

[54] ULTRASONIC MOTORS

[72] Inventor: Lewis Balamuth, New York, N.Y.

[73] Assignee: Ultrasonic Systems, Inc., Farmingdale, N.Y.

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[58] Field of Search 310/8.0, 8.2, 8.3, 8.5, 8.6, 310/8.7, 9.1, 20, 25, 26; 30/272, 228; 74/155, 430

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Primary Examiner—L. T. Hix

Assistant Examiner—Mark O. Budd

Attorney—Leonard W. Suroff

[57]

ABSTRACT

An ultrasonic motor construction wherein the compressional wave mechanical energy is transmitted through a transmission member into flexural vibrational wave energy to a working tip or surface removed a distance from the transducer associated therewith. Various forms of ultrasonic motor constructions are illustrated as in the form of a welding instrument or scissor.

4 Claims, 11 Drawing Figures

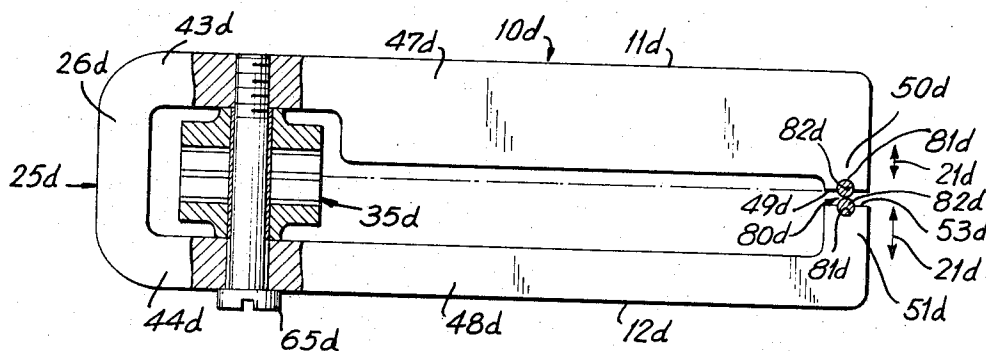


FIG. 1

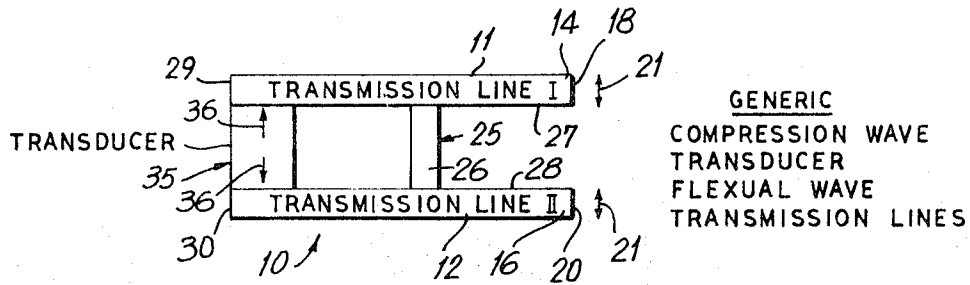


FIG. 2

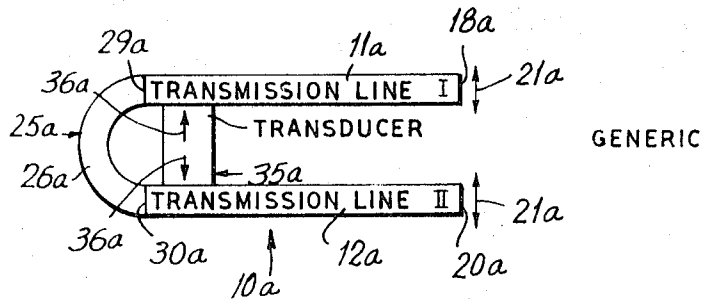
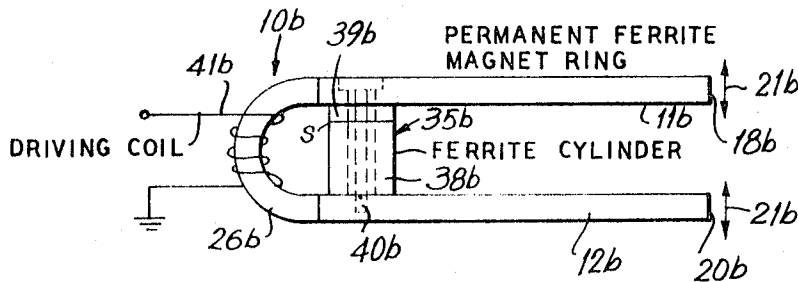
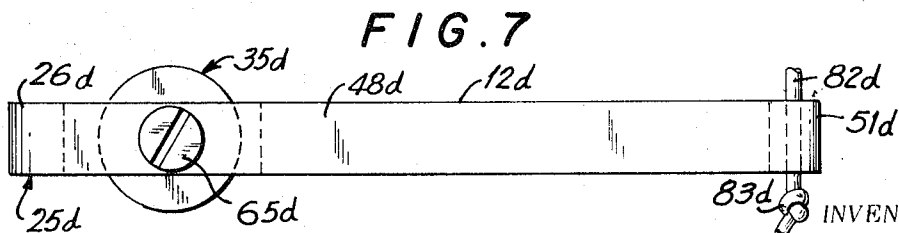
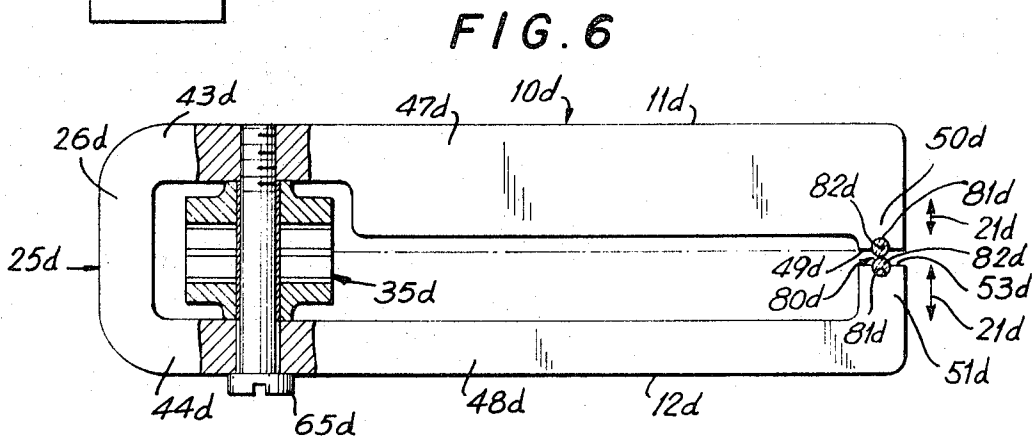
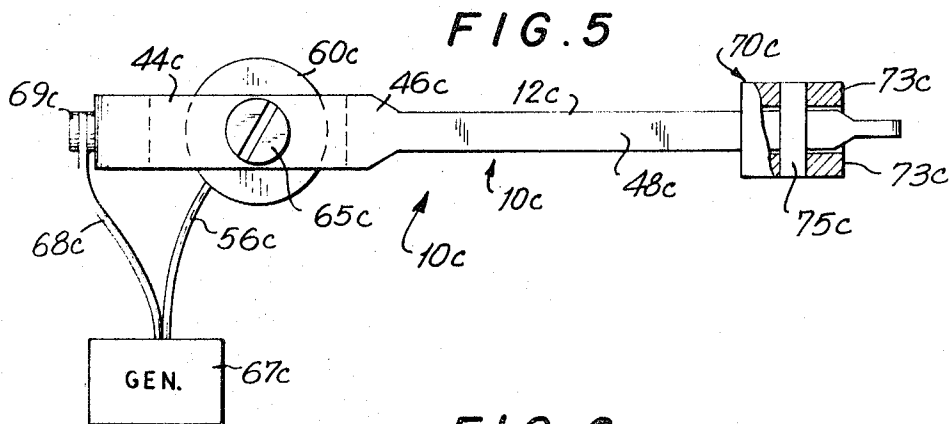
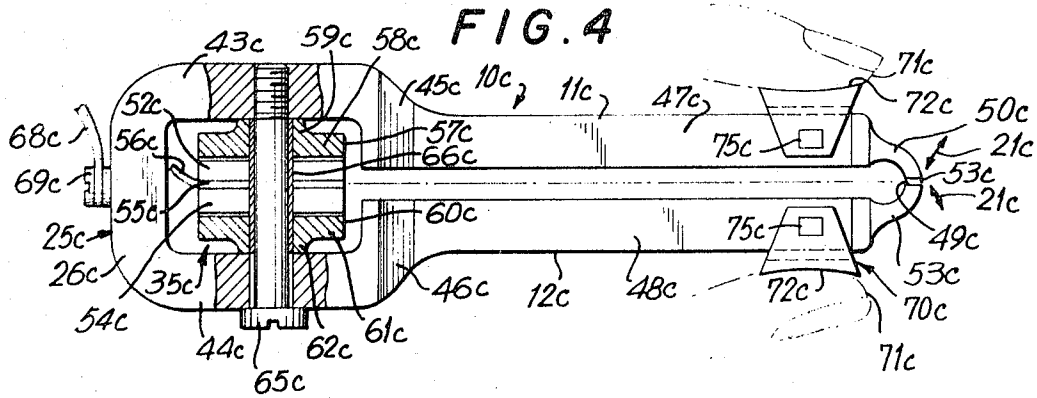


FIG. 3



INVENTOR
LEWIS BALAMUTH

BY
Leonard W. Suoff
ATTORNEY



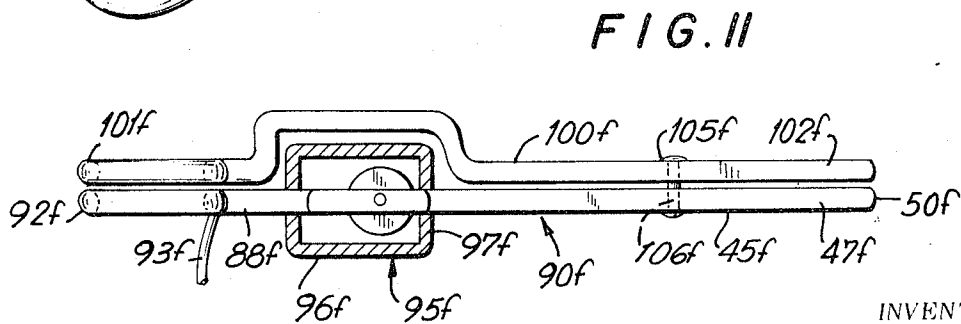
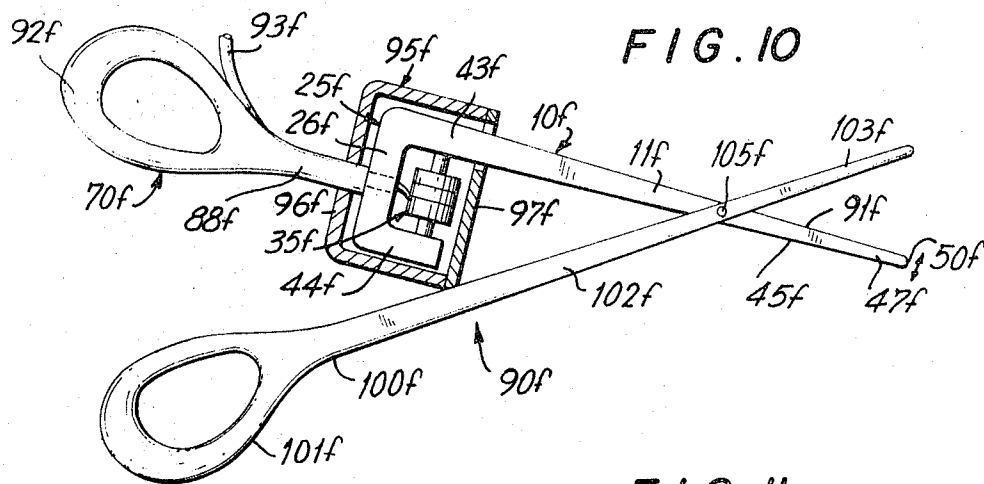
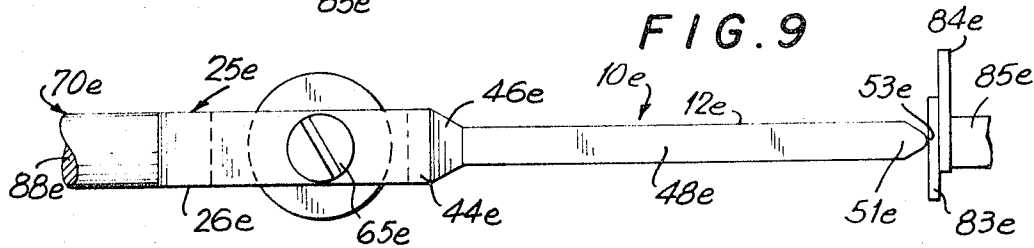
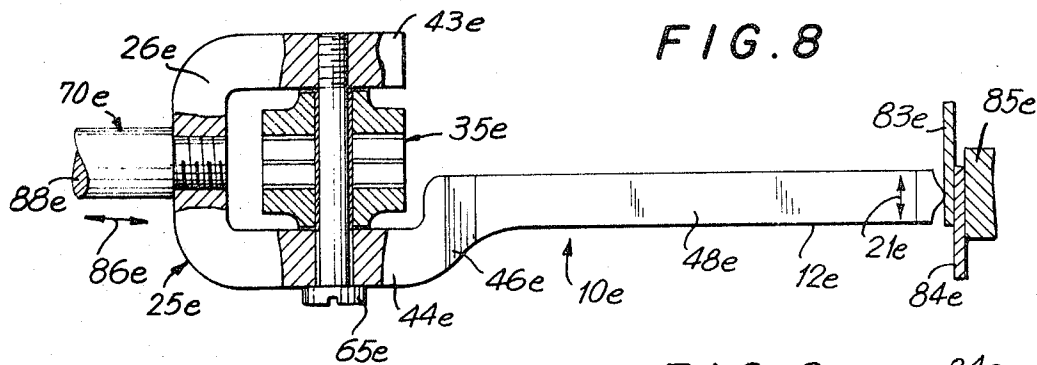
INVENTOR.
LEWIS BALAMUTH

BY
Leonard W. Snoff
ATTORNEY

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INVENTOR.
LEWIS BALAMUTH

BY
Leonard W. Snoff
ATTORNEY

ULTRASONIC MOTORS

BACKGROUND OF THE INVENTION

The present invention describes ultrasonic motors in which the vibratory mechanical energy is transmitted to a point remote from the generating source for transmitting vibratory energy and particular adaptations thereof for use as for example, a welding device and scissor.

The prior art designs of ultrasonic motors are generally limited in that the vibratory energy generated thereby is transmitted and used in a plane substantially along the axis thereof and not at a point or plane remote from the axis along which the mechanical vibrations are generated.

The ability to be able to transmit these mechanical vibrations at an ultrasonic frequency, herein defined to include vibrations in the range of 1,000 to 1,000,000 cycles per second, permits the design of various motor constructions not heretofore possible.

Numerous types of hand held ultrasonic motors have been disclosed in the prior art, however, in this invention we have to do with a new type of ultrasonic motor, which involves mode conversion in going from the transducer to the tool or transmission part, and which takes advantage of this mode conversion in order to create novel means for a variety of purposes. Among such purposes, for example, are included a system in the form of hand shears for the purpose of securing suture knots in surgery, another form of hand shears to embody an ultrasonic scissors capable of smooth cutting of tissue even down to miniature levels, such as are required in eye surgery, a form of said motor may be adapted to be used as a tooth brush, razor, scalpel, etc.

OBJECTS OF THE INVENTION

An object the invention is to provide an ultrasonic motor construction in which the energy is transmitted through transmission means by flexural vibrations applied at a point remote from the transducer generating the vibrations.

Another object of the invention is to provide a compact ultrasonic motor construction adaptable to be hand held by the user.

Another object of the invention is to provide an ultrasonic motor adaptable to be incorporated into a variety of functional instruments.

Other objects and advantages of the invention will become apparent as the disclosure proceeds.

SUMMARY OF THE INVENTION

The invention discloses an ultrasonic motor having a variety of applications since it permits the generation of mechanical vibrations at selected locations in spaced relation to the transducer initially generating the compressional waves. The motor may include a pair of spaced apart elongated arm transmission members, at least one of which has a free end adapted to be used for transmitting vibrations and coupling means for maintaining the transmission arms in a relatively fixed position with respect to each other. Transducer means extend between the transmission members for inducing ultrasonic mechanical vibrations in the transmission members in spaced relation to the free ends thereof, wherein vibrations are transmitted therethrough to induce flexural vibrations at the free end. Gripping means may be secured to one or both of the spaced apart transmission members and adapted to be manipulated by the user thereof for hand held size motors. The gripping means may be positioned at nodal regions of vibration for minimum vibrational transmission to the gripping means. In accordance with one form the gripping means are in the form of finger rests containing extending tabs which overlap the respective transmission members with a pin extending transversely through the transmission members and into the tabs.

To enclose the transducer housing means may be provided which permits the transmission members to extend therethrough. The transmission members may have inwardly directed projections containing positioning means therein for

retaining the members, for example, to be welded, in a relatively fixed position with respect to each other. The amplitude of flexural vibration at the free end of each transmission member may be varied or selected by having a different mass via the cross-sectional area of each member.

BRIEF DESCRIPTION OF THE DRAWINGS

Although the characteristic features of this invention will be particularly pointed out in the claims, the invention itself, and the manner in which it may be made and used, may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part hereof, wherein like reference numerals refer to like parts throughout the several views and in which:

FIGS. 1, 2 and 3 show in somewhat schematic form ultrasonic motor constructions generic to the present invention;

FIG. 4 is a plan view of an ultrasonic motor embodying the invention in a particular form;

FIG. 5 is a side elevational view of the motor of FIG. 4;

FIG. 6 is a plan view of another ultrasonic motor embodying the invention in a particular form;

FIG. 7 is a side elevational view of the motor of FIG. 6;

FIG. 8 is a plan view of another ultrasonic motor embodying the invention in a particular form;

FIG. 9 is a side elevational view of the motor of FIG. 8;

FIG. 10 is a plan view of an ultrasonic scissor in accordance with the present invention; and

FIG. 11 is a side elevational view of the ultrasonic scissor of FIG. 10.

DETAILED DISCUSSION OF PREFERRED EMBODIMENTS

Referring to the drawings and initially to FIGS. 1-3 thereof, we have somewhat schematic representations of the motor construction of the present invention in which as illustrated in FIG. 1 the motor 10 includes a pair of spaced apart elongated arms or transmission members or lines 11 and 12, which may be referred to as the first and second transmission members for convenience. The transmission members may each have a free end 14 and 16 with a respective output end or tip 18 and 20 adapted to be vibrated in a flexural mode, as hereinafter described, to obtain flexural vibrations as indicated by the double headed arrows 21.

The transmission members 11 and 12 are maintained in a relatively fixed position with respect to each other by coupling means 25 which may include a support member 26 conventionally secured to the respective transmission members 11 and 12, as at their inner edge or surface 27 and 28. The support member 26 is positioned in longitudinally spaced relation to the free ends 14 and 16 and may be located at the rear ends 29 and 30, or therebetween as shown. The support member 26 may be joined to the transmission members 11 and 12 at substantially a nodal region of flexural vibration where the amount of transmitted mechanical vibrations is maintained at a minimum.

Extending between the transmission members 11 and 12 and in energy coupling relation thereto is transducer means 35 capable of generating compression waves in the frequency range of 1,000 to 1,000,000 cycles per second which mechanical energy waves indicated by arrows 36 are transmitted to the first or second transmission lines, or both, to excite them in their flexural mode for effecting the flexural vibrations at their free ends 14 and 16 as indicated by the arrows 21.

The ultrasonic elastic waves of a compressional wave form are produced by a transducer 35 which is energized by an oscillation generator adapted to produce electrical energy having an ultrasonic frequency which for the purposes of this invention is defined between the approximate range of 1,000 cycles per second to 1,000,000 cycles per second. The transducer 35 may be one of a variety of electro mechanical types, such as electrodynamic, piezoelectric or magnetostrictive.

Preferably the transducer 35 and generator may be operated at both a fixed frequency or modulated over defined frequency range. The specific oscillation generator and transducer 35 for accomplishing the result may be conventional, and as such, a detailed description thereof need not be included in this disclosure since it is known to those skilled in the art.

FIG. 2, illustrates an ultrasonic motor 10a similar to that illustrated in FIG. 1, wherein the transmission members 11a and 12a extend in substantially spaced apart relation to each other with the coupling means 25a extending between the rear ends 29a and 30a at one end of the motor. The support member 26a may have a substantially U-shaped configuration to provide the necessary coupling effect. The transducer means 35a extends between the transmission members 11a and 12a to generate the longitudinal vibrations as indicated by arrows 36a to set up flexural vibrations that are transmitted to the tips 18a and 20a as indicated by arrows 21a.

FIG. 3, illustrates a motor 10b in which the transducer means 35b is of a magnetostrictive type using a ferrite cylinder 38b with a permanent ferrite magnet ring 39b adjacent thereto and clamped together by a bolt 40b that extends between the transmission members 11b and 12b to induce flexural vibrations at the output ends 18b and 20b as indicated by the arrow 21b. A driving coil 41b, connected to an electrical source not shown, extends around the support member 26b to excite the transducer 35b to cause it to vibrate.

FIGS. 4 and 5, illustrate an ultrasonic motor 10c which includes a pair of spaced apart elongated arms or transmission members 11c and 12c having respective rear sections 43c and 44c that may be integrally formed with the support member 26c of the coupling means 25c which is positioned at one end of the motor 10c. The rear sections 43c and 44c merge with middle sections 45c and 46c which extend inwardly and decrease in cross-section and merge with respective front sections 47c and 48c which form the transmission members 11c and 12c. The front sections 47c and 48c merge with contoured tips 50c and 51c respectively, that terminate in an output edge or surface 49c and 53c for engagement with the work to be contacted and to which the mechanical vibrations indicated by arrows 21c is transmitted. The tips 50c and 51c, as well as the transmission members 11c and 12c, may be of equal or different cross-sectional configuration depending upon the specific need or application of the motor. Accordingly, the amplitude and direction of mechanical vibration designated by each arrow 21c may be varied by the selection of the proper design criteria of the transmission members.

The transducer means 35c may include two piezoelectric wafers or disks, which may be referred to as the front disk 52c and rear disk 54c separated by an electrode 55c electrically connected to a power source in a conventional manner by wire 56c. The disks may be located at, or in the region of a node of longitudinal vibration of the transducer 35c. The piezoelectric disks may be of commercially available PZT-4 material from the Clevite Corporation. The front disk 52c is directly connected to a metallic output transmission section 57c which includes a flanged portion 58c, which may have a circular cross-sectional substantially equal to that of the circular cross-section of the crystal 52c, with an output portion 59c of a reduced diameter for engagement with the rear section 43c. A second output transmission section 60c may be provided which includes a flange portion 61c which may have a circular cross-section substantially equal to that of the circular cross-section of the crystal 54c, with an output portion 62c of a reduced diameter for engagement with the rear section 44c. The axial length of the transducer may be of a half wavelength at the frequency of vibration of the overall motor. The disks 52c and 54c, electrode 55c and transmission sections 57c and 60c may be secured or bonded together with an epoxy cementing compound alone or by a bolt 65c. The bolt 65c extends through the rear section 44c and 43c in a conventional manner to compress the disks together. An insulating sleeve 66c may surround the bolt 65c in a conventional manner.

The electrical connection of the motor 10c is to a converter or generator 67c of any well known type, with lead 56c and lead 69c connected thereto with the latter lead coupled by fastener 69c. The converter 67c may be provided with conventional power control adjustments, etc.

The motor 10c to be used is generally positioned in a mechanical device or may be hand held to perform the desired transmission of the ultrasonic mechanical vibrations to a work object. As seen in FIGS. 4 and 5, gripping or retaining means 70c is provided and secured to the spaced apart transmission members 11c and 12c to permit the respective members to be manipulated by the user 71c. The gripping means 70c may be in the form of finger rests 72c with formed tabs 73c which overlap the front sections 47c and 48c, with a pin 75c extending transversely through the transmission members into the tabs 73c. The pin 75c may have a rectangular cross-section to prevent angular rotation of the grips 72c when positioned between the fingers of the user 71c and the static force applied thereto will flex the transmission members 11c and 12c so that the output edges 49c and 53c may be moved towards and away from each other. The gripping means may be positioned at a node of flexural motion so that the vibratory energy transmitted to the user 71c is not present or minimal. The rigidity of the transmission members are selected to have a longitudinal length and cross-sectional area to permit a preselected degree of gross movement when held in the hand of the user. In addition the amplitude of vibration is also a factor of the longitudinal length and cross-sectional area of the transmission members 11c and 12c, and by selecting these variables each output edge 49c and 53c may exhibit the same or different amplitudes of vibration. The shape and cross-section of the tips 50c and 51c also dictate the direction and amplitude of mechanical vibrations exhibited by the arrows 21c.

The motor in operation may have the output edges 49c and 53c first placed over the work object, which for welding may be overlapping sheets of thermoplastic material, and then compressed by the user 71c placing his fingers on the gripping means 70c and applying the necessary static force against the objects with the power from generator 67c then turned on to energize the transducer means 35c. The mechanical vibrations are then transmitted via the transmission members 11c and 12c to the work edges 49c and 53c. The spacing between the opposing edges 49c and 53c may be in the order of 0.001 inch to 1.0 inch for most applications, but may extend to as much as 1 foot or more for large objects such as the welding of rigid plastic members.

FIGS. 6 and 7, illustrate another form of the invention in which the motor 10d is of a design in which the transmission members 11d and 12d are of different cross-sectional areas such that the degree of vibration exhibited by the arrows 21d will differ. The transducer 35d transmits the mechanical vibrations to the rear sections 43d and 44d which are mechanically joined together by coupling means 25d in the form of a support member 26d that is connected to or integrally formed with the rear sections 43d and 44d. The rear section 43d is joined to the front section 47d and in turn to a tip portion 50d having an output edge 49d. The rear section 44d is coupled to front section 48d and terminates in a tip portion 51d having an output edge 53d. Positioning means 80d is provided in the form of a recess or depression 81d on each of the output edges 49d and 53d to contain therein the work object illustrated in the form of filaments or wires 82d. As seen in FIG. 7, a knot 83d is shown, as for example as used in suturing where it is desired to weld or bond ultrasonically overlapping segments thereof which are welded together when a static force is applied to the spaced apart transmission members 11d and 12d. The gross movement of the transmission members 11d and 12d may be obtained manually or by other mechanical means as in a press for welding larger size objects.

FIGS. 8 and 9, illustrate another form of the invention in which the motor 10e is designed to have a single transmission member 12e that is ultrasonically vibrated by means of transducer means 35e coupled to rear section 43e and 44e, that are

joined together by coupling means 25e in the form of support member 26e. The rear section 44e tapers downwardly by middle section 46e which in turn is connected to front section 48e which terminates in a tip 51e that may taper downwardly to an output edge 53e. The flexural vibrations generated, as shown by arrows 21e, may be used for various applications of ultrasonic energy since the motor 10e has use in various fields with one application being illustrated for convenience only. For welding of materials as sheets 83e and 84e, the motor is used in combination with supporting or anvil means 85e on which the sheets are contained. The static force is applied by moving the motor 10e along an axis indicated by arrow 86e. Retaining means 70e is provided in the form of a shaft 88e threadably engaged with the coupling means 25e. The shaft 88e may be coupled to a press that is automatically cycled to compress and weld the sheets 83e and 84e.

FIGS. 10 and 11, illustrate a form of the motor 10f as incorporated and made part of a cutting instrument 90f which is illustrated in the form of an ultrasonic scissor. The motor 10f includes a transducer 35f mounted between the rear section 43f of transmission member or first arm 11f and rear section 44f with the coupling means 25f in the form of support member 26f connecting them together. The middle section 45f extends into a front section 47f terminating in a tip 50f. The transmission member 11f may be tapered as in a scissor with a shearing or cutting edge 91f provided to extend along one surface or edge of the first arm 11f.

To control the movement of the transmission member 11f gripping means 70f is provided in the form of a shaft 88f secured in any conventional manner to the support member 26f such that at least no noticable vibration is transmitted thereto. The shaft 88f at its opposite end is formed as a finger grip 92f for the finger of the user. The shaft 88f and finger grip 92f may be hollow to accommodate the power lines in a conduit 93f which is coupled to an electrical converter for energizing the motor.

To enclose the motor 35f housing means 95f is provided and includes a hollow shell 96f which covers a portion of the transmission member 11f with a front plate 97f attached to the housing casing 96f and having an opening therein for a portion of the transmission member 43f to extend therethrough. Obviously the shape and configuration of the housing means will vary as to the shape and size of the motor which is a factor of the frequency of the motor, i.e., 20 Kc, 40 Kc, 80 Kc, etc., as well as if it is magnetostrictive or piezoelectric.

A second arm 100f is provided having a finger grip 101f at one end thereof with a tapered member 102f having a complementary cutting or shearing edge 103f for use in conjunction with edge 91f. As seen in FIG. 11, the arm 100f is contoured to avoid engagement with the housing 95f and to permit free movement therebetween. If desired the second arm may be similarly constructed as the first arm in that an ultrasonic motor may be incorporated therein such that each arm is ultrasonically vibrated to effect a severing of the tissue or any other material for which the ultrasonic scissor is used with a minimum of friction.

To connect the arms 11f and 100f for pivotally moving them, connecting means 105f is used and may consist of a pin

106f that extends through the arms and is headed over at each side thereof. The location of the pin may be at substantially a node of motion so that the pin 106f remains substantially isolated from vibrational energy. If desired a rubber or other acoustic material to absorb vibrations may be used in conjunction with the connecting means.

The scissor may be used for industrial applications as well as medical as in the cutting of human or other animal tissue for surgical purposes. By reducing the frictional effect by vibrating the cutting edge controlled movement of the scissor with minimal effort can take place. Although the scissor is designed for movement between the arms a shearing action may take place with the blades maintained in a fixed position after they have been set in place by the user.

The instrument illustrated in FIGS. 10 and 11, is also capable of being used for other applications of hand held instruments in which ultrasonic energy is to be applied, as for example, in welding of materials. The cutting edge is essentially a free end and may have various configurations adapted for use on the particular application of ultrasonic energy. For example, a series of indentations may be provided so that a welding and cutting action may be simultaneously obtained as in the welding of sutures.

Although illustrative embodiments of the invention have been described in detail herein with reference to the accompanying drawings it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be effected therein without departing from the scope or spirit of the invention.

I claim:

1. A hand held instrument, comprising:

A. a pair of arms each having a cutting edge extending along one edge from one end thereof,

B. gripping means on each of said arms at the other end thereof,

C. means pivotally connecting said arms together to permit cooperation between said cutting edges,

D. means for ultrasonically vibrating at least one of said arms to obtain high frequency mechanical vibrations at said cutting edge, at a frequency range of 1,000 to 500,000 cycles per second, said means including:

1. a vibration generator,

2. an ultrasonic motor including a plurality of piezoelectric crystals held by a center bolt and connected to said vibration generator, and

3. means connecting said ultrasonic motor to said vibrated arm for transmitting said vibrations thereto, and

E. housing means enclosing said ultrasonic motor.

2. A hand held instrument as in claim 1, wherein one of said arms has a cutting edge, to permit the instrument to be used as a scissor.

3. A hand held instrument as claimed in claim 1, wherein said means pivotally connecting said arms together is located at a node of vibrational motion.

4. A hand held instrument as claimed in claim 1, wherein said arm is vibrated along its length to obtain the ultrasonic mechanical vibration at its cutting edge.

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