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On the alterations of tone produced by a violin-"mute"

Experiments on the "wolf-note" of the violin or 'cello (see *Nature* (*London*) June 29, and September 14, 1916, and *Philos. Mag.* October, 1916) suggest an explanation of the well-known and striking alterations in the tone of the instrument produced by a "mute," which at first sight seems somewhat difficult of acceptance, viz. that they are due to the lowering of the pitch of the free modes of vibration of the *entire body of the instrument* produced by the added inertia. This view of the action of the mute (which was suggested by way of passing reference in my paper on the "wolf-note") has, I find, excited some incredulity, and its correctness has, in fact, been questioned in a note by Mr J W Giltay in the *Philos. Mag.* for June, 1917. The following brief statement may therefore be of interest as establishing the correctness of my view of this important phenomenon:

If N_1, N_2, N_3, etc. be the frequencies of the free vibrations of the body (in ascending order), the frequencies as altered by the addition of the "mute" are determined by equating to zero the expression (see Routh's *Advanced Rigid Dynamics*, section 76),

$$(N_1^2 - n^2)(N_2^2 - n^2) \times \text{etc.}, - \alpha n^2(n_2^2 - n^2)(n_3^2 - n^2) \times \text{etc.},$$

where α is a positive quantity proportionate to the added inertia, and n_2, n_3, etc. are the limiting values of N_2, N_3, etc. attained when the load is increased indefinitely [$n_1 = 0$, and $n_2 < N_1$, $n_3 < N_2$, etc.]. The forced vibration due to a periodic excitation of frequency n is determined by the same expression, being inversely proportional to it except in the immediate neighbourhood of points of resonance. The sequence of the changes in the forced vibration produced by gradually increasing the load is sufficiently illustrated by considering a case in which n lies between N_1 and N_2. If $n_1 < n_2$, the load decreases the forced vibration throughout, but if $n > n_2$, the load at first *increases* the forced vibration until it becomes very large, when n coincides with one of the roots of the equation for free periods, subsequent additions of load decreasing it. The *increase* in the intensity of tone indicated by this theory has actually been observed experimentally by Edwards in the case of the graver tones and harmonics of the violin (*Phys. Rev.* January, 1911). Edwards's observation that the intensity of tones and harmonics of high pitch is *decreased* by "muting" is also fully explained on this view, as in the case of the higher modes of free vibration of the instrument a very small load would be sufficient to make the frequencies approximate to their limiting values.

Comparison of the effects of loading the bridge of the instrument at various points on the free periods and the tones of the instrument furnishes a further confirmation of the foregoing theory. For instance, on a 'cello tried by me, the lowering of the "wolf-note" pitch produced by a load fixed on *either* of the feet of the bridge was small compared with that obtained by fixing it on top of the bridge, and the observed "mute" effect was correspondingly smaller. In fact, the alterations of free period produced by loading furnish us with quantitative data regarding the relative motion of different parts of the instrument, and of their influence in determining the character of its tones.

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