

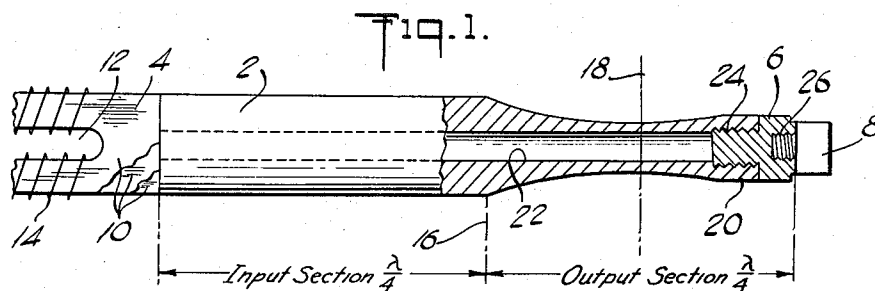
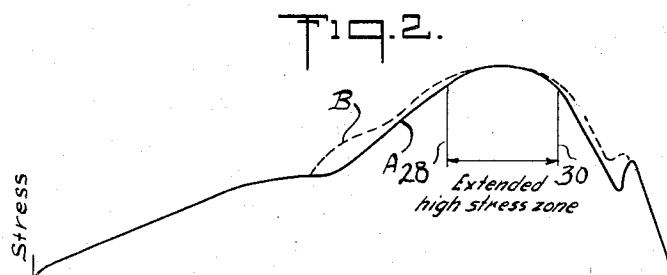
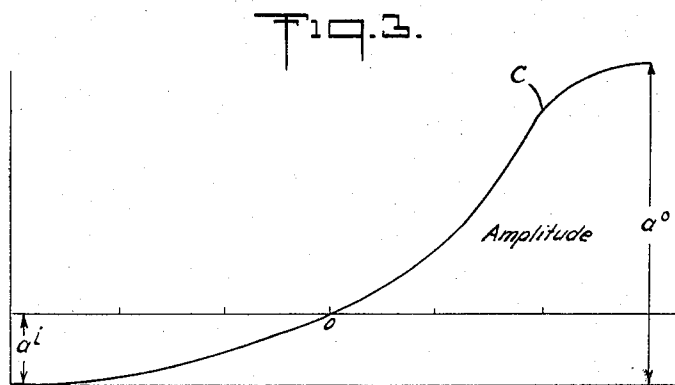
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C. KLEESATTEL

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ACOUSTIC IMPEDANCE TRANSFORMER

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INVENTOR

CLAUS KLEESATTEL

BY

Eyre, Mann & Burrows
ATTORNEYS

1

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ACOUSTIC IMPEDANCE TRANSFORMER

Claus Kleesattel, Kew Gardens, N.Y., assignor to Cavitron Corporation, a corporation of New York

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The present invention relates to acoustic impedance transformers of the type utilized for transmitting ultrasonic vibrations to a tool from an electromechanical transducer such as a magnetostrictive transducer. Acoustic impedance transformers are used, for example, in ultrasonic cutting or drilling processes of the type disclosed and claimed in Balamuth Patent No. 2,580,716 dated January 1, 1952.

The new transformer, or tool holder, of the present invention is particularly suitable for use in ultrasonic drilling equipment such as is now employed in dental applications wherein the hand piece comprises a magnetostrictive transducer, an acoustic impedance transformer or tool holder secured at one end to an end of the transducer and a tool secured to the other end of the tool holder. The transformer or tool holder serves to transmit to the tool longitudinal vibrations generated in the transducer and to increase the amplitude of such vibrations. Various shapes of transformers or tool holders have been used, including exponentially tapered tool holders, conical tool holders, multiple section cylindrical tool holders and the like. The tool holder should be of such length that during operation at the operating frequency a loop of motion of the longitudinal vibrations occurs at or near the tool attaching end of the holder. The total stress comprising the sum of the axial stress and the radial stress developed varies along the holder with the distance from a node and with the configuration of the holder. Any abrupt change in cross sectional area causes an abrupt stress rise. A tool holder employed in ultrasonic equipment is ordinarily provided at its end with a short axial threaded aperture for reception of the threaded stud of a tool. The stress rise occasioned by the abrupt change in cross sectional area at the base of the aperture weakens the tool holder at such location, creating a tendency to crack or break in the region of the aperture. An object of the present invention is therefore to minimize abrupt variation in total stress along the length of the transformer and particularly at the tool end thereof to thereby reduce danger of breakage.

In the practice of ultrasonic drilling processes it is necessary to change the tool at relatively frequent intervals. For this reason the tool is attached to the tool holder by screw threads. Frequent change of tool tends to wear the threads and shorten the life of the holder. Furthermore, when the tool is short, the abrasive slurry employed in the drilling process of the said Balamuth patent tends to penetrate the screw threads. This results in greater wear of the threads and further shortens the useful life of the tool holder. Another object of the invention, therefore, is to provide means for protecting the threaded end of the tool holder and thereby to increase the useful life of the equipment.

In accordance with the invention the new acoustic impedance transformer attains these objects and solves the above indicated difficulties by providing in an acoustic impedance transformer or tool holder a longitudinal opening extending axially from the tool end to or beyond

2

the location of a node of motion of the longitudinal vibrations transmitted by the holder and by providing a conformation of tool holder which substantially eliminates abrupt changes in cross sectional area. The longitudinal passage at the tool end of the transformer is threaded. This construction results in a tool holder having no abrupt stress rise along the length but with a relatively extended high stress zone intermediate its ends. The extension of the threaded aperture into a relatively long passage which extends to or beyond the node avoids the abrupt stress rise heretofore resulting at the point of connection to the tool. In the preferred embodiment of the invention wear of the threads of the tool holder is avoided by the provision of an intermediate coupling member between the tool and transformer which threads into the passage in the tool holder and into which the tool is threaded. The coupling member is preferably made of a metal of great strength and low density, such as titanium, and the two threaded sections thereof, the one section for connection to the tool holder and the other for reception of the threads of the tool, are of different pitch-diameter ratio to avoid loosening of the coupling member in the tool holder during removal of a tool. The coupling member may thus be removed and replaced when the threaded connection between the tool and the coupling member becomes fouled as a result of abrasive action. The useful life of the tool holder is thus prolonged.

For a better understanding of the invention and of a specific embodiment thereof, reference may be had to the accompanying drawing of which

Fig. 1 is a diagrammatic view, partly in longitudinal section, of ultrasonic cutting equipment incorporating an improved acoustic impedance transformer and coupling member embodying the invention;

Fig. 2 is a graph showing the variation in stress, both axial and radial, along the transformer of Fig. 1; and

Fig. 3 is a graph showing the change in amplitude along the transformer of the compressional waves transmitted thereby during operation of the equipment.

In Fig. 1 a tool holder or acoustic impedance transformer 2 embodying the invention is shown as fixedly connected at one end to an end of a magnetostrictive transducer 4 and is coupled at its other end through the intermediary of a coupling element 6 to a tool 8. The magnetostrictive transducer 4, which may be of any well known construction, has been schematically and but partially illustrated in the drawing, as including a laminated stack 10 of nickel or other magnetostrictive material provided with a slot 12 through which is threaded the turns of an energizing winding 14. It will be understood that high frequency alternating current together with a suitable direct current for proper bias will be delivered to the coil 14 from any suitable source (not shown). Compressional waves generated in the stack 10 are transmitted through the transformer 2 and coupling 6 to the tool 8. The transformer or tool holder 2 and magnetostrictive transducer 4 are fixedly secured together, as by soldering, and the dimensions of the transducer are such that during energization at the operating frequency say, 25 kc., a loop of motion occurs at the junction between the tool holder and transducer. In the particular embodiment of the invention illustrated in Fig. 1 the transformer 2 comprises a cylindrical one-quarter wavelength input section terminating in the region of a node of motion indicated by the broken line 16 and a one-quarter wavelength output section the cross sectional area of which gradually decreases from the input end to a minimum cross section in the neighborhood of the broken line 18 and then increases gradually to merge with a cylindrical end portion 20 of a diameter substantially less than that of the

cylindrical input section of the transformer. The transformer is provided with a longitudinal axial passage 22 which extends for the entire length of the two sections and is threaded in the region of the open end thereof within the cylindrical portion 20.

The tool 8 could be directly secured to the output section of the transformer by means of the threads within the passage 22 and for some purposes such an arrangement would be satisfactory, for example, where tool change was only desired after relatively long use of a tool and where the tool was intended for operation without the use of an abrasive slurry. Preferably, to reduce wear on the threads of the transformer and thereby to prolong the useful life thereof, there is provided a coupling member 6 having a threaded stud 24 thereon, the threads of which mate with the threads of the transformer. The coupling 6 is provided with an axial threaded passage 26 for reception of the threaded stud of the tool. The coupling member 6 should be of light strong material. Titanium has been found in practice to be particularly suitable for this purpose, but other materials, such as steel or Monel could be used. Threads of a different pitch-diameter ratio are used in the coupling member 6 to avoid any tendency of loosening of member 6 in the transformer during removal of a tool.

Because there is no abrupt change in cross sectional area of the transformer 2, when constructed of the configuration above described with reference to Fig. 1, there is no abrupt change in total stress along the length of the transformer which could lead to dangerous stress peaks and fracture of the tool holder.

In the graph of Fig. 2, where the ordinates represent stress on an arbitrary scale and the abscissae represent distance along the tool holder 2 and coupling member 6, the curve A illustrates typical variation of the longitudinal stress in a holder of the configuration of Fig. 1 when transmitting vibrations at the operating frequency. Curve B represents the combined longitudinal and radial stress. It will be apparent that although curve B indicates a relatively extended zone of high stress, that between the lines indicated by the reference numerals 28 and 30, there is no abrupt stress rise over the length of the holder. Moreover the total stress at the neighborhood of the threaded connection between the coupling member 6 and the tool holder 2 is relatively low, actually slightly less than that at the node. The shape of the stress curve B indicates that the transformer or holder of Fig. 1 will not have any critically weak zone where breakage is apt to occur, and therefore can be expected to have a relatively long operating life.

In Fig. 3, variation in amplitude of the compressional wave transmitted by the transformer 2 when the transducer is energized at the operating frequency is illustrated by the curve C. The magnification effected by the shape of the transformer 2 of Fig. 1 is apparent from a comparison of the amplitude a^i at the input end with the larger amplitude a^o at the output end of the transformer. It will be noted that the gradual and slight increase in cross sectional area of the output section of the transformer, beginning at line 18 and merging into the short cylindrical section 20 has but a relatively small effect in reducing the amplitude of vibrations at the output end of the transformer and coupling, while the overall effect of the transformer is to magnify the amplitude of vibration of the compressional waves.

The increase in cross sectional area at the output end serves to give additional strength along the threaded region. The provision of the removable and replaceable coupling member adds substantially to the life of the entire equipment.

The invention has now been described with reference to a single embodiment thereof. Various changes, within the scope of the accompanying claims, could be made

in the particular configuration of the acoustic impedance transformer. For example, a shorter longitudinal passage could be employed, one terminating in the neighborhood of a node of motion of the longitudinal vibrations, or the minimum cross sectional area of the holder could be at the tool end thereof, rather than short of the end as in the illustrated embodiment. Other variations will occur to those skilled in the art.

Although a magnetostrictive transducer has been shown and described as the source of the longitudinal vibrations transmitted by the new acoustic impedance transformer, obviously the invention is not limited to such specific type of transducer.

The following is claimed:

1. An acoustic impedance transformer for transmission of longitudinal vibrations from an electromechanical transducer to a tool, comprising an input section fixed at one end to the transducer, an output section integral at one end with the other end of said input section, said output section having a longitudinal open ended axial passage therein extending therethrough, the cross sectional area of said output section being greater at the input end than at the output end, and being a minimum intermediate the input and output ends, the change in cross sectional area along the length of the output section being gradual to prevent abrupt change in total stress, the wall of said passage adjacent the output end thereof being provided with screw threads, and a coupling member of hard, light weight material and provided with a stud having screw threads therein adapted to mate with the threads on the wall of said passage, said coupling member being provided with means for ready attachment thereto of a tool.

2. An acoustic impedance transformer for transmission of longitudinal vibrations from an electromechanical transducer to a tool, comprising an input section fixed at one end to the transducer and an output section integral at one end with the other end of said input section, said output section having a longitudinal open ended axial passage therein extending therethrough, screw threads formed on the interior wall of said axial passage at the output end of said output section, the cross sectional area of said output section gradually diminishing from a maximum at the input end to a minimum short of the output end and gradually increasing from the minimum to a magnitude at the output end substantially less than at the input end, whereby during transmission of longitudinal vibrations of a frequency such that a node of motion occurs at the junction of the input and output sections there is an extended high stress zone in the region of the minimum cross sectional area of the output section but no abrupt stress rise at any point along the output section; and a coupling member of hard, light weight material and provided with a stud having screw threads therein adapted to mate with the threads on the interior wall of said axial passage, said coupling member being provided with means for ready attachment of a tool thereto.

3. An acoustic impedance transformer for transmitting longitudinal vibrations of high frequency and small amplitude when rigidly attached to the output end of an electromechanical transducer, said transformer having a total wave length approximately corresponding to one-half the wave length or multiples thereof at the vibration frequency injected into the input end thereof by the transducer as fixed thereto, said transformer presenting an input section of substantial uniform cross sectional area and a variable cross sectional area output section integral with the input section, said output section having a wave length substantially equal to the wave length of the input section to thereby provide a node of motion at the area of juncture, said output section having a tool attaching end portion of substantially uniform cross sectional area, said output section having a gradually decreasing cross sectional area extending from

5

its nodal juncture with said input section to the intermediate region thereof and thence having a gradually increasing cross sectional area extending from said intermediate region to its juncture with said end portion, said end portion having a cross sectional area greater than the cross sectional area of the intermediate region of said output section but of lesser cross sectional area than the nodal juncture of said output section with said input section, whereby an extended high stress zone is provided in the intermediate region of the output section but no abrupt stress zone occurs at any point along the length of the transformer.

4. An acoustic impedance transformer for transmitting longitudinal vibrations of high frequency and small amplitude when rigidly attached to the output end of an electromechanical transducer, said transformer having a longitudinal passage extending axially therethrough and total wave length approximately corresponding to one-half the wave length or multiples thereof at the vibration frequency injected into the input end thereof by the transducer as fixed thereto, said transformer presenting an input section of substantial uniform cross sectional area and a variable cross-sectional area output section integral with the input section, said output section having a wave length substantially equal to the wave length of the input section to thereby provide a node of motion at the area of juncture, said output section having a tool attaching end portion of substantially uniform cross sectional area, said output section having a gradually decreasing cross sectional area extending from its nodal juncture with said input section to the intermediate region thereof and thence having a gradually increasing cross sectional area extending from said intermediate region to its juncture with said end portion, said end portion having a cross sectional area greater than the cross sectional area of the intermediate region of said output section but of lesser cross sectional area than the nodal juncture of said output section with said input section, whereby an extended high stress zone is provided in the intermediate region of the output section but no abrupt stress zone occurs at any point along the length of the transformer.

5. An acoustic impedance transformer for transmitting longitudinal vibrations of high frequency and small amplitude when rigidly attached to the output end of an electromechanical transducer, said transformer having a total wave length approximately corresponding to one-half the wave length or multiples thereof at the vibration frequency injected into the input end thereof by the transducer as fixed thereto, said transformer presenting a cylindrical input section of substantially uniform cross sectional area and a variable cross sectional area output section integral with the input section, said output section having a wave length substantially equal to the wave length of the input section to thereby provide a node of motion at the area of juncture, said output section having a cylindrical tool attaching end portion of substantially uniform cross sectional area, said output section having a gradually decreasing cross sectional area extending from its nodal juncture with said input section to the intermediate region thereof and thence having a gradually increasing cross sectional area extending from said intermediate region to its juncture with said end portion, said end portion having a cross sectional area greater than the cross sectional area of the intermediate region of said output section but of lesser cross sectional area than the nodal juncture of said output section with said input section, whereby an extended high stress zone is provided in the intermediate region of the output section but no abrupt stress zone occurs at any point along the length of the transformer.

6. An acoustic impedance transformer for transmitting longitudinal vibrations of high frequency and small amplitude when rigidly attached to the output end of an electromechanical transducer, said transformer having a longitudinal passage extending axially therethrough and

6

total wave length approximately corresponding to one-half the wave length or multiples thereof at the vibration frequency injected into the input end thereof by the transducer as fixed thereto, said transformer presenting a cylindrical input section of substantial cross sectional area and a variable cross sectional area output section integral with the input section, said output section having a wave length substantially equal to the wave length of the input section to thereby provide a node of motion at the area of juncture, said output section having a cylindrical tool attaching end portion of substantially uniform cross sectional area, said output section having a gradually decreasing cross sectional area extending from its nodal juncture with said input section to the intermediate region thereof and thence having a gradually increasing cross sectional area extending from said intermediate region to its juncture with said end portion, said end portion having a cross sectional area greater than the cross sectional area of the intermediate region of said output section but of lesser cross sectional area than the nodal juncture of said output section with said input section, whereby an extended high stress zone is provided in the intermediate region of the output section but no abrupt stress zone occurs at any point along the length of the transformer.

7. An acoustic impedance transformer for transmitting longitudinal vibrations of high frequency and small amplitude when rigidly attached to the output end of an electromechanical transducer, said transformer having a total wave length approximately corresponding to one-half the wave length or multiples thereof at the vibration frequency injected into the input end thereof by the transducer as fixed thereto, said transformer presenting an input section of substantial uniform cross sectional area and a variable cross sectional area output section integral with the input section, said output section having a wave length substantially equal to the wave length of the input section to thereby provide a node of motion at the area of juncture, said output section having a tool attaching end portion of substantially uniform cross sectional area and presenting a threaded bore, said output section having a gradually decreasing cross sectional area extending from its nodal juncture with said input section to the intermediate region thereof and thence having a gradually increasing cross sectional area extending from said intermediate region to its juncture with said end portion, said end portion having a cross sectional area greater than the cross sectional area of the intermediate region of said output section but of lesser cross sectional area than the nodal juncture of said output section with said input section whereby an extended high stress zone is provided in the intermediate region of the output section but no abrupt stress zone occurs at any point along the length of the transformer; and a tool attaching coupling member presenting a body section snugly abutting against the terminal end of said transformer end portion and a threaded stud portion extending into a threaded bore formed in said end portion.

8. An acoustic impedance transformer for transmitting longitudinal vibrations of high frequency and small amplitude when rigidly attached to the output end of an electromechanical transducer, said transformer having a longitudinal passage extending axially therethrough and total wave length approximately corresponding to one-half the wave length or multiples thereof at the vibration frequency injected into the input end thereof by the transducer as fixed thereto, said transformer presenting an input section of substantial uniform cross sectional area and a variable cross sectional area output section integral with the input section, said output section having a wave length substantially equal to the wave length of the input section to thereby provide a node of motion at the area of juncture, said output section having a tool attaching end portion of substantially uniform cross sectional area which presents a threaded bore,

said output section having a gradually decreasing cross sectional area extending from its nodal juncture with said input section to the intermediate region thereof and thence having a gradually increasing cross sectional area extending from said intermediate region to its juncture with said end portion, said end portion having a cross sectional area greater than the cross sectional area of the intermediate region of said output section but of lesser cross sectional area than the nodal juncture of said output section with said input section whereby an extended high stress zone is provided in the intermediate region of the output section but no abrupt stress zone occurs at any point along the length of the transformer; and a tool attaching coupling member presenting a body section tightly abutting against the terminal end of the

5

10

15

end portion of said transformer output section and a threaded stud portion extending into the threaded bore of said end portion.

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