On the Pressure Compensation for the B-cell Cavity in the MARK II Cryostat

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Abstract

In this note we explain how the tuner and proposed earlier pressure compensation scheme work together and show how to calculate various forces and displacements and the area of the pressure compensation bellows using an equivalent schematic.

I. How Tuner Works

The B-cell superconducting cavity is tuned by mechanically stretching the cavity along the beam line relative to the cryostat. The drive train consists of a stepping motor followed by a 4.38:1 dual leverage mechanism terminating in a dual parallel flex hinge arrangement (tuner flexure) with mechanical advantage of 3.9:1. The flexure is patterned after the proposed LANL PILAC cavity tuner [1]. The total mechanical advantage of the tuner mechanism is 17:1. Such a flexible linkage system is advantageous because there is no bearings with the inherent alignment and backlash problems. The prototype of the tuner [2] has been built and tested during the Beam Test in August 1994 [3].

As it was reported in [4], the measured value of the frequency sensitivity to pressure (*df/dP*) is high. It is equal to 250 kHz/Bar for the cavity in the MARK II cryostat. A possible solution with using internal compensation bellows was proposed in [4]. Later another scheme, with external bellows, was proposed as easier to adjust. The bellows volume is connected to the He vessel and therefore pressure inside the bellows is the same as the pressure acting on the cavity. Thus, the compensation force is proportional to the He bath pressure and to the bellows area.

In order to decrease the required compensation force and hence the bellows area, it was proposed to apply the force to the same point as the tuner motor to take benefit of the total tuner mechanical advantage. Originally the motor screw had been rigidly connected to the cryostat wall which would prevent any movement of the tuner except that due to the stepping motor. To allow the compensation force to move the tuner, a coil spring was introduced between the screw and the cryostat. The pictorial of the final version of the tuner is shown in Figure 1.

II. How to Calculate Forces and Displacements

To simplify understanding of how the pressure compensation scheme works it is beneficial to draw an electrical equivalent circuit of the tuner mechanism. One can establish an analogy between mechanical quantities and electrical ones: the displacement corresponds to the voltage, the force corresponds to the current, and the spring constant corresponds to the conductivity. Then any mechanism with the mechanical advantage does the same as a transformer does in electric circuits. This means that while drawing an equivalent scheme one must scale forces and displacements linearly with the mechanical advantage, but spring constants must be scaled quadratically. By doing so we can draw the diagram as shown in Figure 2.

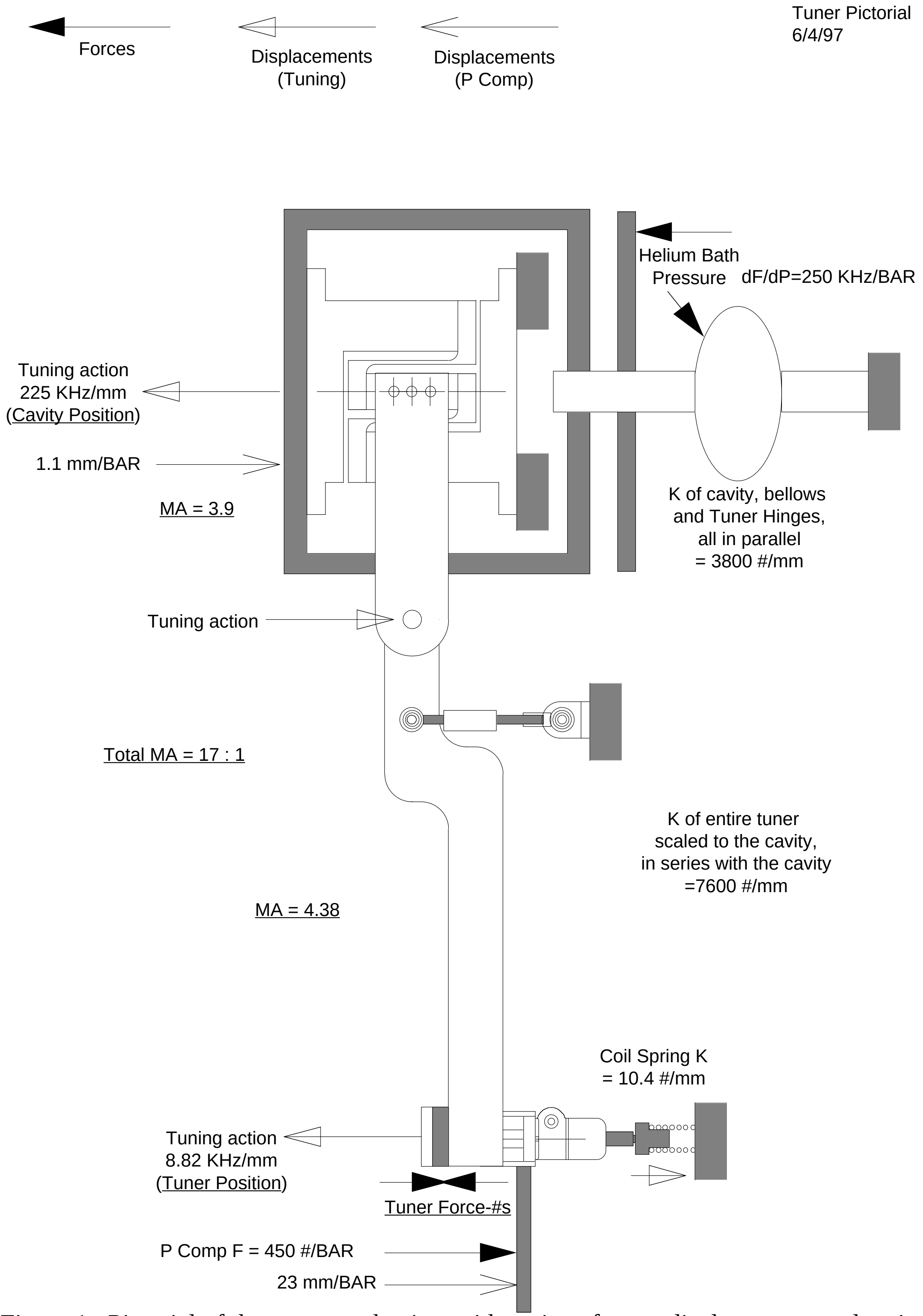

Figure 1. Pictorial of the tuner mechanism with various forces, displacements and spring constants.

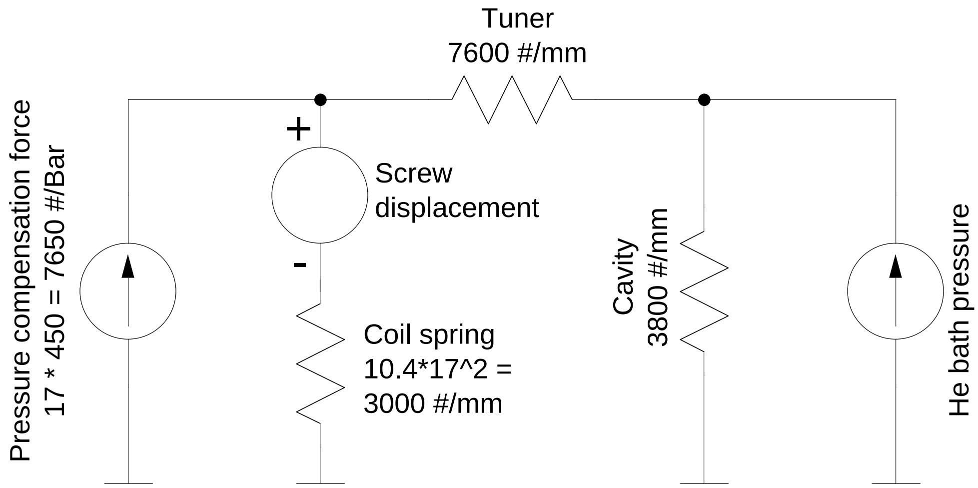

Figure 2. Equivalent electrical scheme of the tuner and pressure compensation.

Now it is easy to calculate forces and displacements due to the pressure compensation scheme using the diagram. We measured the sensitivity of the cavity resonant frequency to the He vessel bath pressure of 250 kHz/Bar. Also, we measured frequency sensitivity to the tuner action of 225 kHz/mm. Thus, to compensate 250 kHz of the resonant frequency change we have to squeeze the cavity by

$$D_{cav} = 225/250 = 0.9 \text{ mm/Bar} .$$

Hence, the force due to the pressure compensation at the cavity end should be

$$F_{cav} = 3800*0.9 = 3420 \text{ lbs/Bar} ,$$

the tuner displacement then is equal to

$$D_{tuner} = 3420/7600 = 0.45 \text{ mm/Bar} ,$$

and the total cavity and tuner displacement is equal to

$$D_{total} = 0.45+0.9 = 1.35 \text{ mm/Bar} .$$

A force due to the pressure compensation applied to the coil spring is

$$F_{spring} = 1.35*3000 = 4050 \text{ lbs/Bar} ,$$

and the total force of pressure compensation bellows is

$$F_{total} = 3420+4050 = 7470 \text{ lbs/Bar} .$$

To calculate the necessary area of the bellows we have to scale the force back using the mechanical advantage of the tuner:

$$F'_{total} = 7470/17 = 440 \text{ lbs/Bar} = 30.3 \text{ lbs/psi} .$$

Thus, the area of the pressure compensation bellows should be equal to 30.3 square inches.

The system will be tested using these parameters and values.

III. References

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