

[54] **WIRE DRAWING APPARATUS USING VIBRATORY-MECHANICAL ENERGY AND CURVED TRANSMISSION LINE**

[72] Inventor: **Lytton A. Kendall, Jr.**, Columbus, Ohio

[73] Assignee: **The Ohio State University**, Columbus, Ohio

[22] Filed: **Feb. 24, 1970**

[21] Appl. No.: **13,538**

[52] U.S. Cl. **72/56, 72/57, 72/285, 72/DIG. 20**

[51] Int. Cl. **B21d 26/02, B21j 5/04**

[58] Field of Search **72/56, 57, 285, DIG. 20**

[56] **References Cited**

UNITED STATES PATENTS

3,209,572 10/1965 Boyd et al. **72/277**

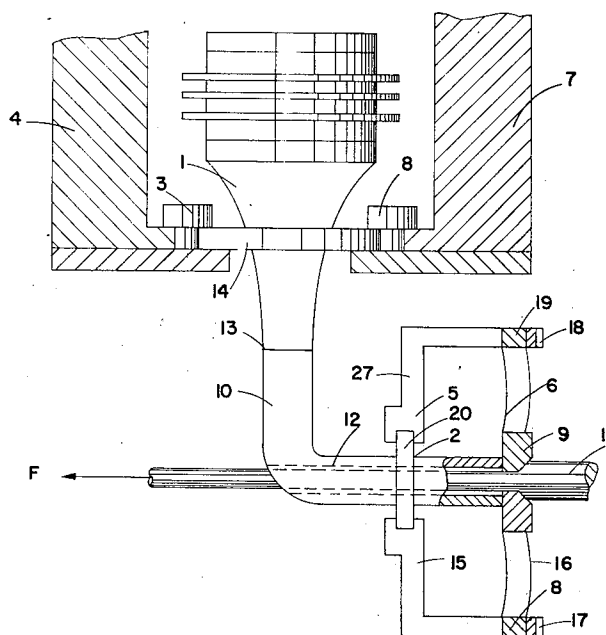
3,485,307 12/1969 Riley, Jr. et al. **72/DIG. 20**
1,889,893 12/1932 Gurne. **72/285**
3,550,417 12/1970 McMaster. **72/DIG. 20**
3,212,313 10/1965 Boyd et al. **72/DIG. 20**
3,212,312 10/1965 Boyd et al. **72/DIG. 20**

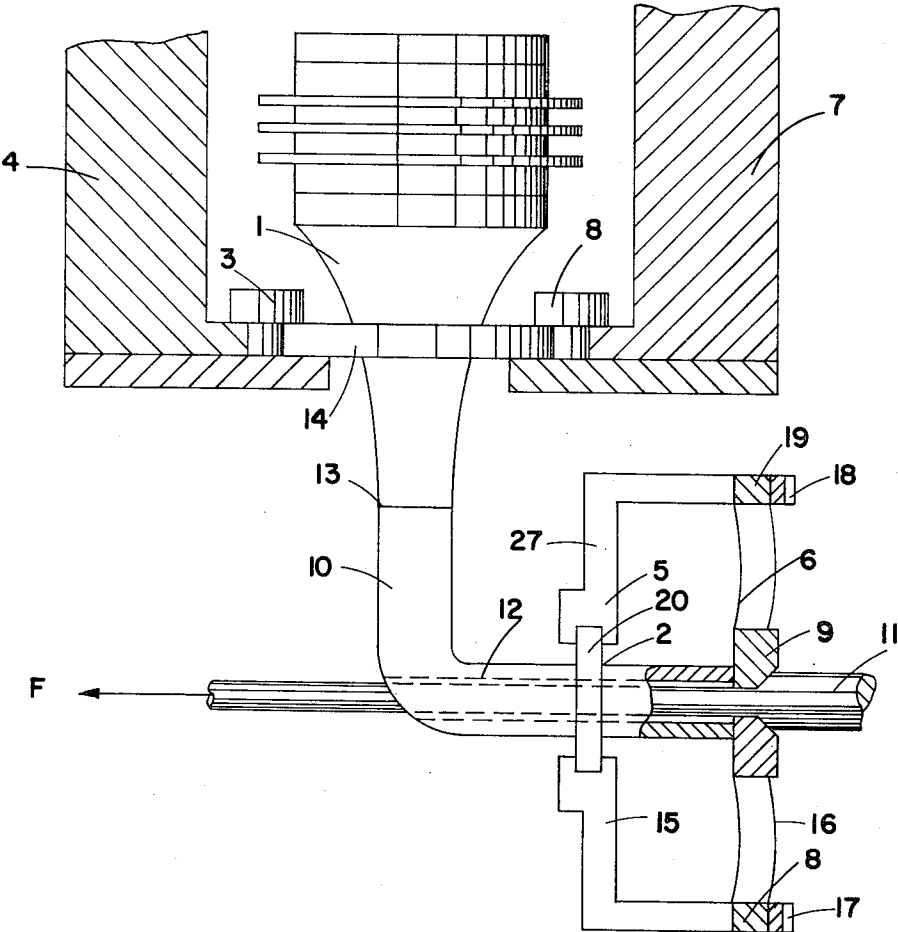
Primary Examiner—Charles W. Lanham
Assistant Examiner—Michael J. Keenan
Attorney—Cennamo, Dunbar and Kremblas

[57] **ABSTRACT**

Apparatus for drawing wire utilizing a piezoelectric electromechanical transducer and an axially drilled curved transmission line in conjunction with a wire-drawing die to reduce the cross section of the wire. Static force exerted on the die by retaining diaphragms hold the die intermittent contact with the free end of the transmission line.

3 Claims, 1 Drawing Figure





There is disclosed in patent, U.S. Pat. No. 3,396,285, for "Electromechanical Transducer," by Hildegard M. Minchenko, a transducer capable of delivering extremely high power, i.e., measureable 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 piezoelectric 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.

In my copending patent application for Wire Drawing Apparatus and Method Using Intermediary Impact Device, filed April 28, 1969; now Pat. No. 3,613,422, and assigned to The Ohio State University, describes an apparatus for drawing wire utilizing an axially drilled piezoelectric electromechanical transducer and axially drilled straight vibratory-mechanical energy transmission energy introduced directly into the wire drawing die from the vibratory-mechanical energy transmission in conjunction with a wire drawing die. Vibratory-mechanical energy introduced directly into the wire drawing die from the vibratory-mechanical energy transmission line facilitates the reduction of cross section of wire. The die is forced against the wire thereby reducing the cross section of a finite length of the wire. The die is forced to return to the vibratory-mechanical energy transmission line tip by forces attributable to diaphragms attached to the die and the tension in the wire being drawn. In sum, the die alternately impacts the vibratory-mechanical energy transmission line and the work surface of the wire being drawn. The reduced cross section of the drawn wire passes through the axially drilled electro-mechanical transducer and transmission line.

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 pro-

duction of a satisfactory product the die must be made of strong material highly resistant to wear, and the 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 or wire. Among those patents are U.S. 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 introduce 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, U.S. Pat. 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., measureable in horsepower (or kilowatts) at an acoustical frequency range. There-

fore, 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 into a curved vibratory-mechanical energy transmission line. The curved vibratory-mechanical energy transmission line transfers the vibratory-mechanical energy from the electromechanical transducer to a wire-drawing die used for reducing the cross section of the wire to be drawn. One "leg" of the curved transmission line is attached to the vibrating tip of the horn of the electromechanical transducer. The unattached leg is drilled through the longitudinal axis and on through the curved wall of the curved transmission line. The wire-drawing die, essentially an intermediary impacting device is attached to flexible diaphragms and positioned against the end of the unattached leg of the vibratory-mechanical energy transmission line. Static force exerted on the die by the retaining diaphragms hold the (vibrating) die in intermittent contact with the unattached end of the curved transmission line.

The work surface interface (of the wire to be reduced) is forced against the die by tension in the wire and flexible diaphragms. The die, in turn, is forced into contact with the unattached end of the curved vibratory-mechanical transmission line. The vibratory action of the end of the vibratory-mechanical energy transmission line drives the die against the wire forcing the wire through the die thereby reducing the cross section of a finite length of the wire. The die is thereafter forced to return to the end of the curved transmission line by the forces attributable to the diaphragms attached to the die and the tension in the wire being drawn. Hence, it is clear that as this action is repeated the die alternately impacts the end of the unattached leg of the curved vibratory-mechanical energy transmission line and the work surface causing the cross section of the wire to be reduced. The wire whose cross section has been so reduced passes through the hole drilled axially in the unattached leg of the curved vibratory-mechanical energy transmission line.

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 on the wire drawn.

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 this invention is to provide a means of increasing the drawing speed while maintaining the same tension on the wire as was required without sonic die excitation.

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 single FIGURE.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a schematic illustration of a wire drawing apparatus comprising a piezoelectric electromechanical transducer and a curved transmission line with an axially drilled leg with a wire drawing die held against the end of the transmission line by a diaphragm support device.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing, there is shown an apparatus for the drawing of wire. The electromechanical transducer is that disclosed and claimed in the above-mentioned U.S. Pat. No. 3,396,285. This transducer is machine mounted such as by rigid supports comprising L brackets 4 and 7. The brackets are clamped to the transducer by bolts 3 and 8 through clamping bar 14. The embodiment of FIG. 1 further incorporates a curved transmission line 10 supported at node points 2 by structure 5. The design and operation of curved vibratory-mechanical transmission lines is disclosed in the copending patent application for "Curved Sonic Transmission Line," Ser. No. 833,072, filed June 13, 1969, by Robert C. McMaster, Hildegard M. Minchenko, and Charles C. Libby, and assigned to The Ohio State University now U.S. Pat. No. 3,546,498. The one end of the curved transmission line 10 is attached or secured to the tip 13 of the electromechanical transducer 1. A nodal diaphragm support 5 comprising a pair of flanged L-shaped members 15 and 27 is secured to a node point of the curved transmission line 10 by clamping bar 20. Twin parallel flexible diaphragms 6 and 16 are secured to the cross member of the nodal diaphragm support 5 by nuts 17 and 18. The die 9 is secured to the flexible diaphragms 6 and 16. The flexible diaphragms 6 and 16 are separated by spacers 8. The flexible diaphragms 6 and 16 hold the die 9 in position against the curved transmission line 10 with the hole in the curved transmission line. Force F is exerted on the work material 11 which causes the work material 11 to be drawn through the die 9; the reduced portion of the work material 11 is thereafter pulled through the axially drilled hole 12 in the unattached leg of the curved transmission line 10.

In the embodiment of the FIGURE, the curved vibratory-mechanical energy vibrates in the axial direction of the unattached leg of the curved transmission line 10 thereby striking the die 9 and causing the die 9 to move away from the unattached leg of the curved transmission line 10. The flexible diaphragms 6 and 16 constrain the movement of the die 9 to movement collinear with the axial movement (with reference to the axis of symmetry of the unattached leg) of the end of the unat-

tached leg of the curved transmission line 10. The die 9, having been struck by the end of the curved transmission line 10, moves away from the curved transmission line 10 along the axial direction. The die 9 advances against the work material 11 which is kept under tension by force F. As the die 9 advances into the work material 11 a portion thereof passes through the die 9 thereby reducing the cross section of that 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 hole 12 drilled axially in the unattached leg of the curved transmission line 10.

The static force F applied in the drawing direction is of such magnitude as to cause the die 9 to return against the end of the curved transmission line 10 after the dynamic energy of the die 9 has dissipated itself plastically deforming the work material 11. The static force F 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 or bias force which draws the wire through the axially drilled hole 12 in said unattached leg of said curved transmission line 10.

It is to be understood that the invention is not limited to a curved transmission line with the axially drilled hole 12. The curved transmission line 10 may be completely hollow. Hollow curved transmission lines are more fully disclosed and discussed in the copending patent application, Ser. No. 833,073, filed June 13, 1969, by Hubert T. Tyler, et al., for "Sonic Transmission Line for Electromechanical Transducer." In the apparatus as shown in the drawing use of the impact coupling principle effectively prevents the masses associated with the die 9, the flexible diaphragms 6 and 16, the nodal diaphragm support 5, and the work material 11, from affecting the resonant characteristics of the electromechanical transducer 1.

It is to be further understood that the systems described hereinabove need not be used singly. That is, a plurality of any of the embodiments described hereinabove or any combination of any of the embodiments described hereinabove may be used to produce successive reductions in the cross section of the work material 11.

Although a certain and specific embodiment has been illustrated, it is to be understood that modifications may be made thereto without departing from the true spirit and scope of the invention.

I claim:

1. A combination for drawing wire comprising: an electromechanical transducer, a curved vibratory-mechanical energy transmission line secured to at one end to the vibrating tip of the horn of said electromechanical transducer, a hole drilled axially through the straight portion of the axis of symmetry of the unattached leg of said curved vibratory-mechanical energy transmission line; a die having an axial hole therethrough for reducing the diameter of the work material, means for positioning said die adjacent the opposite end of said transmission line, said means aligning the hole in said die with the axially drilled hole in said unattached leg of said curved vibratory-mechanical energy transmission line, and said die being operatively unsecured to said line through said die whereby said die receives vibratory-mechanical energy by impact coupling.

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

3. A combination as described in claim 2 further comprising a structure securing said diaphragm support to a node of the curved vibratory-mechanical energy transmission line.

* * * * *

40

45

50

55

60

65