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ELECTROSTRICTIVE EFFECT IN A TRANSDUCER
FOR DRAWING WIRE, ROD OR TUBE
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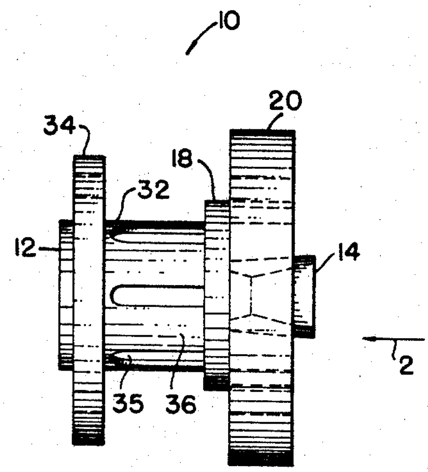

FIG. 1

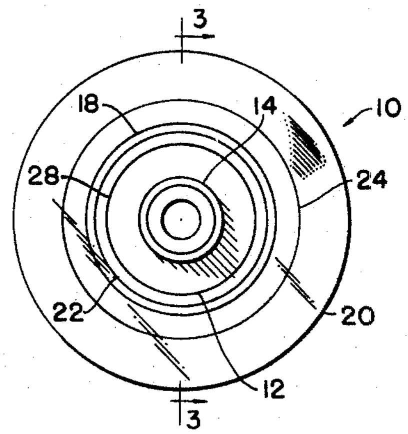

FIG. 2

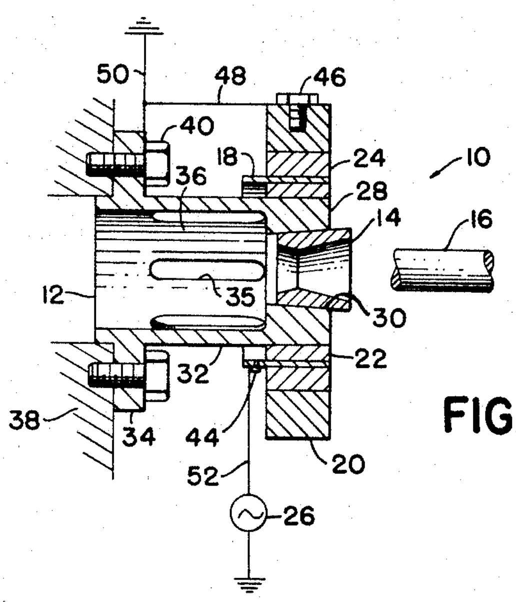

FIG. 3

INVENTOR.
RALPH W. GOBLE
BY Whittemore,
Hulbert & Belknap
ATTORNEYS

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ELECTROSTRICTIVE EFFECT IN A TRANSDUCER FOR DRAWING WIRE, ROD OR TUBE

Ralph W. Goble, Boulder, Colo., assignor to Calumet & Hecla, Inc., Allen Park, Mich., a corporation of Michigan

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ABSTRACT OF THE DISCLOSURE

Structure for radially contracting and expanding a die for drawing wire, rod or tube at a predetermined frequency is disclosed. The structure includes an annular member for holding the drawing die, at least one radially polarized electromechanical transducer surrounding the annular drawing die holding member, means for energizing the electromechanical transducer at the predetermined frequency and means for supporting the annular member at a distance therefrom which is substantially a quarter wave length of the resonant frequency of the structure by means permitting radial expansion and contraction of the annular member. A first annular ring, a second electromechanical transducer and a second annular ring may be provided radially outwardly of the annular drawing die holding member and first electromechanical transducer to increase the expanding and contracting force.

The invention relates to piezoelectric transducers and refers more specifically to holding structure for wire, rod or tube drawing dies or the like including radially polarized piezoelectric transducers for periodically radially expanding and contracting the die holding structure at the resonant frequency of the die holding structure on application of an alternating electric signal thereto, and a method of construction thereof.

Large forces are necessary for drawing wire, rod, tube or the like through annular dies to reduce the diameter and/or the wall thickness and the like thereof. In drawing operations a large part of the force necessary is dissipated in overcoming external friction between the outer surface of the stock drawn and the inner surface of the die through which the stock is drawn.

In the past it has been known to sonically drive a wire, rod or tube through a drawing die. Pulses of electric energy at sonic frequencies have been applied to stock to be drawn to act along the longitudinal axis thereof. With such methods of drawing, the size reduction of the stock is not accomplished directly by the sonic energy applied.

It is one of the objects of the present invention to provide an improved drawing die holding structure.

Another object is to provide drawing die holding structure comprising a die actuator including a die holding annulus, a radially polarized annular piezoelectric transducer surrounding the die holding annulus, an inner ring member surrounding the piezoelectric transducer and means for applying the opposite terminals of a source of alternating electric energy to the die actuator and ring.

Another object is to provide die holding structure as set forth above and further including a second annular piezoelectric transducer polarized radially and opposite to the other piezoelectric transducer surrounding the inner ring member and an outer annular ring member surrounding the second piezoelectic transducer and electrically connected to the die actuator.

Another object is to provide die holding structure as set forth above including means for mounting the die actuator at a nodal point with respect to the frequency of the die holding structure.

Another object is to provide a radially polarized, annular, piezoelectric transducer.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawing, illustrating a preferred embodiment of the invention, wherein:

FIGURE 1 is an elevation view of die holding structure constructed in accordance with the invention.

FIGURE 2 is an end view of the die holding structure illustrated in FIGURE 1 taken in the direction of arrow 2 in FIGURE 1.

FIGURE 3 is a cross section view of the die holding structure illustrated in FIGURES 1 and 2 taken substantially on the line 3—3 in FIGURE 2 and illustrating a source of alternating electric energy connected thereto and a part of a rod to be drawn in conjunction therewith.

With particular reference to the figures of the drawing, one embodiment of the present invention will now be considered in detail.

As shown best in FIGURE 3, the die holding structure **10** of the invention includes a die actuator **12** for receiving the drawing die **14** through which the rod **16** may be drawn to, for example, reduce the external diameter thereof. The die holding structure **10** further includes the inner and outer annular ring members **18** and **20**, respectively, and the inner and outer annular piezoelectric transducers **22** and **24**. A source of alternating electric energy **26** is electrically connected to the outer ring member **20** and the die actuator **12** at one terminal and to the inner ring member **18** at the other terminal.

In operation as the rod **16** is drawn through the die **14** a sonic frequency electric signal is applied to the piezoelectric transducers **22** and **24** to cause contraction and expansion of the annulus **28** of the die actuator **12** and produce a periodic radial compressing force on the die **14** through annulus **28** of the die actuator **12** at the resonant frequency of the die holding structure **10**. The compressing force applied at high frequency on the die **14** relieves the external friction between the die **14** and rod **16** to permit easier drawing of the rod **16**.

More specifically, the die actuator **12** includes an annulus portion **28** having the opening **30** extending therethrough which is tapered as shown in FIGURE 3 to receive the drawing die **14**. The die actuator **12** further includes the sleeve portion **32** having the longitudinally extending angularly separated slots **35** therein forming fingers **36** therebetween. The sleeve **32** is connected to the collar portion **34** of the die actuator **12** as shown. The collar **34** is provided to rigidly secure the die actuator **12** to a fixed support **38** as by means of the bolts **40**. The slots **35** and fingers **36** add flexibility to the die actuator **12** to permit easier radial contraction and expansion of the annulus **28** to produce periodic radial compression of the drawing die **14** positioned within the opening **30**.

The annular piezoelectric transducers **22** and **24** are radially polarized oppositely so that the outer surface of the inner transducer **22** has the same polarity as the inner surface of the outer transducer **24**. The transducers **22** and **24** may be constructed of lead zirconate, barium titanate or other suitable piezoelectric transducer material capable of being formed into annular members of the required size and being polarized.

The transducers **22** and **24** are provided with an electro-deposited film of silver on the radially inner and outer surfaces as an electrode. However, the piezoelectric transducers **22** and **24** are not strong in tension so that any attempt to compress a tube drawing die or the like directly with a transducer would result in mechanical failure of the transducer in tension. The inner and outer ring members **18** and **20** are therefore carefully designed to preload the transducers **22** and **24** in compression, in which they are very strong, and to maintain a net compression in the transducers even during maximum output of the transducers.

The inner ring member **18** extends inwardly of the die actuator **12** a short distance beyond the transducers **22** and **24**, as illustrated in FIGURE 3. Means are provided in conjunction with the inner ring member **18**, such as the bolt **44**, for securing an electrical conductor **52** thereto. Similarly means, such as bolt **46** are provided in conjunction with the outer ring member **20** for securing a conductor **48** thereto. The die actuator **12**, and ring members **18** and **20** are constructed of electrically conductive material, such as steel.

While the inner and outer ring members **18** and **20** serve as connecting points for applying electric energy to the piezoelectric transducers **22** and **24**, this is not their prime function. The size and thickness of the ring members **18** and **20** have a direct influence on the two fundamental resonant frequencies of the die holding structure **10**. Thus, by carefully controlling the dimensions of the ring members, the resonant frequencies of the die holding structure can be regulated.

The resonant frequencies of the individual piezoelectric tarnsducers **22** and **24** operating without load are not the same as the resonant frequencies of the die holding structure **10** as a whole. The transducers **22** and **24** are principally intended to provide a source of mechanical energy at the resonant frequency of the die holding structure as a whole. Thus, one of the ways of determining proper coupling of the piezoelectric transducers **22** and **24** to the ring members **18** and **20** and annulus **28** is to determine that neither of the two resonant frequencies of the individual piezoelectric transducers is detectable (by increased amplitude) in the die holding structure **10** after assembly.

The die holding structure **10** as a whole has two fundamental and predominate resonant frequencies; they are the hoop or ring mode and the thickness mode. The hoop mode is a radial oscillation of the die holding structure **10** wherein the mean diameter of the ring members alternately grows and shrinks. Therefore, in the hoop mode of operation the inside and outside surfaces of the ring members are travelling in the same direction at the same time. The thickness mode of operation of the die holding structure is indicated by an alternating change in the thickness dimension of the ring. In the thickness mode of operation the inside and outside surfaces of the rings are travelling in opposite directions at the same time.

The electrical conductor **52** is connected between the ring member **18** and the hot side of the source of alternating electric energy **26**, as shown in FIGURE 3. The electrical conductor **48** is connected between the outer ring member **20** and the electrical conductor **50**, one end of which is connected to the die actuator **12** and the other end of which is grounded to complete a circuit through the electric energy source **26**. With the circuit as shown, the inner ring member **18** is hot and is semi-protected so that it can be shielded from the operator with ease. Also, with the structure and circuit shown, thin piezoelectric elements can be driven at a much lower voltage, to achieve the same stress, then piezoelectric elements of thicker cross section.

It is important in the die holding structure **10** that the annulus **28**, ring member **18** and ring member **20** maintain tight engagement with the annular piezoelectric transducers **22** and **24** so that the annular piezoelectric transducers **22** and **24** are maintained in compression in the assembled die holder structure. To this end the die holder structure **10** is produced in a particular manner.

The outer ring member **20** is first heated in, for example an oven at 225° F. for one hour to expand the ring member and the outer annular piezoelectric transducer **24** is cooled by, for example being packed in Dry Ice for one hour. The outer ring member and the outer transducer **24** are machined to provide a slip-fit with the temperature difference thus produced. The outer transducer is then positioned within the outer ring member.

Care should be taken after either heating or cooling the transducer **24** to discharge the transducer by a jumper wire between the radially inner and outer terminals thereof as a considerable charge may build up on the transducer due to the contraction and expansion of the transducer resulting from the temperature change provided therein. A similar potential build-up may be achieved mechanically by straining the transducer as for example when the metal ring member is shrunk into the transducer and should be guarded against.

The sub-assembly consisting of the outer ring member **20** and the outer transducer **24** is then heated to produce expansion thereof and the inner ring member **18** is cooled to again provide a slip-fit and the ring member **18** is positioned within the outer transducer **24** as illustrated. The sub-assembly so formed is then heated to produce expansion thereof and the inner transducer **22** is cooled to cause contraction of the transducer whereby a slip-fit is provided between the inner transducer **22** and the inner ring member **18**. The inner transducer **22** is then positioned in the inner ring member **18** as illustrated in FIGURE 3.

The sub-assembly so formed is then again heated while the die actuator **12** is cooled and the sub-assembly is positioned over the annulus **28** of the die actuator **12** as illustrated. The piezoelectric transducers **22** and **24** will thus be in radial compression resulting primarily from the forces produced by the annulus **28** tending to expand radially outwardly and the annulus **20** tending to contract radially inwardly.

Thus in operation, with the rod **16** extending through the annular drawing die **14** and with a drawing force applied thereto an electric signal at sonic frequency is generated by the signal generator **26** and passes through a circuit including the conductor **52**, the inner ring member **18** and the outer piezoelectric transducer **24** toward the outer ring member **20** and the inner piezoelectric transducer **22** toward the die actuator **12** in parallel, through the conductors **48** and **50** and back to the hot side of the signal generator **26** through the ground connections. Thus an alternating electric signal is impressed on the opposite terminals of the radially polarized piezoelectric transducers to cause the die holding structure **10** to expand and contract radially at the resonant frequency thereof in accordance with the radial mode of operation of the die holding structure.

The die actuator annulus **28** is thus compressed radially periodically whereby the exterior friction between the tube **16** and the drawing die **14** is materially reduced to allow the rod **16** to be drawn through the die **14** by a considerably smaller force than previously considered possible.

With the die actuator collar placed at a nodal point with respect to the resonant frequency of the die holding structure **10** along the length of the die actuator sleeve portion **32** and with the flexibility provided by the slots **34** in conjunction with the fingers **36**, substantially all of the energy of the generated electric signal is dissipated in compression of the annulus **28** and is not absorbed by the rigid support **38**. Particularly efficient drawing of the rod **16** is thus accomplished due to the simple and relatively inexpensive die holding structure **10**.

While one embodiment of the present invention has been considered in detail it will be understood that other embodiments and modifications thereof are contemplated by the inventor. Thus, while the greatest amplitude of expansion and contraction of the die holding structure **10**, and therefore the most output energy, will be produced when the applied signal has one of the fundamental resonant frequencies of the die holding structure, that is the frequencies which produce the "hoop" mode and the "thickness" mode of operation, the generator frequency may vary up to several megacycles to produce expansion and contraction of the die holding structure of lesser amplitude in other modes of operation. It is the intention to include all embodiments and modifications as are defined by the appended claims within the scope of the invention.

What I claim as my invention is:

1. Drawing structure comprising an annular die actuator, a drawing die held within the die actuator, and means operably associated with the die actuator for contracting and expanding the die actuator at a predetermined frequency including an annular piezoelectric transducer surrounding and engaged with the die actuator and a ring member surrounding and engaged with the annular piezoelectric transducer and means for producing and passing an alternating electric signal between the die actuator and inner ring member through the transducer.

2. Structure as set forth in claim 1 and further including an outer annular piezoelectric transducer surrounding and engaged with the inner ring member and an outer annular ring member surrounding and engaged with the outer piezoelectric transducer and wherein the means for producing the electric signal includes a pair of opposite terminals one of which is connected to the annular structure and the outer ring member and the other of which is connected to the inner ring member.

3. Drawing structure comprising an annular die actuator including a sleeve portion extending from one side thereof having axially elongated angularly spaced apart slots therein forming fingers therebetween and means for connecting the sleeve portion to a rigid support at a nodal point with respect to a predetermined frequency, a drawing die held within the die actuator and means operably associated with the die actuator for periodically contracting and expanding the die actuator at the predetermined frequency.

4. Drawing structure comprising an annular die actuator including a die holding annulus, a sleeve extending at one end from one side of the annulus and an annular collar connected to the other end of the sleeve at a nodal point axially thereof with respect to a predetermined frequency, a drawing die held within the die holding annulus of the die actuator and means operably associated with the die holding annulus for periodically contracting and expanding the die holding annulus at a predetermined frequency including an inner annular radially polarized piezoelectric transducer surounding the annulus and engaged therewith, an inner ring member surrounding the inner piezoelectric transducer and engaged therewith, an outer annular piezoelectric transducer surrounding the inner ring member and engaged therewith having a radial

polarity opposite to that of the inner piezoelectric transducer, and an outer ring member surrounding and in engagement with the outer piezoelectric transducer and an alternating electric signal generator operating at the predetermined frequency, one terminal of which is connected to the die holding annulus and the outer ring member and the other terminal of which is connected to the inner ring member.

5. Drawing structure for drawing wire, rod, tube or the like comprising an annular die actuator, a drawing die positioned radially within and in contact with the die actuator, an annular radially polarized electromechanical transducer sleeved over and in contact with the die actuator and means for electrically exciting the electromechanical transducer to produce radial expansion and contraction thereof.

6. Structure as set forth in claim 5 wherein the die actuator is supported for radial expansion and contraction at a nodal point with respect to the resonant frequency of the drawing structure.

7. Structure as set forth in claim 5 and further including a conducting inner ring member surrounding the electromechanical transducer and in engagement therewith and a second annular radially polarized electromechanical transducer sleeved over the inner ring member and in contact therewith and means for electrically exciting the second electromechanical transducer.

8. Structure as set forth in claim 5 and further including means in peripheral contact with the electromechanical transducer for maintaining the transducer in compression.

9. Drawing structure for drawing wire, rod, tube or the like comprising an annular die actuator, a drawing die positioned radially within and in contact with the die actuator, an annular electromechanical transducer in peripheral contact with the die actuator and means for exciting the transducer to produce radial expansion and contraction of the die actuator.

10. Structure as set forth in claim 9 and further including means engaged with the transducer for maintaining the transducer in compression.

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MILTON S. MEHR, *Primary Examiner.*