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WIRE DRAWING APPARATUS AND METHOD
USING INTERMEDIARY IMPACT DEVICE
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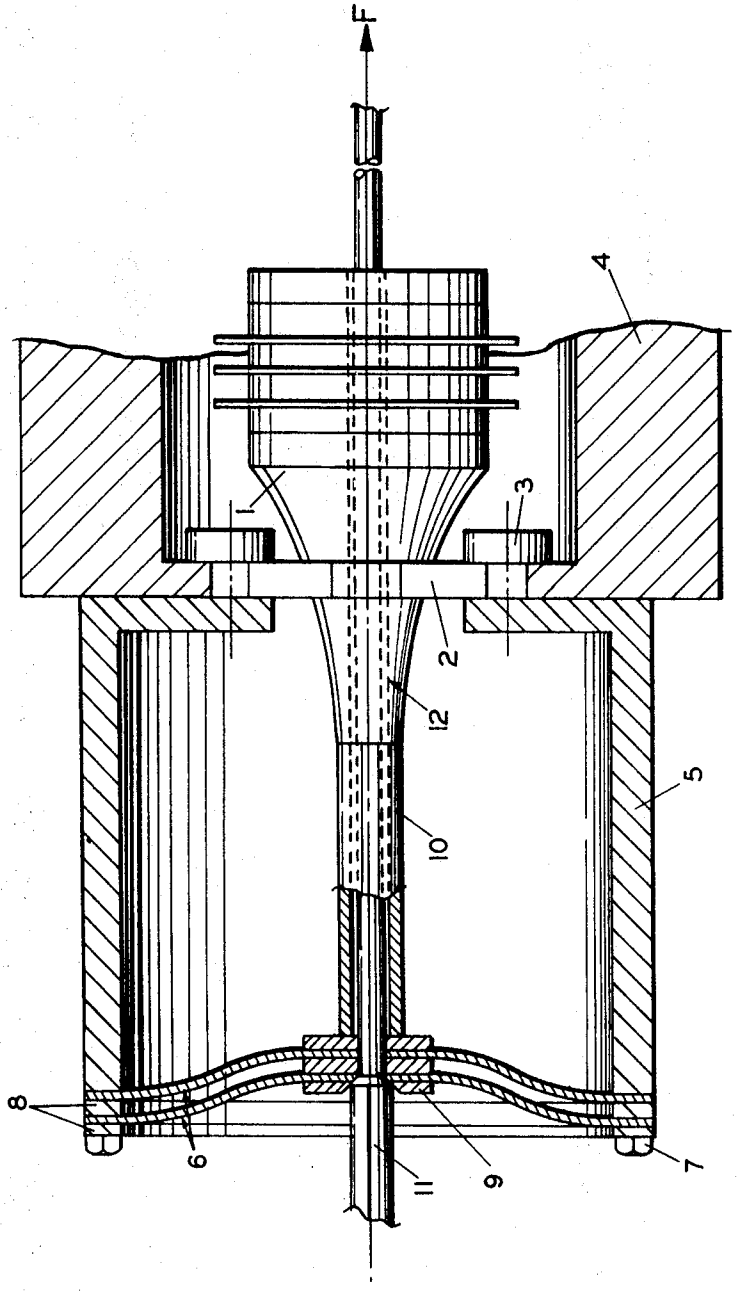


FIG. 1

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WIRE DRAWING APPARATUS AND METHOD USING INTERMEDIARY IMPACT DEVICE

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ABSTRACT OF THE DISCLOSURE

This invention is an apparatus for drawing wire utilizing an axially apertured piezoelectric electromechanical transducer and axially apertured straight vibratory-mechanical transmission line in conjunction with a wire-drawing die (impacted by the transmission line) to reduce the cross section of the wire. Reference is made to the claims for a legal description of the invention.

CROSS REFERENCES

There is disclosed in patent, No. 3,396,285, for "Electromechanical Transducer," by Hildegard M. Minchenko, a transducer capable of delivering extremely high power, i.e., measurable in horsepower (or kilowatts) at an acoustical frequency range. The principle underlying the high-power output is in the structural arrangement of the components immediately associated with the piezoelectric driving elements. In theory and practice, the piezoelectric elements are under radial and axial pressure that assure that they do not operate in tension even under intense sonic action. Significantly, the structural design of this transducer, that permits the extraordinary power output from the driving elements, resides in the novel method of clamping the piezoelectirc elements both radially and longitudinally (axially). In this way the acoustic stresses in the piezoelectric elements are always compressive, never tensile, even under maximum voltage excitation.

The transducer disclosed in the aforementioned patent is intended, and therefore utilized, to deliver a steady-state vibratory power output signal. That is, the piezoelectric assembly is a component of a resonant structure that will produce a mechanical vibratory output at the frequency of the driving electrical signal—and vice versa.

There is disclosed in the copending patent application for "Sonic Transducer Assembly," Ser. No. 713,031, filed Mar. 14, 1968, now continuation application Ser. No. 14,777, filed Feb. 27, 1970, by Robert C. McMaster, Charles C. Libby, and Keith Likins, and assigned to The Ohio State University, an improved enclosure design for a sonic or ultrasonic transducer. More specifically, the enclosure design is for a resonant structure type of sonic transducer that completely encloses the transducer but yet does not affect the electrical or mechanical characteristics thereof. The enclosure covers the entire structure and even though it is clamped to the structure of the transducer the enclosure permits the nonrestrictive movement of the transducer tip. The enclosure follows the outside contour of the transducer and is fixedly clamped to the transducer at its node (point of minimum amplitude). The top portion of the enclosure is closed, whereas the bottom of the enclosure has an opening to permit vibration of the transducer horn without contact with the housing.

Further, it has been disclosed in copending patent application, for "Power Conversion Means," Ser. No. 713,034, filed Mar. 14, 1968, by Robert C. McMaster and assigned to The Ohio State University, an apparatus wherein an impact coupling means may be used as an intermediate mechanical member for transmitting the vibratory-mechanical energy from one transducer to another. The intermediate mechanical member for so transmitting the vibratory-mechanical energy is in position by a diaphragm spaced between the two opposing transducers of the system of the invention.

There is further disclosed in copending patent application for "Intermediary Impact Device," Ser. No. 819,886, filed Apr. 28, 1969, by Charles C. Libby, William J. White, and assigned to The Ohio State University, a device for effectively delivering vibratory-mechanical energy from the tip of the horn of an electromechanical transducer to a work surface. As disclosed in the last-mentioned application an intermediary impact device is positioned against the tip of an electromechanical transducer. The vibratory-mechanical energy of said transducer is concentrated at the tip of said transducer causing the tip to extend and contract in the axial direction. The transducer tip impacts the intermediary impact device and drives said intermediary impact device against the surface of the material to be formed. The movement of the intermediary impact device is constrained to movement colinear with the axial direction of movement of the transducer tip by means of a dual diaphragm made either of metal or an organic material.

The transducer tip impacts against the intermediary impact device driving said intermediary impact device away from the transducer tip. The dynamic energy of said intermediary impact device moving away from the transducer tip is absorbed upon impact with the work surface. After the dynamic energy is substantially absorbed, the intermediary impact device recoils causing the intermediary impact device to return to the transducer tip where the device is impacted again by the transducer tip. The dual diaphragm constrains the motion of the intermediary impact device to travel in a direction colinear with the axial movement of the transducer tip.

BACKGROUND

Wire is a term which may be applied to any thread or filament, or to any slender rod or bar of metal that has a uniform cross section. A great many products shaped by pulling metal through a die are called wire. The most common shapes are round, square, hexagonal, octagonal, oval, half-oval, half-round, and flat or rectangular. Numerous other regular and irregular shapes are produced.

The limits for drawn wire range from approximately 0.001 inch to approximately 1 inch in diameter. The process of drawing wire from steel begins with the rod hot rolled in coils. Combinations of composition, heat treating of rods and process wire, and cold working, may produce a wide range of properties for varied range of applications.

In general, a wire-drawing die can be defined as a small plate or nib of suitable material, containing one or more tapering holes called "die holes." For the production of a satisfactory product the die must be made of strong material highly resistant to wear, and the hole must be smooth and properly shaped. Chilled iron, several of the alloy steels, tungsten carbide, and diamond possess the required qualities and are used for particular applications. Although the tungsten carbide single-hole die is becoming more widely used, diamond dies are still preferred for finishing drafts on very fine sizes of wire; because of the limited production of "shape" wire, hardened, punched chromium steel dies are employed. However, tungsten carbide dies are being used increasingly for drawing shapes.

In dry drawing, some form of lubricant is required. A suitable lubricant is usually placed in the box of the die holder so that the rod or wire passing through will draw a sufficient amount into the die hole. Various substances are used for this purpose, including specially prepared greases or drawing compounds, tallow, pulverized soap,

or a mixture of oil and flour or meal. The choice of lubricant depends on the number of drafts a wire is to be drawn, as well as the coating or freedom from coating desired on the finished wire. In wet drawing, a thin solution of liquid soap or soluble oil may be used to coat the rod or wire prior to entry into the forming die.

Several patents have issued pertaining to the use of vibratory energy in the drawing or forming of wire. Among those patents are Pat. Nos. 3,295,349; 3,209,574; 3,209,573; 3,212,312; and 3,203,215. The systems, apparatus, and methods of these patents all contemplate the use of a plurality of magnetostrictive devices or the like to introduced vibrations or movement into the wire drawing die and/or the material being drawn. In the devices of the last-mentioned patents, the wire drawing dies incorporated into the systems are all firmly attached or secured to the magnetostrictive devices at the point where such magnetostrictive devices create the greatest amount of vibration. While it is true that the devices of the last-mentioned patents offer some advantages by way of reducing die wall friction and the tension required to draw the wire through the die, any advantages so gained are minimal. The magnetostrictive devices used in these patents are grossly inefficient in their conversion of electrical power into vibrational energy. In order to develop commercially adaptable systems incorporating the concepts of wire drawing with the magnetostrictive devices to reduce the die wall friction and the required drawing tension, the size and power consumption of the magnetostrictive devices as related to the power output of the magnetostrictive devices would be very large indeed. Hence, the inefficiency of the magnetostrictive devices in converting electrical power to vibratory energy is the key factor which inhibits the economical commercial application of the principles espoused in the prior art.

It has been disclosed in the patent, No. 3,396,285, for "Electromechanical Transducer," by Hildegard M. Minchenko, a means for the efficient conversion of electrical power to vibratory-mechanical energy. It is understood from the teachings of this patent that the piezoelectric electromechanical transducer therein disclosed is capable of delivering extremely high power, i.e., measurable in horsepower (or kilowatts) at an acoustical frequency range. Therefore, it is clear that the transducer of the last-mentioned patent certainly has sufficient efficiency to render it capable of being adapted to commercial applications. This becomes more clear when it is understood that the efficiency of the conversion of electrical energy to mechanical energy by the electromechanical transducer far exceeds the efficiency of even the conventional brush-type electric motor which, in turn, far exceeds the efficiency of magnetostrictive devices.

SUMMARY OF THE INVENTION

The present invention is an apparatus for drawing wire utilizing sonic or ultrasonic energy from a piezoelectric electromechanical transducer. Vibratory-mechanical energy generated by the electromechanical transducer is introduced directly into a die used for reducing the cross section of the wire being drawn. More specifically, the die is an intermediary impacting device attached to diaphrams and positioned against the vibratory-mechanical energy source, the electromechanical transducer tip or vibratory-mechanical energy transmission line. Static force exerted on the die by tension in the wire being drawn maintains the die in intermittent contact with the vibratory-mechanical transmission line. The flexible diaphragms are positioned so as to align the aperture of the die with an axial aperture in the electromechanical transducer and transmission line.

In use, the work surface interface (of the wire to be reduced) is forced against the die by tension in the wire. The die, in turn, is forced into contact with the vibratory-mechanical energy transmission line. The vibratory action at the end transmission line accelerates the die against the wire thereby reducing the cross section of a finite length of the wire. The die is forced to return against the transmission line by the forces attributable to the tension maintained in the wire being drawn. Hence, it is clear that the die alternately impacts the transmission line and the work surface (of the wire to be reduced); the driving force is the vibratory-mechanical energy associated with the electromechanical transducer and transmitted through the vibratory-mechanical energy transmission line.

The reduced cross section of the drawn wire passes through the axial aperture in the transmission line and electromechanical transducer. Such construction enables the wire reduced in cross section to be drawn through the axial aperture with the tension in the wire being colinear with the axial movement of the vibratory-mechanical energy transmission line and the die.

OBJECTS

The principal object of the present invention is to provide an apparatus for drawing wire.

Another object of the invention is to provide an apparatus which will reduce the cross section of a wire in one continuous operation.

Another object of the invention is to provide an apparatus which will produce a very smooth surface finish.

Another object of the invention is to provide an apparatus which will reduce by a factor of 10 to 100 the tension which need be placed on a wire in order to reduce the cross section of the wire by drawing the wire through a die.

Still another object of the invention is to provide an apparatus which will increase the life of wire drawing dies.

Other objects and features of the present invention will become apparent from a reading of the following detailed description when considered in conjunction with the figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of an intermediary impacting die positioned in conjunction with an axially drilled transmission line and axially apertured piezoelectric electromechanical transducer so as to facilitate the drawing of wire.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring generally to FIG. 1, there is shown the preferred embodiment of the invention. A piezoelectric electromechanical transducer **1** is supported at its node **2** by a clamp **3** which secures the transducer **1** to both a machine frame **4** and the nodal diaphragm support **5**. Twin parallel flexible diaphragms **6** are secured to the nodal diaphragm support **5** by cap screws **7**. The tool **9** or die **9** is secured to the flexible diaphragms **6**. The flexible diaphragms **6** are separated by spacers **8**. The diaphragms **6** retain the die **9** with its aperture aligned with an axially apertured vibratory-mechanical energy transmission line **10**. The nodal diaphragm support **5** may be secured to a node of the transmission line **10** or some fixture external to the aforedescribed combination. Force F creates tension in the work material **11** causing the work material **11** to be drawn through said die **9**; the reduced portion of the work material **11** is guided through the axially drilled aperture **12** in the transducer **1** and transmission line **10** by the force F.

The apparatus of the present invention provides a means for utilizing the impact coupling principle in transferring vibratory-mechanical energy generated in the transducer **1** to a work surface to be reduced in cross section. The die **9** illustrated in FIG. 1 of the preferred embodiment is for drawing wire into a shape with a circular cross section. Of course, it is understood that virtually any shape die may be used to form a desired cross section. Such alternative shapes might include square, hexagonal, octagonal, oval, half-oval, half-round, and flat or rectangular as well as numerous other regular and irregular shapes.

In operation, the present invention is used for wire drawing. The transmission line **10** is an optional arrangement which may be used or not depending on what arrangement is more convenient. Alternatively, the die can be positioned directly against the tip of the electromechanical transducer **1**. Arrangements for the positioning of the die **9**, which is an intermediary impacting device, are considered in greater detail in the copending patent application for "Intermediary Impact Device," Ser. No. 819,886, filed Apr. 28, 1969, by Charles C. Libby, and William J. White, and assigned to The Ohio State University. The vibratory-mechanical energy transmission line **10** vibrates (moves) axially and impacts the die **9** causing it to move away from the transmission line **10**. The flexible diaphragms **6** constrain the movement of the die **9** to movement colinear with the axial movement of the electromechanical transducer **1** tip or colinear with the movement of the tip of the transmission line **10** as the case may be. A single diaphragm of sufficient thickness may also be used in lieu of the dual diaphragm arrangement. The diaphragm arrangement prevents "canting" or "cocking" of the die. After the die **9** has been struck by the transmission line **10** it moves away from the transmission line **10** along the axial direction of the transmission line **10**, the die **9** advances against the work material **11** which is kept under tension by force F. As the die **9** so impacts the work material **11** a portion of the work material **11** plastically deforms as it passes through the die **9** thereby reducing the cross section of the portion of the work material **11**. The work material **11** so reduced in cross section after passing through the die **9** then passes through the aperture **12** drilled axially through the axis of symmetry of the cylindrical transmission line **10** and the electromechanical transducer **1**. The static force, F, applied in the drawing direction is of such magnitude as to cause the die **9** to return against the transmission line **10** after the dynamic energy of the die **9** has been substantially dissipated by plastically deforming the work material **11**. The static force, F, required is reduced by a factor of 10 to 100 when compared to those forces necessary to draw wire using conventional drawing techniques not employing vibratory-mechanical excitation as herein described. Hence, the static force, F, is of the nature of a guiding force which draws the wire through the axial aperture of the electromechanical transducer **1**.

The impact coupling means for transferring vibratory-mechanical energy to the work material enables the electromechanical transducer **1** to freely operate at its electrical frequency. By using the impact coupling principle, the masses associated with the die **9** holding fixture, the flexible diaphragms **6**, the nodal diaphragm support **5**, the die **9**, and the work material **11**, do not substantially affect the resonant characteristics of the electromechanical transducer **1**. Neither the die **9** nor the work material **11** "couple" with the structure of the electromechanical transducer **1**; that is, neither the die **9** nor the work material **11** remain in contact with the transducer for a period of time sufficient to substantially alter the electrical frequency of the electromechanical transducer **1**. Therefore, the electromechanical transducer **1** provides an essentially continuous source of vibratory-mechanical energy so long as it is excited with an alternating-polarity input current at its electrical frequency.

Use of the impact coupling means to deliver vibratory-mechanical energy from the transducer **1** to the die **9** and then to the work material **11** establishes two essentially independent systems. One system is the transducer **1** which operates freely at its electrical frequency as disclosed hereinabove. The second system is the work material **11** or wire **11** and die **9**. Unlike wire drawing systems utilizing vibratory energy as disclosed in the prior art, the wire **11** or work material **11** being drawn using the present invention does not need to be supported at node points created by the vibratory-mechanical waves transmitted through the work material **11**. Vibratory-mechanical energy is introduced into the work material **11** at the interface of the die **9** and work material **10**. This vibratory-mechanical energy so introduced creates dynamic stresses within the work material **11** at the aforesaid interface which are additive to those stresses created by tension in the wire or work material **11**. The tension required to reduce the cross section of a wire or work material is therefore decreased. Since the vibratory-mechanical energy is introduced locally at the interface of the work material **11** and die **9** (where deformation occurs), it is not necessary for vibratory-mechanical energy to be transmitted through the work material **11**. Were that the case, the work material **11** would have to be supported at node points to facilitate efficient transmission of the vibratory-mechanical energy. The system of the present invention, however, does not rely on transmission of vibratory-mechanical energy through the work material **11**.

Even though the resonant frequency of the electromechanical transducer **1** is essentially dependent on the mass of said electromechanical transducer **1**, the slight reduction in mass due to the axial aperture **12** does not substantially affect the resonant frequency of the transducer **1**. The design of high power electromechanical transducers is disclosed in the patent, No. 3,396,285, for "Electromechanical Transducer," by Hildegard M. Minchenko, and the patent, No. 3,368,085, for "Sonic Transducer," by Robert C. McMaster and Berndt B. Dettloff, both assigned to The Ohio State University.

It is further to be understood that the systems and methods described hereinabove need not be used singly. That is, a plurality of any of the embodiments described hereinabove may be used to produce successive reductions in the cross section of the work material **11**. Accordingly, although certain and specific embodiments of the present invention have been illustrated, it is to be understood that modifications may be made thereto without departing from the true spirit and scope of the invention.

What is claimed is:

1. A resonant structure electromechanical transducer including a horn concentrator defining a point of maximum amplitude,

said horn concentrator having an aperture axially aligned through its axis of symmetry,

a material forming die positioned adjacent said point of maximum amplitude on said horn concentrator,

said die being operatively unsecured thereto whereby said die receives vibratory-mechanical energy by impact coupling,

said positioning including positioning the opening in said die in alignment with said axial aperture in said transducer,

means for supportng said transducer at a point of minimum vibration, and means for supporting said die at said position of maximum amplitude.

2. A combination as described in claim **1** wherein said means for supporting said die comprises a plurality of flexible diaphragms secured to said die, and means for securing said flexible diaphragms to said diaphragm support.

3. A combination as described in claim **2** wherein said diaphragm support comprises a structure securing said diaphragm support to the node of the electromechanical transducer.

4. A combination as described in claim **1** wherein said die is positioned with the mouth thereof on the side of said die opposite that side adjacent to said vibrating tip of said horn of said electromechanical transducer.

5. A combination as described in claim **1** wherein said die is positioned so that the mouth of said die is on the side of said die adjacent to said vibratory tip of said horn of said electromechanical transducer.

6. A combination as described in claim **1** wherein said combination further comprises a straight, cylindrical vibratory-mechanical energy transmission line apertured

axially through its axis of symmetry and positioned between said die and said electromechanical transducer and secured to said vibratory tip of said horn of said axially apertured electromechanical transducer and wherein the aperture in said axially apertured vibratory-mechanical energy transmission line and said electromechanical transducer are aligned.

7. A combination as described in claim **6** wherein said die is positioned adjacent to the unsecured end of said vibratory-mechanical energy transmission line with the aperture in said die aligned with the axial aperture in said vibratory-mechanical energy transmission line.

8. A combination as described in claim **7** wherein the means for supporting said die comprises a plurality of flexible diaphragms secured to said die, a diaphragm support to which said flexible diaphragms are secured, and means for supporting said diaphragm support.

9. A combination as described in claim **8** wherein said means for supporting said diaphragm support comprises a structure securing said diaphragm support to the node of the electromechanical transducer.

10. A combination as described in claim **8** wherein said means for supporting said diaphragm support comprises a structure securing said diaphragm support to a node of the vibratory-mechanical energy transmission line.

References Cited

UNITED STATES PATENTS

2,568,303	9/1951	Rosenthal	72—60
3,209,572	10/1965	Boyd et al.	72—277
3,212,312	10/1965	Boyd et al.	72—60
3,295,349	1/1967	Maropis	72—60
3,396,285	8/1968	Minchenko	310—8.7

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