June 15, 1948. W. P. MASON 2,443,471

PIEZOELECTRIC DAMPING MEANS FOR MECHANICAL VIBRATIONS

Filed March 29, 1945

FIG. 1

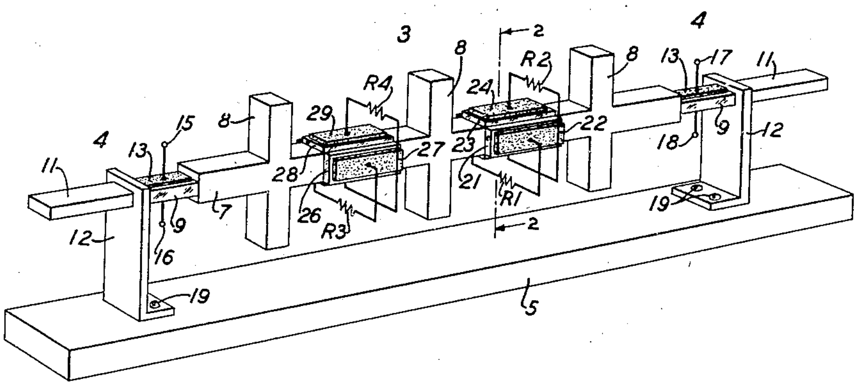
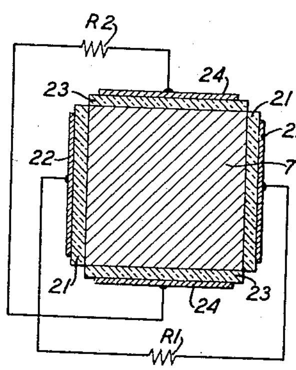


FIG. 2



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PIEZOELECTRIC DAMPING MEANS FOR MECHANICAL VIBRATIONS

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1

This invention relates to mechanical vibratory elements and more particularly to means for damping an undesired mode of vibration in such an element.

The object of the invention is to damp an undesired mode of vibration in a mechanical vibratory element without appreciably affecting the desired mode.

A mechanical vibratory element such, for example, as is used in mechanical wave filters is subjected to vibration in some desired mode. However, there may be set up in the element an undesired extraneous mode of vibration which interferes with the propagation of the desired mode. It is, therefore, advantageous to eliminate the undesired mode.

In accordance with the present invention this undesired mode is damped by associating a pair of piezoelectric crystal plates with opposite sides of the mechanical vibratory element and connecting an electrical impedance between the plates. The plates are so poled that the voltages generated therein are additive for the undesired mode but opposing for the desired mode. The energy associated with the undesired mode is thus dissipated in the electrical impedance but the desired mode is substantially unaffected.

For example, the mechanical vibratory element may be a bar of rectangular cross-section which forms a part of a mechanical wave filter and is subjected to desired longitudinal vibrations but in which undesired flexural vibrations occur. In this case a pair of piezoelectric crystal plates are attached to the sides of the bar which flex and connected through an electrical impedance which may comprise a resistor. The plates are so poled that the voltages generated therein are opposing for the longitudinal vibration and, therefore, have negligible effect upon it, but are aiding for the flexural vibration and, therefore, damp it out by dissipating the associated energy in the electrical impedance. The damping action on the flexural vibrations may be increased by attaching one or more additional pairs of crystal plates, with their associated electrical impedances, at other points on the same sides of the bar. If flexural vibrations occur in the bar in the other direction also, one or more other pairs of crystal plates, with their associated electrical impedances, may be attached to the other sides of the bar.

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

2

Fig. 1 is a perspective view of an electromechanical wave filter of the cross bar type including damping means in accordance with the invention; and

Fig. 2 is a cross-sectional view of the filter of Fig. 1 taken along the line 2—2.

The electromechanical wave filter shown in Fig. 1 comprises a mechanical portion 3 and electromechanical converters 4 at each end, rigidly mounted on a base 5. The mechanical portion 3 consists of a longitudinal bar 7 and three cross bars 8 which form a three-section filter of the type disclosed in my United States Patent 2,345,491 issued March 28, 1944.

Each electromechanical converter 4 comprises a piezoelectro crystal element 9, a metallic resonator 11, and a support 12. The crystal 9 has one end attached to the end of the bar 7 and the other end to one side of the support 12. The resonator 11 has one end attached to the other side of the support 12, opposite the crystal 9. The crystal 9 and the resonator 11 each have a length approximately equal to a quarter wavelength at the midband frequency of the filter. Each crystal 9 has a pair of electrodes 13 on its major faces. One pair of electrodes 13 are connected, respectively, to the input terminals 15, 16 and the other pair to the output terminals 17, 18. Since the ends of the crystal 9 and the resonator 11 attached to the support 12 coincide with nodes or motion, the supports 12 may be secured at their lower ends to the base 5 by means of the screws 19 to provide a rigid mounting for the filter.

When an alternating electromotive force is impressed upon the input terminals 15, 16, the crystal 9 will vibrate longitudinally and set up corresponding longitudinal vibrations in the bar 7. However, there are likely to be set up also in the bar 7 undesired flexural vibrations which interfere with the desired longitudinal vibrations and impair the proper operation of the filter. These extraneous flexural vibrations are more likely to occur in a rigidly mounted, multisection, filter of the cross bar type such as is shown in Fig. 1. In accordance with the invention, means are provided for damping the flexural vibrations without appreciably affecting the longitudinal vibrations, thereby improving the operation of the filter.

As shown in Figs. 1 and 2, these damping means comprise a pair of piezoelectric crystal plates 21 attached to the sides of the bar 7 which tend to flex. The plates 21 are preferably thin 45-degree Y-cut slabs from a Rochelle salt crystal or thin 45-degree Z-cut slabs from an ammonium dihydrogen phosphate crystal. A 45-degree Y-cut plate has its major faces substantially perpendicular to a Y axis and its length dimension inclined at an angle of 45 degrees to the X and Z axes of the crystal. A 45-degree Z-cut plate has its major faces substantially perpendicular to a Z axis and its length dimension inclined at an angle of 45 degrees to the X and Y axes of the crystal. The plates 21 are preferably located at a point on the bar 7 intermediate two of the cross bars 8 and may be secured in position by means of melted Rochelle salt cement or urea formaldehyde cement, or they may be otherwise suitably attached. The plates 21 are provided with the usual electrodes 22 which are connected through an electrical impedance comprising a resistor R1. For maximum damping the resistance of the resistor R1 is made equal to the sum of the reactances of the two crystal plates 21 at the midband frequency of the filter.

The plates 21 are so poled that the voltages generated therein are aiding for the unwanted flexural vibrations but opposing for the desired longitudinal vibrations. The energy associated with the flexural vibrations is thus dissipated in the resistor R1 and, therefore, this mode is effectively damped out, without appreciably affecting the propagation of the longitudinal mode.

If the other sides of the bar 7 also tend to flex, a second pair of crystal plates 23 may be attached thereto and provided with associated electrodes 24 and a second resistor R2. Furthermore, the damping action may be made more complete by providing additional damping means, such as the pair of crystal plates 26, with electrodes 27 and resistor R3, and the plates 28, with electrodes 29 and resistor R4.

What is claimed is:

1. In combination, a mechanical vibratory element subjected to two modes of vibration and means for damping one of the modes without appreciably affecting the other mode, said means comprising a pair of piezoelectric crystal plates associated with opposite sides of said element and an electrical impedance connected between said plates, said plates being so poled that the voltages generated therein are aiding for said one mode but opposing for said other mode.

2. The combination in accordance with claim 1 in which said one mode is flexural.

3. The combination in accordance with claim 1 in which said other mode is longitudinal.

4. The combination in accordance with claim 1 in which said one mode is flexural and said other mode is longitudinal.

5. The combination in accordance with claim 1 in which said impedance comprises a resistor.

6. The combination in accordance with claim 1 in which said impedance comprises a resistor having a resistance approximately equal to the sum of the reactances of said crystal plates at an operating frequency of said element.

7. The combination in accordance with claim 1 in which said element forms part of a mechanical wave filter.

8. The combination in accordance with claim 1 in which said element is in the form of a bar.

9. The combination in accordance with claim 1 in which said element constitutes a longitudinal bar in a mechanical wave filter.

10. The combination in accordance with claim 1 in which said plates are thin, 45-degree Y-cut slabs from a Rochelle salt crystal.

11. The combination in accordance with claim 1 in which said plates are thin, 45-degree Z-cut slabs from an ammonium dihydrogen phosphate crystal.

12. The combination in accordance with claim 1 which includes additional damping means, similar to said first-mentioned damping means, associated with said opposite sides of said element.

13. The combination in accordance with claim 1 which includes additional damping means, similar to said first-mentioned damping means, associated with the other sides of said element.

14. The combination in accordance with claim 1 which includes two additional damping means, each similar to said first-mentioned damping means, one being associated with said opposite sides of said element and the other being associated with the other sides of said element.

15. The combination in accordance with claim 1 which includes three additional damping means, each similar to said first-mentioned damping means, one being associated with said opposite sides of said element and the other two being associated with the other sides of said element.

16. In combination, a mechanical vibratory element, means for impressing longitudinal vibrations upon one end of said element, and means for damping extraneous flexural vibrations in said element without appreciably affecting said longitudinal vibrations, said means comprising a pair of piezoelectric crystal plates attached to opposite sides of said element and an electrical impedance connected between said plates, said plates being so poled that the voltages generated therein are aiding for said flexural vibrations but opposing for said longitudinal vibrations.

17. The combination in accordance with claim 16 in which said impedance comprises a resistor.

18. The combination in accordance with claim 16 in which said impedance comprises a resistor having a resistance approximately equal to the sum of the reactances of said crystal plates at the frequency of said longitudinal vibrations.

19. The combination in accordance with claim 16 in which said element forms part of a wave filter.

20. The combination in accordance with claim 16 which includes additional damping means, similar to said first-mentioned damping means, attached to said opposite sides of said element.

21. The combination in accordance with claim 16 which includes additional damping means, similar to said first-mentioned damping means, attached to the other sides of said element.

22. In combination, two rigidly supported electro-mechanical convertors, an interposed mechanical vibratory element along which longitudinal vibrations are transmitted from one to the other of said convertors, and means for damping extraneous flexural vibrations in said element without appreciably affecting said longitudinal vibrations, said means comprising a pair of piezoelectric crystal plates attached to opposite sides of said element and an electrical impedance including a resistance connected between said plates, said plates being so poled that the voltages generated therein are aiding for said flexural vibrations but opposing for said longitudinal vibrations.

23. The combination in accordance with claim 22 in which said resistance has a value approximately equal to the sum of the reactances of

said crystal plates at the frequency of said longitudinal vibrations.

24. The combination in accordance with claim 22 which includes additional damping means, similar to said first-mentioned damping means, attached to said opposite sides of said element.

25. The combination in accordance with claim 22 which includes additional damping means, similar to said first-mentioned damping means, attached to the other sides of said element.

26. In combination, a longitudinal bar having a plurality of cross bars, means for impressing longitudinal vibrations upon one end of said longitudinal bar, and means for damping extraneous flexural vibrations in said longitudinal bar without appreciably affecting said longitudinal vibrations, said means comprising a pair of piezoelectric plates attached to opposite sides of said longitudinal bar at a point intermediate two of said cross bars and an electrical impedance including a resistance connected between said plates, said plates being so poled that the voltages generated therein are aiding for said flexural vibrations but opposing for said longitudinal vibrations.

27. The combination in accordance with claim 26 in which said resistance has a value approximately equal to the sum of the reactances of said crystal plates at the frequency of said longitudinal vibrations.

28. The combination in accordance with claim 26 which includes additional damping means, similar to said first-mentioned damping means, attached to said opposite sides of said longitudinal bar.

29. The combination in accordance with claim 26 which includes additional damping means, similar to said first-mentioned damping means, attached to the other sides of said longitudinal bar.

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REFERENCES CITED

The following references are of record in the file of this patent:

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