May 12, 1953 R. P. GUTTERMAN 2,638,207

METHOD AND APPARATUS FOR FORMING WIRE AND THE LIKE

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FIG. 1.

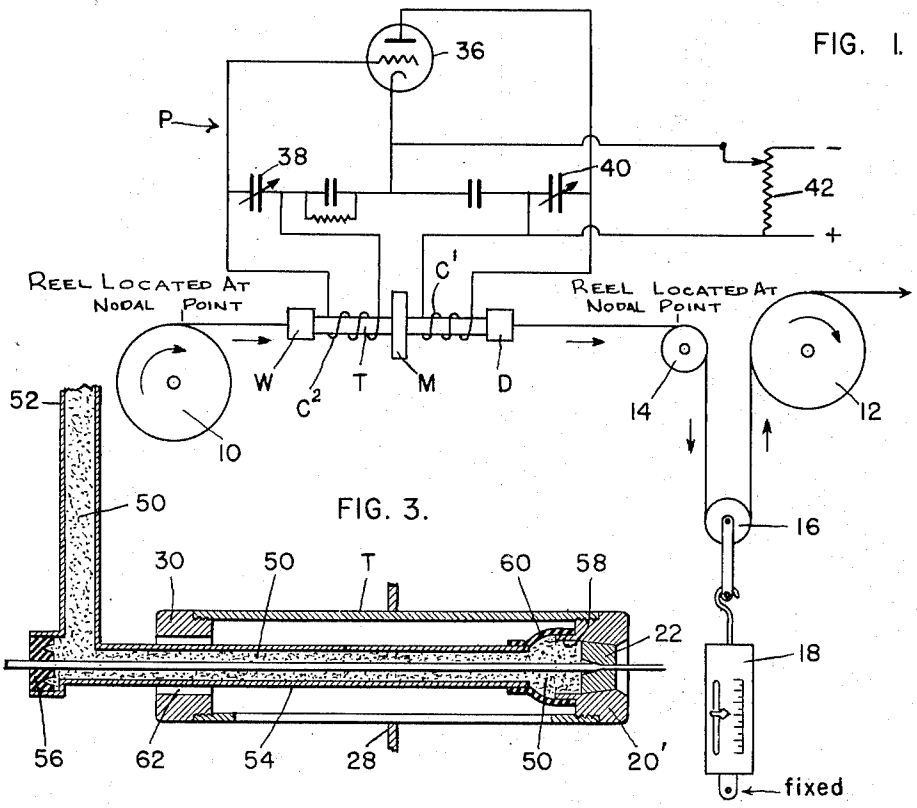


FIG. 3.

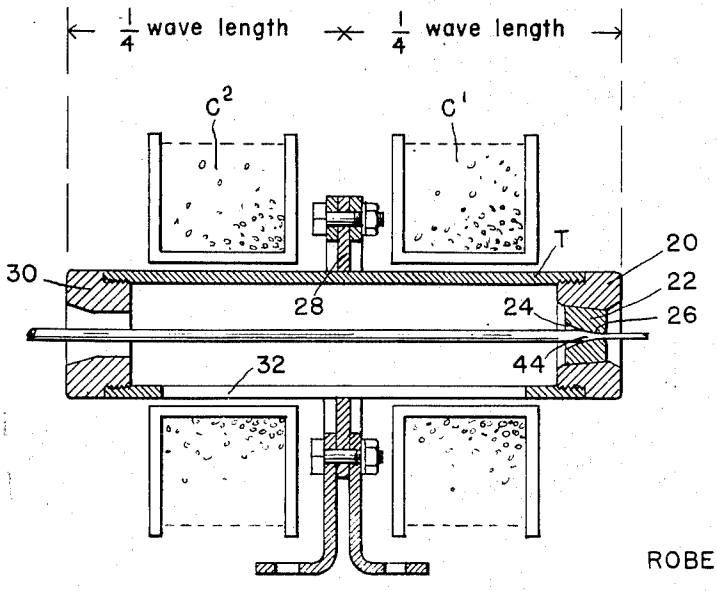


FIG. 2.

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METHOD AND APPARATUS FOR FORMING WIRE AND THE LIKE

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2 Claims. (Cl. 205—16)

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The present invention relates to drawing wire and other attenuated articles by continuously pulling the raw wire or similar stock through a die member having a restricted throat to thereby reduce the diameter of the raw wire or other stock.

While the invention is particularly applicable and of pronounced usefulness when applied in the attenuation of wire, it will be understood that the invention may also be useful in connection with the drawing of other attenuated stock, such as rod, tube, and thin sheet stock. Throughout the specification, reference will be made to the drawing of wire, but it will be understood that the disclosure also contemplates the drawing of other and similar attenuated products where applicable.

The principal object of the invention is to improve presently used methods and apparatus for the above purposes whereby the friction which must be overcome in usual practices is so diminished that the wire may be drawn at a desired speed with the application of a substantially reduced pulling force, the power consumed by the drawing apparatus thus being substantially reduced.

Working toward the above objective, I have discovered that by causing the wire or the die to vibrate with small amplitude and at high frequency, preferably in the supersonic range, and longitudinally of the movement of the wire through the die, the force necessary to pull the wire through the die is greatly reduced, this advantage being accomplished by reason of the very large acceleration produced between the wire and the surface of the die.

Another accomplishment of the invention is the reduction in the tension in the wire whereby breakage of wires of smaller sizes is avoided due to hard spots in the wire or dirt in the die, and whereby wire of more uniform diameter is produced due to less "necking down" when a hard spot passes through the die. I have also found that the invention will improve the surface quality of the wire, by the polishing action of the wire as hereinafter described, and that heat and wear on the die may be reduced in the use of the present invention.

Due to the relative action of the wire and die, as hereinafter described, lubrication of the die during its operation is facilitated.

The above advantages of the invention will permit rapid wire drawing using less power and applying less tension to the wire, whereby savings will be effected in the reduction of breakage of

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wire during the drawing operation, as well as in the consumption of power. Various other objects and advantages of the invention will be apparent as the description herein progresses.

In the drawings, which are generaly diagrammatic and illustrative of apparatus which may be employed in carrying out the invention:

Figure 1 is a diagrammatic view of the essential parts of a wire drawing machine having associated therewith equipment for the practice of the present invention, and

Figure 2 is an enlarged vertical, sectional view through the die assembly, including the magnetostrictive tube which is driven by a self-oscillating thermionic circuit as hereinafter described.

Figure 3 is a partial sectional view through the die assembly, and similar to Figure 2 but of a slightly reduced scale, and showing the application of apparatus for supplying lubricant to the throat of the die. The surrounding driving and pick up coils and other associated parts are omitted merely to simplify this view.

I have found that the reduction in tension of the wire may be brought about in two ways; first, by the introduction of large shear forces in the interface between the die and the wire; and second, by oscillatory swaging of the wire at the entrant shoulder of the die. If the first of these forces can be made large enough, it is possible to eliminate to a great extent the frictional drag normaly encountered as the wire passes through the die. For example, a die used to produce a steel wire of 0.05 inch diameter may be considered. If such a die is caused to vibrate sinusoidally at a frequency of 25,000 cycles per second at an amplitude of 0.0001 inch, the peak acceleration of the die will then be very closely equal to forty times the amplitude times the square of the frequency, or 201,600 feet per second per second. This acceleration is 6,300 times that of gravity. Since there exists a frictional force between the wire and the die, the wire will tend to follow the motion of the die and vibrate with it. This action will set up longitudinal vibrations in the wire so that the smallest length of the wire which will always tend to move in phase with the die will include a distance corresponding to one-fourth wave length of the wire's vibration extending on each side of the die, or one-half wave length total. For steel wire at 25,000 C. P. S., this length is approximately four inches. The weight of steel in this length is approximately .002 pound, which may be considered as the minimum weight reacting against the acceleration of the die to produce a shear force at the

interface. This force is equal to the weight of one-half wave length of the wire times the ratio of the acceleration of the die to the acceleration of gravity and has a peak value of approximately 130 pounds. This peak force, when applied in an oscillatory fashion at a rate of 25,000 C. P. S. will have the effect of continuously sliding the die back and forth along the wire as the drawing operation is performed. If the force causing this sliding exceeds the frictional force normally generated during drawing, its average effect will be to reduce the tension necessary to pull the wire through the die. The second effect will be occasioned by continued application and removal of the die at the entrant shoulder of the wire, resulting in a hammering of the wire into shape as it enters the die.

In addition to these two primary effects, the use of die vibration as described herein will allow more efficient lubrication during the drawing operation, since the die is being continuously withdrawn from the entering portion of the wire by a very small amount, thus providing short periods during which it is possible to force lubricant between the die and the entering portion of the wire. In addition to the above, the vibratory motion of the die relative to the wire permits a polishing action on the wire surface which could not otherwise be obtained.

In accordance with the above, I have provided a means for supporting a wire drawing die in such manner that it may be caused to vibrate at frequencies preferably in the supersonic range, for example, between 20 and 30 kilocycles. Vibration of the die is accomplished by making it a part of a magnetostrictive oscillator which is powered by means of appropriate driving and pick-up coils connected to a power oscillator so that the frequency of oscillation is controlled by the mechanical characteristics of the die holder. The above is preferably accomplished by making the die holder in the form of a slotted or laminated nickel tube whose length is equivalent to one-half wave length of longitudinal vibration at the desired frequency. The tube is supported at its center (which is a node of oscillation), while the ends of the tube are made to oscillate at the fundamental resonant frequency of the tube.

Illustrative practical apparatus for carrying out the above is shown in the drawings. In Figure 1, the parts are shown somewhat diagrammatically, comprising a tube T centrally supported as at M, and having a die D at its forward end and a counterweight W at its rearward end. The raw wire is continuously fed to the die from any suitable source of supply such as the feeding reel or drum 10, and tension may be applied to pull the wire through the die from any suitable source such as the motor driven pulling drum 12. Several turns of wire are maintained around this drum. Suitable means may be provided to continuously indicate the tension applied to the wire, and I have shown a fixed pulley or similar device 14 over which the drawn wire passes, there being a movable pulley 16 supported by the length of wire between pulley 14 and drum 12, and this moving pulley supports a tension indicating device 18.

The tube T is better shown in Figure 2. It is preferably made of nickel and it has a die carrier or bushing 20 secured as by threading into its forward end, and this carrier retains the die proper 22 which has a bevelled entrant throat portion 24 and a restricted throat portion 26.

The tube T serves as a feed-back of the magnetostrictive power oscillator P generally indicated at Figure 1. The length of the tube is preferably equal to one-half the wave length of the frequency at which the die is to be vibrated, and it is centrally fixed or anchored to the support M (comprising a bracket 28), so as to make its center a nodal point of the magnetostrictive waves set up in the tube by the driving coil C', which surrounds the tube between its support and the die member. Obviously, the mounting of the tube is such that during vibration, its ends will be 180° out of phase. In order that both half lengths of the tube may be similarly loaded, a bushing or the like 30 is secured as by threading into the rearward end of the tube, this bushing being of such mass as to compensate for the weight of the die at the forward end of the tube, thereby preserving the center of oscillation at the center of the tube.

The pick-up coil C2 of the power oscillator is mounted as shown in Figure 2 between the central support and the rearward end of the tube, the coils C1 and C2 being housed in suitable forms as shown. In order to reduce eddy current losses, which are quite severe in the frequency range contemplated for the equipment, the nickel tube is slit as at 32. The grid of the thermionic tube 36 of the power oscillator is tuned to the desired frequency by a variable condenser 38 which is disposed in parallel with the pick-up coil C2. The plate circuit is tuned to the same frequency by a variable condenser 40 which is in parallel with the driving coil C1. The direct plate current through the driving coil provides a steady polarizing field to the magnetostrictive tube. A magnetostriction induced in the tube by the current in the driving coil C1 arrives at the pick-up coil in phase with the electrical oscillation therein due to the phase reversal provided by the tube, and oscillations are thus sustained. The amplitude of the physical vibrations of the tube may be controlled in the particular circuit by varying the amount of direct current voltage applied to the plate of tube 36, by means of a potentiometer 42.

Although the magnetostrictive oscillator, as described, is not the only type of such a device which could be used, the fact that the mechanical vibrations set up in the tube can be used to vibrate the die and also to provide feed back necessary to maintain oscillation, makes it highly desirable.

It will be noted in Figure 2 that the wire is threaded through the center of the nickel tube T and is drawn through the die in a direction which tends to stretch, rather than compress, the tube. Thus, no force is generated which would tend to buckle a thin walled tube.

It will be understood that most efficient operation is obtained when the die is located at an antinode of the longitudinal vibrations imposed on the wire by the vibrating die. It is contemplated that appropriate auxiliary elements of the wire drawing apparatus will be positioned so that the length of wire immediately adjacent to the die may be brought into mechanical resonance with vibrational energy imparted from the die. Such auxiliary elements, for example, associated with the drum 10 and the pulley 14, should be provided at proper nodal points on either side of the die to confine the vibration to the wire between them. Maximum efficiency in drawing the wire will be attained by controlling the reaction of the wire against the die, either by resonating the wire or

by controlling the phase of the vibrations reflected along the wire as it proceeds through the vibrating die.

In the apparatus described, all parts of the die will move in substantially the same direction and in the same phase with the same amplitude. Motion is imparted to the entire die structure by affixing it to the vibrating member which may or not be in resonance.

It will be apparent from Figure 2 that when a continuous and steady pulling force is applied to the wire by the winding drum 12, the restricted throat 26 of the die member will progressively reduce the diameter of the raw wire stock, as illustrated. The relative vibratory movements imposed between the throat and wire longitudinally of the direction of movement of the wire will cause the throat of the die to rapidly move forwardly and rearwardly toward the point of reduction 44 of the raw wire stock, thus facilitating the drawing operation by rapid intermittent rearward hammering action against the larger entrant shoulder on the wire stock at approximately the point 44. As the throat of the die periodically moves from the entrant shoulder on the wire stock, lubricant may be applied in any appropriate manner at the interface of the throat and wire. The vibratory movements of the die are of such frequency and amplitude as to cause a slipping action of the die relative to the wire, and as the throat intermittently moves forwardly from the point of reduction in the wire stock, it will polish portions of the wire which have been previously reduced in said throat.

In connection with the proper placement of such elements as pulleys, feed drums, and winding drums, as previously referred to, a sufficiently reflective discontinuity can be established at a nodal point on the wire by merely causing the wire to make a sharp turn of 90° or more around a pulley of small diameter. The smaller the diameter of the pulley, the more efficient it will become in creating a reflective discontinuity. In order to establish resonance of the wire, such a discontinuity should be placed at a nodal point on the wire. The location of this point will be primarily controlled by the longitudinal velocity of sound waves in the particular material being drawn, and by the frequency of the wave-length in the wire. A secondary controlling factor, which will become important only at rather high wire speeds will be the speed of drawing itself. At high drawing speeds, the actual wave-lengths relative to a fixed system will be subject to shortening on the exit side of the die and lengthening on the entrance side of the die due to the Doppler effect; i. e., the effect of wave-length variation in an acoustic wave propagated through a medium which has a velocity component of appreciable magnitude in a direction parallel to the direction of acoustic propagation.

Figure 3 discloses an apparatus useful in supplying lubricant to the die. The magnetrostrictive vibrator tube T and its nodal support 28 may be the same as in the embodiments previously described. Lubricating material 50, either of a fluid or plastic type, is introduced to the die under pressure through a system of pressure-tight tubes 52 and 54, the latter passing centrally and longitudinally through the tube T. The wire is drawn through the lubricant in the horizontal portion 54 of the tube system, entering the lubricant chamber through a pressure seal 56 of any standard type, the parts of said seal preferably being made of an oil resistant flexible material such as neoprene. The forward end of the tube section 54 is connected to a flange 58 on the die member 20' through a suitably bonded flexible connection 60 which also may be fabricated from neoprene and the like. Thus, a flexible joint is provided and which is sealed pressure-tight to the forward end of the tube 54 and to the die carrier 20', surrounding the throat portion 22 of the die. Various types of flexible joints for the above purpose will be evident to those skilled in the art, it merely being necessary to accomplish the proper pressure seal in such manner as to facilitate dismantling in order to introduce new wire stock into the die. The connection 60 should be flexible in order to reduce the damping effect which would be exercised on the vibratory structure by the pressure feeding system and its contained viscous lubricant if the feed system were rigidly attached to the vibrating die. For the same reason, a clearance space 62 is left between the tube 54 and the open end 30 of the support T.

It will be obvious from the above description, that means is provided to apply lubricant under pressure to the interfaces of the wire and die at all times during the vibration of the die. Obviously, during those periods when the vibratory system partially withdraws the shoulder of the die from the entering shoulder of the wire, a small amount of lubricant will be forced into the intervening space.

It will be apparent from the above that I have provided apparatus and methods whereby the friction incident to the wire drawing operation is substantially diminished and whereby the pulling force required for a given speed of drawing may therefor be substantially reduced. It is contemplated that the pulling force applied to the wire for a desired speed of drawing will be regulated in accordance with the reduced friction resulting from the imposed vibration.

If the die is oscillated at a high enough frequency with a given amplitude it will slide with respect to the wire during a major portion of the cycle. Because the maximum force that can be supplied in this manner is equal to the force of friction between the wire and the die, a force equal to the frictional force is applied first in one direction and then in the other. When the force is opposed to the pull exerted by the winding drum, the situation is the same as in the normal drawing methods where the die is stationary with respect to the wire, but during the half cycle that this force is applied in a direction the same as that of the pull applied by the power driven winding drum, the pull applied to the wire may be less. Therefore, the average effect of friction over a cycle is substantially less than in conventional drawing operations, whereby the applied pulling power may be substantially reduced.

When the die moves against the shoulder in the raw wire it can exert shear forces that are greatly in excess of friction, said forces being approximately equivalent to the total mass of the half wavelengths of wire that are in phase with the die times the acceleration.

The drawings disclose apparatus whereby the die is vibrated, the vibrations being set up in the wire by the die. The method contemplated herein includes the use of a fixed die with appropriate mechanism for imposing the forced vibrations on the wire stock being drawn.

While the description above discloses the use of only one die, for action on a particular batch of wire, I contemplate the use of two wire draw-

ing dies operating on the same wire, which dies will be caused to vibrate both axially and radially in such manner that a feeding action may be obtained, whereby the wire is gripped by one die and drawn through the second die in a cyclic fashion, thus eliminating the need for any other source of external power to accomplish passage of the wire through the die. The second die would then grip and move the wire through the then relaxed gripping die on the following half cycle of operation. The vibrations will be at supersonic frequencies as set out in the foregoing specification.

I claim:

1. Apparatus for continuously drawing attenuated metal stock in great lengths, comprising a die, means for vibrating said die parallel to the movement of the stock, a drum of raw stock, a power driven drum at the leading end of the stock that provides the drawing force for the stock, and means for damping out imposed longitudinal vibrations in the stock on either side of the die, said means being located at nodal points of the longitudinal vibration of the stock, said die being located at an antinodal point of the longitudinal vibration of the stock.

2. The method of drawing attenuated stock in great lengths which comprises continuously pulling raw stock through the restricted throat of a die member to progressively reduce the diameter of the stock, imposing rapid vibratory movements of supersonic frequency on the die in both directions longitudinally of the movement of the stock and such amplitude as to cause the die to slip relative to the stock, and supporting the stock on either side of the die at nodal points of the longitudinal vibration of the stock.

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