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When designing new instruments or rebuilding old instruments it is helpful to have qualitative information about the tone and tension of a string. The tension of each string must be with-in certain bounds in order to give a good tone for the note. I like the tension to be between 50% and 70% of the breaking point. Knowing the total tension on an instrument is important because this over-all tension must match the structural aspects of the instrument. The tone of a string can be quantified using an equation for the inharmonisity (H). The inharmonisity is a measure of the harmonic distortion or out-of-tuneness of the upper-partials of a string due to the fact that a string is not perfectly flexible. This calculation does not take into account how the body of the instrument contributes to the tone heard by the listener. It does give an accurate indication of how the string is vibrating.

WOUND STRINGS

(copper on steel music wire)

$$\begin{aligned} T &= (2.4 \times 10^{-4}) Z F^2 \ell^2 \\ Z &= d^2 + 8.5 D^2 \\ H &= (5.4 \times 10^{13}) \frac{d^4}{F^2 \ell^4 Z} \end{aligned}$$

UNWOUND STRINGS

(steel music wire)

$$\begin{aligned} T &= (2.45 \times 10^{-3}) F^2 \ell^2 d^2 \\ T(\text{break}) &= (2.69 \times 10^{5}) d^2 \\ H &= (5.4 \times 10^{12}) \frac{d^2}{F^2 \ell^4} \end{aligned}$$

(brass spring wire)

$$\begin{aligned} T &= (5.65 \times 10^{-4}) F^2 \ell^2 d^2 \\ T(\text{break}) &= (6.21 \times 10^{4}) d^2 \\ H &= (1.25 \times 10^{12}) \frac{d^2}{F^2 \ell^4} \end{aligned}$$

$$\begin{aligned} T &= \text{tension in pounds} \\ T(\text{break}) &= \text{tension where the core wire breaks} \\ F &= \text{frequency in cycles per second (Hz)} \\ \ell &= \text{length of string in inches} \\ d &= \text{core wire diameter in inches} \\ D &= \text{overall wire diameter in inches} \\ D &= 2w + d \\ w &= \text{diameter of copper winding wire} \\ H &= \text{coefficient of harmonic distortion} \end{aligned}$$

octave	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
H	0.2	0.1	0.2	0.2	0.5	1.5	3.1	8.0

$$\begin{aligned} N^2 H &= \text{number of cents sharp} \\ N &= \text{upper partial number} \end{aligned}$$