

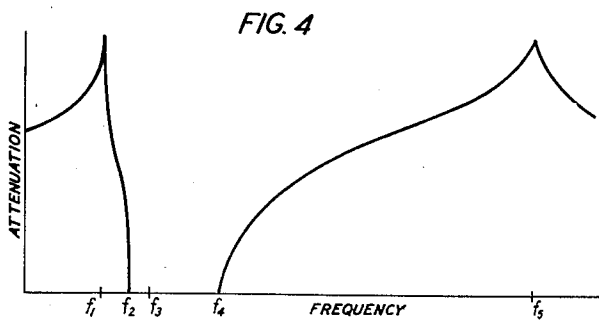
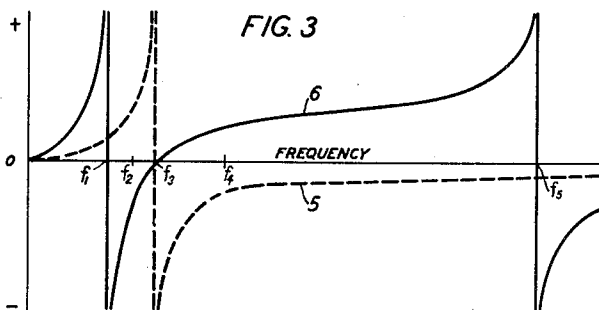
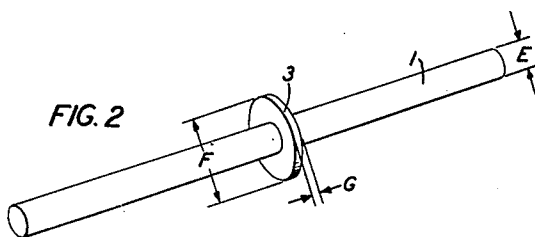
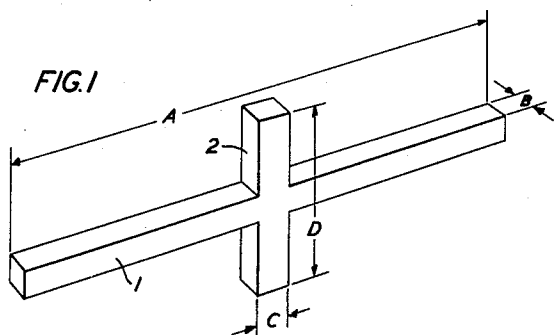
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MECHANICAL WAVE FILTER

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MECHANICAL WAVE FILTER

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19 Claims. (Cl. 178-44)

This invention relates to mechanical wave filters and more particularly to those which comprise a transverse member adapted for flexural vibration.

The principal object of the invention is to increase the attenuation obtainable with a mechanical wave filter which employs a single transverse member.

The mechanical wave filter in accordance with the invention comprises a central rod of acoustic material and a centrally located transverse member adapted to be set into flexural vibration when longitudinal vibrations are impressed upon an end of the rod. The transverse member may, for example, be a crossbar or a disc driven at its center. A peak of attenuation will occur at each frequency at which the transverse member has a flexural antiresonance. Heretofore, in filters of this type, only the first antiresonance has been utilized, thus providing only one attenuation peak. In accordance with the present invention, however, a single transverse member is made to provide two peaks of attenuation, thus substantially doubling the attenuation at all frequencies away from the peaks. To accomplish this, the transverse member is so designed that it has a flexural resonance, usually the first, at a frequency for which the central rod is approximately a half wave-length. The two peaks occur at the flexural antiresonances on each side of this frequency. The transmission band extends on both sides of this frequency and, for a given rod, has a width which decreases as the mass of the transverse member is increased. A simple graphical method of determining the cut-off frequencies is presented.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing in which like reference characters refer to similar or corresponding parts, and in which:

Fig. 1 is a perspective view of one embodiment of the invention in which the transverse member is a crossbar;

Fig. 2 is a perspective view of another embodiment employing a disc as the transverse member;

Fig. 3 gives curves from which the cut-off and peak frequencies may be found; and

Fig. 4 is a typical attenuation-frequency characteristic of the filter.

Taking up the figures in more detail, Fig. 1 shows in perspective a mechanical filter comprising a central rod 1 and a centrally located transverse member 2, both made of acoustic ma-

terial. The transverse member 2 is adapted to be set into vibration in the flexural mode by longitudinal vibrations impressed upon one end of the rod 1. As shown in Fig. 1, the member 2 is in the form of a crossbar which extends equal distances on each side of the rod 1. Other forms of the transverse member 2 may, however, be employed, so long as they are adapted for flexural vibration. The rod 1 and the crossbar 2, as shown, have rectangular cross sections, but other forms of cross section, such, for example, as circular, may be used equally well.

The cross-sectional dimensions of the rod 1 are small compared to its length A, which is approximately a half wave-length at some chosen frequency f_3 falling within the band to be transmitted. As shown, the rod 1 and the crossbar 2 have the same thickness B, but it is to be understood that they may differ in this dimension. The transverse member 2 is designed to have a flexural resonance coinciding with the frequency f_3 . When this member is a crossbar of rectangular cross section driven at its center, as shown in Fig. 1, and the first flexural resonance is employed, as is usually the case, the width C and the length D may be proportioned in accordance with the approximate formula:

$$f_3 = \frac{4.72^2 \pi C V}{2\sqrt{12} D^2} = \frac{10.08 C V}{D^2} \quad (1)$$

where V is the velocity of propagation in the acoustic material and is equal to the square root of the ratio of Young's modulus Y to the density M.

The peaks of attenuation will occur at the frequencies of flexural antiresonance in the transverse member 2. In the embodiment shown in Fig. 1 the first antiresonance will be at the frequency f_1 , below f_3 , given approximately by the formula:

$$f_1 = \frac{1.875^2 \pi C V}{2\sqrt{12} (D/2)^2} = \frac{6.36 C V}{D^2} \quad (2)$$

The second antiresonance will be on the upper side of f_3 , at the frequency f_5 , which may be found from the approximate formula:

$$f_5 = \frac{4.72^2 \pi C V}{2\sqrt{12} (D/2)^2} = \frac{40.32 C V}{D^2} \quad (3)$$

It is seen from Equations 1, 2, and 3 that, for the crossbar type of filter shown in Fig. 1, the first peak occurs at about $0.63 f_3$ and the second peak at about $4 f_3$.

Fig. 2 shows in perspective another embodiment of the invention in which the central rod

1 has a circular cross section of diameter E and the transverse member is a disc 3 having a diameter F and a thickness G. The disc 3 is located at the center of the rod 1, with its faces perpendicular to the longitudinal axis thereof. When driven in flexure at its center the disc 3 will have an impedance characteristic which exhibits resonances and antiresonances. The disc 3 is so designed that its first flexural resonance occurs at the frequency f_3 within the band. The antiresonant frequencies determine the peaks of attenuation. The frequencies f_m of resonance and antiresonance for the disc 3, corresponding to the different flexural modes of vibration, are given approximately by the formula:

$$f_m = \frac{k^2 G}{2\pi} \sqrt{\frac{Y}{12M(1-P)}} \quad (4)$$

where P is Poisson's ratio and the value of k , which involves the diameter F, is found for each of the modes of interest by the solution of an equation involving Bessel functions, as explained, for example, in the Philosophical Magazine and Journal of Science, series 7, vol. 24, No. 165, December 1937, pages 1041 to 1055.

The transmission band of the filter cuts off at the frequencies where

$$\tan \frac{\omega A}{2V} = j \frac{Z_1}{2Z_0} \quad (5)$$

in which Z_0 is the characteristic impedance of the rod 1; Z_1 is the impedance of the transverse member when driven in flexure at its center; ω is equal to 2π times the frequency f ; and j is the quadrantal operator. In Fig. 5, the broken line curve 5 shows the characteristic of

$$\tan \frac{\omega A}{2V}$$

and the solid line curve 6, the characteristic of

$$-j \frac{Z_1}{2Z_0}$$

both plotted against the frequency f , for a typical filter. Since the curves 5 and 6 have ordinates which are equal in magnitude but opposite in sign at the frequencies f_2 and f_4 , these are, therefore, respectively, the lower and upper cut-offs. For a given rod 1, the width of the band decreases with an increase in the mass of the transverse member. For narrow bands, therefore, the disc 3 is to be preferred to the crossbar 2. The peaks of attenuation occur at the frequencies f_1 and f_3 at which the impedance Z_1 , and therefore curve 6, is infinite. A typical attenuation characteristic is shown in Fig. 3, with cut-off and peak frequencies marked.

The image impedance Z of the filter, given by the formula

$$Z = Z_0 \sqrt{\frac{\sin \frac{\omega A}{V} - j \frac{Z_1}{Z_0} \cos^2 \frac{\omega A}{2V}}{\sin \frac{\omega A}{V} + j \frac{Z_1}{Z_0} \sin^2 \frac{\omega A}{2V}}}$$

is generally made to match the impedance of the terminal load at the frequency f_3 within the band.

What is claimed is:

1. A mechanical wave filter for transmitting a band of frequencies comprising a central rod and a transverse member both made of acoustic material, said rod having a length equal to a half wave-length at a frequency within said band and

said transverse member being located near the center of said rod and having a flexural resonance approximately at said frequency.

2. A filter in accordance with claim 1 in which said flexural resonance is the first.

3. A filter in accordance with claim 1 in which said transverse member is a crossbar extending equal distances on each side of said rod.

4. A filter in accordance with claim 1 in which said transverse member is a disc mounted at its center.

5. A filter in accordance with claim 1 in which the cross-sectional dimensions of said rod are small compared to its length.

6. A filter in accordance with claim 1 in which said flexural resonance is the first and the cross-sectional dimensions of said rod are small compared to its length.

7. A mechanical wave filter for transmitting a band of frequencies comprising a central rod and a crossbar both made of acoustic material, said rod having a length equal to a half wave-length at a frequency within said band and said crossbar being located near the center of said rod and having a flexural resonance approximately at said frequency.

8. A filter in accordance with claim 7 in which said flexural resonance is the first.

9. A filter in accordance with claim 7 in which said rod and said crossbar have the same thickness.

10. A filter in accordance with claim 7 in which said rod and said crossbar have rectangular cross sections of the same thickness.

11. A filter in accordance with claim 7 in which said flexural resonance is the first and said rod and said crossbar have the same thickness.

12. A filter in accordance with claim 7 in which said flexural resonance is the first and said rod and said crossbar have rectangular cross sections of the same thickness.

13. A filter in accordance with claim 7 in which said flexural resonance is the first and the cross-sectional dimensions of said rod are small compared to its length.

14. A filter in accordance with claim 7 in which said flexural resonance is the first, the cross-sectional dimensions of said rod are small compared to its length and said rod and said crossbar have the same thickness.

15. A filter in accordance with claim 7 in which said flexural resonance is the first, the cross-sectional dimensions of said rod are small compared to its length and said rod and said crossbar have rectangular cross sections of the same thickness.

16. A mechanical wave filter for transmitting a band of frequencies comprising a central rod and a transverse disc both made of acoustic material, said disc being mounted at its center perpendicularly to the longitudinal axis of said rod and having a flexural resonance at a frequency within said band.

17. A filter in accordance with claim 16 in which said flexural resonance is the first.

18. A filter in accordance with claim 16 in which said rod has a length approximately equal to a half wave-length at said frequency and said disc is located near the center of said rod.

19. A filter in accordance with claim 16 in which said flexural resonance is the first, said rod has a length approximately equal to a half wave-length at said frequency and said disc is located near the center of said rod.

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