

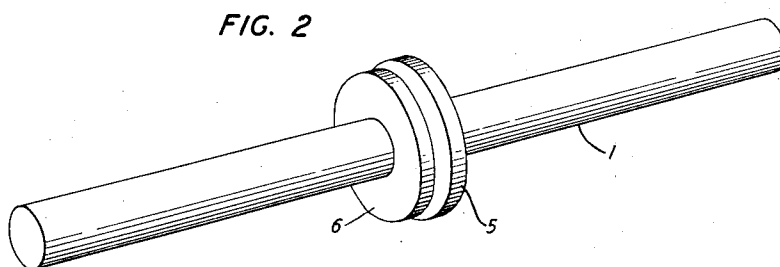
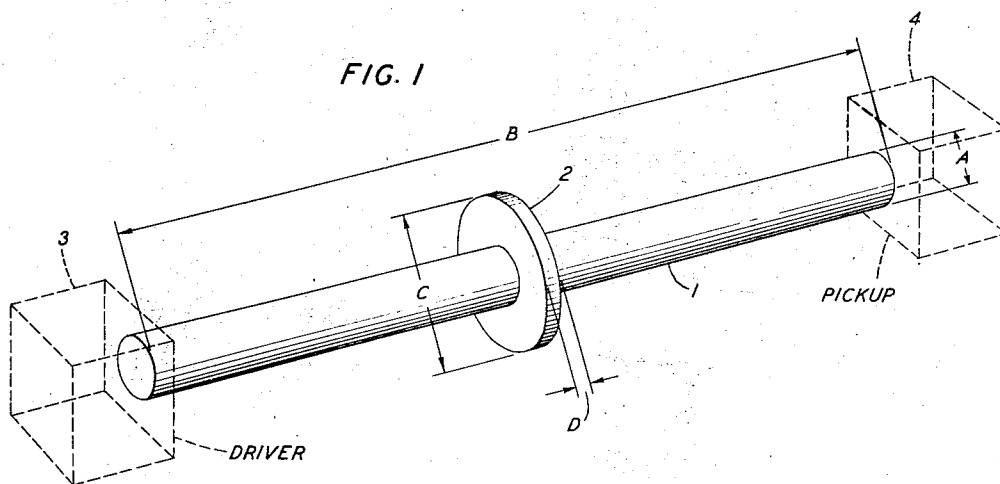
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MECHANICAL WAVE FILTER

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MECHANICAL WAVE FILTER

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This invention relates to mechanical wave filters and more particularly to those which comprise one or more transverse members adapted for flexural vibration.

An object of the invention is to reduce the minimum width of transmission band obtainable in a mechanical wave filter which employs a transverse flexural vibratory member.

Other objects of the invention are to simplify the mechanical structure and reduce the cost of filters of this type.

One form of mechanical wave filter comprises a central rod of acoustic material and one or more centrally located transverse members adapted to be set into flexural vibration when longitudinal vibrations are impressed upon an end of the rod. For a given rod, the width of the transmission band decreases as the mass of the transverse members is increased. Peaks of attenuation occur at the antiresonant frequencies of the transverse members, and these peaks are usually located close to the band limits to obtain sharp cut-offs.

Heretofore, the transverse members have been made in the form of crossbars. The flexural antiresonance of a bar is directly proportional to its width and inversely proportional to the square of its length. Since the antiresonant frequency is fixed, to increase the mass, and thereby narrow the band, the width of the bar may be increased by a factor K and its length increased at the same time by the square root of K . However, a point is reached at which the ratio of the width to the length is so large that the bar will no longer vibrate satisfactorily in the flexural mode. There is, therefore, a fairly definite limit on the minimum band width obtainable with filters using crossbars.

In accordance with the present invention this limitation on minimum width of band is overcome by using a flexurally vibrating disc, mounted at its center, as the transverse member. By using a disc the mass is greatly increased and therefore a much narrower band may be obtained. A single disc will provide a peak of attenuation either above or below the band. Two discs located near the mid-point of the central rod and close together will provide a peak above and a peak below the band. The central rod has a small cross-sectional dimensions compared to its length, which is approximately equal to a half wave-length at a frequency within the band.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying draw-

ing, in which like reference characters refer to similar parts and in which:

Fig. 1 is a perspective view of a mechanical wave filter in accordance with the invention employing a single disc, and

Fig. 2 is a perspective view of a two-disc filter.

Taking up the figures in more detail, Fig. 1 shows a mechanical wave filter in accordance with the invention comprising a central rod 1 of circular cross section and a transverse disc 2, both made of suitable acoustic material. The diameter A of the rod 1 is small compared to its length B , which is approximately a half wave-length at a cut-off frequency. The disc 2 has a diameter C and thickness D and is centrally mounted near the center of the rod 1. Longitudinal vibrations impressed upon an end of the bar 1 by a suitable driving device, represented diagrammatically by the box 3 shown in broken outline, will cause the disc 2 to vibrate in the flexural mode. The longitudinal vibrations of the rod 1 may be picked up at the other end of the filter by some suitable device, represented by the box 4 shown in broken outline. A peak of attenuation will occur at each frequency at which the disc 2 is antiresonant. The dimensions C and D of the disc 2 are, therefore, so proportioned that the first flexural antiresonance f_1 , given approximately by the following formula, occurs at a frequency, usually near a band limit, at which a peak is desired:

$$f_1 = \frac{1.872D}{C^2} \sqrt{\frac{Y}{M(1-P^2)}} \quad (1)$$

where C and D are in centimeters, M is the density of the material, P is Poisson's ratio and Y is Young's modulus. If f_1 is on the lower side of the transmission band, the length B of the rod 1 is made approximately equal to a half wave-length at the upper cut-off frequency. If f_1 is above the band, B is made approximately equal to a half wave-length at the lower cut-off.

If two peaks of attenuation are desired, one on either side of the band and close to the band limits, the structure shown in Fig. 2 may be used. The filter comprises a central rod 1 and two transverse, centrally mounted discs 5 and 6, located close together one on either side of the center of the rod 1. One of the discs has its first flexural antiresonance at a frequency close to one limit of the band and the other disc has its first flexural antiresonance close to the other limit of the band. In this case the length B of the rod 1 is approximately equal to a half wave-length at the mid-band frequency.

In mechanical filters of the type shown in Figs. 1 and 2, employing transverse impedance members, for a given rod 1 the width of the band decreases with an increase in the mass of the transverse members. The use of discs, such as 2, 5 and 6, for these members allows their mass to be greatly increased as compared, for example, with crossbars, and therefore a much narrower band may be obtained. The former limit on the minimum band width obtainable with filters using the disc-type filters of the present invention. Another distinct advantage of the disc-type filter is its mechanical simplicity. The filter may, for example, be made from a single piece of metal and cheaply turned out on a lathe.

The image impedance Z of the filter, which should match the image impedance of the driving means at the mid-band frequency, is given by the formula:

$$Z = Z_0 \sqrt{\frac{\sin \frac{\omega B}{V} - j \frac{Z_D}{Z_0} \cos^2 \frac{\omega B}{2V}}{\sin \frac{\omega B}{V} + j \frac{Z_D}{Z_0} \sin^2 \frac{\omega B}{2V}}} \quad (2)$$

where ω is the angular frequency, j is the quadrantal operator, V is the velocity of propagation, equal to the square root of the ratio of Y to M , Z_0 is the characteristic impedance of the rod 1 and Z_D is the impedance of the disc 2, for the filter of Fig. 1, or the sum of the impedances of the two discs 5 and 6, for the filter of Fig. 2. This image impedance is of a type which can be readily matched by a driver comprising a piezoelectric crystal attached at its end to an end of the rod 1.

The filter will have a transmission band below, and one or more bands above, the principal band which has been here considered. These extraneous bands, if objectionable, may be eliminated by attenuation provided by the driving means, which should be designed to have a transmission band coinciding with the principal band of the mechanical filter. The discrimination of the filter may, of course, be increased by connecting in tandem two or more sections of the type shown in Fig. 1 or Fig. 2.

What is claimed is:

1. A mechanical wave filter for transmitting a band of frequencies comprising a rod and a transverse disc both made of acoustic material, said rod having a length approximately equal to a half wave-length at a frequency within said band and said disc being centrally mounted near the center of said rod and adapted to be set into flexural vibration by longitudinal vibrations impressed upon an end of said rod and having a flexural antiresonance at a frequency close to one limit of said band.

2. A filter in accordance with claim 1 in which said rod has a circular cross section.

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

4. A filter in accordance with claim 1 in which said rod has a circular cross section the diameter of which is small compared to its length.

5. A filter in accordance with claim 1 in which said flexural antiresonance of said disc is its first.

6. A mechanical wave filter for transmitting a band of frequencies comprising a rod and a transverse disc both made of acoustic material, said rod having a length approximately equal to a

half wave-length at a frequency within said band and said disc being centrally mounted near the center of said rod and adapted to be set into flexural vibration by longitudinal vibrations impressed upon an end of said rod and having its first flexural antiresonance at a frequency on one side of said band and said rod having a length approximately equal to a half wave-length at the band limit on the other side of said band.

7. A filter in accordance with claim 1 in which said flexural antiresonance of said disc is its first and said rod has a length approximately equal to a half wave-length at the other limit of said band.

8. A mechanical wave filter for transmitting a band of frequencies comprising a rod and a transverse disc both made of acoustic material, said rod having a length approximately equal to a half wave-length at a frequency within said band and said disc being centrally mounted near the center of said rod and adapted to be set into flexural vibration by longitudinal vibrations impressed upon an end of said rod and having its first flexural antiresonance at a frequency on the upper side of said band and said rod having a length approximately equal to a half wave-length at the lower limit of said band.

9. A filter in accordance with claim 1 in which said flexural antiresonance of said disc is its first and is located above said band and said rod has a length approximately equal to a half wave-length at the lower limit of said band.

10. A mechanical wave filter for transmitting a band of frequencies comprising a rod and a transverse disc both made of acoustic material, said rod having a length approximately equal to a half wave-length at a frequency within said band and said disc being centrally mounted near the center of said rod and adapted to be set into flexural vibration by longitudinal vibrations impressed upon an end of said rod and having its first flexural antiresonance at a frequency on the lower side of said band and said rod having a length approximately equal to a half wave-length at the upper limit of said band.

11. A filter in accordance with claim 1 in which said flexural antiresonance of said disc is its first and is located below said band and said rod has a length approximately equal to a half wave-length at the upper limit of said band.

12. A mechanical wave filter for transmitting a band of frequencies comprising a rod and two transverse discs, said rod having a length approximately equal to a half wave-length at a frequency within said band, said discs being centrally mounted, located close together near the center of said rod and adapted to be set into flexural vibration by longitudinal vibrations impressed upon an end of said rod, one of said discs having a flexural antiresonance at a frequency below said band and the other of said discs having a flexural antiresonance at a frequency above said band.

13. A filter in accordance with claim 12 in which said discs are located one on either side of the center of said rod.

14. A filter in accordance with claim 12 in which said rod has a length approximately equal to a half wave-length at the mid-band frequency.

15. A filter in accordance with claim 12 in which said flexural antiresonances are located, respectively, close to the limits of said band.

16. A filter in accordance with claim 12 in which said flexural antiresonance of said one disc is the only one occurring below said band and

said flexural antiresonance of said other disc is its first.

17. A mechanical wave filter for transmitting a band of frequencies comprising a rod and two transverse discs, said rod having a length approximately equal to a half wave-length at a frequency within said band, said discs being centrally mounted, located close together near the center of said rod and adapted to be set into flexural vibration by longitudinal vibrations im-

pressed upon an end of said rod, one of said discs having its first flexural antiresonance at a frequency close to one limit of said band and the other of said discs having its first flexural antiresonance at a frequency close to the other limit of said band.

18. A filter in accordance with claim 17 in which said rod has a length approximately equal to a half wave-length at the mid-band frequency

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