hairspring(which stores and releases energy in fixed time intervals hence undergoing extension and compression) to be negligible.

c. We consider the viscous drag in the hands of the watch due to the surrounding medium to be negligible

d. The contact between various gears in the gear train is small and also the time of contact is small. Hence losses can be neglected here too while doing the calculations.

e. Hence our major sources of loss includes the one in the Escapement mechanism. The losses between the pallet fork and the escape wheel are considered while doing our calculations as they are quite significant compared to other losses.

3 Calculations Of Number Of Turns Of Main-Spring Barrel

From our model,we have that:
$z1 = 108$
$z2 = 18$
So,if we want to run the watch for a duration of 40 hours which is the case for most of the mechanical watches,we will take $n2 = 40$. Substituting all these values in (1) we will get:
$n1 = 6.66$ which can be taken as 7.
This implies that the mainspring barrel must be turned for a total of **7** turns to run our watch for a duration of **40** hours.

4 Calculations of Energy

Using Rawling's analysis of energy stored in the main spring, we can write ENERGY stored as:

$$\frac{V\sigma_{max}^2}{6E}$$

where V = volume of mainspring, σ_{max} = max permissible stress, E= Young's Modulus of the material used in the main spring.

We have used stainless steel for our main spring.
$E_{stainlesssteel} = 190 \times 10^9 Pa$
$\sigma_{max} = 12LT/Ebt^3$
$N = 7$

Calculating the value of T using (2) we get: $T = 1.29 \times 10^{-7} Nm$.
V can be calculated as :
V = $t \times l \times h$

where,
t = thickness of mainspring = 0.05mm.
l = length of mainspring = 167.63mm (calculated using (2)).
h = height of mainspring = 0.25mm.

So,V = 2.0954 mm^3
Writing the total energy stored in the spring in terms of the torque T calculated

above,we get:

Energy=$6LT/Ebt^3$

Substituting,all these values in the energy equation,we get;the energy stored in the spring as equal to: **0.218kJ**.
Therefore,this much amount of energy is stored in the MainSpring in order for it to run for about 40 hours.